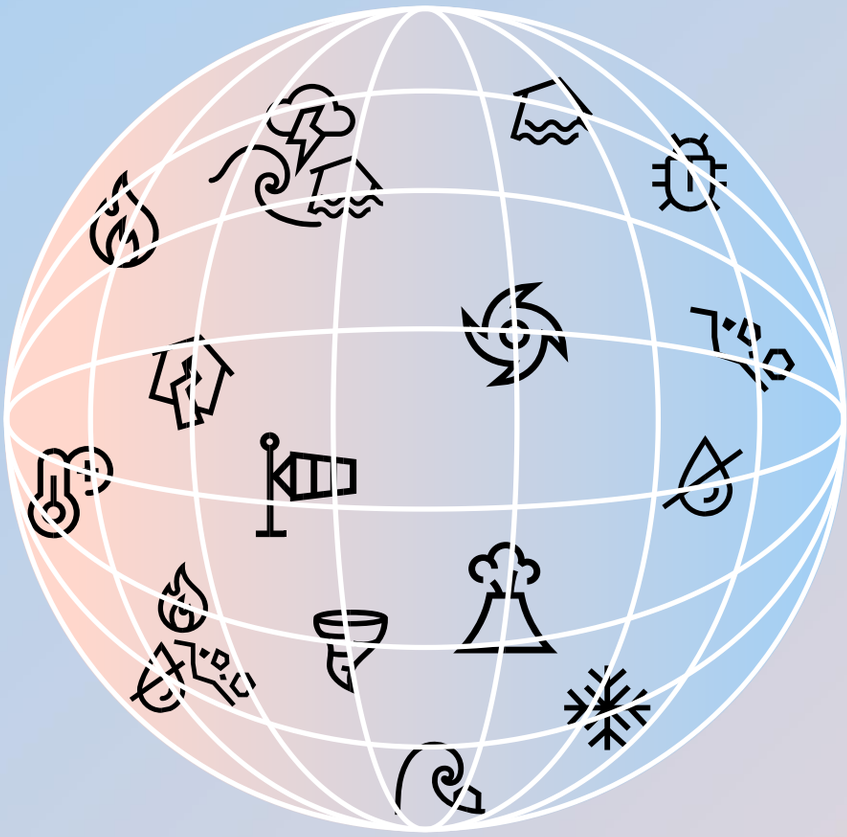
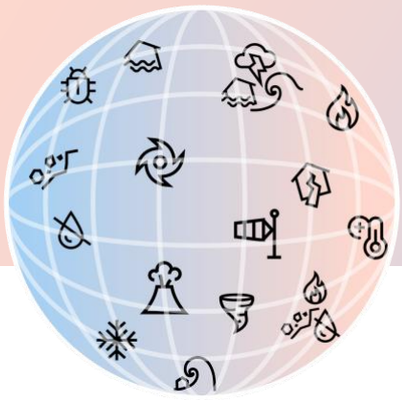


3rd International Conference

Natural Hazards and Risks in a Changing World

Addressing Compound and Multi-Hazard Risk

#ChangingWorldRisks2024



Natural Hazards and Risk in a Changing World

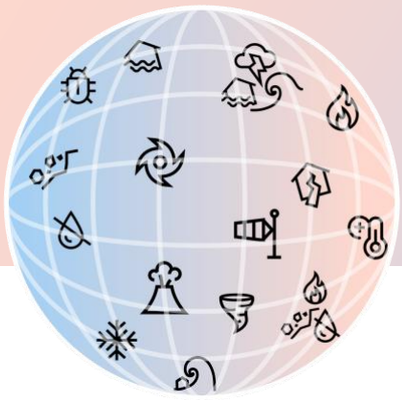
Addressing Compound and Multi-Hazard Risk

ABSTRACTS – 3RD INTERNATIONAL CONFERENCE

The conference will take place at Rode Hoed in the centre of Amsterdam. It will feature a mix of plenary sessions and more focused parallel sessions. The plenary sessions will include several keynote speakers, panel discussions, and interactive and fun ways of engaging as a community.

Day 1

Oosterhuis	Keizer	Grachten
08:00 - 09:00 Registration and coffee		
09:00 - 10:45 Plenary opening session		
10:45 - 11:15 Break	10:45 - 11:15 Break	10:45 - 11:15 Break
11:00 - 12:45 Dynamics, interdependencies and interactions of risk drivers	11:00 - 12:45 Learning from the past: historical perspectives and 'success stories' of DRR	11:00 - 12:45 Science for policy and practice: synergising disaster risk reduction and climate change
12:45 - 13:45 Lunch	12:45 - 13:45 Lunch	12:45 - 13:45 Lunch
13:45 - 15:15 How can stakeholder engagement and knowledge co-production enhance effective multi-risk management?	13:45 - 15:15 Dynamics, interdependencies and interactions of risk drivers	13:45 - 15:15 Assessing multi-hazard risk using earth-observation data
15:15 - 15:45 Break	15:15 - 15:45 Break	15:15 - 15:45 Break
15:45 - 16:45 How can stakeholder engagement and knowledge co-production enhance effective multi-risk management?	15:45 - 16:45 Health and disasters	15:45 - 16:45 Advancing critical infrastructure modelling in a complex world
16:45 - 17h45 Poster session		
17:45 - 19:15 Drinks		



Natural Hazards and Risk in a Changing World

Addressing Compound and Multi-Hazard Risk

ABSTRACTS – 3RD INTERNATIONAL CONFERENCE

The conference will take place at Rode Hoed in the centre of Amsterdam. It will feature a mix of plenary sessions and more focused parallel sessions. The plenary sessions will include several keynote speakers, panel discussions, and interactive and fun ways of engaging as a community.

Day 2

Oosterhuis	Keizer	Grachten
08:30 - 09:00 Registration and coffee		
09:00 - 11:00 General advances in disaster risk science and compound climate events	09:00 - 11:00 Artificial intelligence and machine learning for multi-risk assessment	09:00 - 11:00 Storylines and narratives for multi-hazard, multi-risk decision-making
11:00 - 11:30 Break	11:00 - 11:30 Break	11:00 - 11:30 Break
11:30 - 12:30 Poster session	11:30 - 12:30 Demonstration of tools and services	
12:30 - 13:30 Lunch	12:30 - 13:30 Lunch	12:30 - 13:30 Lunch
13:30 - 15:30 General advances in disaster risk science and compound climate events	13:30 - 15:30 Nature-based Solutions for disaster disk reduction / Recent developments in multi-hazard early-warning systems	13:30 - 15:30 Systemic risk-assessing, modeling, coping
15:30 - 15:45 Break	15:30 - 15:45 Break	15:30 - 15:45 Break
15:45 - 17:15 Plenary closing session		

MYRIAD-EU project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement No. 101003276

Session 1: Dynamics, interdependencies and interactions of risk drivers

Author(s): Andreas Trojand[1]; Henning Rust[1,2]; and Uwe Ulbrich[1]

Affiliation: (1) Freie Universität Berlin; (2) Hans-Ertel Centre for Weather Research

Title of abstract: Temporal dynamic vulnerability - Impact of antecedent events on residential building losses to wind storm events in Germany

Abstract: Severe storm events are one of Central Europe's most damaging natural hazards, requiring particular attention in disaster risk management. Vulnerability is a crucial factor in reducing risks. By assuming vulnerability as constant, risk assessments often overestimate future risk. This study aims to quantify vulnerability's temporal dynamics to assess future risks more accurately. An essential factor for the dynamics of vulnerability is the interaction with the hazard itself. Extreme events destroy the most vulnerable elements, which are rebuilt less vulnerable. The intensity of previous events and resulting damage are decisive factors for the reduction. A second key factor is the period between events. If the next event occurs during the reconstruction phase rather than once the reconstruction phase is completed, vulnerability is assumed to be higher. In this study, we examine how past storms affect the vulnerability of residential buildings. Generalized additive models are used to estimate vulnerability curves, which depend on the previous event's intensity and the duration between events. The German Insurance Association provided a 23-year data set on daily storm and hail damages for insured residential buildings in Germany, which was analyzed to determine the extent of damages on the county level. The hazard component is determined by calculating the daily maximum wind load from ERA5 reanalysis data. We found a negative correlation between the intensity of the prior event and the damage caused by the subsequent event. The duration between two events shows a significant reduction of the damage for events occurring one or more winter seasons ago compared to events occurring within the same season. On a daily basis, the first seven days are the most critical for reducing

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Author(s): Hannah Schuster[1]; and Johannes Wachs[2]

Affiliation: (1) Complexity Science Hub Vienna; (2) Corvinus University of Budapest

Title of abstract: Mortality Risks of an Ageing and Warming Austria

Abstract: Hot weather stresses the body and can be lethal, especially for the elderly. Austria is an aging country and faces significant warming in the coming decades. Though there is substantial geographic variation in age structure and heat in the country, we know little about heat-related mortality rates in different parts of Austria. We use a linear regression model with district, year, and week-of-year fixed effects to measure the effect of heat days on mortality in Austrian districts (Bezirke), finding that an additional heat day (max. temperature at least 30 degrees) in a summer week leads to an estimated 2.1% increase in weekly mortality. A second model shows that heat has a significantly larger impact on districts with an older population. A three-day heat wave in a district with a 65+ population one std. dev. above average (23%) predicts a 10% increase in weekly mortality. Furthermore, we recognize the importance of exploring various factors influencing urban heat buildup in summer, like the availability of trees in the residential area. Our analysis aims to identify conditions for mitigating or minimizing this phenomenon. Once other factors besides a high 65+ population are identified,

we utilize them to create a heat resilience ranking of Austrian municipalities. We conclude by reflecting on future mortality risks of extreme heat for an aging population using the derived ranking and different weather forecasts.

Author(s): Malte von Szombathely; Franziska S. Hanf; Benjamin Poschlod; and Jana Sillmann

Affiliation: Center for Earth System Research and Sustainability, Universität Hamburg

DOI: 10.1007/s13753-023-00517-7

Title of abstract: Hamburg Risk Map: Combined indexing of urban exposure, social vulnerability and urban flooding

Abstract: The "Hamburg Risk Map" aims to improve our understanding of the drivers, dynamics and interactions of climate-induced (disaster) risks in Hamburg. In this sense, we combine data from the newly published Social Vulnerability Index (von Szombathely et al., 2023) with state-of-the-art data on urban flooding from the high-resolution heavy rain hazard map of the city of Hamburg (BKG 2023, FHH 2023). This unique hazard mapping features a hydrodynamical modelling at 1-meter- resolution bidirectionally coupled with a storm water management model providing information on water levels, flow directions and speeds triggered by a heavy rain event. We also propose exposure modeling in the context of urban flooding. Following the risk framework of the IPCC, we calculate a risk index based on the hazard, exposure and (social) vulnerability. The decisions made to weight the individual input parameters are shown and justified in the presentation, as are the first results. Presented in high-resolution spatial maps, these risk indices can be a useful tool for identifying areas where the city population is most at danger to climate-related hazards. Thus, this analysis can help to identify needs for adaptation and in prioritizing political measures.

Author(s): Sara Nieto[1]; Edier Vicente Aristizabal Giraldo[1,2]; and Ugur Ozturk[2,3]

Affiliation: (1) Universidad Nacional de Colombia; (2) University of Potsdam; (3) GFZ German Research Centre for Geosciences

Title of abstract: Coupled Evolution of Medellin City and Landslides

Abstract: The metropolitan area of Medellin, Colombia, has progressively extended towards steep hillslopes, influenced by the challenging topography surrounding the city. Steeper hillslopes inherently carry a higher risk of landslides, and when coupled with inadequate planning due to population pressure, the city's landslide risk escalates disproportionately. We analyzed the city's expansion in 18 steps since 1770, particularly examining the empirical connection between urban growth and landslide incidents. Between 1976 and 2023, the city nearly doubled its size, expanding from 56 km2 to 110 km2. Steeper hillslopes experienced increased urbanization, especially since 1941, with a growing portion falling within high landslide hazard zones. Landslide activity predominantly occurred on the outskirts, impacting newly developed neighborhoods.

From 2005 to 2023, we categorized the metropolitan area into consolidated urbanization (compact regular mesh, compact irregular mesh, condominiums, and equipment) and unbound urbanization (scarce urbanization, road deficit/scattered urbanization, and urbanization scattered around an axis). Each category was analyzed in relation to hillslope angles, landslide risk, and socioeconomic strata. Unbound urbanization was identified on steeper hillslopes, coinciding with lower socioeconomic strata areas. Consequently, we assert that Medellin's expansion into landslide-prone zones poses a significant threat, particularly to those with limited opportunities in deprived neighborhoods.

By documenting the city's evolution in relation to landslide occurrences, we aim to emphasize the pressing landslide risk for local and international policymakers. We believe that adequate planning and educational initiatives can effectively mitigate the landslide risk.

Author(s): Eva Preinfalk; John Handmer

Affiliation: International Institute for Applied Systems Analysis (IIASA)

Title of abstract: Fuelling the fires - An exploration of the drivers and the scope for management of European wildfire risk under the Shared Socioeconomic Pathways

Abstract: Future wildfires are exacerbated by two main drivers: climate change and socioeconomic dynamics. While modelling studies account for changes in fire patterns under different climate scenarios, they largely disregard anthropogenic dynamics determining wildfire risk. Building on the notion that risk arises at the intersection of hazard, exposure and vulnerability, we screen the relevant empirical literature to identify key socioeconomic drivers of wildfire risk in a European context and integrate this with the Shared Socioeconomic Pathways (SSP). The resulting wildfire risk scenario space serves two main purposes: (i) providing a qualitative navigator for incorporating socioeconomic uncertainty in model-based wildfire risk assessments and (ii) establishing boundary conditions for evaluating the feasibility of management strategies. Applying the SSP framework for envisioning plausible trajectories, we evaluate the role of socioeconomic dynamics in determining wildfire risk. Sustainable land use practices reduce hazard (SSP1), while poor environmental regulation (SSP5) and the loss of competitive value chains (SSP4) increase it. Ineffective land use planning raises settlement exposure in areas dominated by unmanaged vegetation (SSP3, SSP5), with an escalation of livelihood exposure on agricultural land (SSP4). Vulnerability is a distinctive driver of risk in scenarios with low economic and human development (SSP3, SSP4). Across scenarios, social, economic and ecological challenges may lead to paradoxical situations in risk management. Results stress the importance of considering socioeconomic drivers in shaping future wildfire risk and keeping management strategies adaptive to changing circumstances.

Author(s): Nele Rindsfüser[1,2]; Andreas Zischg[1,2]; and Margreth Keiler[3,4]

Affiliation: (1) Oeschger Centre for Climate Change Research, Mobiliar Lab for Natural Risks, University of Bern (2) Institute of Geography, University of Bern; (3) Department of Geography, University of Innsbruck; (4) Institute for Interdisciplinary Mountain Research, Austrian Academy of Sciences

Title of abstract: Monitoring flood risk evolution in Switzerland

Abstract: The spatial-temporal evolution of flood risk is a challenge for flood risk management. Climate change, land-use change, human interventions, and socio-economic development lead to high dynamics in the main risk components - hazard, exposure, and vulnerability. These dynamics require continuous adaptation of flood risk management strategies to ensure the safety level of humans and their assets in the long term. In order to enable adaptive flood risk management, the monitoring of flood risk evolution is required. With flood risk monitoring, a better understanding of flood risk evolution is gained, spatial- temporal differences are identified, the safety level is maintained, and possible drivers of change are detected. Key principles of flood risk monitoring are the periodically measurement of factors that influence the risk components, model those risk components, and combine them to quantify risk. However, the application of a monitoring concept in flood risk management is missing. In this study, the application of the flood risk monitoring concept is evaluated on a national scale (Switzerland). Data streams for hazard (continuously updated hazard maps), exposure (number of houses in potential endangered areas), and vulnerability (degree of loss) analysis were collected and stored over a time period of 10 years. By calculating the potential damage for each year timestep, a trend curve of risk is established. The

disentangling of risk factors that describe the risk components in comparison with the risk evolution enables a better understanding of important drivers leading to an increase or decrease in risk. Further, difficulties in data mining and modelling are observed and can be discussed.

Author(s): Dominik Paprotny[1]; Alois Tilloy[2]; Simon Treu[1]; Michalis I. Vousdoukas[3]; Luc Feyen[2]; Heidi Kreibich[4]; Oswaldo Morales-Napoles[5]; and Matthias Mengel[1].

Affiliation: (1) Potsdam Institute for Climate Impact Research (PIK), Member of the Leibniz Association; (2) European Commission, Joint Research Centre (JRC); (3) University of the Aegean, Department of Marine Sciences; (4) GFZ German Research Centre for Geosciences, Section Hydrology; (5) Delft University of Technology, Department of Hydraulic Engineering

Title of abstract: Climatic and human drivers of flood losses in Europe in the Anthropocene

Abstract: Climatic and human drivers that regulate flood occurrence and impacts are evolving rapidly. Present outlook on flood risk in Europe is very different compared to the beginning of the Anthropocene (c. 1950). In this work, we attribute impacts of 1504 significant historical floods across 35 European countries to multiple drivers. We were able to reconstruct the magnitude of each event (riverine, coastal or compound) under 64 different scenarios, representing all possible combinations of six factors contributing to flood risk, each under factual (historical) and counterfactual (a static 1950 world) conditions. The hazard component, modelled utilizing high-resolution climate reanalysis and hydrodynamic simulations, comprises (1) changes in meteorological and oceanic conditions controlling river discharges and sea levels, and (2) human impact on catchment hydrology through changing land use, water demand and reservoir capacity. The exposure component is represented by (3) demographic and economic growth at regional (subnational) level, and (4) redistribution of exposure within the regions through land use change. Finally, the vulnerability component includes a set of vine-copula models that can reconstruct (5) changes in flood protection levels (primarily from structural defences), and (6) changes in flood vulnerability (relative loss at given intensity of hazard). Overall, the results show that both hazard and particularly exposure increased substantially since 1950. Importantly, we find that human alterations to catchments overall increased the flood risk in Europe due to land-use change, despite intense reservoir construction. On the other hand, we find a relatively modest improvement in flood protection standards, but a considerable decline in flood vulnerability.

Author(s): Tailin Huang[1]; Jean-Daniel Rinaudo[2]; Shih-Yao Lee[3]; and Hwa-Lung Yu[3]

Affiliation: (1) Disaster Prevention Education Center, National Cheng Kung University; (2) French Geological Survey BRGM; (3) Department of Bio-environmental Systems Engineering, National Taiwan University

Title of abstract: Unraveling Interconnected Risks: A Systemic Approach to Understanding Flood, Drought, and Land Subsidence in Choshui River Basin, Taiwan

Abstract: Climate change has notably changed rainfall patterns, increasing the likelihood of water-related disasters such as floods, droughts, and land subsidence, which can lead to higher agricultural disaster and infrastructure maintenance costs. Presently, disaster management often treats floods, droughts, agricultural disasters, and infrastructure damage as separate areas, each with its own set of solutions. Unfortunately, this approach often results in stakeholders working in isolation, without a clear understanding of how these disasters are interconnected.

Our research delves into the interconnected risks in the Choshui River basin in Taiwan, an area grappling with water scarcity and land subsidence. We bring together the insights and knowledge of diverse stakeholders—farmers, local government

officials, and policymakers—who are directly impacted by and play crucial roles in managing these multi-risks. This collaborative approach allows us to explore the systemic drivers of these risks in depth.

Activities engaging stakeholders in the systems led to a comprehensive causal loop diagram that visually illustrates the risk dynamics. This diagram sheds light on the complex relationships between risk factors and system operations—details that are often missed in traditional disaster risk assessment studies.

Our research shows that these multi-risks are closely tied to groundwater management, and food, agriculture, and land policies in Taiwan, interacting in a nonlinear way. These findings highlight the fragmented nature of disaster management across different sectors, which often overlooks the interconnectedness of their drivers. The insights are valuable for policymakers and practitioners as they navigate these complex issues.

Author(s): Edward Sparkes; Ananya Ramesh; Dominic Sett; Davide Cotti; Himanshu Shekhar; Saskia E. Werners; and Michael Hagenlocher

Affiliation: United Nations University - Institute for Environment and Human Security

Title of abstract: Advancing our understanding of complex risks with conceptual models: lessons from case studies in Asia, Africa and Europe

Abstract: While communities, sectors and regions face unique challenges that require context specific interventions, the impacts of climate change, natural hazards and other human-generated shocks transcend borders, sectors and systems, highlighting the complex nature of risks. Risk assessments need to account for this complexity, while acknowledging specificities rooted in lived experiences of communities. To this aim, we developed a novel conceptual risk modelling approach named Impact Webs. Impact Webs are inspired by the Impact Chains approach, taking a systems oriented view to map interconnections between hazards, impacts, their underlying risk drivers and root causes and response risks across various scales. We applied the Impact Webs approach across different case studies to assess complex risks, adapting it to account for local realities, stakeholder priorities and context specific objectives. Drawing on case studies in South and East Asia, Southern Africa and Europe, we reflect on the use of conceptual risk models for advancing understanding of complex risks. Co-creating conceptual risk models with stakeholders triggers social learning, capacitating thinking in an interconnected manner about cascading effects, feedbacks and response risks, and identifies impacts grounded in local realities. Moreover, using conceptual models to map complex risks supports identifying drivers and root causes of risks that are shared across communities, sectors and regions. Doing this identifies key leverage points, in which targeted risk management interventions can create positive cascading effects across systems. We find that synthesising lessons from a diverse set of cases is an effective exercise to improve methodological development, and advance our understanding of complex risks.

Author(s): Ajay Devda[1]; Vishal Verma[2];

Affiliation: (1) Interdisciplinary Program in Climate Studies, Indian Institute of Technology (IIT) Bombay, India; (2) School for the Environment, University of Massachusetts, Boston, USA

Title of abstract: How coupled impacts of flood control infrastructure and socio-economic disparities exacerbate flood risk: A Hydrogeomorphic and Socio-Economic assessment of Kosi river embankment program, India

Abstract: Floods impact natural and human systems from multiple dimensions. In the long run, flood control infrastructure such as embankments evolve with the hydrogeomorphic and socio-economic properties and co-produce a new set of risks and vulnerabilities. Assessment of the maladaptive contribution of flood control infrastructure is crucial in redefining risk

and adaptive decision-making. The Kosi River embankment region is home to nearly 0.8 million people facing a trifecta of issues, including regular flooding, scarcity of basic amenities, and loss of livelihood. The study investigates a new set of risks for the communities associated with embankments and socio-economic disparities. The present study analyzed flood vulnerability in 283 villages within the Kosi embankment and the rest of the basin. The analysis incorporates satellite products and census data to exhibit risk through 8 socio-economic and five hydrogeomorphic parameters. The results show that nearly the entire population in the embankment region is susceptible to the effects of flooding. Furthermore, the outcomes reveal the maladaptive consequences of infrastructure solutions, manifesting as socio-economic disparities and exclusionary effects. Residents within the embankment area exhibit notably impoverished socio-economic indicators and livelihood options, significantly lower than outside the embankment. Moreover, the annual flood and extended periods of waterlogging cut off the population from other parts of the state. This new set of risks developed a complex challenge in developing equitable flood resilience solutions. Lastly, the study discussed the innovative methods of risk assessments incorporating narratives, satellite products, and economic loss to improve flood adaptation programs.

Author(s): Tang Luu; Annegret Thieken; Philip Bubeck;

Affiliation: University of Potsdam

Title of abstract: The role of social norms on the implementation of flood risk adaptation measures in Central Vietnam

Abstract: Asia is among the global hotspots in terms of flooding. Research has found that individual flood adaptive behaviour like preparing emergency devices, retrofitting houses, or adapting livelihood, e.g., adjusting crop schedule, can successfully reduce flood impacts. A literature review suggests that perceived social norms could be a potentially highly influencing factor on adaptive behaviour especially in collective societies like Vietnam and should therefore be investigated. Perceived social norms can be categorized into three types: (1) injunctive norms (i.e. an individual's beliefs of the approval by others toward a behavior), (2) descriptive norms (i.e. an individual's beliefs of what others actually do), and (3) subjective norms (i.e. an individual's beliefs of what important others expect the individual to do). While few papers have studied the influence of social norms on flood adaptive behavior generally, none of them has fully explored all three types of social norms. This paper examines the role of three types of social norms, among other theoretically derived factors such as coping appraisals, on flood adaptive behaviour in a developing context. Logistic regression was performed in R based on 355 interviews in Central Vietnam. Results show that beside the important role of coping appraisal, social norms significantly influence the implementation of flood risk adaptation measures. However, different types of adaptive measures are influenced by different types of norms. Specifically, descriptive norms influence preparing emergency devices and retrofitting houses, while subjective norms significantly influence adapting livelihood. Different types of social norms should therefore be considered when communicating flood adaptive strategies to reduce flood impacts.

Author(s): Sry Handini Puteri; dr. Eefje Hendriks; and Nannete Kingma

Affiliation: University of Twente

Title of abstract: Monitoring flood risk evolution in Switzerland Comparing Scientific Flood Risks with Household Perception to Improve Preparedness Strategies in Lumbini Province, Nepal

Abstract: Annual flooding in Nepal has occurred frequently due to the heavy rain during monsoon season. The most frequent flooded area occurred in Terai region, the southern part of Nepal. After the continuous occurrence of flooding, the climate change will add more likelihood for extreme precipitation events that result into more frequent and intense

flooding in Nepal. From a physical analysis standpoint, efforts have been made to reduce the impact of the flood, such as the flood hazard modelling from governmental agencies. At the same time, seeds of research about disaster risk perception are increasing from a social aspect standpoint. This dichotomy provides room to understand how the objective risk and risk perception interplay. This research aims to compare the flood risk with household perception with the case study in Lumbini Province, Nepal. The research will be conducted by combining the result of flood simulation using fastflood with the risk perception analysis derived from the household surveys. The analysis will focus to see whether there are alignments or discrepancies between the objective risk and subjective risk in flood prone area. The analysis will then be used to inform a recommendation for disaster preparedness practices in Lumbini Province.

Author(s): Hedwig van Delden[1,2], Roel Vanhout[1], Amelie Jeanneau[2], Douglas Radford[2], Holger R. Maier[2], Aaron C. Zecchin[2]

Affiliation: (1) Research Institute for Knowledge Systems (RIKS); (2) The University of Adelaide

Title of abstract: Integrating hazard, vulnerability and exposure to simulate dynamic risk profiles in support of strategic scenario development and risk reduction

Abstract: Natural hazards pose a significant risk to societies across the world. This risk will likely increase in the future, due to climate change, urban development and changing demographics. Understanding the range of potential future conditions, and the associated key uncertainties, is essential in designing disaster risk management strategies that holistically account for these drivers.

For this purpose, we have developed a spatially explicit, dynamic, multi-hazard decision support system called UNHaRMED, which calculates dynamic risk profiles as a combination of hazard, exposure and vulnerability. The aim of UNHaRMED is to better understand current and future risk, and assess the impact of (a combination of) risk reduction options under various future conditions. In order to do so, UNHaRMED consists of coupled models integrated into a policy support system. It allows users to understand the impact of climate change, socio-economic developments and risk reduction options on the future evolution of exposure, hazard and vulnerability and hence the resulting risk.

Use of the system will be illustrated through an application to a region in Australia for wildfire and flood risk, for which we developed storylines and simulated associated risk profiles. We found that in a rapidly growing area, the impact of socio-economic development exceeds the impact of climate change, and well thought out spatial planning strategies can substantially reduce future risk.

The application of UNHaRMED showcases its potential in better understanding future uncertainties and leveraging this information to assess the impact of risk reduction options under a range of conditions. Lessons learned from this can then be incorporated in the design of robust and/or adaptive risk management strategies.

Poster presentations

Author(s): Anastasia Vogelbacher; Milad Aminzadeh; Mehdi H. Afshar; and Nima Shokri

Affiliation: Institute of Geo-Hydroinformatics, Hamburg University of Technology, Germany

Title of abstract: How does groundwater level influence the occurrence and frequency of heatwaves?

Abstract: Climate extremes (e.g., 2023 European heatwave) have severe consequences on built and natural environments, posing a threat to human wellbeing and economic resilience. A changing climate is expected to increase the frequency

and intensity of climate hazards but also their impacts might intensify due to increasing exposure and vulnerability. Land-atmosphere interactions have been identified as key drivers for heatwaves, relying significantly on groundwater interactions through its effect on soil moisture, evaporation and thus surface heat fluxes (1, 2). Variation of rainfall patterns and the increase in water demands are expected to influence groundwater dynamics, soil moisture-air temperature feedback processes and subsequently the occurrence of preconditioned compound events, where climate-driven preconditions (rainfall-variability and increase of air temperature), worsen the effects of a hazard (heatwave). The current understanding of groundwater as driver for heatwaves are often limited to regional studies or specific land covers, with few endeavors seeking to characterize global- scale trends and responses. We aim to globally investigate the relation between groundwater levels and heatwave events considering different land cover types and environmental variables by conducting a wide-ranging statistical analysis. We combine a variety of datasets, making use of an existing high resolution groundwater model, climate reanalysis data and remote sensing data. This allows us to distinguish potential drivers of heatwave occurrence which contribute to the development of effective action plans to mitigate climate change's adverse effects.

References:

1) Maxwell, R., Kollet, S., doi: 10.1038/ngeo315

2) Sadeghi, M., Shokri, N., Jones, S.B, doi:10.1029/2012WR01206

Author(s): Asrat Tekle Asresu[1,2]; Elisa Furlan[1,2]; Fabienne Horneman[1,2]; Ngoc Diep Nguyen[1,2]; Silvia Torresan[1,2]; Federica Zennaro[1,2]; Donata Canu[3]; Leslie Aveytua Alcazar[3]; Celia Laurent[3]; Cosimo Solidoro[3]; Antonio Marcomini[1,2]; and Andrea Critto[1,2]

Affiliation: (1) Department of Environmental Sciences, Informatics and Statistics, University Ca'Foscari Venice, I-30170 Venice, Italy; (2) Risk Assessment and Adaptation Strategies Division, Fondazione Centro Euro-Mediterraneo sui Cambiamenti Climatici, Venice, Italy; (3) National Institute of Oceanography and Experimental Geophysics (OGS), Trieste, 34010, Italy

Title of abstract: Climate change multi-hazards impacts on transitional ecosystems and the role of nature-based solutions in maintaining water quality

Abstract: Transitional environments are particularly susceptible to multiple pressures like climate change, land use, or pollution that can lead to the deterioration of their water quality (WQ) and ecosystem services. Nature-based solutions (NBS) can be implemented as adaptation strategies essential for maintaining WQ regulation. Numerical models offer valuable support to understand the WQ dynamics of transitional environments and the influence of NBS, together with the evaluation of the effects induced by interacting stressors and different management schemes. A literature review revealed that current assessment and modeling approaches of the effects of climate change on WQ are characterized by limited integration of multiple ecosystem processes and catchment scale management strategies. Considering these challenges, a new WQ modeling system will be developed for the Venice Lagoon by integrating a vegetation module for saltmarshes into an existing coupled hydrodynamic- biogeochemical model. The vegetation module will represent the effects of NBS, i.e. saltmarsh restoration measures, to evaluate their role in regulating WQ through their influence on the hydrodynamics, and nutrient cycle associated with the distribution, growth, and mortality of saltmarsh vegetation. Onsite monitoring of WQ indicators will be utilized to support and validate the modeling methodology. For this purpose, automatic recording instruments with high temporal resolution have already been placed providing data on different WQ parameters that can be related to hydrodynamic conditions and the ongoing restoration activities. Furthermore, the

designed model will support the evaluation of WQ changes in the Lagoon against future climate change scenarios and several 'what-if' scenarios representing different NBS.

Author(s): Lars de Ruig; Bram Evers; Joost Trommelen; and Danilo Amaral Cançado

Affiliation: Royal HaskoningDHV

Title of abstract: Assessment of multi-hazard disruption losses on road infrastructure – Case studies on three African countries

Abstract: Road infrastructure is essential for economic and social development in developing countries. It enables the movement of goods and people, enhances trade and economic integration, and improves access to basic services and livelihood opportunities. Disruption of road infrastructure can be caused by acute natural hazards or chronic natural hazards that are longer-term climatic shifts. Traditional methods for climate change risk assessments often only take indirect impact as a percentage of direct damage, not capturing local dynamics that cause these impacts. Our study assesses direct and indirect multi-hazard impacts on road infrastructure, applied to three case studies in African countries. The risk assessment approach applies a commonly used Hazard-Exposure-Vulnerability framework for present day and future climatic conditions for multiple hazards, including heat stress, fluvial and pluvial flooding, landslides, dune migration, and siltation. The methodology is extended for indirect, disruptive losses to quantify the impact to passenger transport, and the impact to due to journey delays. The results of the risk assessment are used as input for a Cost-Benefit framework to evaluate the economic efficiency of climate adaptation investment options. Results show that relative indirect impact varies significantly: from 5% of total risk for road sections with many alternative routes, up to over 90% for remote sections. These results not only highlight the importance of incorporating local dynamics, and interactions within a climate risk assessment instead of assuming a prescribed percentage, but also serve as input for the development of appropriate climate adaptation strategies that are tailored to the physical and social context where the road infrastructure is located.

Author(s): Mohamed Abdelfattah; Timo Hartmann;

Affiliation: Technische Universität Berlin

Title of abstract: Enhancing Disaster Resilience with Multi-Agent Deep Reinforcement Learning: Incorporating Social Interdependencies in Community Recovery Strategies

Abstract: After an urban hazard, decision-makers need to plan the repair sequences for the recovery of communities, specifically with the nature of interdependent infrastructures. This study proposes a decision-support process to optimize restoration policies to enhance resilience. It introduces a comprehensive simulation environment that assesses hazard intensity, evaluates system disruption and recovery, and quantifies resilience. To do so, the following steps are applied: 1) From GIS network data, the model classifies interdependencies among infrastructure systems to better understand community interconnectivity. 2) A graph neural network is employed to clarify topology and interdependency data, while 3) optimal repair policies are derived via a multi-agent deep reinforcement learning algorithm. The model incorporates an approach to social diversity within the decision- making process, studying how social factors such as gender, disability, and economic status influence resilience planning. This inclusion aims to address the gap in the literature concerning the impact of diversity on resilience modeling and resource allocation following disasters. The model is validated through Berlin infrastructures by simulating power outage scenarios to assess their effects on critical services, leveraging semi-real data to navigate the challenges of incomplete information. The case study demonstrates the model's effectiveness and efficiency in supporting robust post-hazard repair decisions. This research marks a critical step towards developing high-

performance, resilient decision-support tools that not only account for the physical and operational intricacies of urban infrastructures but also embrace the social dimensions of community resilience.

Author(s): Srividya Hariharan Sudha; Elisa Ragno; Oswaldo Morales-Nápoles; and Matthijs Kok

Affiliation: Hydraulic Structures and Flood Risk, Delft University of Technology, Delft, The Netherlands

Title of abstract: Understanding hydrological response to wet and dry extremes: A case study in the Geul River basin (NL)

Abstract: Floods and droughts, or more broadly, wet and dry extreme events, represent extremes within the same hydrological cycle. The interaction between the physical drivers of these events can exacerbate their impacts when compared to their isolated occurrences. This prompts the question of whether these opposing phenomena should be simultaneously considered in hydrological risk assessments to ensure both water availability and safety. Hence, this study investigates the hydrological response of the Geul catchment, situated in the southeast of the Netherlands, to extreme wet and dry events. Initially, a novel framework is devised to define wet and dry extreme events based on precipitation and temperature. Unlike conventional normalized climate indices, such as the standardized precipitation index prevalent in the literature, this framework preserves the magnitude of event characteristics, including precipitation intensity and average temperature. Subsequently, the study explores the joint occurrence and transitions of opposite extreme events within the water year using probabilistic dependence models. Finally, the Geul catchment's hydrological response to the interplay between these identified opposite extremes is simulated using the wflow_sbm model. This study provides insights into the necessity for an integrated water management approach where both wet and dry events are simultaneously considered in the risk assessment process.

Author(s): Annika Maier; Andreas Schaefer; James Daniell; Johannes Brand; Bijan Khazai; and Trevor Girard

Affiliation: Risklayer GmbH

Title of abstract: Volcanoes and tsunamis – multi-risk scenarios for tourism in the Canary Islands

Abstract: While multi-hazard events may be less frequent compared to single-hazard occurrences, they present significant economic and socio-economic threats. Volcanic eruptions, as inherently multi-hazard events, can occur over an extended period, lasting several months or even years. Should another natural disaster coincide within the affected region, municipalities and decision- makers must implement adjusted measures to effectively mitigate the consequences on lives, economies, and infrastructure.

Specific case studies and scenarios based on known historic multi-hazard events as well as scientifically probable events, contribute substantially to a better understanding of such multi-hazard events and the corresponding resulting multi-risk factors. This presentation showcases a possible multi-hazard event affecting the Canary Islands. The scenario involves a tsunami initiated south of the coast of Portugal similar to the 1755 Lisbon earthquake and tsunami, coinciding with an ongoing, active volcanic eruption. The scenario is simulated for volcanic eruptions at Teide and Cumbre Vieja, respectively. Within the framework of this study, a comprehensive multi-risk assessment with an emphasis on the impact on the tourism sector is performed.

The exploration of potential multi-hazard events, such as the one presented here for the Canary Islands, outlines the demand for proactive multi-risk management strategies and resilient planning in vulnerable regions, especially those heavily dependent on tourism.

Author(s): Wiebke Jäger[1], Tristian Stolte[1], Timothy Tiggeloven[1], Marleen de Ruiter[1], Kelley De Polt[1,2], Sophie Buijs[1], Judith Claassen[1], Nicole van Maanen[1], Davide Ferreira[3], Ngoc Diep Nguyen[3], Silvia Torressan[3], Rene Orth[4], James Daniell[5] and Philip Ward[1,6]

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Title of abstract: Integrating Exposure and Vulnerability Dynamics in Forward-Looking Multi-Hazard Risk Modeling: Examples of Qualitative and Quantitative Functions

Abstract: While long-term trends in exposure and vulnerability are increasingly being recognized and incorporated into risk modeling, changes of these variables can also arise due to interactions between multiple hazards, risk reduction measures to address those hazards or during long-lasting hazard conditions. Within the MYRIAD-EU project we are collecting empirical evidence of such dynamics in an online database and developing methods that allow their explicit representation in forward-looking risk models.

Here we compare, discuss and consolidate key results from multiple studies within the project that use various qualitative and quantitative data sources and approaches. These include use of traditional disaster loss and damage databases as well as novel data sources such as night-time lights and online media, enhanced with regional stakeholder narratives that are collected in interviews. The studies apply various techniques including statistics, disaster forensics, systematic literature reviews, and machine learning methods.

We highlight our collective empirical evidence on dynamic exposure and vulnerability and translate it into functions for forward-looking risk assessment. In particular, we focus on determining time-dependent intensity-damage functions, social vulnerability indicators and exposure values. As an additional measure of dynamic vulnerability, we compare hazard return periods and recovery times. The resulting functions can be integrated in existing risk modelling approaches and applied to a diverse range of case studies. We envision to test and showcase this within the MYRIAD project in the future.

Session 2: Learning from the past: historical perspectives and 'success stories' of DRR

Author(s): Benjamin Poschlod

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Title of abstract: Sub-daily extreme rainfall triggering multiple hazards in Alpine Germany in July 2021 – have we experienced “recent climate change”? Implications for local risk management.

Abstract: The storm “Bernd” hit Alpine south-east Germany on 17 July 2021. Amplified by orographic lifting, it induced intense short- duration rainfall triggering multiple hazards: flash floods, debris flows, landslides, pluvial and riverine flooding. Damage to private and public property (including world's oldest artificial ice bobsleigh track), long-term restrictions on mobility, and one death are documented.

I show the advantages and shortcomings of observational data (rain gauges, rain radar, river discharge) for sub-daily extremes and the according challenges for a spatio-temporal event monitoring reflecting multiple hazards and impacts. I apply the unique high-resolution (0.11°) single model initial-condition large ensemble (SMILE; 50 members) of the CRCM5 to identify shifts in the occurrence probability of the driving rainfall event. Compared to a historic time period (1970–1999), the driving rainfall event is found to occur 3 times more likely under current climate conditions (2006–2035). In other words, I extend the framework of probabilistic event attribution, comparing the probabilities of current climate and recent past, rather than pre-industrial conditions. This is more relevant for risk management, as experience and observational data from the recent past were crucial to the design of infrastructure and still influence current planning.

Even though a careful evaluation of the CRCM5 shows good agreement for extreme rainfall, this finding is to be interpreted considering model uncertainty, as the SMILE only uses a single climate model. On the other hand, the 50-member setup covers the range of internal climate variability and enables robust extreme value statistical assessment due to the large sample size, recommending SMILEs as valuable tool for risk modellers.

Author(s): Ana M. Petrović

Affiliation: Research Associate at the Geographical Institute "Jovan Cvijič" of the Serbian Academy of Sciences and Arts

Title of abstract: Recent Torrential Floods in Serbia from a view of a century-long story

Abstract: In Central Serbia, south of the Danube and Sava Rivers, torrential floods are the most frequent natural hazards. The series of large-scale torrential floods in the last decade starting from the cataclysmic May 2014 and finishing with June/July 2023 are presented. The May 2014 torrential floods occurred in plenty of small catchments and affected more than 1.6 million people (22 % of the total population) in 38 municipalities in Central and Western Serbia, took 51 human lives, and caused damage to more than 1.6 million Euros. Five months later in the same year, Eastern Serbia experienced an extreme event of debris flow in the small settlement of Tekija and torrential floods in many other settlements taking 5 human lives. The rainy spring of 2023 with extreme rainfall episodes caused a long series of torrential floods followed by victims. The past 2014–2023 decade is perceived from a view of a longer story—the Inventory of torrential floods in Serbia (1915–present) providing the spatial and temporal characterization of torrential flood phenomenon in Serbia. The categorization of flood events on the base of material damages and the death toll in this period is presented. One of the most important lessons learned with a view of the flood death toll and mitigation of larger damages is that education focusing on natural hazards and risks in elementary and secondary schools as well as for adults needs to be fostered, especially for those living in areas prone to torrential flooding. Continued gathering of information on this type of natural hazards is essential for improving the system of preventive, organizational, and other measures, as well as instruments for mitigation of torrential flood consequences to an acceptable level.

Author(s): Mathilde Bossut; and Ashish Tyagi

Affiliation: Frankfurt School of Finance / ETHZ

Title of abstract: Financial recovery after a flood event: Evidence from French manufacturing SMEs

Abstract: In Europe, global climate change induces a rise of flooding risks with resulting economic damages projected to increase 4-fold for riverine floodings and 10-fold for coastal flooding. Such extreme events have important repercussions for local enterprises. Traditionally, impacts of floods on firms have been measured by the balance sheet size. Recent literature, however, presented diverging results from evidence of creative destruction to a 2% decrease in assets after two years.

We argue that such measure might be biased as accounting practices might prevent a balance sheet from reflecting flood-induced damages (e.g., no property re-evaluation, replacement with higher-valued machinery and equipment or insurance payout). Furthermore, measuring firm-level total assets ignores alternative coping strategies such as compensation with capital buffers or raise of borrowed or shareholder capital, that ultimately affect financial performance.

We geolocalised 500,000 firms in France. Using the French national register for national disasters and the distance to coast and rivers, we identify about 10,000 flood-affected firms, a third of which has been affected more than once. We used propensity score matching estimated using pre-flood covariates. We fit a linear regression model to estimate the average effect of exposure to floods on balance sheet size as well as profitability, solvency, and liquidity ratios.

We find that, if floods are indeed associated with losses in total assets, it leads to lower solvency and lower profitability up to three years after the flood event. We find evidence of competing strategies in financial recovery in the aftermath of floods, providing valuable insights for corporate strategies in flood-prone areas and disaster relief planning.

Author(s): N. Nithila Devi[1]; Nivedita Sairam[1]; Abinesh Ganapathy[1,2]; Sergiy Vorogushyn[1]; and Heiko Apel[1]

Affiliation: (1) Section Hydrology, GFZ German Research Centre for Geoscience, Potsdam - 14473, Germany; (2) Department of Hydrology, Indian Institute of Technology Roorkee, Roorkee 247667, India

Title of abstract: Impact of the disappeared water bodies on the rising flood risk in the Chennai Metropolitan Area in India

Abstract: The Adyar River basin constitutes the southern portion of the Chennai Metropolitan Area (CMA). It is prone to recurrent flooding during the northeast monsoon season. Lack of sufficient drainage and the low-lying terrain exacerbate the flood risk. In particular, the floods of 1985, 2005 and 2015 inflicted severe damage to lives and property. The recent 2015 flood affected a total area of 39.5 km2 and caused an estimated ~500 fatalities and $ 3 billion of damage. CMA is a business hub, and the population is expected to grow in leaps due to urban migration. On the downside, rapid urbanization has culminated in unregulated settlements in the flood plains of the city's rivers, wetlands and water bodies.

Around 20 water bodies (6.8 km2) that were present on the floodplains of the Adyar River in the year 1911 had transitioned into concrete settlements. Nevertheless, the impact of retention storage that was offered by these waterbodies in flood moderation remains unstudied. Therefore, we simulate the 2015 flood event under two scenarios - (1) the true event - based on the existing terrain and (2) a counterfactual event - assuming that the historical water bodies were preserved at the time of the event. The impact is quantified in terms of inundated areas, flood intensity (inundation depth, duration and velocity of flood water), built-up areas (including socio-economic characteristics) and the population exposed to the flooding risk, highlighting the feedback effects between urban growth and rising flood vulnerability. A subgrid-based local inertial hydraulic model is utilized to capture the flooding in the complex high-resolution urban terrain. The quantification of the role played by the disappeared water bodies in flood moderation is valuable to flood risk management practi

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Author(s): Claudia Berchtold

Affiliation: Fraunhofer Institute for Technological Trend Analysis (INT)

Title of abstract: Synthesising wildfire event reviews: changes in wildfire regimes and resulting recommendations

Abstract: A lot of research is conducted on the review of past fire events in Europe including extreme events such as those in Portugal in 2017 (e.g. Castellnou et al. 2022; Almeida et al. 2022; Pronto et al. 2023). However, the reports vary in their geographic focus (from Mediterranean to the whole of Europe), the type of events analysed (large/critical vs. extreme events), the temporal scope (annual analysis vs. insights over the past seven years) and the types of conclusions and recommendations they draw (from the local, operation context to European investment funds and support mechanisms).

This mosaic review of events and recommendations currently lacks a synthesis in the form of joint and coherent recommendations towards science, policy and practice at multiple geographic scales and towards different stakeholders, ranging from responder organisations to land managers and infrastructure providers. Our work hence synthesises the insights from existing research in order to develop such recommendations towards different stakeholders. The complexity of wildfire risk might thereby allow to extract (procedural) risk management insights for other hazards.

Author(s): Md Moynul Ahsan;

Affiliation: Department of Real Estate Development and Management, Ankara University, Ankara, Türkiye.

Title of abstract: A Critical Analysis on Disaster Housing Policy Before and after Kahramanmaraş-Centred Earthquakes in Türkiye.

Abstract: This study examines the disaster housing policies and their applications in Türkiye with special emphasis on before and after the Kahramanmaraş-centred earthquakes on February 6, 2023. Over the last two decades, massive loss and damage have been happening (more specifically earthquakes) in Türkiye. After the Gölcük earthquake in 1999, the Turkish government took many policy actions but in reality, these policies could not ensure desired satisfactory results. Even, after the Kahramanmaraş- centred earthquakes (entitled as “disaster of the century”), the Turkish government has taken various policy actions starting from aid to constructing and supplying housing as well as ensuring affordable housing for the disaster victims. In this study, secondary sources have been used focusing on the state of disaster housing (more specifically disaster housing of Housing Development Administration- HDA) in Türkiye; reviewed Twelve 5-year development plans; housing and disaster policies, plans before and after the earthquake with a critical perspective; and later on policy shift from adequate supply to affordability issues to disaster resiliency have been evaluated. Though HDA ensures various projects and applications that are carried out in line with its own standards but it is still a question of resiliency. This study has focused the aspects of disaster housing policies and necessary policy prescriptions with a retrospective and prospective perspective. This study tries to find out what new government interventions have been taken and provides answers of the needed policy action and its application which is helpful not only for Türkiye but also for other similar disaster-prone countries in the world.

Author(s): Hamed Seddighi

Affiliation: University of Groningen

Title of abstract: Disaster Risk Reduction in Iran in the last 100 years: A critical policy analysis

Abstract:

Background

During the past 20 years, Iran has been experiencing a significant increase in the occurrence of disasters mainly due to the emergence of anthropogenic climate change. This paper aims at analyzing the trend of national budget allocation in Iran

over the last 100 years to evaluate the focus of the Iranian state on the four phases of Preparedness, Mitigation, Response, and Recovery and propose modifications.

Methods

It is used a critical policy analysis with what's the problem represented approach. In this approach is focused on problematization and policy gaps. The most important policy statement in any government is the budget. During the first screening, 1028 regulations and laws were found from 1910 to 2020. After full text screening, 494 regulations and laws related to budget allocation to disasters were analyzed.

Results

The Iranian government has spent around 29 billion USD on disasters during the last 100 years. Droughts, earthquake and flood have costs the government more than other disasters, accounting for more than 14, 6.9, and 6.1 billion USD, respectively, in the allocated budget. Most of the Iranian government expenditure during the last 100 years on various disasters such as drought, flood, earthquake, and COVID-19 has been spent on involuntary costs including Response and Recovery. Mitigation and Preparedness are the two critical disaster management phases with very small shares of national budgeting.

Conclusions

From policy audit and policy gaps it is concluded that Iranian governments during last 100 years, problematized the issue of "disasters strike" and not "disasters' risks". In time of disasters, governments tried to solve the issues or impacts of disasters with budgeting to response and recovery.

Author(s): Kun Arsanti Dewi[1] ; Prof. Kun Harismah, Ph. D[2]; Nurul Aini Sinta Dewi[1]; Wahidin Sektianto[3]

Affiliation: (1) Housing and Settlement Areas Agency Magelang Municipality – Indonesia; (2) Universitas Muhammadyah Surakarta – Indonesia; (3) Regional Disaster Management Agency Magelang Municipality - Indonesia

Title of abstract: The availability of government public facilities that can be utilized in receiving and serving evacuees of volcano eruption, case study: the readiness of Magelang municipal government to accept evacuees of Merapi volcano, central Java

Abstract: Volcanic eruption disasters can be classified as rare disasters that occur regularly every year, but can still be detected when they will occur. Serving evacuees affected by volcanic eruptions is one of the responsibilities of a government. Not all governments are financially capable of preparing special public facilities to serve evacuees. The eruption of Merapi Volcano in Central Java on October 26, 2010 resulted in 389 deaths and 507,849 evacuees. A total of 3,749 evacuees fled to the administrative area of Magelang Municipality. The Magelang Municipal Government at that time could not serve it perfectly, this was because the number of existing public facilities could not accommodate the number of evacuees who came. Apart from that, at that time the Magelang Municipal Government, which is around 26 km from the disaster-prone area of Merapi Volcano, had not yet mapped out existing public facilities that could be used to accommodate evacuees from the eruption of Merapi Volcano. This study was created to find out whether Magelang Municipal Government is able to serve the arrival of evacuees from the eruption of Merapi Volcano in the coming years with several public facilities that have been built. The research uses qualitative research methods, with persuasive narrative writing so that readers can feel the same view of things seen by the author

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Poster presentations

Author(s): Nour Samaro

Affiliation: Civil systems engineering department, Technische Universität Berlin, Berlin, Germany

Title of abstract: Assessing Overheating Risks and Mitigation Strategies for an Existing Residential Building under Extreme Future Conditions

Abstract: In the midst of persistent and intense heatwaves in the Mediterranean region throughout July and August 2023, this research seeks to evaluate and address the risk of overheating in existing residential structures in three distinct climate zones (2A, 3A, and 2B) in the middle east region. The analysis considers both historical and projected climates (2035, 2065, and 2090) by employing ASHRAE 55 standards. The findings indicate that the current design of buildings, characterized by low energy efficiency prevalent in Palestine, exposes inhabitants to overheating risks, particularly in climate zone 2B. Improving the energy efficiency of building envelope features, along with implementing additional measures like exterior shading and cool roofs, proves effective in achieving thermal comfort in the warmest rooms within climate zones 2A and 3A, even in the face of future climate changes. However, for climate zone 2B, reaching the thermal comfort threshold may require the incorporation of mechanical cooling alongside passive mitigation strategies.

Author(s): Sara Carolina Soares Guerra Fardin[1,2]; Silvio Jorge Coelho Simões[1]; and Tatiana Sussel Gonçalves Mendes[1]

Affiliation: (1) IFES; (2) UNESP

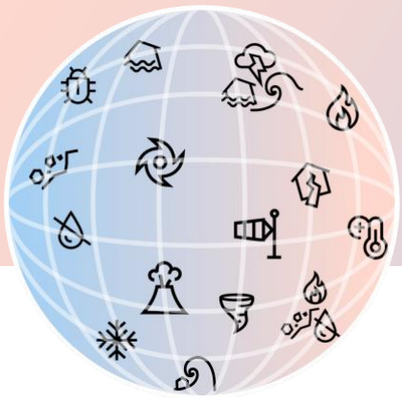
Title of abstract: Urban Multi-Hazard Research Analysis: Systematic Review

Abstract: The use of the term multi-hazard and its variations in the literature is not new and, despite this, awareness of the importance of addressing multiple hazards in urban environments has grown over the last few years. The Sendai Framework for Disaster Risk Reduction 2015-2013 indicates the needs for a multi-hazard and multisectoral approach to achieve disaster risk reduction and highlight the idea of multi-hazard management of disaster risk at all levels. Embedding multi-hazard analysis into urban planning includes not only Disaster Risk Reduction, but the comprehension of how to integrate the existing hazards. Since urbanization modifies living patterns, hazard damage potential can be amplified by human activity. According to the Global Assessment Report of 2022, the outcome of a hazard event depends on how the elements of the affected systems interact with each other. In this context, this study conducted a systematic review of urban multi-hazard research in recent years. A search was conducted on the Web of Science database, resulting in documents from 1995 to 2023 and 190 documents, showing how narrow are urban multi-hazard research. Most of the studies (166 documents) were publicized after Sendai Framework publication, and are still growing. Results showed that the main studied topics were related to Vulnerability, Resilience, Multi-hazard, Disaster Risk Reduction, Earthquake and Urban Resilience, with International Journal of Disaster Risk Reduction and Natural Hazards and Sustainability being the most relevant sources of publication. Research also indicated that authors of different institutions have few connections, demonstrating a need to strengthen multi-hazard research efforts between researchers. Trends in the research highlight terms such as 'Disaster risk,'

Author(s): Hendrik Bruns

Affiliation: University of the Bundeswehr Munich

Title of abstract: Improving the Evaluation of Civil Protection Exercises



Abstract: The prevention phase is of particular importance in the strategic crisis management cycle. Response capacities, decision- makers and the general public must prepare themselves in the best way possible for crises that cannot be avoided. Civil protection exercises provide a controlled framework within which future crisis scenarios can be practised. Depending on the focus of the exercise, the exercises can take on different formats and range from discussion-based approaches to full-scale exercises with deployed forces. As part of its civil protection mechanism (UCPM), the European Union has been promoting the planning, implementation and evaluation of full-scale exercises for years in order to practise cross-border assistance in major emergencies. At a national level, strategic crisis management exercises have been established in Germany, for example, which are intended to address decision-making at an official level (LÜKEX).

In both cases, the systematic evaluation of these exercises has become increasingly important in recent years. Particularly in the face of cyclically occurring extreme events, the realisation has matured that although such exercises identify the appropriate scenarios, the findings are often not systematically recorded after the exercise is completed, are limited in their informative potential or are not implemented in further progress. This raises questions about the collection and evaluation of exercise findings, which include the type of methodology, the application during the exercise and the implementation afterwards. The contribution therefore presents current evaluation approaches in the context of civil protection exercises at European level and provides an outlook on research projects that address and further develop this area.

Author(s): Ruben Weesie[1]; Anne van Loon[1]; Moses Mwangi[2]; Johanna Koehler[3]; Melanie Rohse[4]; and Marlies Barendrecht[5];

Affiliation: (1) VU Amsterdam; (2) SEKU Kenya; (3) WUR Wageningen; (4) ARU Cambridge; (5) King's College London

Title of abstract: Learning from the past through participatory storytelling: history of droughts and floods in Eastern Kenya

Abstract: With a case study in Eastern Kenya, we would like to show how learning from past disasters can be done in contexts where measurements and direct observations are not available. Using participatory storytelling, we present a historical timeline (1940s-2020s) of droughts and floods from a semi-arid seasonal river basin. Based on oral histories, we would like to demonstrate how these stories provide 1) insights on the underlying trends that have led to a situation of recurrent droughts and floods today, 2) changes in drought and flood experiences; and 3) important lessons for contemporary and future disaster risk strategies in African drylands.

Author(s): Heather J. Murdock; Anna Heidenreich; and Annegret Thieken

Affiliation: Institute of Environmental Science and Geography, University of Potsdam, Germany

Title of abstract: Flood early warning and flood damage: analysis of survey data for the July 2021 flood in Belgium

Abstract: In July 2021, a heavy rainfall event affected Germany, the Netherlands, Luxembourg, Belgium and other countries. Over 200 fatalities have been recorded due to this flood event and 39 of these were in Belgium and within the province of Wallonia in the south east of the country. Issues with flood early warning and high levels of damage were reported. For this event we address the following questions; were people in Belgium were warned in time and how effective flood warnings are linked to flood damage. To determine what warnings reached residents and what impacts were experienced, a short survey was made available online from June 9th 2023 to September 9th 2023. A total of 550 people participated in the survey which was advertised using Facebook.

In this study we investigate the performance of the flood early warning system to determine which proportion of people were warned and how were they warned. We are also interested in the levels of preparedness, situational knowledge,

response, and damage reported and how these are linked to the warnings. The results for Belgium will be compared to similar studies in Germany and the Netherlands.

Session 3: Science for policy and practice: synergising disaster risk reduction and climate change adaptation

Author(s): Annegien Tijssen[1]; Philip J. Ward[1,2]; Jim Lily[1]; Niels Vlaanderen[3]; and Babette Gräber[3]

Affiliation: (1) Deltares; (2) VU Amsterdam; (3) Ministry of Infrastructure and Water Management, the Netherlands

Title of abstract: Showcasing existing practices, tools and methods to enhance coherence and synergy between DRR and CCA

Abstract: In our study, we identify common themes in the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals and the Paris Agreement that support a coherent approach to Disaster Risk Reduction (DRR) and Climate Change Adaption (CCA). In addition, we distill opportunities for bridging the gaps between these policy domains based on a literature review. Capitalizing on these opportunities for a coherent approach and for breaking the silos, we will present good practices, tools and methods that can be used to ensure that CCA measures do not inadvertently increase disaster risk, and that DRR measures are adaptive in nature.

A comparison between the Sendai Framework for Disaster Risk Reduction, the Sustainable Development Goals and the Paris Agreement makes it abundantly clear that these global agendas have been developed in different policy domains. This has led to fragmented responses, hindering our ability to holistically reduce risks and promote climate resilience.

However, much can be gained by fostering collaboration and coherence among these interrelated policy domains. Promoting the necessity of implementing CCA with a DRR mind-set, and vice versa, should enhance collaboration between these two policy domains and hopefully eventually lead to an integrated approach to DRR and CCA.

Author(s): Carolyn Hayles

Affiliation: Cardiff Metropolitan University

Title of abstract: Embedding climate adaptation policy within the historic environment sector

Abstract: The adaptation pathway approach is a response to the increasing awareness that climate adaptation requires dynamic, long term and transitional approaches to decision making that can both accommodate uncertainty and avoid future maladaptation. In addition, it is acknowledged that asset stakeholders need tools to move beyond strategic planning towards dynamic action. The adaptation pathway approach is designed to facilitate knowledge sharing in support of climate adaptation decision- making. It identifies the decisions that need to be taken now and those that may be taken some time in the future. The approach supports strategic, flexible and structured decision-making that promotes effective knowledge management. This action research project, funded by the UKRI through its Policy Fellowship scheme aims to

embed climate adaptation pathway thinking within Welsh Government, using Cadw, its historic environment branch, as a test bed. Practical application is essential to the development of the training, toolkits and guidance for Welsh Government. Historic environment case studies include buildings, monuments, sites, places, areas and landscapes of historic interest. These assets are serviced by a multidisciplinary group of people, engaged with and impacted by a range of policy areas. Therefore, the fellowship has the potential for significant reach and research outputs will help to deliver the goals of the Well-being of Future Generation (Wales) Act. The research outputs to be shared at the conference include the development of a methodology for capturing climate impacts and hazards for Cadw sites, practical case studies and a discussion on approaches to communicating pathway outcomes that support better communication and consultation with wider stakeholder groups.

Author(s): Julius Schlumberger[1,2]; Marjolijn Haasnoot[1]; Jeroen C.J.H. Aerts[1,2]; Veerle Bril[2]; Lars van der Weide[2]; and Marleen de Ruiter[2]

Affiliation: (1) Deltares; (2) VU Amsterdam

Title of abstract: Unravelling the complexity of multi-risk systems and adaptation pathways

Abstract: Disaster Risk Management (DRM) is increasingly complex due to interacting climate risks from concurrent hazards. The Dynamic Adaptive Policy Pathways for Multi-Risk (DAPP-MR) framework has been introduced to assess DRM policies' effectiveness under deep uncertainties - such as future climate change - and to develop integrated adaptive strategies considering interactions across hazards, sectors, and time. So far, no use cases were available that provide evidence regarding the utility of DAPP-MR.

In this presentation we examine DAPP-MR through a synthetic multi-risk modeling case study, focusing on DRM pathways for managing flood and drought risks across different sectors for a period of 100 years. The case study, inspired by a Dutch river delta, accounts for multi-hazard interaction effects such as including co-occurring or preceding droughts amplifying flood risk, and consecutive flood events as well as multi-sector dynamics. While providing insights into the model development process, the result analysis and conclusions, we also discuss the challenges and benefits of combining multi-risk thinking and climate change adaptation decision-making approaches and the implications of multi-risk dynamics on trade-offs and synergies of different risk management strategies.

Author(s): Bethany Liss[1]; Lena Grobusch[1]; Mia Wannewitz[1]; Dina Magnaye[2]; Sheilah Napalang[2]; Carmeli Chaves[2]; and Matthias Garschagen[1]

Affiliation: (1) Ludwig-Maximilians-University Munich (LMU); (2) UP-SURP

Title of abstract: Stay or leave? Mainstreaming in-situ upgrading vs. planned resettlement in high-risk contexts - Lessons from the Philippines

Abstract: The UN estimates that 1 billion people presently live in informal settlements worldwide. One hot debate in climate adaptation sciences questions whether upgrading or relocating such settlements results in more long-term climate resilience. Metro Manila, the capital of the Philippines, is an ideal case to assess the ins and outs of upgrading vs. resettlement as it is home to roughly 500,000 informal settler families, who are exposed to various climate change impacts. The Philippines' long history and collective experience coping with such challenges has made the country a leader in integrating the risks of climate change and natural hazards into their policy and planning documents at all governance scales. We conducted an in-depth qualitative document analysis, complemented by interviews, to understand how strategies on upgrading vs. resettlement of informal settlements have been addressed in conjunction with CCA and DRR.

Though well mainstreamed on paper, inconsistencies were identified regarding the implementation of upgrading and resettlement strategies. Our findings suggest that roles and responsibilities are insufficiently defined, delegated, and cascaded to stakeholders, alongside lacking financial capacity, technical knowledge and operational capacity, and discontinuity due to political cycles. These insights are crucial for optimizing the mainstreaming process to achieve just outcomes in land use planning for all parties as well as vertical and horizontal policy integration. Future research should focus on how to more clearly define roles and responsibilities for upgrading and resettlement strategies given the current gaps between policy and practice, especially considering the provisions on responsibilities made in the Sendai Framework and New Urban Agenda.

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Title of abstract: A system dynamics approach to understanding urban flood risk and barriers to adaptation under climate change using causal loop diagrams: Case study of the city of Hamburg, Germany

Abstract: While cities are facing increasing challenges of flood risk due to combined effects of climate change and socioeconomic development, understanding of the complexity of urban flood risk is still limited, hampering decision-making and effective urban adaptation planning. A socio-ecological system (SES) perspective offers a promising approach to analyze risk as a non- isolated entity by recognizing human and natural systems as complex and coupled structures and considering their interactive dynamics.

This study applies a qualitative system dynamics modeling framework to holistically investigate urban flood risk under climate change and barriers to adaptation in a SES using the city of Hamburg as a case study. The study deals with urban flood risk in the context of 'water from 4 sides' taking into account interactions within and among determinants of risk. We present our stepwise approach, in which a qualitative system dynamics model was developed based on interdisciplinary expert knowledge. Disciplinary mental maps were created in various group interviews, followed by the development of an overall group model to integrate the different disciplinary perspectives. In our model analysis, particular emphasis is placed on identifying and highlighting the reinforcing feedback loops that perpetuate and hinder the adaptation process and reinforce flood risk in the city. We found that the visual value of these system dynamics modeling tools is promising for further discussion with local stakeholders, linking science, policy and practice. Finally, we will give an outlook on how we intend to use the tools to stimulate a joint discussion with local authorities and practitioners in the debate on sustainable adaptation measures that offer the potential for transformational change.

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Title of abstract: How to consider climate change in flood risk management? – Current practices in Germany and the Benelux countries

Abstract: In the coming decades, river floods are expected to change in frequency and intensity due to climate change. The flood hitting Europe in July 2021 might be considered an example of the change that is unfolding: attribution studies

estimated that the occurrence probability of comparable rainfall events is now significantly higher than in a 1.2°C colder climate. In NW Europe, river floods have been increasing over the last decades and are also expected to increase in future. Other studies suggest that only rare floods are increasing in magnitude, while frequent floods might decrease, which could be particularly challenging for flood risk management (FRM). The event in 2021 also demonstrated the need for dealing with transboundary floods. Floods do not obey administrative borders, and so also FRM should take transboundary approaches. The aim of this study is to provide an extensive overview of how climate change (CC) is currently considered in FRM in Germany and the Benelux countries. It addresses how CC is integrated in flood estimations and how this transfers to management practices. Through literature review and stakeholder interviews, the current statuses are identified and compared. For example, the Netherlands estimated four nationwide flood risk scenarios (high/low level of CO2, wet/dry future) through a defined model set. In Flanders (BE), regionwide flood hazard and risk maps are developed for a high impact climate scenario. In contrast, in Germany only two regions have specified approaches for considering CC in FRM, while others are waiting for an improved knowledge base. Establishing a well-founded overview of current practices, demands and concerns of stakeholders is an important first step towards a more climate-resilient transboundary FRM in the study region.

Author(s): Sarah Michaels

Affiliation: University of Nebraska-Lincoln

Title of abstract: Utilizing Variegated Uncertainty to Integrate Disaster Risk Reduction and Climate Change Adaptation

Abstract: A nuanced and variegated appreciation of uncertainty is needed to move towards a holistic approach to capturing synergies across Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) bridging science, policy and practice. This is because those engaged in the complex, multi-facetted, interlinked world of DRR and CCA rarely confront a shared, single form of uncertainty. Consequently, a means is needed to understand how different forms of uncertainty contribute to, or hamper, creating synergy and integration between DRR and CCA. An important first step in doing so is to recognize the range of forms of uncertainty associated with three drivers of potential harm salient to DRR and CCA and creating synergy and integration between them: hazard, exposure and vulnerability. The range of forms of uncertainty can be identified for each of these drivers by asking three sets of questions. (1) Where is the uncertainty situated? This determines which people in what capacities have how much ability, if any, to manipulate the causes of uncertainty. (2) How much uncertainty is there? Are there clear indicators about outcomes and future conditions because there is low uncertainty or not because there is high uncertainty? (3) What is the nature of the uncertainty? Is it because of rectifiable imperfections in knowledge or because of inherent, irreducible variability? The answers matter because different answers suggest alternative paths to address diverse forms of uncertainty in science, policy and practice salient to creating synergy and integration between DRR and CCA. This is illustrated by the DRR and CCA planning undertaken for the administratively and culturally significant vicinity of The National Mall, Washington, District of Columbia, United States.

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Title of abstract: Looking back, Looking forward: INFORM suite provides opportunity to design country tailored climate resilient pathways

Abstract: Despite progress in crisis risk management approaches, risk of natural and anthropogenic crises is growing at an unprecedented rate globally due to various factors. Building crisis risk resilience requires effective disaster risk reduction management aligned with sustainable development and climate change adaptation. Sound risk-informed policy and investment decisions can help societies break free from ongoing crises and accelerate development and adaptation efforts to reduce future vulnerabilities. INFORM is a suite of quantitative multi-hazard products that focus on understanding, analyzing, and monitoring major current and future risk drivers as well as ways to cope with residual impacts. Insights into how the structural factors that result in crises evolve are presented using an analysis of risk trends over the last decade from the INFORM Risk Index and projected climate change impacts by mid 21st century from INFORM Climate Change. The findings illustrate that most regions and countries are steadily progressing in capacity building and transformational processes, but many are still not able to absorb the effects of severe shocks and emerging hazards. Africa and low-income countries largely failed to tackle increasing crisis risks in the last decade, and will be worst affected by amplified climate-related hazards. Therefore, they will require the largest investments in crisis prevention, risk management and climate change adaptation to avoid potentially devastating risk increases in future. Combination of INFORM products helps creating synergy and integration between DRR and CCA communities in providing better insights on how to address climate resilient pathways tailored to country's predisposition across science, policy and practice.

Poster presentations

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Affiliation: (1) University of Groningen; (2) Wuhan University;

Title of abstract: Urban Flood Risk Perception and Trust: Insights from a Survey in Wuhan, China

Abstract: The extreme precipitation poses challenges to urban safety and sustainability. Preparing people well is imperative for improving urban resilience against flood risks. This study focuses on residents' flood risk perceptions, exploring influencing factors, with a particular emphasis on mechanisms validating trust in public flood protection capacity, flood risk perception, and flood risk communication. Utilizing a literature-based analysis, we propose a comprehensive framework and present four hypotheses on interrelations among influencing factors of flood risk perception. Wuhan is selected as a case city facing complex risks of urban flood. Analyzing residents in high and low-risk areas of Wuhan, China, through cluster sampling, flood risk maps, and questionnaires, we gather 568 valid responses. Employing Partial Least Squares Structural Equation Modeling, we establish a structured framework to examine reciprocal relationships between flood risk perception and its influencers. Mediation analysis confirms complex mechanisms linking trust, risk perception, and risk communication. Analysis of variance compares high and low-risk area residents' flood risk perceptions, and correlation analysis compares objective and perceived flood risks of the urban residents. The study's theoretical significance lies in further elucidating a testified structural framework of inflicting factors of flood risk perception. In practical terms, it clarifies trust, risk perception, and risk communication mechanisms, facilitating policy improvements, enhancing risk communication, and contributing to a flood-safe city with social resilience. Ultimately, this research improves understanding of residents' flood risk perception mechanisms within China's governance model and provides localized insights.

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Title of abstract: Risk-Tandem Framework: enhancing risk governance through knowledge co-production with DRR and CCA actors

Abstract: Decision-makers working to adapt to climate change and strengthen disaster resilience to extreme weather and multi-risk events experience complex, interconnected, and systemic challenges, which require novel approaches to enable collaborative and inclusive governance that fosters transformation. The DIRECTED project works with four Real World Labs (RWL) led locally by government agencies, practitioners and private-sector partners, representing multiple risks across Europe. RWLs aim to reduce vulnerability to extreme weather events and foster disaster-resilient societies by promoting interoperability of data, models, communication and governance on all levels and between all actors enabling disaster risk reduction (DRR) and climate change adaptation (CCA). Risk-Tandem is a novel framework being developed in DIRECTED to support the RWLs to co-produce knowledge, understand the governance system and capture opportunities for synergies and integration across DRR and CCA actors' knowledge, policies, and practice. RWLs facilitate a stakeholder engagement process through interactive co-production workshops with scientists, modellers, decision-makers, private sector representatives, practitioners and civil society organizations. In parallel, RWLs build an understanding of existing governance systems in relation to the actor networks, policy/ legal frameworks, and resources, as well as the mechanisms/processes concerned with how relevant risk information is collected, analysed and communicated, and decisions are taken. Risk-Tandem aims to continuously strengthen the capacity of RWL hosts and participants to understand the governance context, identify problems and bridge scientific models and data with needs to identify integrated DRR and CCA solutions for enhanced resilience.

Author(s): Stefan Kienberger[1]; Mainetti, L.[1] ; Schinko, T.[2]; Spiekermann, R.[1]; Themessl, M.[1]; Fresolone, A.[2]; Glaser, A.[1], Mayer, K[1], Heller, H.[3]; Altmann, M.[3]; Thaler, T.[2]; Leitner, M[3]; and Haslinger, K.[1]

Affiliation: (1) GeoSphere Austria; (2) IIASA; (3) Quantuum ; (3) UBA

Title of abstract: Identifying tools and methods to co-create a climate risk service for managing drought risk in Austria - CRiSDA

Abstract: The aim of CRiSDA is to support knowledge-based, comprehensive climate risk management and disaster risk reduction by jointly developing and researching essential building blocks for a drought climate risk service for Austria. Together with potential end-users, a co-creation methodology was developed and used to identify the requirements for such a service. In addition, a climate risk perspective was added to the CRiSDA climate services by expanding the concept from a hazard focus to a risk focus by including exposure and vulnerability, and by implementing corresponding services as a demonstrator. Impact chains for drought in the key sectors of agriculture, forestry and water management have been developed in an iterative process with stakeholders and relevant indicators have been identified. Most climate (risk) services in Europe and Austria have a hazard focus. However, they usually only provide data without a corresponding translation into recommendations for action. It is precisely this process support service that many users want. There is no one-size-fits-all service that covers the different needs of different user groups. Most climate (risk) services in Europe and Austria have a hazard or risk focus. However, they usually only provide data without a corresponding translation into recommendations for action. It is precisely this process support service that is desired by many users. There is no one-size-fits-all service to meet the different needs of different user groups. Two potential user groups were identified through an online survey and stakeholder interviews: 1) government administration and extension services: short and long term

action recommendations, formulated warnings and reports, 2) regional/municipal/individual level. Monitoring of crop failure

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Author(s): Alexandra Malmström; Scott Williams; Alexandra Malmström; and Sirkku Juhola

Affiliation: University of Helsinki

Title of abstract: Disconnects between Climate Change Adaptation Research and Practice: Evidence from a Systematic Review of Urban Heat Island Modelling Research

Abstract: Climate change adaptation planning requires stakeholders to have a plethora of information about climate risk. Integrating and understanding information about hazard, exposure, vulnerability, and response is a complex challenge that must be addressed for efficient and sufficient planning. We conducted a systematic review of 177 papers published in peer-reviewed journals about quantitative modelling approaches to urban heat island in order to characterize the nature of this field of research. We found that the vast majority of papers in our sample were concerned with the earlier stages of the adaption planning process, such as identifying the climate hazard or virtually testing hypothetical adaptation solutions. Very few papers assessed the efficacy of planned or implemented adaptation solutions and even fewer papers had non-superficial measures of stakeholder participation. There is clearly a disconnect between adaptation research and adaptation practice in the published literature evident in the focus on the risk assessment stages of the adaptation planning process, and not monitoring and reassessment. What does this disconnect mean for adaptation planning professionals? How can researchers conduct studies that more thoroughly approach the adaptation planning process? In this session, we will pose answers to these questions based on trends identified in the review and highlights of notably exceptional papers. Then, we will identify common approaches to modelling the various dimensions of urban heat risk and describe the patterns of research that may lead to the research-practice gap. Finally, we will conclude with directions for further research on better connecting modelling work to practical adaptation planning.

Author(s): Michiel Ingels[1]; Jeroen C.J.H. Aerts[1,2]; W.J. Wouter Botzen[1]; Jan Brusselaers[1]; Max Tesselaar[1]

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Title of abstract: Climate Risk Insurance Modeling: A Literature Review

Abstract: This article provides a comprehensive review of the existing literature on climate risk insurance modeling, emphasizing the increasing relevance of such models in the face of rising losses attributable to climate change. Insurance models are used to estimate risk for different perils in combination with simulating risk related parameters for insurance schemes such as premiums and deductibles. However, not all existing insurance models are prepared for simulating the effects of climate change. Therefore, this article will identify significant knowledge gaps, highlighting disparities between current practices and those essential for addressing climate related challenges.

Gaps that we identify in this literature include an overemphasis on flood insurance in the model applications, a bias toward developed nations, and insufficient coverage for non-agricultural commercial sectors. Furthermore, less than half of the analyzed papers take a forward-looking approach by incorporating climate change scenarios, and an even smaller percentage consider socio-economic development scenarios. This limitation diminishes the effectiveness of these papers in assessing the future outlook for insurance.

The article emphasizes the need to address these gaps, advocating for more refined models, expanded geographical and hazard coverage, enhanced inclusion of the commercial sector, and a forward-looking approach. The insights from these

model advancements can help the insurance sector to proactively adapt to the challenges posed to insurance for climate risks due to climate change and socio-economic developments.

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Title of abstract: Circling the Policy Drain: A Systematic Review of Governance Strategies concerning Urban Planning for Water-Centric Circular Cities towards Climate Change Adaptation

Abstract: Increase in urbanization, projects frequent and severe natural hazards due to climate change, impacting both people and biodiversity in cities. Water stress is also exacerbated by longer droughts and rising evaporation temperatures. Despite the availability of climate projection data. While future climate projections are available, it is extremely difficult to model future urban growth and its direct effects on biodiversity and urban water systems. This brings urban planning to the forefront of climate change adaptation, as cities have the capacity to promote circularity in water systems. To make urban water circularity a comprehensive and credible concept in urban planning governance, a more thorough examination of the benefits and hazards linked with urban water is required. We aim to conduct a systematic review of the existing literature to gain insights into the basic concepts and theoretical issues within the research field. Our methodology consists of four main components: 1) conduct a search string including climate change and urban planning as keywords within peer-reviewed journals and secondary sources (1990-2023); 2) evaluate a selection of case study-specific journals; 3) categorize the literature based on circular economy strategies related to urban waters; and 4) conduct a critical text mining analysis to identify emerging themes and cross-benefit synergies of urban water circularity and disaster risk reduction in the literature. We aim to develop a framework for examining the challenges and synergies in implementing circular economy principles in urban water systems. Additionally, we aim to provide a more refined understanding of the localized and contextualized consequences of universal strategies for addressing environmental issues in urban settings.

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Title of abstract: Prioritizing measures and instruments for flood risk management – what do experts recommend after the devastating flood of 2021?

Abstract: In July 2021, severe flooding impacted Western Europe. In Germany, the federal states of North Rhine-Westphalia and Rhineland-Palatinate were particularly affected. Destruction of infrastructures and buildings as well as injured, missing and dead people were recorded on a scale unprecedented in recent decades. In the aftermath, a large number of statements and recommendations for action were published by scientists, political parties, water agencies, civil defence organizations, professional associations and NGOs, urging changes in risk management. In the framework of the Heavy Rain Initiative of the German Climate Consortium (DKK), an expert survey was undertaken in 2022 to prioritize the diverse need for action identified so that all stakeholders can develop a common understanding of the adaptation tasks ahead. The survey was conducted online following a systematic, two-stage Delphi approach. A wide range of experts dealing with heavy rainfall and flash floods were asked in two rounds for their assessment and weighting of eight general fields of action as well as of 148 specific measures. The survey shows that the field "Hazard Analysis, Warning and Communication" was initially assessed clearly as the most effective field with the most urgent need for action. In contrast

the field “Reconstruction” was valued as surprisingly unimportant. However, this picture changed when specific measures were assessed. Here, measures from “Civil Protection”, “Water Storage”, “Reconstruction” and “Resilient Critical Infrastructures” scored higher on average than measures from "Hazard Analysis, Warning and Communication". The survey does not only provide a list of recommended actions, but also reveals gaps in strategic considerations and needs for better societal learning processes.

Author(s): Julie Van de Valk

Affiliation: Public Safety Canada

Title of abstract: Bridging between Natural Hazard Data, Science, and Policy to keep Canadians Safe

Abstract: In Canada, Public Safety Canada’s (PS’s) mandate is to keep Canada safe from a range of risks such as natural disasters, crime and terrorism. A growing part of our work includes connecting data, analysis, and engineering with policy to work towards effective adaptation. Our team of data scientists and engineers is imbedded in a policy directorate where we provide data analysis and technical policy input for programs including standing up Canada-wide flood insurance, modernizing the Disaster Financial Assistance Arrangements (Canada’s post-disaster funding program), and creating and sharing Canada- wide flood risk ratings. In this presentation, we will share our team’s efforts across departments and multiple hazards to work towards data-informed, aligned and effective adaptation policy. Our work includes pioneering and validating novel approaches for characterizing and communicating probabilistic flood hazard, developing a Canada-wide flood risk assessment over 4 years, characterizing error and uncertainty in this model, evaluating optimal mitigation thresholds from big datasets, providing flood risk information for Canada-wide financial exposure analysis, and more. We will highlight our challenges and successes bridging the gap between data, science, and policy to keep Canadians safe.

Author(s): Markus Mosimann; Olivia Martius; and Andreas Paul Zischg

Affiliation: Mobiliar Lab for Natural Risks, University of Bern

Title of abstract: Exploring Interconnected Dynamics: Hydrometeorological Uncertainties in Impact-Based Flood Warning Systems and the Climate Change Sensitivity of Floodplains

Abstract: We identify sensitive ranges in magnitude-impact relationships within floodplains, focusing on the main rivers and lakes in Switzerland. The research addresses key challenges in flood risk management, namely hydrometeorological uncertainties in flood warnings and the climate change sensitivity of floodplains. The proposed Floodplain Sensitivity Index (FSI), derived from the magnitude-impact curve, offers a consolidated measure of floodplain impact sensitivity to uncertainty / future changes in flood magnitude ranges.

Practical applications of the FSI in flood risk management, indicating impact-relevant magnitude thresholds, include improved impact-based warnings on the short- and climate change adaptation strategies in the long-term. The proposed index helps to communicate uncertainties in forecasting models (short- and long-term) under different levels of uncertainty.

The study concludes that the magnitude-impact relationship, combined with the quantitative FSI approach, addresses interconnected challenges of climate change sensitivity and the relevance of hydrometeorological uncertainties in impact-based warning systems. Finally, we discuss the need for further refinement of methodologies and models to enhance the applicability of the FSI in diverse floodplain contexts. As the concept of magnitude-impact relationships is adaptable to any natural hazard, the approach is applicable in a multi-hazard context.

Author(s): Ilyas Masih

Affiliation: IHE Delft Institute for Water Education

Title of abstract: An analysis on the alignment of drought policy and planning guidelines with the SENDAI framework for disaster risk reduction 2015-2030

Abstract: Drought policy and planning guidelines are developed and used to support the transition from crisis to risk management. However, there is a need to better align the available guidelines to the changing needs and contemporary science-policy- practice discourses. This study examines twelve drought guidelines for their alignment with the four priority actions of the SENDAI Framework. A qualitative scoring matrix was used in the evaluation, and each priority area was scored at the scale of 0-100 (Very low-0-10; Low: 11-30; Medium-low: 31-50; Medium-high: 51-70; High: 71-90; and Very high: 91-100). The examined guidelines scored high (e.g., WMO and GWP 2014, and MEDROPLAN, 2007) to very high (e.g., UNCCD, 2019; World Bank, 2019) on understanding disaster risk (priority 1). Strengthening disaster risk governance to manage disaster risk (priority 2) was ranked high in most cases, but some guidelines (based on "three pillars" of integrated disaster risk management) do not provide sufficient coverage on governance aspects. Investment in disaster risk reduction for resilience (priority 3) was rated in the medium category. The lower scores were due to lack of guidance on implementation, financial investments, coherence of policies and plans, and sustainable development. Enhancing disaster preparedness for effective response, and to «Build Back Better» in recovery, rehabilitation and reconstruction (priority 4) scored in the medium to high range. Detailed guidance in this area should cover integrated disaster risk reduction measures, gender balance, universally accessible approaches, and effective relief and recovery response.

Session 4: How can stakeholder engagement and knowledge co-production enhance effective multi-risk management?

Author(s): Nicole van Maanen[1]; Marleen de Ruiter[1]; Wiebke Jäger[1]; Veronica Casartelli[2], Anne Sophie Daloz[3]; David Geurts[4]; Stefan Hochrainer-Stigler[5]; Lin Ma[3]; Letizia Monteleone[2], Noemi Padron[6], Karina Reiter[5]; Robert Šakić Trogrlić[5]; Silvia Torresan[2]; Sharon Tatman[4]; MYRIAD-EU team; and Philip Ward[1]

Affiliation: (1) Vrije Universiteit Amsterdam; (2) CMCC; (3) CICERO; (4) Deltares; (5) IIASA; (6) Universidad de La Laguna

Title of abstract: Conversations on multi-hazard risk: Qualitative and quantitative insights from MYRIAD-EU interviews on the dynamics of risk drivers and disaster risk reduction synergies in Europe

Abstract: Navigating the complexities of multi-hazard risks poses a significant challenge, requiring a holistic understanding that extends beyond theoretical frameworks. Although recent frameworks have contributed greatly to theoretical advancements, a critical gap remains in providing practical insights for on-the-ground stakeholders. These stakeholders, including policymakers, decision-makers, and practitioners are often responsible for preparing and dealing with the risks arising from multi-hazard events. Within the MYRIAD-EU project, the objective is to empower stakeholders on the ground with a systemic approach encompassing multi-risk and multi-sector assessment and management.

To unravel the intricate web of systemic risk interdependencies across and within Europe and facilitate an improved assessment and management of multi-hazard risks, several comprehensive semi-structured interviews were conducted within the Pilot regions of the MYRIAD-EU project. These interviews spanned diverse geographic, hazard, and sectoral domains. The Pilot regions are the Canary Islands, the Veneto region, the Danube region, Scandinavia, and the North Sea.

The insights obtained from these interviews, both qualitative and quantitative, including perspectives from both land and sea, offer a nuanced understanding of hazard combinations, vulnerability characteristics, changes in exposure and vulnerability over time, and the synergies and asynergies inherent in disaster risk reduction measures across Europe. Our findings aim to bridge the gap between theoretical frameworks and practical applications, providing valuable information for stakeholders to enhance their preparedness and response strategies in the face of multi-hazard risks. At the same time, the results will be used to develop a better

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Author(s): Anke Wessels; and Beate Ratter

Affiliation: University of Hamburg, Institute of Geography

Title of abstract: Interrupting the Cascades – How compound event thinking contributes to successful disaster risk reduction and climate change adaptation

Abstract: Compound events resulting from complex interactions between various physical drivers are increasingly recognized as regional challenges of climate change, especially in low-lying coastal areas where storm surges and heavy rainfall can independently cause extensive flooding, as seen in recent floods in Lower Saxony, Germany. However, these challenges are compounded by the simultaneous or successive occurrence of individual events, significantly impacting coastal communities' health, livelihoods, and infrastructure.

In climate change adaptation, a deeper understanding of compound events and how their cascading effects can be mitigated remains lacking, with analysis primarily confined to scientific research rather than practical implementation. This gap highlights the need for integrating diverse knowledge bases at the municipal level to address compound events in strategic planning. This contribution focuses on compound events and their impact cascades in a German coastal community. For addressing these new challenges, a reflexive and iterative bottom-up approach is proposed to foster transdisciplinary collaboration with local stakeholders. Collaborative efforts in identifying compound events have enhanced understanding of regional compound events from a systems perspective. Co-created influence diagrams shed light on diverse physical and societal drivers and complex cascading impacts. This process paved the way for developing suitable adaptation measures that not only mitigate drivers but also interrupt resulting cascading effects. The collaboration enhances the perception of cross-sectoral impacts and synergies and promotes transparent multi-risk decision-making and joint action in climate change adaptation based on compound event thinking.

Author(s): Markus Groth; Janna-Malin Gehrke; and Peer Seipold

Affiliation: Climate Service Center Germany (GERICS)

Title of abstract: A transdisciplinary process model approach to integrate future climate change into corporate risk management strategies

Abstract: To prepare for climate-related risks, a scientifically sound forward-looking integration and disclosure of climate-related data is key. Furthermore, companies also face an increasing demand in non-financial reporting, such as the use of climate change scenarios as part of risk analyses as well as the need for substantial contributions to the environmental

goals according to the EU Taxonomy Regulation. Currently, however, companies are still leaving notable gaps in the incorporation of forward-looking climate data and scenarios into reporting and long-term planning strategies.

Against this background, the paper describes and discusses an eight-step process model as an innovative way to integrate future climate change into corporate processes. This problem-driven approach is developed in close collaboration and co-creation with companies. It comprises the following phases: i) inventory, ii) prioritization, iii) identification, iv) availability, v) enablement, vi) derivation and implementation of measures, vii) evaluation, and viii) process reinforcement. Also taking into account existing regulations, standards and recommendations for risk assessment and reporting, the process model aims to enable decision makers in companies to identify and assess climate change-related impacts and to take regional climate change information into account. Based on this information – combined with additional local knowledge –, companies can identify suitable adaptation options and develop transformative risk-management solutions. This includes new forms of collaboration, embedded in a framework of a transdisciplinary co-production process. Thereby, a close and trust- based cooperation between internal and external stakeholders right from the outset is a key factor for success.

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Affiliation: (1) University of Antwerp; (2) European Commission

Title of abstract: Integrating stakeholder preferences with systemic multi-risk data on disasters and climate change: A stochastic decision-making analysis

Abstract: The systemic and multi-hazard risk landscape of climate change and extreme events is and will be a wicked problem for effective, equitable and forward-looking resource prioritisation globally and at almost any scale. The number of criteria, stakeholders, scenarios, and behaviours to consider at the definite decision-making window can be overwhelming when trying to cut the funding cake in a fair manner and a need to operationalise climate modelling is evident. IPCC has explored that multi-criteria decision analysis and decision-making (MCDA/MCDM) could be one avenue to manage the issue at hand (AR6 WG2 chpt. 17).

Here, we will use stochastic multi-criteria acceptability analysis (SMAA), a variant of MCDA/MCDM, to compute explicit prioritisations of resource allocations on climate change adaptation and disaster management for fragile countries with a humanitarian response plan and by comparing it to real-world decision-making. The mechanism will be run according to indicator data from the INFORM indices and IPCC scenarios corresponding with criteria preferences gathered previously from a panel of key stakeholders (e.g., United Nations, European Union, World Bank, the research sector, the public sector, Save the Children, World Vision). The SMAA method is designed for cases where information can be deeply uncertain or inaccurate.

We hypothesise that the results will confirm and suggest Occam's razor-type avenues for streamlining co-production between stakeholders, pinpoint indicator groups that are and are not critical for equitable and needs-driven assessments, and showcase a beneficial novel practice in integrating multi-risk data into policymaking in a pragmatic format.

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Ludwig-Maximilians-Universität München, Department für Geographie; (7) Max-Planck-Institute for Meteorology, Hamburg, Germany; (8) Department of Philosophy, Kiel University, Germany

Title of abstract: Accounting for the multiple risks of transitioning towards low carbon emission scenarios

Abstract: Extreme events like droughts and floods are becoming more frequent and more intense due to climate change, and we are increasingly likely to experience unprecedented impacts unless substantial climate mitigation and adaptation actions are taken (IPCC, 2023). A major issue remains with regards to the tensions between working towards the overarching objective of limiting global warming and the local implementation of the Paris Agreement. Deploying mitigation technologies for carbon dioxide removal at scale, such as bioenergy with carbon capture and storage and afforestation and reforestation, requires substantial amounts of land which leads to land use conflicts and indirect land use change. This often entails an unequal distribution of benefits and risks across the globe and societal groups. In this context, socioeconomic scenario building is a widely deployed method for mapping out possible future socioeconomic development. These scenario-generating processes must go hand in hand with stakeholder-oriented dialogues "on the ground" to understand the local implications of global warming and the implications of proposed adaptation and mitigation strategies beyond socioeconomic impact alone.

In this presentation, we propose that scenario building should be accompanied by stakeholder engagement processes to assure that what matters most to the people directly affected by the policy options is being considered. However, this requires that scenarios (global to regional) are further scaled down to shed light on impacts at the community level. Furthermore, we propose developing evaluation metrics which ensure transparency and comparability across scenarios so that technology- based solutions can be evaluated coherently based on their ecological, economic, and societal impacts.

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Title of abstract: Integrating multi-faceted spatial perspectives from researchers to stakeholders on climate- and water-related risks

Abstract: The current societal and scientific debates on climate- and water-related risks need to be underpinned and informed by a systemic or multi-risk framework to account for the realities and tradeoffs of possible mitigation and adaptation options. Within the transdisciplinary Einstein Research Unit CliWaC (Climate and Water under Change) we engage with a diverse group of regional stakeholders to develop a more comprehensive understanding of the interlinked challenges around Berlin and Brandenburg, Germany. The aim of this presentation is to showcase multi-facetted spatial perspectives on climate- and water- related risks for the region that were assessed using different methods for different target groups, as well as their integration in our newly developed web-based platform. Conducted formats include participatory mapping on a smart board with experts, an interactive exhibition piece at a public museum with the public, a series of expert workshops, anthropological field work, art- based research, and surveys with residents. Some of the collected perspectives are intrinsically spatial, while others rather implicitly relate to a place. The web-based platform is used to synthesize the knowledge gained and to disseminate results to a broader audience. This platform contains spatial data & software, as well as a thematic mode for story-driven (non-spatial) exploration. Scientific hazard- and risk models are included in this platform to allow for an interactive comparison between perceived and projected risks. This platform will also be used in further stakeholder activities to jointly explore scientific results and stories from a wide range of

perspectives. Ultimately, we aim at knowledge co-production and critical reflection to aid the development of adaptation strategies.

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Title of abstract: Enhancing Multi-Hazard Analysis in Conflict Settings: A Collaborative Approach with Red Cross Red Crescent Movement partners

Abstract: The Red Cross Red Crescent (RCRC) faces challenges of responding to the compounded impact of armed conflicts, climate, and environmental crises on vulnerable communities. Particularly in conflict zones such as Burkina Faso, Myanmar, and Lebanon, addressing multi-hazard risks and impacts requires a more integrated approach to Climate Change and Conflict- related data in decision-making.

Within a pioneering collaboration between 510 – The Netherlands Red Cross (NLRC), the ICRC in Burkina Faso, Myanmar and Lebanon, the RCRC Climate Center (RCCC) and the Lebanese Red Cross (LRC), it was explored how the intersection of impacts on vulnerable populations from conflict and could be visualized to support timely and climate-informed decision-making.

The foundational framework for the project outcomes was built by insights from stakeholder and community engagement with ICRC, RCCC, LRC, local authorities and community responders. The multi-hazard platforms built were tailored to each country, prioritizing the combination of quantitative and qualitative information. In Lebanon, co-created impact chains integrate qualitative insights from local actors, using a powerful methodology to inform and conceptualize knowledge about multi- hazards pathways. In Myanmar, a co-designed powerful tool was developed that empowers to personalize interventions to address challenges posed by climate change and conflict in humanitarian contexts. In Burkina Faso a story map based on extensive social science research was created to inform on multi-hazard risks. The insights gained and tools created will enhance the capability of the ICRC and other RCRC movement partners to incorporate quantitative and qualitative insights in multi-hazard pathways to make their (long-term) projects more sustainable.

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Title of abstract: Examining Conditions for Sustained Integration of Different Knowledges within Climate Services

Abstract: Climate change has been described as a 'wicked' problem and managing it often leads to knowledge challenges including, a lack of usable information that can inform decision-making at various levels. Integration of local knowledge has been proposed as a way to make climate information credible, salient, and legitimate for its end users. This has led to more and more climate services being co-produced, a negotiation process between the different knowledge systems (scientific and local) of climate service providers, purveyors, and end users. While there are several examples of "one-off" CS interventions where local knowledge has been considered, there has been less discussion on the conditions that favour the sustained integration of local knowledge to develop, deliver and communicate these climate services. This continued interaction is important as both local and scientific knowledges are not static but dynamic and continuously changing, as are the needs of climate services users.

This research provides a conceptual framework to understand enabling conditions that can lead to the sustained integration of local knowledge across the climate service provision process so that we can avoid projects paying mere lip

service to local knowledge. We present examples from the different living labs that have been established in the I-CISK project (an EU research initiative) to elaborate current practices and to explain the extent to which local knowledge permeates back into the climate service value chain. We list factors favouring this integration on a continuous basis, and finally to show how local knowledge of experts (local providers and purveyors) within climate service value chains can inform the functions of translation, delivery, and communication of climate services.

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Title of abstract: Transboundary climate adaptation solutions: co-developing services to manage climate risks

Abstract: Long-term climate adaptation solutions must be considered alongside disaster risk management measures, in order to preserve lives and protect infrastructure from increasingly severe natural hazards. Climate impacts will not stop at borders and it is imperative that we overcome the prevalence towards siloed working to address these transboundary and cascading climate risks. For effective disaster risk management and climate adaptation, instruments that engage all relevant societal actors and allow decision-makers to collaborate and coordinate responses are essential.

Climate services provide people and organisations with climate related information and tools to support places to analyse hazards, exposure and vulnerability, and plan and implement solutions that will build resilience. Co-developing these climate services with place-based stakeholders gives them greater legitimacy and has been shown to increase impact. A number of research projects and initiatives on the island of Ireland are engaging stakeholders to develop climate services that utilise the co-production of knowledge and co-creation of adaptation solutions, supporting a tailored approach to action that is context specific. These climate services include risk analysis tools, communication tools, an adaptation partnership framework, a creative co-creation toolkit, and pathway methodologies being developed through the REACHOUT, TALX and BluePrint projects.

All of these projects are using the co-production of knowledge from public, private and third sector actors, and from local communities, as an effective method of allowing a discourse on the challenges faced in different local contexts. Such knowledge co-production can improve governance around multi-risk management and climate action.

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Title of abstract: Engaging plurality in the application of co-creation concepts in the development of climate services for disaster risk reduction

Abstract: Climate services are meant to guide decision-making around disaster risks to minimise impacts from climate extreme events. However, the use of climate services in decision-making has been hindered as information is often inaccessible to the user, lacks contextual relevance and scales, and end users having limited capacity for effective use. Co-creation approaches have been identified as key to bridging this gap between scientific innovation in climate services and their use in decision-making. Various frameworks and guidelines have been produced over the years to outline various stages of co-creation in climate service development.

However, the context specificity of co-creation entails different applications of the concept in practice. To date, there has been limited engagement with the facets of co-creation that exist in practice, what shapes these, how they are structured, in what situations these would be most effective, and for whom. Engaging such plurality would enable an understanding

of what the concept of co-creation may look like in different contexts, how to evaluate and assess different facets of co-creation, and what successes or failures may look like under each facet.

In this study, we aim to outline the practical application of the concept of co-creation in the development of climate services for the disaster risk reduction sector. Through in-depth semi-structured key informant interviews with climate service providers, purveyors, and end users; we identify distinct approaches to climate services co-creation in practice and present them on a spectrum. We highlight key challenges, opportunities, as well as lessons learnt from each facet of co-creation for the benefit of both practitioners and researchers implementing co-creation processes.

Poster presentations

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Title of abstract: Open R-code to communicate the impact of co-occurring natural hazards

Abstract: Hydro-meteorological hazard is often estimated by university-based scientists using publicly funded climate models, whilst the ensuing risk quantification uses proprietary insurance sector models, which can inhibit the effective translation of risk-related environmental science into modified practice or policy. For co-occurring hazards, this work proposes as an interim solution open R-code that deploys a metric (i.e., correlation coefficient r) obtainable from scientific research, usable in practice to estimate impact on losses without restricted data (climate or risk) being exposed. This tool is evaluated for a worked example (Bank of England, Aon, Met Office, Loughborough University) that estimates the impact on joint risk at an annual 1-in-200 year level of wet and windy weather in the UK co-occurring rather than being independent, and the approach can be applied to other multi-hazards and compound events in various sectors (e.g. road, rail, telecommunications).

Bank of England blog on the work: https://bankunderground.co.uk/2023/04/13/what-if-its-a-perfect-storm-stronger-evidence- that-insurers-should-account-for-co-occurring-weather-hazards/

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Title of abstract: Towards a Multi-Criteria Analysis for evaluating the effectiveness of risk reduction strategies in multi-hazard environments

Abstract: In the context of the Italian RETURN project, WP 7.2 aims to establish national guidelines for evaluating the effectiveness of intervention alternatives in natural risks management, considering in detail Multi-Criteria Analysis (MCA) tools. The focus is on multi-risk contexts for which knowledge is currently limited, the different phases of risk management chain, and the variety of structural and non-structural measures for adoption. The present contribution describes the results reached so far towards this direction. In particular, we propose a flowchart that illustrates the process leading to the ranking of alternative strategies through MCA. Its objective is to highlight the necessary operational steps, including: (i) the identification of intervention alternatives and their characterization in terms of spatial and temporal scale of effectiveness, potential risk reduction (or increase) with respect to the different natural hazards, and secondary impacts on interested communities, (ii) the recognition of stakeholders' objectives and their respective dimensions, (iii) the definition of attributes and indicators according to which alternatives are evaluated, (iv) the selection of the most appropriate MCA tool and definition of related parameters, and (v) the performance of sensitivity analysis. The development of the flowchart pointed out that defining guidelines for applying MCA to multi-risk management requires two ongoing fundamental steps. First, the development of a matrix that classifies the elements exposed to the multiple single hazards and analyzes the potential direct and indirect impacts on them in case of an event. Second, the definition of an abacus of alternatives which identifies the most promising measures that can be implemented in a specific context.

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Title of abstract: Micro-, Mezzo-, and Macro-level Cross-sectoral Cooperation: An Innovative Approach to Support Animal Farming Community's Evacuation during the 2021 Pacific Northwest Floods in Fraser Valley, British Columbia, Canada

Abstract: The animal farming communities in the Fraser Valley were devastated by the 2021 Pacific Northwest floods. These communities, as well as public, private, and not-for-profit sectors, were engaged in the evacuation. In the decision-making stage of the disaster evacuation, farm-animal ownership was identified as a risk factor for the survival of humans, primarily because they refused to leave their animals behind the evacuation lines. This project employs a phenomenological approach by examining these cross-sectoral, multi-stakeholder engagements in evacuation decision-making to identify promising practices and areas for improvement. Through qualitative interviews of animal farm owners, community-based service agencies, and governmental emergency responders, this project discovers that during the decision-making stage of the disaster evacuation (1) at the micro-level, the animal farmers' long-term engagement with their natural, built, and social environments enabled them to develop the initiatives for evacuation strategies but lacked resources and equipment to facilitate their evacuation; (2) at the mezzo-level, community-based service and professional organizations were equipped with specific knowledge, skills, and services to support the animal farmers' evacuation but lacked the capacity of large-scale coordination; and (3) at the macro-level, the governmental emergency responders could swiftly coordinate different resources to support the evacuation in Fraser Valley, but did not comprehensive understand the animal farming communities' characteristics. These three-level challenges were solved through community-based rapid response meetings, where the micro- (grassroots), mezzo- (community-based agencies), and macro-level stakeholders collaboratively share their strengths

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Title of abstract: Building Climate Resilience Northern, Tanzania: A Participatory Action Research Approach to Enhancing Effective develop Early warning system for drought and Rain.

Abstract: In Northern Tanzania, agriculture is rain-fed, making livelihoods highly vulnerable to unpredictable rainfall patterns and prolonged droughts. Traditional prediction systems often fail to resonate with farmers' needs, hindering effectiveness. To address this, we implemented a participatory action research project engaging farmers across three climatic zones: High, middle, and lower zones. Participatory methods, including surveys, focus group discussions, and iterative design workshops, informed system development and ensured it addressed community needs and priorities. By co-designing solutions informed by community needs, we developed an early warning system (EWS) utilizing IoT weather stations, remote sensing data, and accessible communication channels. This EWS empowers communities to anticipate droughts and rainfall, enabling proactive adaptation and safeguarding agricultural sustainability. The different zones seem to be most affected differently by climate change. While the high and mid zones highlight the variability of rainfall as having a more significant effect, the lower zone indicates that drought has a higher impact on crop productivity. The designed solution concludes that an early warning system for drought and rainfall events is crucial. The system will inform the community when to expect rainfall and when to anticipate drought. The project emphasizes the transformative power of engaging stakeholders throughout the process, fostering trust, enhancing the capacity for local adaptation, and increasing system uptake. Challenges encountered, such as limited technological literacy and data access, underscore the need for ongoing capacity building and inclusive knowledge-sharing strategies.

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Title of abstract: Untapped potential: Integrating first responders’ perspectives into Impact Chains

Abstract: Over the last decades, there has been an increasing trend in natural risk and vulnerability assessments to incorporate the perspectives of various stakeholders. Among these, first responders in emergency interventions stand out as valuable information sources that should not be overlooked when diagnosing risk management strategies and in the pursuit of learning from past experiences. Nevertheless, research on integrating first responders’ feedback into broader emergency management schemes is limited, and the particular value of this feedback remains insufficiently investigated.

This study aims to take an in-depth look at the input provided by first responders on the challenges that arise during emergency interventions, their perception of intervention experiences, and the broader framework of emergency management in Romania. The feedback of first responders is integrated into two Impact Chains focusing on 1) the flood events that affected Romania in 2020-2021, and 2) the potential outcomes of a major earthquake that may strike Bucharest in the present or future. The vulnerabilities pinpointed by first responders are then examined within the Impact Chains, along with those identified by experts in Disaster Risk Reduction. This cross-examination aims to uncover their distinct value and the facets of emergency management that may have eluded the scrutiny of scientists.

The proposed comparative approach enhances the Impact Chain, building it upward from the grass-roots level involving emergency interventions to the more intricate aspects conveyed by experts. The bird's view of the Impact Chain shows the significant value held by both components, showcasing their mutual complementarity in the analysis of natural risks.

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Title of abstract: From Data to Disaster-Management Decisions: Intermediaries as Catalysts for Effective Climate Services

Abstract: Amid escalating climate risks, effective climate services (CS) are crucial. Despite their potential to significantly enhance responses to climate impacts, a persistent research-implementation gap has hindered widespread adoption, resulting in delayed acceptance or limited use. Previous studies underscore that enhanced climate data alone is not sufficient to close this gap; but that the value of CS is contingent upon alignment to specific decision-making contexts. This study addresses this gap by identifying intermediary actors, such as service providers and purveyors, as a potential leverage point within the CS value chain.

Intermediaries, bridging experts and decision-makers, play a vital role in translating complex climate data into actionable insights and usable formats for diverse audiences. Moreover, intermediaries are uniquely positioned to aggregate knowledge from individual projects, identifying best practices and barriers to CS product uptake through their own stakeholder engagement and co-production experiences.

Therefore, this research centers on intermediary organizations to understand contextual factors influencing the development and use of CS in drought and flood-stricken regions (Netherlands and Lesotho). Utilizing qualitative analysis (key informant interviews and literature review), contextual factors (e.g., specific information needs, organizational structure, legislature, and regional history) influencing the success and development of CS in vulnerable regions are identified. By gaining a deeper understanding of contextual factors that influence the use and development of existing CS products, the study aims to improve CS design practices, promoting greater implementation in disaster management decision-making and increasing climate resiliency.

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Title of abstract: Building Disaster Resilient Societies: Towards a Disaster Reconstruction Support Framework

Abstract: Societies are increasingly impacted by natural hazards, requiring adaptation and resilience building. Especially in low-income countries, unsafe houses and natural hazards are growing threats. Unfortunately, houses are often re-created with similar vulnerabilities. Therefore, understanding inclusive decision-making and effective communication among stakeholders in the recovery and reconstruction stages is essential for disaster resilience. The growing complexity of our societies and the increasing presence of cascading, compounding and multi-hazard risks, require a holistic and systematical analysis of what effectively enhances resilience. This paper explores concepts, ideas, and experiences which can contribute to holistic frameworks and indicators for inclusive decision-making in resilience building of the built environment. For this study, data is collected from desk research, as well as a survey and workshops with experts working in the fields of DRR, shelter, and other related disciplines. Our results reveal a clear ranking of indicators and conceptual frameworks analysed and developed by participants. Our study highlights different weights of indicators and different priorities in frameworks across disaster contexts and calls for differentiation and personalization of assistance.

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Title of abstract: Using co-production to understand compound and multi-hazard extreme weather risks for rural stakeholders: Scotland's National Parks.

Abstract: Compound and multi-hazard extreme weather events, such as droughts, storms, or wildfires, are increasing in frequency and severity with climate change (IPCC, 2021). These events can have profound impacts on rural landscapes, including direct losses to agriculture, fisheries, forestry, tourism, and infrastructure networks. To comprehensively understand the compound and multi-hazards that affect rural stakeholders within Scotland's National Parks, this study employs the co-production approach. We work with numerous practitioners and policymakers, in a collaborative effort to outline the range of compound and multi-hazard events that affect operations and management within the parks. Participants identify and prioritise compound and multi-hazard events of high concern, emphasising indicators and timescales relevant to their domain of expertise. The resulting consensus-driven collective prioritisation of compound and multi-hazard events provides a roadmap for future research endeavors. By employing co-production, stakeholders actively contribute their expert knowledge and lived experiences, thus enriching the ability to develop research tailored to user-needs. This study emphasises the benefits of using co-production as a methodological tool to align research priorities with the practical needs of stakeholders, ensuring that research impacts are not only academically robust but also directly applicable to practitioners and policymakers. Co-produced research, as demonstrated in this study, thus emerges as a crucial instrument in enhancing the utility and usability of climate- related research, facilitating more effective management of compound and multi-hazard risks for rural stakeholders.

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Title of abstract: Engaging Stakeholders in Co-Creating Knowledge for Multi-Risk Adaptation Strategies

Abstract: To foster resilient mountain communities equipped with adaptive capacities and comprehensive knowledge on hazard and risk perceptions, implementing a robust transdisciplinary approach is essential. This approach should effectively bridge the gap between natural and social sciences, while also strengthening partnerships between stakeholders to ensure effective disaster and climate risk management for both current and future challenges. The CAUTION project (Austrian Climate Research Programme) is an excellent example of this interplay as scientists from different disciplines engage with multiple stakeholders with the aims to explore the interactions between natural (multi-)hazards, climate change and physical, economic, institutional and social dimensions and to collaborate on local climate change and natural hazard adaptation and risk management strategies in several Austrian study areas. This contribution discusses how a transdisciplinary approach, with its unique opportunities and challenges, is playing out in this project. It focuses on the process of co-creating knowledge that enhances our understanding of the multi risk environments, its drivers, interconnections and impacts with local and regional stakeholders and the tools that we have used. It also discusses how this new knowledge is subsequently being used to co-develop adaptation strategies and to support capacity building in mountain communities. Additionally, it addresses the challenges and pitfalls encountered during the co-creation process, such as managing expectations, ensuring feasibility of locally adapted strategies, dealing with limited resources and competing interests. The contribution concludes with the first contours of climate change adaptation and risk management strategies for the study areas.

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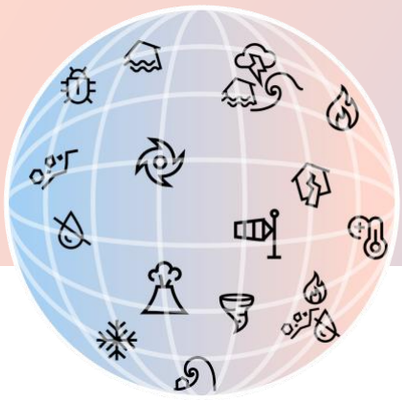

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Title of abstract: The Kivu Citizen Observer network: creating and disseminating knowledge about natural hazard disasters to improve Disaster Risk Reduction

Abstract: In the Tropics, disasters associated with natural hazards (storms, floods, landslides) occur regularly. However, the general scarcity of reliable and accurate data collected on these events does not allow for a complete picture of their frequency and magnitude, thus hindering effective Disaster Risk Reduction (DRR). Such situation is observed in the Kivu region, located in eastern DR Congo.

Based on this situation, a group of 20 citizen observers was co-developed by scientists and the Civil Protection to collect data on various types of natural hazard disasters using a smartphone application. This citizen science approach significantly improves the documentation and understanding of the spatio-temporal occurrence of disasters affecting the North and South Kivu provinces. Since the network was set up in December 2019, over 1,100 events have been recorded.

While the data collected provides an unprecedented amount of information on disasters occurring in this tropical environment, it also allows a WebGIS and regular reports, illustrated with maps and graphs, to be compiled and distributed by the Civil Protection to key DRR stakeholders, for a more tailored response, its planning and, to some extent, the anticipation of such events. Scientists from local universities and research centers are associated to that data collection and analysis. Moreover, citizen observers position themselves within their communities as key actors in raising awareness about disaster risks.

Although this type of approach has proven to be effective in the short term by increasing the capacity of decision-makers to develop appropriate policies and contingency plans, the long-term motivation of the citizen observers has been identified as a challenge to be addressed.

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Title of abstract: Do participation and co-production help the water sector in multi-hazard risk management?

Abstract: Water resources management requires the process of planning, developing, allocating, distributing and managing the use of water resources to meet the demands for now as well as in the near and distant future. Climate change poses major challenges to the water sector particularly when the country is vast and has uneven distribution of water sources such as China. While most water managers are comfortable with using historic, seasonal and annual climate data, there is little or limited appetite for longer term climate information such as multi-annual and multi-decadal data. Because of this, systemic (multi-)risks, particularly with cascading effects, are often ignored or taken for granted by water managers. This presentation will be focused on a research study conducted in using participatory, co-production approach to help water managers in China in use longer term climate information to develop prototypes to understand the challenges induced by changing in climate in terms of water availability and water flows in the region/water catchment area. Based on different scenario simulations, the developed prototypes also help water managers to gain insights into the (multi-hazard) risks they may face. Although the prototypes are in the development stage, the potential to be transferred and adopted in other sectors such as agricultural/food production and regional planning will also be discussed.

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Title of abstract: Stakeholder engagement and co-production of knowledge in complex interdisciplinary projects – the case of MYRIAD-EU

Abstract: This study outlines the stakeholder engagement and knowledge co-production process for the first two and a half years of the HORIZON 2020 MYRIAD-EU project (Multi-hazard and systemic framework for enhancing risk-informed management and decision-making in the EU). The main aim of MYRIAD-EU is to provide useful tools for creating forward-looking disaster risk management pathways that assess trade-offs and synergies across sectors, hazards, and scales for decision-makers, practitioners, and the wider disaster risk community. To achieve this, we developed a strategy for stakeholder engagement and a set of tools and approaches for assessing knowledge co-production across (internal and external) groups with diverse types of expertise, knowledge, and focus. In this work, we present i) the strategy for the selection of stakeholders in five cross- European pilots, ii) the deliberative process used to engage them in knowledge co-production via pilot workshops, focus groups, and interviews, iii) the tools and methods used to monitor and assess the collaborative process and iv) the outreach activities. To ensure continuous improvement and learning, we also evaluated the status of our partnership with project partners against a set of criteria and principles of good practice, monitored changes in work plans, and elicited feedback regularly. Preliminary results are discussed here and key reflections on generating knowledge in collaborative, interdisciplinary multi-stakeholder projects are presented. Further work will integrate lessons learned from the finalisation phase of the project and the creation of a legacy of learning for use by future similar initiatives.

Session 5: Assessing multi-hazard risk using earth-observation data

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Title of abstract: Multi-Sensor Data Fusion with Artificial Intelligence for Operational Flood Mapping

Abstract: Hazard maps derived from earth observation (EO) or models are an important element of hazard and risk assessments. Additionally, in operational settings, they can provide relevant information for disaster management, such as mitigation measures and relief efforts. However, this is not always available to decision makers or lacks the required information and detail. For EO this is, in part, due to reliance on activation-based approaches (e.g. International Charter Space and Major Disasters), which are not initiated for each event, or continuous monitoring services (e.g. Copernicus Global Flood Monitor), which are often based on a single satellite or (type of) sensor, limiting their ability to capture the

event in both space and time. Furthermore, while the use of multiple satellites is recommended, this can lead to uncertainties or contradicting information, which is often not understood by end users, as they lack the required understanding of the underlying data.

The HYDrologic Remote sensing Analysis for Floods (HYDRAFloods) platform is set up within the SERVIR program to help overcome this issue for floods over Southeast Asia. This open-source tool based on Google Earth Engine can provide near real-time maps derived from multiple EO sources. It has been applied and field tested over events in the region, which has revealed recommendations for improvements. To overcome single sensor weaknesses and provide actionable information, we're currently researching data fusion utilizing artificial intelligence (AI), combining different sensors into a single consistent map. We present the current status of this research, exploring multiple AI methods while considering operational constraints. We also anticipate this research to be relevant outside the domain of flood mapping.

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Title of abstract: Insights into the vulnerability of vegetation to volcanic hazards from interpretable machine learning and big Earth observation data

Abstract: Although the generally high fertility of volcanic soils is often seen as an opportunity, short-term consequences of the multiple hazards of eruptions on natural and cultivated vegetation are likely to be negative. The empirical knowledge obtained from post-event impact assessments and dedicated lab experiments provides crucial insights into the eruptive, environmental and anthropogenic parameters controlling the magnitude of impact and the recovery of crops. However, their limited coverage in time and space does not provide a representative sample of all possible eruptive and environmental conditions. As a result, a generally applicable model of vulnerability of vegetation to volcanic hazards is still lacking, which prevents quantitative impact analyses required to model potential cascading impacts.

Here, we explore how the application of Earth Observation data, remote sensing and interpretable machine learning (ML) can provide an alternative large-scale approach to identify the nature of, and infer relationships between, drivers controlling vegetation impact and recovery. We developed a methodology using Google Earth Engine to systematically revisit the impact of past eruptions and constrain critical hazard and vulnerability parameters. The application of this method to the 2011 eruption of Cordón Caulle volcano (Chile) reveals its ability to capture different impact states as a function of hazard and environmental parameters. Model-agnostic interpretable ML tools also provide insights into feedbacks and thresholds controlling the impact and recovery of vegetation, both natural and cultivated. This approach has the potential to complement existing impact datasets and suggests how EO data can power new types of dynamic and large-scale vulnerability models.

Author(s): Amelia Lin; Conrad Zorn; and Liam Wotherspoon

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Title of abstract: Multi-scenario approach for seismic hazard assessments across New Zealand State Highways

Abstract: New Zealand is exposed to a range of natural hazards including earthquakes as well as earthquake-triggered liquefaction and landslides. Events such as the 2010–2011 Canterbury Earthquake Sequence or the 2016 Kaikōura earthquake demonstrated the potential impacts of (co-)seismic hazards on the infrastructure networks and highlighted

the importance of large-scale hazard assessments. Based on the ground shaking intensity of 478 actual and hypothetical earthquake scenarios, this paper introduces a new approach for the estimation of seismic exposure across the State Highway network, using the number of events (NoE) that might trigger liquefaction or landslides along the network. The multi-scenario approach differs from other methods, such as return period assessments, as it considers ground shaking as an aggregated hazard rather than a probability, which helps identifying network sections that could be repeatedly affected during earthquakes. The highest liquefaction exposure is observed in Bay of Plenty (Whakatāne), suggesting that the State Highways in this region could be affected by liquefaction during 37 earthquakes. The highest landslide exposure is measured in Wellington, presenting up to 25 earthquakes that could block State Highway sections by seismic landslides. Despite providing an alternative perspective on co-seismic hazards, the findings show severe skewness in the NoE values, affecting the interpretation of the results and indicating need for further research. Moreover, network criticality and vulnerability could be incorporated to better understand the potential impacts. The multi-scenario approach can be applied to other networks and offers valuable information, supporting decision making processes regarding mitigation or preparedness for future earthquakes.

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Title of abstract: The contribution of multi-frequency satellite InSAR data in multi-risk modelling of buildings exposed to ground instability hazards

Abstract: The burgeoning urbanization trend worldwide necessitates a comprehensive understanding of geological phenomena that pose a threat to these environments. Urbanization not only alters landscapes but also introduces complex geotechnical challenges, heightening the risk of ground instability-related hazards. Satellite Interferometric Synthetic Aperture Radar (InSAR) allows the detection of millimetric ground movements, providing a critical foundation for evaluating risks such as landslides posing a prevalent threat in hilly or steep terrain regions, sinkholes causing unexpected damage, and subsidence leading to structural damage.

Addressing these concerns, our study introduces an innovative, data-driven multi-risk model for urban buildings, employing a combination of multi-frequency multi-temporal satellite InSAR data, multi-hazard maps, and physical characteristics of the built environment. This research work offers a dynamic, semi-quantitative framework for assessing multiple risks, enabling proactive mitigation strategies. The model ensures the consideration of numerous hazards over large geographic scales and high-resolution mapping unit, delivering scalable and easily interpretable results. It computes single- and multi-risk scores by evaluating hazard probabilities, potential damage, and building displacement rates, thereby aiding in prioritising high-risk structures for targeted intervention, aiming at enhancing urban resilience and reducing future economic losses. A case study in Rome (Italy) illustrates the model's efficacy. Assessing multi-risk for approximately 90x103 buildings, it found that 60% are exposed to ground instability hazards. Specifically, 33%, 22%, and 5% exhibit the highest multi-risk score for sinkholes, landslides, and subsidence, respectively.

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Title of abstract: Appraising the Potential Implications on Vulnerable GLOF Sites in High Mountain Asia through Geospatial Techniques: A Case Study of Northern Pakistan

Abstract: The deglaciation due to global warming and changing climate has given rise to the formation and expansion of numerous glacial lakes, particularly in the High Mountain Asia (HMA) region. Many of these glacial lakes are susceptible to experiencing glacial lake outburst floods (GLOFs) events which can release millions of cubic meters of water and debris, leading to widespread impacts on lives, property, infrastructure, agriculture and livelihoods amongst remote and impoverished downstream communities in Pakistan. The research investigates the potential of multi-source data, focusing on District Chitral in Northern Pakistan, with elevated potential implications for GLOF and associated risk. A total of 12 vulnerable GLOF sites are chosen from Pakistan Meteorological Department's (PMD) GLOF inventory, out of which 5 are highly susceptible to GLOF. A spatio-temporal analysis of the vulnerable sites have been carried out considering key contributing factors with high impact potential including, lake area change, elevation, slope, aspect, temperature and precipitation, LULC, change in snow and glacier cover area, distance from fault line, and proximity to impact area, among others. A pronounced decline in the snow and glacial cover, and an increase in land surface temperature (LST) retrieved from satellite data could be responsible snow/glacial melting resulting to higher frequency of GLOFs and flash floods. The potential implications on population, infrastructure, schools, forest and agriculture, and water quality of District Chitral have been estimated. The findings are of great significance for policymakers and disaster management authorities, providing valuable insights to formulate efficient and effective measures for mitigating the identified risks.

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Title of abstract: Regional landslide and flash flood compound event analysis in the African tropics

Abstract: Rainfall-triggered landslides often occur in a compounding/cascading manner together with flash floods. Combined inventories of landslide and flash flood events over different climatic zones and a large range of landscape conditions are crucial to unveil the effect of climatic extremes on their spatio-temporal occurrence. This is particularly important in low-capacity and data- scarce regions such as the tropics where long and comprehensive multi-decadal time series are absent but the current and projected impacts of landslide and flash flood events are disproportionally high. Here we present an unprecedented comprehensive multi-temporal landslide and flash flood event inventory from 2017-2021 from optical and radar remote sensing over the western branch of the East African Rift covering about 400.000 km2. We identify a total of 107 events (roughly 15.000 individual features) with a median timing uncertainty of 6 days. For each event we classify landslide source, landslide runout and flash flood area using logistic regression and random forest which allows us to analyse each specific aspect of the event. We then analyse the landslide and flash flood compound events in terms of geophysical (e.g., slope, aspect, elevation, soil content), land use/land cover (e.g., forest fraction, forest loss), and rainfall (e.g., rx1day, rx5day, standardized precipitation index, local climate anomalies) properties using a cluster analysis approach. Preliminary results show a clear spatial pattern in event timing and a distinct difference in flash flood density in relation to the location within the study area. Ongoing analysis focusses on identifying potential pre-conditioning or multivariate controls of abovementioned variables on landslide and flash flood event occurrence.

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Title of abstract: Cloudiness variability and long-term decrease over a productive rice and vegetable region of South-Eastern South America: insights from Surface Observations and Satellite-Derived Data

Abstract: Through dialogues with vegetable and rice producers of Northeastern Argentina (NEA), a significant productive region of South-Eastern South America, the key role of cloud cover in crop yields has been brought to the forefront. Few studies have examined the Total Cloud Cover (TCC) changes in South America (SA), and none in the densely populated, highly productive sub-region of Northeastern Argentina (NEA). Since climate information at local and regional scales is considered to be more impact and risk-relevant climate change information, the objective of the present study is to present the climatology and the observed long-term changes and variability of TCC in NEA.

The analyses are based on two independent Earth-Observation datasets: TCC ground-based (GB) observations and satellite- based estimates from the International Satellite Cloud Climatology Project (ISCCP). The datasets cover a common period, from December 1983 to November 2016 (satellite period), while the GB TCC observations extend further, from March 1961 to February 2021 (GB period). To study the GB TCC and its temporal variations, we introduce a novel cloud index (CI), expressed in a familiar unit (%). We ensured the reliability of our results by comparing the two datasets. In addition, our study examines the interannual variability of the Cloud Index (CI) over the NEA, both annually and seasonally.

Our results provide evidence for a consistent decrease in cloudiness over the NEA over the last six decades, based on ground-based and satellite information, and provide valuable insights into the complex interplay between cloudiness and regional climate dynamics. All this provides a basis for informed risk decision-making in a region of economic and agricultural importance in the context of a changing climate.

Author(s): Sophie Buijs; Marleen de Ruiter; and Philip Ward

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Title of abstract: From Single to Multi-Hazard Recovery: A Statistical Approach Using Nighttime Light Satellite Data

Abstract: In a multi-hazard context, the recovery process after a disaster can be more demanding or challenging than in a single-hazard context. Rescue teams can for example be physically hindered in their rescue efforts and humanitarian personnel and financial resources can get depleted after a first disaster. Meanwhile, societal needs and dependence on humanitarian aid can remain high or become even higher after the second event. Nonetheless, research into post-disaster recovery is still mainly done from a single-hazard perspective, ignoring the spatial and temporal connections and feedback loops that are involved when multiple disasters coincide.

Satellite-based proxies are a promising option to derive more generalized quantitative observations of recovery dynamics over time, allowing for a comparison between recovery after single and multi-hazard events. This study uses nighttime light (NTL) satellite data as a proxy for economic recovery to assess general trends in recovery speed and duration for a large number of single- vs. multi-hazard events in Europe, North America, and Asia. To this end, 8-day composites of NASA's daily Black Marble NTL data are created and statistically analyzed using a Difference-in-Difference approach, comparing general trends that are observed for single and multi-hazard events. The results of this study can be used by policy-makers and aid organizations to improve their disaster management strategies. Moreover, the resulting characterisation of

economic recovery after single- and multi-hazard events will support future research into the identification of socio-economic and hazard specific factors that affect the recovery in a multi-hazard context.

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Title of abstract: Assessing Cascading and Compound Climate Extremes and Associated Vulnerabilities Across the United States

Abstract: Climate change is intensifying diverse extreme weather events across the United States, yet most research focuses on individual extremes in isolation. This fails to capture the cascading, amplifying, triggering and compounding nature of simultaneous or sequential extremes, and their interaction with social vulnerability. This study categorizes US regions based on exposure to cascading and compound hazards - when singular extremes precipitate or amplify subsequent extremes. We analyze overlapping spatial and temporal patterns of temperature, precipitation, hydroclimatic and other extremes using historical and projected climate data. The likelihood of cascading hazards arising from floods, droughts and heatwaves are quantified for counties and states. By overlaying multidimensional hazard exposure and adaptive capacity indices, generated through machine learning, we reveal locations facing the highest risks from compound and cascading climate extremes. Understanding where vulnerable communities face exposure to interlinked hazards can aid targeted adaptation policies to reduce disasters. The methodology provides a framework to evaluate cascading climate risks globally, moving beyond studying singular extremes.

Poster presentations

Author(s): Micky Maganini[1]; Amanda Markert[1]; Eric Anderson[1]; and Arjen Haag[2]

Affiliation: (1) SERVIR Science Coordination Office; (2) Deltares

Title of abstract: A Regional Intercomparison of Open Source Surface Water Extent Mapping Products and Packages

Abstract: The open source revolution of Earth Observation (EO) science has resulted in an increased openness of EO data, workflows to transform that data into end products (e.g. surface water extent maps), and the products themselves. However, this revolution has oversaturated decision-makers with products that can give conflicting results. Thus, it is increasingly crucial for scientists to communicate their methodologies and assumptions so scientific products can be used accurately. Recognizing this challenge, SERVIR – a joint initiative between NASA, USAID, and geospatial organizations in Asia, Africa, and Latin America – is conducting a regional intercomparison of open source surface water extent products and packages. SERVIR's Hindu Kush Himalaya and Southeast Asia "hubs" have developed satellite-based surface water mapping services involving customizable code packages that are operationally run at each hub. These services are regionally and locally tailored to inform specific decisions and early actions. Conversely, the scientific community has released surface water products that are global or near-global, but are not customizable. These packages and products employ different methodologies and sensors, causing decision-makers to evaluate trade-offs related to physical sensor characteristics (e.g. spectral, temporal, and spatial resolution, and latency). We will discuss the tradeoffs, strengths, and weaknesses of the sensor characteristics and methodologies associated with each product/package, and provide preliminary results of a validation effort intercomparing products/packages for case studies in South and Southeast Asia.

Understanding the strengths and weaknesses of these products is crucial in both the aftermath of a flood event and in preparing for future floods.

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Title of abstract: Using AI and traditional methods to map cascading torrential hazards in tropical regions

Abstract: In tropical mountain regions, cascading torrential hazards that include landslides, debris flows and floods have led to extensive disasters. Despite their severity, their hazard assessment faces several challenges, including a lack of terminology to describe them, and their common occurrence in remote, undeveloped regions where they are poorly or not documented.

This study aims to address these gaps by offering a description of the main conditioning and triggering factors of hydro-meteorological hazards in tropical regions. We combine artificial intelligence and traditional multi-temporal image analysis to map multi-hazard events automatically and focus on ways of objectively differentiating the different subprocesses involved in the disasters.

Using a new dataset of 10 cascading torrential events that occurred between 2017 and 2023 in tropical regions and freely available remote sensing sources, we extracted information concerning the geomorphology, soil texture, and triggering rainfall of each study area. Using different statistical tools, we analysed the relationship between different features to distinguish the main characteristics of such events in both the basin and the sub-process scale. We applied some deep learning algorithms, together with traditional NDVI multi-temporal mapping, to delineate the source and runout of the multi-hazard events, using topographic information to differentiate between the landslide, debris flows, and flooding components involved.

This research offers a novel perspective on multi-hazard assessment in tropical mountains, emphasizing the integration of AI with traditional detection techniques. By improving their knowledge and documentation, we aim to advance a key step to their further risk reduction strategies.

Author(s): Roxana Ciurean; Annie Winson; Erin Mills; Kay Smith; and Luke Bateson.

Affiliation: British Geological Survey, Nottingham, UK

Title of abstract: Exploring the use of remote-sensing data for impact assessment in areas affected by dry conditions compound events in the UK

Abstract: The 2021- 2022 high temperatures leading to drought and heatwaves in the UK placed a significant burden on first responders and the healthcare system, disrupted transport infrastructure, energy, and the utility sectors, and caused economic losses at the local, regional, and national levels. Moreover, structures such as buildings, roads, and other infrastructure not only contribute to urban heat island effects increasing human health risks but are also damaged due to land subsidence in clay-rich soils.

Remote sensing data provides global, timely, objective observations to monitor the effects of high sustained temperature leading to urban heat islands (UHI) and ground movement over time, for example. However, there are opportunities to maximise the use of satellite-based earth observations in combination with socio-economic data for the collection of

dynamic vulnerability and exposure data as well as impact assessment across different interacting hazards. In this study, we present several case studies in the UK where multi-sectoral impacts associated with compound or cascading multi-hazard events interact resulting in loss of functionality, reduced capacity, productivity, or failure. We develop network diagrams and narratives to visualize and summarize drought and heatwave cascading effects on the society, economy, or environment. The results are integrated with socio-economic and damage data derived from catalogues, census, or processing of satellite imagery. Future work will focus on comparing the timeline of identified impact relationships with thresholds in observable environmental changes that indicate the onset of compounding or cascading multi-hazard events.

Session 6: Health and disasters

Author(s): Zélie Stalhandske[1,2]; Jonathan Chambers[3]; Chahan Kropf[1,2]; Marleen C. de Ruiter[4]; and and David N. Bresch[1,2]

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Title of abstract: Hotspots of Multi-hazard Risk to Human Health in a Changing Climate

Abstract: The health effects of climate change, from intensified heatwaves to increased environmental suitability for infectious diseases, have become increasingly evident in recent years. In this study, we investigate the intersection of multiple climate-related health hazards from 2003 to 2022 using indices from the Lancet Countdown on Health and Climate Change, including heatwaves, drought, malaria, and wildfire smoke exposure. Through a global analysis at a 0.25-degree resolution, we identify regions where these hazards have overlapped, highlighting hotspots of simultaneous exposure. We then perform detailed case studies in countries most affected by these hazards, where we explore the interactions between seasonal climate variations, demographic shifts, and the exposure to health hazards. The findings of this study can help guide health system adaptations and inform policy by revealing where, when, and whom these hazard combinations affect. Finally, while the health effects of some of these combinations have been studied, the compounding effects are generally unknown. Mapping their co- occurrence can help in designing relevant epidemiological studies to better understand these consequences.

Author(s): Marie-Luise Zenker; Philip Bubeck; and Annegret Thieken

Affiliation: Institute of Environmental Science and Geography, University of Potsdam

Title of abstract: Unveiling long-term mental health effects after flooding: Influence of spatiotemporal elements on recovery after the 2021 German floods

Abstract: Severe flood events have been found to significantly impact mental health. They are associated with an increased prevalence of mental disorders like posttraumatic stress disorder (PTSD), which is initialized by experiencing or witnessing an event that poses a severe threat of death or serious injury to oneself or another person.

Moreover, the person has to react to that event with intense fear, helplessness or horror. In July 2021, Germany experienced severe flooding that caused overall damage of € 33 billion and 190 fatalities. Many people lost their homes or loved ones, suffered injuries or are still occupied with rebuilding and financial recovery. Given the severity of the 2021

flooding event, we expect that a significant share of the affected population was exposed to a situation matching the PTSD conditions.

However, there is a lack of knowledge and understanding of the long-term mental health effects of severe flooding, the factors that influence them, and the recovery process. To address this gap, we conducted online surveys 12 to 18 months after the flood event in the district of Ahrweiler, the most affected region in Germany, and other affected areas of North Rhine- Westphalia. The survey utilized a short epidemiological screening scale to detect indications of PTSD. Through empirical modeling, we aim to gain a nuanced understanding of factors influencing PTSD with regard to the recovery process. Further, we will investigate the effects of spatial context factors. With this study, we aim to contribute valuable insights to the existing body of knowledge on the long-term mental health effects of severe flooding, emphasizing the influence of spatiotemporal elements on recovery.

Author(s): Samuel Lüthi[1]; Erich M. Fischer[1]; and Ana M. Vicedo-Cabrera[2]

Affiliation: (1) ETH Zürich; (2) University of Bern

Title of abstract: Storylines for heat-mortality extremes

Abstract: Recent heat extremes reached records far out of the observational temperature range. These extremes challenged the risk view of climate scientists on what could be physically possible within the current climate conditions. However, it is precisely such unprecedented events that pose a large risk to underprepared societies. To better anticipate and prepare for such potential extreme events, the climate risk community started producing storylines which are designed to draw plausible worst- case scenarios.

The recent development of the ensemble boosting method allows investigating physically plausible extreme heatwaves by re- initializing a climate model with perturbed atmospheric initial conditions shortly before the onset of a great heat anomaly. This allows for creating storylines whilst ensuring physical consistency. However, so far these storylines were only used to estimate the pure physical climate extreme without the additional quantification of impacts on society.

In this study, we therefore aim to produce several storylines for potential worst-case heat-mortality scenarios. For that, we aim to combine ensemble boosted climate model output with methods from environmental epidemiology to quantify heat-mortality. Concretely, we model the empirical relationship between daily mean temperature and daily mortality counts using a well- established approach in climate change epidemiology. We then combine these empirical relationships with the bias-corrected extreme storylines that we developed by ensemble boosting a fully-coupled free-running climate model (CESM2).

The findings of this study have significant implications for societies, particularly in the context of public health policy development, to effectively respond to unprecedented but anticipatable heat extremes.

Poster presentations

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Title of abstract: Regional differences in the impact of heat on public health within Europe

Abstract: Heatwaves can lead to increased human mortality and therefore have severe socio-economic impacts. Comparing the results of previous studies in this domain reveals differences in these relationships, which imply differences in the vulnerability of communities to heat. As most studies examine mortality in select locations, there is a need for a comprehensive analysis using a common methodology to identify heat-health relationships.

In this study, we identify and assess the relationship between mortality and temperature across Europe. For this purpose, we fit a Generalised Additive Model (GAM) to obtain region-specific mortality-temperature relationships, and from these we identify critical temperatures for each region, above which mortality increases markedly. By spatially mapping the thresholds derived from the GAM, we gain insight into the geographic and social factors that drive these critical temperatures. In addition to spatial variation, our study looks at specific scenarios, such as warm antecedent temperatures and combined hot and dry conditions, utilizing a multi-hazard approach.

This large-scale analysis can reveal spatial patterns and differences in the response of human mortality to warming temperatures, which is key to improving societal resilience to heat waves in a warming climate. Understanding spatial variation in health responses to high temperatures is critical for formulating targeted interventions that address the specific needs of different regions, while using a common methodology to determine this variation. Our findings contribute to the broader body of knowledge on health-heat relationships and provide actionable insights for a more comprehensive understanding of the interactions between natural hazards and human health.

Author(s): Thi Dieu My Pham[1]; Annegret H Thieken[1]; Paul Hudson[2]; and Philip Bubeck[1]

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Title of abstract: Understanding the cumulative mental health impacts of frequent flooding and COVID-19 in Thua Thien Hue province, Central Vietnam

Abstract: There is an urgent need for better understanding and addressing public health problems induced by extreme weather in the context of climate change. Among natural hazards, floods tend to increase the risk of affective and anxiety disorders, especially the risk of post-traumatic stress disorder. In 2020, several countries suffered severe floods, including Vietnam, simultaneously with the COVID-19 pandemic. Several studies on flood impacts on mental health have covered various countries and target groups with different research methods and purposes. However, research gaps still exist: very few articles from the Global South have focused on the cumulative mental health impacts of frequent floods and COVID-19. To build community resilience, understanding the cumulative effects of two disasters is urgently needed. This research aims to compare the impacts on mental health of single and repeated floods and investigate the cumulative impacts of floods and COVID-19. Four hundred face-to-face interviews were conducted in October 2023 in two coastal communes in Thua Thien Hue province, Central Vietnam. In 2020, the province faced widespread flooding that caused severe damage and loss of lives. At the same time, COVID-19 restrictions and hard lockdowns took place in several communities. Primary results show the long-lasting cumulative effects on the mental health of those affected. In 2023, 70% of respondents feel nervous about floods, and 41% feel stressed about the pandemic. Particularly, 43% of respondents said that flood and COVID-19 still impacted them significantly. Next, we will examine the risk factors and the difference in mental health issues compared to single flood events and explore the cumulative impacts of floods and COVID-19 on the targeted groups in the study site.

Author(s): Rozana Himaz; and Saman Ghaffarian

Affiliation: UCL Institute for Risk and Disaster Reduction

Title of abstract: Understanding changes to mental health in the wake of natural hazards

Abstract: This paper applies deep learning methods, specifically the Long Short-Term Memory (LSTM) model, to longitudinal household survey data for Indonesia collected before after the devastating 2006 Yogyakarta earthquake, to understand the evolution of mental health by sex at birth. The data come from the Indonesian Family Life Survey for 2000 and 2007, and contain a rich tapestry of pre and post earthquake data encompassing 6000 individuals with varying degrees of exposure to the earthquake to train the LSTM model. LSTM's unique ability to analyze sequences of mental wellbeing indicators allows us to untangle the intricate, non-linear relationships and long-term dependencies that traditional models might miss. This provides a deeper understanding of how individual mental wellbeing outcomes such as post-disaster stress reaction and depressive symptoms evolve in the wake of the earthquake. Through meticulous validation using statistical metrics like mean absolute error and R- squared, the LSTM's predictions will be rigorously validated. The LSTM results will be compared against results obtained from statistical methods. The paper shows how deep learning is a powerful tool to understand patterns in the evolution of mental wellbeing post-disaster by sex, especially in developing countries where data and analysis in this regard is sparse, and formal support for mental health may be less available than that for physical health.

Author(s): Gaia Bonini

Affiliation: Humane Society International

Title of abstract: One Health Approaches to Disaster Management: Insights from the Field

Abstract: Communities on the frontlines of natural hazards, complex emergencies, climate change and habitat degradation face a combination of risks to their health, livelihoods and well-being that are best described as One Health crises.

This presentation delves into the practical application of One Health approaches in disaster management, drawing on specific case studies including a drought mitigation project in northeastern Kenya and a community-based veterinary response initiative following last year's earthquakes in Türkiye and Syria. Review of these real-world interventions showcases the tangible benefits of integrating health considerations across human, animal, and environmental domains, as well as the challenges faced in their implementation and lessons learned by our team.

In addition to review of case studies, we'll define the One Health framework and illustrate its relevance in disaster scenarios. Topics covered will include detection and surveillance of zoonotic diseases, the impact of biodiversity on resilience, and the necessity of coordinated responses at all levels to these complex emergencies in our changing world.

In conclusion, the presentation underscores the critical importance of a One Health approach in enhancing preparedness, response, and recovery efforts. By embracing a holistic perspective, communities can better safeguard public health and promote sustainable resilience. This session empowers participants to recognize and act upon the interdependence of human, animal, and environmental health, fostering a comprehensive and effective strategy for disaster resilience in an ever-changing world.

Author(s): Julien Magana; Saba-Hinrichs-Krapels; and Tina Comes

Affiliation: TU Delft

Title of abstract: Including Local Initiatives and Behaviours in Health Disaster Response: A Case-Study Investigation of Patient Flow, Emergency, Health Services, and Community Engagement Following the 2021 European floods.

Abstract: Is everyone performing their own choreography? To puzzle out the dance of local initiatives and behaviours in health disaster responses, this study delves into the integration of local initiatives and behaviours in disasters, specifically examining patient flow logistics during the 2021 European floods. Rooted in a sense-making theoretical lens, the study explores how individuals navigate and respond to the complexities and uncertainties inherent in disasters.

Relevant stakeholders from the Netherlands (Limburg Province), Belgium (Limburg Province), and Germany (Ahr Region) are strategically identified to represent diverse perspectives, including health workers, general practitioners, emergency responders, and communities. Through semi-structured interviews, the research investigates contextual understanding, local initiatives, community behaviours, information-sharing, communication and decision-making mechanisms. The study aims to provide insights on the significance of various stakeholders involvement, local leadership, interconnected actor behaviours, and successful engagement practices during disasters. The findings will be used to build an empirical model of decision-making behaviours for patient flow logistics in disasters.

Ultimately, the goal is to produce empirical knowledge on the pivotal role of locals in adequately answering health disasters, using the 2021 European floods as a case study. This research aligns with the broader theme of health and disasters, shedding light on practical approaches to improve patient flow logistics within the context of disasters.

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Affiliation: (1) TU Delft; (2) 510, An Initiative of the Netherlands Red Cross

Title of abstract: Dynamic and adaptive epidemic control: A case study of anticipatory action to Cholera outbreaks in Cameroon

Abstract: Responding rapidly to epidemic outbreaks presents significant challenges, due to resource and capacity limitations. Anticipatory Action (AA) is a newly emerging strategy aimed at accelerating humanitarian responses. By taking impact- reducing actions before a disaster strikes, AA seeks to minimize human loss and required response efforts. However, AA frameworks currently use static prepared-in-advance plans with one-dimensional triggers and distinct phases of preparedness, anticipatory action and response. As a result, AA is not sufficiently able to deal with the levels of uncertainty in the onset and spreading of epidemics. Effective epidemic response requires plans that can adapt to a constantly changing environment and incoming information, such as the number and location of suspected cases, weather forecasts and population movement, while balancing flexibility with an effective management approach. We show how the Dynamic Adaptive Policy Pathways (DAPP) framework for decision-making under deep uncertainty can be adapted to enhance the common anticipatory action approach with flexibility and effective management for epidemic response. More specifically, we show how DAPP allows to take into account newly available information and change the response to minimize human loss. We illustrate it with a case study of cholera in Cameroon, for which the French and Netherlands Red Cross are developing an early action protocol and a model that assesses the cost-effectiveness of actions for different risk levels and external shocks. Our results suggest that DAPP increase flexibility and coordination in anticipatory action for epidemics and helps optimizing early- response strategies. The DAPP approach is transferable which could have larger implications for global disease control.

Session 7: Advancing critical infrastructure modelling in a complex world

Author(s): Raghav Pant

Affiliation: Environmental Change Institute, Oxford University

Title of abstract: Assessing climate risks to critical minerals supply-chains in Africa due to multi-modal transport disruptions

Abstract: Critical minerals of copper, cobalt, nickel, nickel, manganese and lithium have become increasingly important in the manufacture of clean technologies (e.g. EV's, solar panels) to enable a net-zero energy future [1]. Large quantities of these minerals are mined in Africa and transported across large-scale land and maritime networks. There are risks of disruptions to these networks due to climate hazards such as floods [2]. Understanding these risks and their impacts is very challenging due to the lack of spatially connected data on mines and transport networks.

This paper addresses the above challenge through a spatial risk assessment of Africa's critical mineral supply chains due to extreme flood impacts under climate change. We present a data-driven model of spatial allocation of mines in Africa, their linkages to multi-modal road and railways networks leading towards ports, and the global shipping networks enabling trade. The risk assessment quantifies flood impacts to mining supply chains in terms of the direct damages to network assets and indirect impacts due to increasing transport rerouting costs and flow losses. We investigate uncertainties associated with such large-scale data-driven analysis, by quantifying the global sensitivity of the risk outcomes to changes in flood hazards, damage curves and transport costs.

The overall aim of this paper is to advance data-driven models for critical infrastructure risk modelling at large scales and understand the uncertainties inherent in such risk quantification.

[1] Andreoni, A., & Roberts, S. (2022). Geopolitics of critical minerals in renewable energy supply chains.

[2] Bloomberg. (2023). S. Africa's Transnet Suspends Iron-Ore Railway on Storm Damage.

Author(s): Jonas Wassmer[1]; Seth Bryant[1]; Norbert Marwan[2]; Maria Pregnolato[3]; and Bruno Merz[4]

Affiliation: (1) University of Potsdam; (2) PIK Potsdam; (3) Delft University of Technology; (4) GFZ Potsdam

Title of abstract: Hidden Vulnerabilities in Emergency Response Post-Flood Disasters

Abstract: In this study, we address the escalating risks to emergency response systems posed by flood disasters, exacerbated by anthropogenic climate change. We present a novel method for analysing the impact of natural hazards on transport networks, recognising the significant societal and environmental impacts these events can have, particularly in terms of disruption to transport infrastructure. The method, rooted in the gravity model of travel, provides a unique lens through which we examine the stability of transport networks following a disaster. Specifically, we apply this approach to understand the vulnerability of the emergency response system in Germany to flooding.

To simulate flood scenarios in Germany's major river basins, we use a comprehensive regional flood model. This model includes a weather generator for realistic rainfall prediction, a hydrological model for flow conversion and a hydrodynamic model to simulate channel dynamics and overtopping. This allows us to assess potential damage to road infrastructure, including the destruction of bridges and roads, which can lead to critical traffic congestion and hamper emergency response, even in areas far from the flood epicentre. Our findings reveal non-intuitive vulnerabilities for hospitals that are not in the immediate vicinity of the flood event.

Our research highlights the need for targeted road repair and reinforcement strategies that focus on maintaining traffic flow for emergency response. By providing new insights into the resilience of transport networks, this study contributes to the wider discourse on mitigating the economic and social costs of future extreme weather events.

Author(s): Esther Barrios-Crespo

Affiliation: IHCantabria—Instituto de Hidráulica Ambiental de la Universidad de Cantabria

Title of abstract: Archetype-based methodology for climate risk characterisation in CI and adaptation decision-making

Abstract: Nowadays, numerous critical infrastructures (CI) may be affected by climate impacts, implying severe consequences beyond the purely physical dimension, in the economic and social spheres. Characterizing CI risk by considering different risk components and dimensions independently, but in a holistic approach, may enable the identification of risk patterns between different CI and, thus, help in the design of adaptation strategies. The main objective of the proposed methodology is to establish a CI classification system based on climate risk archetypes, with the aim of using these archetypes as a guideline for the design of adaptation in such CI. These archetypes will allow the characterization, by means of indicators, of the different components of risk: hazard, exposure and vulnerability.

The main steps in the proposed methodology are: (a) selection of indicators for the characterization of climate hazard in the four main categories of climate hazards: water, wind, air and solid-mass; (b) definition of indicators for the characterization of the components of risk, exposure and vulnerability, in their physical, economic and social dimensions and; (c) the identification of patterns by means of statistical techniques, which will allow to identify risk archetypes.

As a case study, this methodology will be applied to airport infrastructures at the European scale. To this end, a set of European airports will be selected for which each of the risk components will be characterized by means of indicators. As result, it is expected to obtain a classification of the different airports analyzed by comparing them through the resulting archetypes, which will serve as a guide for the adaptation of the component or dimension considered most critical from a risk analysis perspective.

Author(s): Alana Weir; Lucia Dominguez; Sebastien Biasse ; Costanza Bonadonna; Corine Frischknecht ;

Affiliation: University of Geneva

Title of abstract: Forensic systemic vulnerability assessment of interdependent critical infrastructure

Abstract: Volcanic eruptions can provoke spatially and temporally extensive impacts to society. These impacts often exceed the spatial and temporal extent of volcanic hazards, initiating far-reaching impact cascades across interdependent critical infrastructure networks. Growing infrastructure interdependencies are increasing volcanic risk, though we lack the frameworks and methodologies to assess systemic vulnerability of critical infrastructure networks in a volcanic context. In this study we conceptualise and apply and new approach to support volcanic risk assessment, which utilises post-event impact assessment methodologies to determine the dynamic systemic vulnerability of interdependent critical infrastructure networks during the 2021 eruption crisis of Tajogaite Volcano, La Palma (Spain). We deduce systemic vulnerabilities of infrastructure before, during and after the 2021 eruption crisis, and discuss implications for future volcanic risk in the La Palma context. The study utilises international best-practice for effective disaster risk assessment (DRA), namely to; 1) partner with risk management agencies to develop credible, relevant and legitimate outcomes for decision-making; 2) to facilitate international networks for knowledge exchange to enhance decision-making; and 3) to advance the spatio-temporal characterisation of disaster risk, including multi-hazard dimensions and systemic impacts and risks.

Author(s): Colin Manning[1], Sean Wilkinson[1], Hayley Fowler[1], Elizabeth Kendon[2], Sarah Dunn[1]

Affiliation: (1) Newcastle University; (2) UK Met Office

Title of abstract: Improved prediction of power outages in windstorms with inclusion of rainfall preconditioning, wind direction and season

Abstract: Windstorms are the main cause of large power outages in the UK. Faults to electricity distribution networks during windstorms are predominantly a result of windthrow, the uprooting or breakage of trees by winds that then fall on assets such as overhead lines. The impact of strong winds on windthrow is influenced by a several conditions: trees uproot more easily in saturated soils, they are more vulnerable to strong winds from unusual directions, and they are more susceptible to strong winds in the growing season when their leaves catch the wind. Despite this, risk assessments of such impacts during windstorms generally focus on wind intensity alone. Using meteorological data from ERA5 and fault data from the UK National Fault and Interruption Scheme (NaFIRs) database (2006-2018), we quantify the influence of contributing variables of windthrow on power outages including antecedent rainfall, wind direction, and the season a windstorm occurs in. We demonstrate that not accounting for their influence produces a 2-5 fold underestimation of the probability of large number of power outages in windstorms, with some regional variability. Furthermore, we show that including these variables in a statistical model alongside wind speed can improve the predictive skill of power outages during windstorms compared to a reference model that only includes wind speed. The results can help improve impact forecasts with benefits for event response teams, and highlight the importance of including these variables in historical and future risk assessments of critical infrastructure to better inform adaptations to climate change. This is important for electricity distribution networks upon which society will become increasingly reliant due to the electrification of transport and heating.

Poster presentations

Author(s): Ruoqing Yin; Liz Varga; and Gemma Cremen

Affiliation: Infrastructure Systems Institute, Department of Civil, Environmental and Geomatic engineering, University College London

Title of abstract: Modelling interdependent critical infrastructure systems under multi-hazard conditions: some recent advances and forward-looking perspectives

Abstract: The increasing frequency and interactions of natural hazards, along with growing interdependencies among different critical infrastructure, pose a rising array of threats to delivering essential services in current and future societies. This paper contributes to the required effort by exploring recent approaches for modelling critical infrastructure interdependencies in the context of evolving multi-hazard and systemic risk challenges. The study aims to:

1. Develop a taxonomy for classifying contemporary interdependencies in critical infrastructure.

2. Categorize diverse risks faced by interdependent critical infrastructure systems and elucidate how these risks interact across multi-hazard scenarios.

3. Develop a classification scheme for natural-hazard critical infrastructure risk modeling methods on the basis of findings from aims #1 and #2, among other considerations.

4. Leverage the classification scheme to propose a series of strategies that can be used to mitigate different types of multi-hazard, systemic risks associated with interdependent critical infrastructure.

The results of this study ultimately provide an organized means of addressing the dynamic intricacies of critical infrastructure risk from natural hazards, and have the potential to facilitate more informed decision making by relevant stakeholders

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Author(s): Fernandez-Perez, A.; Lara, J.L.; and Losada, I.J.

Affiliation: IHCantabria - Instituto de Hidraulica Ambiental de la Universidad de Cantabria, Spain

Title of abstract: Compound and cascading climate risks assessment in port and coastal infrastructures

Abstract: Port facilities hold paramount socio-economic significance, serving as critical nodes in logistical chains and national and supranational economic strategies. They act as gateways for global trade, facilitating shipments through rail and road connections and distributing freight within them. Jointly, coastal infrastructures serve as the primary defense against climate- related hazards, like extreme winds, storms, and tropical cyclones. Such events have complex impacts on coastal and port infrastructures, with direct damages and service interruptions, stemming from harsh conditions that cause downtimes from critical damages. Therefore, evaluating climate effects on coastal and port infrastructures requires identifying critical elements and their potential impact on service interruptions. Complex interactions of multiple climate variables with the exposed coastal and port critical infrastructures shall be evaluated, not only accounting for present climate conditions but also considering climate change effects on future climate. Coherently, the authors propose a methodology in order to (1) consider compound effects arising from the interaction of multiple climate drivers, evaluating the concurrency of extreme values and their synergic impacts, (2) assessing infrastructure physical and operational relationships in order to coherently spill over cascading impacts within the facilities' complex system schemes and (3) stressing particular facilities under present and future conditions. The proposed methodology is applied to a number of ports in Spanish north coast, showing the applicability and replicability of the framework, outputting that interactions between climate risks should not be neglected as non-linear effects emerge in a considerable share of the total value of risk.

Author(s): Xuhui Lin; Qiuchen Lu; and Tim Broyd

Affiliation: University College London

Title of abstract: Enhancing Urban Flood Response: Traffic Flow Prediction Using a Field Theory-Inspired Graph Neural Network Diffusion Model

Abstract: Amidst global climate change, the increasing severity of flood disasters on transportation network system, has become a pressing concern. While various methods to predict and manage traffic flow changes during floods have been developed, they often lack a comprehensive understanding of the dynamic alterations in complex transportation networks, especially in real- time response situations. These models face significant challenges in addressing uncertainties and dynamic changes, such as road closures and emergency evacuation routes. This paper addresses this challenge by presenting a new graph diffusion model, carefully designed to precisely predict transportation flow during flood conditions. Rooted in Graph Neural Networks and field theory principles, this model simulates traffic flow propagation and fluctuations during disasters. It innovatively integrates graph diffusion with field theory, including fidelity terms and higher-order neighbour awareness. This allows for precise modelling of flood impacts on network structure and dynamics. Especially, the model constructs a graph comprising public transportation nodes and road networks. It employs diffusion

equations in field theory to track the dynamic shifts of traffic flow on constructed graph. The model's diffusion coefficients and fidelity terms are carefully calibrated to respond to swift changes in road conditions during floods. Moreover, by integrating data from higher-order neighbours, the model gains an enriched understanding of traffic flow propagation patterns, markedly improving the precision of its predictions. This approach aims to assist in resilient infrastructure design, emergency response, traffic management, and evaluating climate change impacts, thus enhancing flood resilience and decision-making.

Author(s): Edgar Daniel Peregrina Gonzalez[1,2]; Kees C.H. van Ginkel[1,2]; Margreet J.E. van Marle[1]; Sahand Asgarpour[1]; and Elco E. Koks[2]

Affiliation: (1) Deltares, the Netherlands; (2) Institute for Environmental Studies (IVM), Vrije Universiteit Amsterdam, the Netherlands.

Title of abstract: Climate adaptation in critical infrastructure: A layered approach

Abstract: Extreme weather events threaten Critical Infrastructure (CI) by disrupting and damaging it. Climate change may increase event intensity and frequency, resulting in more disruptions and damages. This explains the need for adaptation to avoid a growing burden on society. However, comparing adaptation options systematically has proven to be difficult, mainly due to two limitations. First, adaptation can take place at different levels, for example, asset-specific floodproofing or region-wide flood protection, and it is unclear which is most effective. Second, the benefit of multiple adaptations is not simply additive; their combined effects may exhibit a more intricate interplay. Therefore, simultaneously considering multiple adaptation options makes it possible to quantify their total costs and benefits and understand the most attractive alternatives. We present and demonstrate a framework to overcome both limitations. It can be used to systematically appraise adaptation options for CI that (1) intervene at different levels including hazard-, asset-, network-, and system-level and (2) have a combined effect on CI resilience. The framework is demonstrated in a stylised use case of adapting railways to fluvial flooding along the Rhine River, based on an object-oriented approach using rail data from OpenStreetMap and public flood data reported in the EU Floods Directive. The framework is generic, as such, it can be applied to different CI types (e.g. transport, energy, telecom) and for multiple hazards (e.g. pluvial and coastal floods, wildfires, windstorms). Ultimately, the framework intends to inform decision- making and enable the coordinated adoption of climate adaptation strategies by the many stakeholders of CI systems, including owners, operators, regulators, and users.

Author(s): Elisa G. L. Nobile; Marcello Arosio; Alessandro Caiani; Jlenia Di Noia; and Mario L. V. Martina

Affiliation: University School for Advanced Studies - IUSS Pavia, Pavia, 27100, Italy

Title of abstract: Modelling Flood Shocks Propagation in Economic Networks: An Agent-Based Model for Supply Chains

Abstract: In the context of escalating climate change, accurately quantifying the impacts of natural hazards, particularly floods, is crucial for effective risk management and for building resilient systems. Traditional risk frameworks focus primarily on direct damages, often neglecting indirect economic impacts such as business interruption and contingent business interruption. To address this gap, our study adopts a multidisciplinary approach derived from complexity science, integrating network theory, traditional Input-Output models, and agent-based modelling. This approach aims to intricately represent the heterogeneities within an economic network by detailing relationships between different firms and exploring the dynamics between buyers and suppliers. The methodology involves two key steps: initially, it develops a static representation of commercial links within the economic network using preferential attachment mechanisms; subsequently, it simulates a shock, such as a flooding event, within the supply chain. The model, built using high-resolution

input-output tables and business registry data, includes information on geolocalized firms, economic sectors, and numbers of employees. This integration will provide a comprehensive view of cascading economic effects and enhances traditional models by examining the transport-supply chain nexus. Applied to Tuscany, which is an Italian region, recently impacted by severe flooding, our approach delineates the region's economic structure as an interconnected network. Our findings will provide critical insights for policy-makers, urban planners, and the insurance sector, advocating a shift towards holistic risk assessment to bolster societal resilience against the multifaceted impacts of natural hazards.

Author(s): Peter Priesmeier; and Adrian Rohr

Affiliation: University of Applied Sciences Cologne - Institute of Rescue Engineering and Civil Protection

Title of abstract: Road network criticality model for emergency services: A case study of heavy rain impact on ambulance response time in Cologne, Germany

Abstract: In the response phase of a natural hazard event emergency response services emerge as a crucial critical infrastructure (CI). Nevertheless, rescue CI is often exposed to hazards and depends heavily on secondary CI like the road network for optimal functionality.

This study aims to delineate key segments within urban road networks, that are important for a timely emergency response and must therefore be kept functional and free of blockages. For this purpose, a model is developed that detects bottlenecks in a road network based on the iteration of weighted routing processes and systematic blockages. The blockage of such bottlenecks would result in a high delay to reach the city area behind it. The model is tested on the ambulance service of the Cologne in Germany. The routing and driving patterns of ambulances are derived from statistical travel time data and dispatch locations of the emergency medical service of Cologne.

The intermediate results uncover several particularly critical bottlenecks, which are located around ambulance stations or in arterials that connect remote but densely populated areas to the main city. The result is then combined with a heavy rain hazard map. This reveals that some of the identified bottlenecks would become impassable during severe heavy rainfall events. Consequently, residents in areas secluded by these blockages would experience increased ambulance response delays.

This approach shows the cascading effects induced by flood hazards on the critical infrastructure of emergency services. The result can help decision makers such as fire brigades and urban planners to identify which roads require enhanced protection or prioritization for recovery after incidents, thereby ensuring the functionality of the emergency response infrastructure

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Author(s): Joë Pelmard[1]; Alice Harang[2]; Emily Lane[2]; Cyprien Bosserelle[2]; Rose Pearson[2]; and Conrad Zorn[1]

Affiliation: (1) University of Auckland; (2) New Zealand Institute of Water and Atmospheric Research (NIWA)

Title of abstract: Learning from tropical cyclone Gabrielle: A framework for the modelling of flood response to extreme weather events across New Zealand

Abstract: On February 14th, 2023, Cyclone Gabrielle struck New Zealand, impacting the country at an unprecedented scale, far beyond the regional and district councils' business-as-usual response capabilities. The event caused widespread flooding across the North Island, with consequences including loss of life, material harm to buildings and infrastructures, large volumes of sediment deposits across farmlands and populated zones, levee breaches and soil erosion. The expected increase under climate change of high magnitude events renders essential the assessment of the local implications of

flood events to supply communities, councils, and stakeholders with relevant intel to support their decision making and help mitigate potential future hazards.

As part of a collaboration involving flood and climate experts from local councils and research institutes, the Rapid Flood Hazard Assessment and Modelling project is developing and applying a systematic and comprehensive framework for the multi-scale modelling of flood responses to extreme weather events, which includes: generation of hydraulically conditioned DEMs and roughness maps from LiDAR and infrastructure data; generation of calibrated rain data from gauges records and synoptic rain forecasts; estimation of river flow injections using the hydrological model TopNet; hydrodynamic modelling using the 2D shallow-water solver BG-Flood.

Using Cyclone Gabrielle as a baseline validation case study, the framework was successfully deployed to model 15 flood plains critically hit during the event in the Hawke's Bay and Tairawhiti regions and validated against aerial images and council's gauges records. Despite the need for additional calibration (DEM, rainfall) to accurately capture flood extents and recorded hydrographs in complex dyn

Session 8: General advances in disaster risk science and compound climate events

Author(s): Judith N. Claassen[1]; Philip J. Ward[1,2]; Wiebke Jäger[1]; Elco E. Koks[1]; and Marleen C. de Ruiter[1]

Affiliation: (1) Institute of Environmental Studies, VU Amsterdam; (2) Deltares, Delft, The Netherlands

Title of abstract: A European Perspective on Joint Probabilities Within Multi-Hazards

Abstract: Natural hazards rarely occur in isolation. Frequently, one hazard triggers another, such as an earthquake triggering a tsunami. Likewise, the likelihood of a hazardous event can be amplified by the occurrence of a previous event, such as a drought amplifying the likelihood of a wildfire. However, two extremes can also co-occur as a compound event, leading to even higher combined impacts.

While the field of compound events is advancing rapidly, studies often focus solely on climatic extremes occurring at the same time, excluding non-climate-related hazards or previous triggering and amplifying conditions. Therefore, this research aims to better understand the dependencies between different (pre-conditioning) hazard magnitudes, geographic features, and historic natural hazard footprints, accounting for both climatic and geological hazards.

With the use of a newly created Python vine-copula package, we model the relationships within two different hazard groups. The first group consists of drought, heatwave, and fuel indicators to calculate the likelihood of wildfires. The second group includes earthquakes, precipitation, and slope data to calculate the likelihood of landslides. While the first group is considered a compound event, the second group can be classified as a multi-hazard, with different triggering or amplifying relationships. For both groups, we attempt to use the same method to model synthetic/stochastic events that include a potential hazard footprint for wildfires and landslides on a local/European scale. This model allows users to evaluate potential hazard combinations and footprints in their regions, enabling better preparedness for potential multi-hazard events.

Author(s): Ali Tawalo[1]; and Gianfranco Urciuoli[2]

Affiliation: (1) Scuola Superiore Meridionale; (2) Department of Geotechnical Engineering, University of Naples Federico II

Title of abstract: Probabilistic approach for assessing multi-site slope land displacements induced by groundwater fluctuations

Abstract: The displacements of land induced by fluctuations in groundwater levels carry significant implications for infrastructures. Assessing the risks associated with affected structures requires a proper assessment of these displacements. This task becomes notably complex for widespread infrastructures such as pipelines, railways, and tunnels, where simultaneous assessments are essential across different sites. The complexity arises from the spatial variability of soil properties and the temporal variability of groundwater level. Consequently, a probabilistic approach becomes imperative to effectively evaluate the multi-site slope land displacements resulting from groundwater fluctuations. While previous studies on probabilistic slope stability analysis predominantly focused on the safety factor of slopes, some other studies addressed displacements preceding collapse using deterministic approaches. In this research, a probabilistic approach is introduced to assess multi-site slope land displacements induced by groundwater fluctuations. This approach takes into account both spatial and temporal uncertainties inherent in the input data. To demonstrate its effectiveness, this approach is applied to a real-world case study— the Miscano slope.

Author(s): Dina Vanessa Gomez Rave; Diego A. Urrea; and Manuel del Jesus

Affiliation: IHCantabria - Instituto de Hidráulica Ambiental de la Universidad de Cantabria. Santander, Spain

Title of abstract: Advanced Modelling of Compound Flooding in Estuaries

Abstract: Estuaries often face a unique challenge with compound flooding, where interactions among fluvial, coastal, and pluvial drivers can result in significant local impacts. Although these drivers may not individually reach extreme levels, their combined effects can lead to severe consequences. The detrimental effects on communities and ecosystems underscore the potential transformation of these natural hazards into disasters. Neglecting interactions and dependencies between drivers may result in inaccurate flood risk assessment, inappropriate emergency responses, or deficient disaster risk management. While floods are inevitable, effective flood risk management demands a deeper understanding of triggering mechanisms, advancements in modelling and monitoring techniques, integration of climate data into infrastructure design, and comprehensive community initiatives. However, integrating multiple drivers into risk assessments, despite established practices for individual drivers, remains a complex task lacking universal guidelines. This research delves into the intricacies of multivariate extremes, unravelling relationships and stochastic structure within extreme values. Initially, by leveraging advanced statistical techniques and computational optimizations, we capture and model dependencies among multiple drivers. This enables the transformation of dependencies into potential impacts, outlining hazard scenarios. Afterward, a hydrodynamic model built upon the statistical framework aims to provide a representation of potential impacts arising from the compound hazard. This analysis not only enhances our comprehension of the complex dynamics associated with compound flooding, but also yields tangible advantages for engineering practices and informs policy decision-making.

Author(s): Davide Mauro Ferrario[1,2,3]; Marcello Sano[1,2,4]; Margherita Maraschini[1,2]; Elena Petrovska[2]; Judith Claasen[5]; Timothy Tiggeloven[5]; Marleen de Ruiter[5]; Silvia Torresan[1,2]; and Addrea Critto[1,2]

Affiliation: (1) CMCC; (2) Università Ca' Foscari; (3) IUSS Pavia; (4) Griffith University; (5) Vrije Universiteit Amsterdam

Title of abstract: Multi-Hazard assessment for present and future scenarios: a Myriad-EU case study in the Veneto Region

Abstract: The IPCC advocates for a shift from single-hazard to a more comprehensive understanding of interconnected multiple hazards. However, existing risk assessment methods are not suitable to effectively incorporate non-linear relations and feedback effects across multiple hazards and vulnerability and exposure drivers. Moreover, analyzing future risk projections is crucial for effective preparedness, yet uncertainties in climate change modeling add further complexity to studying future multi- risk patterns.

To address these issues, we propose a multi-hazard risk framework based on Artificial Intelligence (AI) and climate change scenarios analysis for the Veneto region (Italy), co-developed and tested with local stakeholders within the Myriad-EU project to assess risks from heatwaves, droughts, storms, landslides, and wildfires. First, extreme events are identified in the 1991- 2020 period using multiple thresholds, and DBSCAN is applied to extract single hazard footprints. Next, multi-hazard events are analysed, combining footprints of single hazards. Different definitions are tested for identifying multi-hazard events: overlapping in time and space, only in time, and with a time-lag for consecutive multi-hazard events. Footprints of past events are discussed, emphasizing hot/dry (heatwaves, drought, wildfires) and wet chains (precipitation, wind, landslides). Results are validated against time series obtained from remote sensing and disaster catalogs. Finally, we explore future variations in trends and spatial distributions under diverse climate change projections (RCP 2.6, 4.5, 8.5), based on 5 Euro-Cordex models downscaled for Veneto, highlighting an increase of hot and dry events after 2050.

Author(s): Lisa Köhler

Affiliation: University of Potsdam, Helmholtz-Centre for Environmental Research Leipzig

Title of abstract: Compound hazard experience and its feedback on resilience and adaptive behavior

Abstract: While research on compound extreme events is a rapidly evolving field of research (e.g. better understanding and quantification underlying physical processes and feedbacks), our knowledge about how the experience of compounding hazard events (e.g. floods, heat waves and COVID-19) interacts with resilience and adaptive behavior of exposed households remains quite limited. Most studies either focus on single hazards (e.g. adaptive behavior with respect to future flooding) or on the perception of different hazards (e.g. earthquake vs. heat waves). In this paper, we address this knowledge gap. We aim to focus on people's self-reported resilience and adaptation to floods and how they interact with two additional hazards that have been predominant in recent years: the occurrence of heatwaves and the outbreak of a global pandemic, COVID-19. Our analysis mainly consists of three subsequent steps. First, we apply Latent Class Analysis to detect unobserved groups in the sample characterized by the same flood experience but different levels of resilience and adaptation. Second, we examine to what extent the defined groups differ in their exposure to heat and COVID-19. Third, we include demographic variables as well as social context characteristics to get a better understanding of the differences we found with respect to resilience and adaptation. Through our study, we aim to shed some light on compound hazard experience as well as demographic and context variables influencing the resilience and adaptive behavior of exposed households.

Author(s): Katharina Küpfer[1,2]; Susanna Mohr[1,2]; and Michael Kunz[1,2]

Affiliation: (1) Institute of Meteorology and Climate Research, KIT, Germany; (2) Center for Disaster Management and Risk Reduction Technology (CEDIM), KIT, Germany

Title of abstract: Clustering of impact-related compound meteorological extremes in southwest Germany

Abstract: When multiple natural hazards occur simultaneously or in serial clusters, they have considerable potential to aggravate disruptions compared to single events. The goal of this study is to improve the understanding on how and when

combinations of different hazards lead to economic impact. We therefore use a residential building insurance dataset including the number of damage claims reported as well as insured losses aggregated over southwest Germany and from 1986-2023. Only convective storms, hailstorms, winter storms and floods are considered, as these events cause most of the economic damage in the region of interest. After removing high-frequency clustering, damage events are characterised meteorologically. Since the loss data are simply subdivided into storm, flood and hail categories, we refine them into more accurate meteorological types (pluvial vs. fluvial floods, convectively vs. synoptically triggered storms, hail category filtered by season) with the help of observation data. The degree of clustering for single and combined extremes is then assessed by a) identifying time periods with several extremes by a counting algorithm and b) quantifying and comparing the degree of clustering using Ripley's K.

Results include that clusters of single event types occurred mainly in the summer months, except for synoptic storms (related to high loss), and stratiformly dominated floods (lower loss). Events of two or more types particularly cluster in the mid-2000s, with clusters related to high loss occurring exclusively in the summer months. However, a quantitative assessment shows that clustering, compared to a random sample, is only statistically significant for certain combinations of event types, which might be related to the large-scale atmospheric circulation.

Author(s): Federica Romagnoli[1]; Silvia Cocuccioni[1]; Liz Jessica Olaya Calderon[1]; Funda Atun[2]; Massimilano Pittore[1]; Stefan Schneiderbauer[1,3,4]; Cees van Westen[2]; Richard Sliuzas[2]; Iuliana Armas[5]; Cosmina Albulescu[5]; Ruxandra Mucanu[5]; and Seda Kundak[6]

Affiliation: (1) EURAC Research; (2) University of Twente; (3) United Nations University – Institute for Envitonment and Human Security; (4) Department of Geography, University of the Free State, Qwaqwa Campus; South Africa; (5) University of Bucharest; (6) Istanbul Technical University;

Title of abstract: Combining Impact Chains with Forensic Analysis in the analysis of compound events: insights from the Vaia windstorm case study

Abstract: Understanding causal linkages and interactions between risk components is crucial to acquire a comprehensive knowledge of natural hazard impacts and improve risk mitigation measures. Despite several advancements in risk science and hazard modeling, the understanding of dynamics and interactions characterizing compound hazards and multi-risk is still limited. Taking stock of current limitations in risk science, our contribution will present a methodology to unravel the interactions among multiple risk components in a multi-risk context. Impact Chains(ICs) are conceptual models and analytical tools to systematize and visualize the interplay among hazard impacts, compound vulnerabilities, and exposure factors, streamlining the chain of cascading impacts characterizing compound events.

Within the EU Horizon PARATUS project we implemented ICs for the analysis of past events, combining it with Forensic Analysis. Forensic Analysis provided the framework to develop the event storyline and identify core elements of impact chains. The combination of these approaches helped identify past and present risk drivers, connecting them with hazard impacts. To show the merits of this approach, we implemented it in the analysis of Vaia windstorm. The storm hit Italy in 2018 and was characterised by high intensity rainfall and intense wind gusts. Our contribution will present most relevant risk pathways, vulnerabilities and risk drivers and their reciprocal interconnections. The methodology showcases its potential for capturing the variety of risk components, stressing the relevance of connections between physical and social elements. The analysis of past events will provide relevant insights to improve future risk reduction measures, increasing disaster preparedness and resilience.

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Title of abstract: Reclassifying historical disasters: from single to multi-hazards

Abstract: Multi-hazard events pose a significant threat to human lives and assets. This is primarily due to the cumulative and cascading effects arising from the interplay of various natural hazards across space and time. However, their identification is challenging, which is attributable to the complex nature of natural hazard interactions and the limited availability of multi-hazard observations. This presentation, focused on a recently published article (https://doi.org/10.1016/j.scitotenv.2023.169120) presents an approach for identifying multi-hazard events during the past 123 years (1900-2023) using the EM-DAT disaster database. Leveraging the 'associated hazard' information in EM-DAT, multi-hazard events are detected and assessed in relation to their frequency, impact on human lives and assets, and reporting trends. The interactions between various combinations of natural hazard pairs are explored, reclassifying them into four categories: preconditioned/triggering, multivariate, temporally compounding, and spatially compounding multi-hazard events. The results show, globally, approximately 19% of the 16,535 disasters recorded in EM-DAT can be classified as multi-hazard events. However, the multi- hazard events recorded in EM-DAT are disproportionately responsible for nearly 59% of the estimated global economic losses. Conversely, single hazard events resulted in higher fatalities compared to multi-hazard events. The largest proportion of multi-hazard events are associated with floods, storms, and earthquakes, with landslides the predominant secondary hazards. The majority of multi-hazard events exhibit preconditioned/triggering and multivariate characteristics. These results can be used to increase the integration of multi-hazard thinking in risk assessments.

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Title of abstract: Advancing Multi-Hazard Risk Reduction: A Catalog of Integrated Multi-hazard Mitigation Measures for flood and earthquake

Abstract: In response to the evolving landscape of risk management, there has been a persistent call from academia and international organizations to transition from a single hazard to a multi-hazard perspective. This study aligns with this paradigm shift, presenting a catalog of integrated mitigation measures for floods and earthquakes to be applied at building and neighborhood scales. The research organizes these measures into a structured database and develops a universally adaptable catalog with hazard-specific attributes. Furthermore, it systematically addresses potential synergies and drawbacks between risk reduction measures. This dynamic living catalog can be integrated into a Decision Support Tool (DST), serving as a foundation for informed decision-making in the ongoing pursuit of effective multi-hazard risk reduction strategies.

Different measures are identified and categorized using different attributes to facilitate easy navigation, understanding, and selection when integrated into our DST. These attributes are chosen through a literature review, focusing on selection procedures and decision support tools, and specifically examining their decision variables for three distinct domains: earthquake strengthening, flood protection, and energy efficiency interventions. Moreover, multi-hazard related aspects, such as synergies and drawbacks between measures from these three domains, are included.

Attributes applicable to both flood and seismic interventions include life cycle cost, environmental impacts, limitations, pros, and cons. Furthermore, hazard-dependent attributes are introduced to address hazard-specific aspects. For example, in flood interventions, these include the applicability across various flood characteristics (e.g., depth, velocity, debris, duration),

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Title of abstract: Prolonged multi-risk factors behind the 2023 Kahramanmaraş (Türkiye) earthquake disaster

Abstract: In the early hours of 6 February 2023, a magnitude 7.8 earthquake struck south-eastern Türkiye. Nine hours later, a magnitude 7.6 earthquake also rocked the region. The relatively shallow depth of the earthquakes, at about 10 km, resulted in severe shaking over a large area of Türkiye and Syria. The total death toll of over 59,000 makes this event the deadliest in modern Turkish history. In this presentation we discuss the state of knowledge of the seismic hazard and the social preconditioning factors that contributed to the tragic events in Türkiye and Syria. We show that the seismic hazard along the East Anatolian Fault, which hosted the earthquakes was well known, yet the devastating impacts indicate that the risks were not adequately considered. The earthquakes occurred during a winter storm with outdoor temperatures as low as -19 °C. They also triggered major aftershocks, several thousand landslides, dam bursts in Syria and flooding. We discuss how the prolonged multi-hazard context of the earthquakes exacerbated the impact in the hours to months after the main earthquakes. Additionally, we suggest that acute vulnerabilities arising from exposure, corruption and poverty led to a lack of seismic preparedness. We expand on the social factors and discuss how each contributed to amplifying the earthquake risk into the tragic disaster. We end by making recommendations on the ways forward to mitigate seismic risk through better integration of multi-hazard and multi-risk thinking, and management of social vulnerabilities.

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Title of abstract: Long-term hazards variability in coastal areas: multi-scales, dependencies and exposure

Abstract: Long-term natural variability plays a critical role in climate dynamics and contributes to climate change uncertainty, particularly in the near future. However, long-term (multi)hazards variability is rarely implemented into climate risk assessment. For instance, the EU Technical Expert Group on Sustainable Finance (2020) focuses only on changes in average conditions and extreme events, neglecting long-term variability. In turn the European Union has recommended evaluating risks over longer timescales, extending beyond the immediate post-disaster recovery period.

This study aims to classify globally exposed coastal regions to long-term hazards variability, facilitating stakeholder's interpretation of multi-hazards at subnational and national scales. For this purpose, we first examine the variation in seasonal average conditions and the recurrence of extreme events in coastal hazards (sea surface temperature, winds, and waves) induced by the leading modes of climate variability (Arctic Oscillation, Southern Annular Mode and El Niño-Southern Oscillation). Secondly, we identify the exposure systems, including mangroves, coral reefs, and coastal urban

areas. Finally, we synthetize the spatial and time scales, hazards that are (in)dependent to facilitate the integration of long-term variability into existing multi-hazards typologies (e.g., Zscheischler et al. (2020)). In short, the study focuses on integrating long-term hazards variability into multi-risk assessments, a crucial step for a more realistic risk assessment in our complex world.

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Title of abstract: Inequality in exposure to extreme heat in an urbanized world

Abstract: We intersect exposure to physiologically deadly heat with vulnerability indicators to shed light on the equity of climate change impacts across cities. Our study comprises a large number of urban agglomerations from all world regions. Many regions that are projected to experience extreme and physiologically threatening heat are also threatened by further climate hazards such as rising sea levels or drought and suffer from vulnerabilities such as low incomes and inequalities. Importantly, these climate hazards can re-enforce economic and societal challenges such as poverty or conflict that affect the adaptive capacity of these regions, leading to fundamental threats to societal stability and livability.

We incorporate a number of variables into our analysis, including city-level population dynamics, current and future GDP estimates. We investigate exposure inequality with methods borrowed from economics. Sub-Saharan Africa stands out as a region where both trends are pronounced. We also demonstrate that countries with responsibility for high historic emissions are overall less affected by the extreme heat.

The insights from this research contribute to an improved general understanding of global inequality and climate change as a driver of these. They further contribute to the loss and damage discussion.

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Title of abstract: Integrative Analysis of Wave and Wind Climate Single Model Projections Using the CMIP6 Framework Under Shared Socioeconomic Pathways in Europe

Abstract: Global climate models (GCMs) are crucial tools for understanding long-term climate change impacts, informing both scientific and societal responses. The Coupled Model Intercomparison Project Phase 6 (CMIP6), led by the Working Group of Coupled Modelling (WCRP), features the latest generation of climate models, including future projections under various Shared Socioeconomic Pathways (SSPs). However, it is essential to acknowledge that GCM outputs exhibit certain biases when compared to observational and reanalysis data in the historical period.

Recent advancements have shed light on the effects of climate change on ocean wind waves, particularly focusing on the uncertainties in wave climate projections. A notable study by Lobeto et al. (2023) highlights the complexities and uncertainties inherent in wave modeling. Building upon this, our study conducts a dual-faceted analysis of climate projections from CMIP6, examining both wave and wind parameters under different SSPs in the European domain. We utilize two specific models: WAVEWATCH III for wave climate and EC-Earth3 for wind projections, to explore the uncertainties and variations influenced by diverse SSPs on wind and wave climate patterns.

Our methodology involves grouping model data based on SSPs and conducting rigorous statistical checks to ensure assumptions of independence, normality, and homogeneity of variances are met. We then employ statistical tests to

determine if significant differences exist in wind and wave climate projections across the SSPs, followed by post-hoc analysis for pinpointing differences between specific SSP pairs. Crucially, this study also quantifies the uncertainties associated with these projections.

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Title of abstract: A new climate impact database using generative AI

Abstract: Storms, heat waves, wildfires, floods, and other extreme weather climate-related disasters pose a significant threat to society and ecosystems, which in many cases is being aggravated by climate change. Understanding and quantifying the impacts of extreme weather climate events is thus a crucial scientific and societal challenge. Disaster databases are extremely useful for establishing the link between climate events and socio-economic impacts. However, publicly available data on impacts is generally scarce. Apart from existing open disaster databases such as EM-DAT, robust data on the impacts of climate extremes can also be found in textual documents, such as newspapers, reports and Wikipedia articles. Here we present a new climate impact database that has been built based on multiple public textual entries using a pipeline of data cleaning, key information extraction and validation. In particular, we constructed the database by using the state-of-the-art generative artificial intelligence language models GPT4, Llama2 and other advanced natural language processing techniques. We note that our dataset contains more records in the early time period of 1900-1960 and in specific areas such as than the benchmark database EM-DAT. Our research highlights the opportunities of natural language processing to collect data on climate impacts, which can complement existing open impact datasets to provide a more robust information on the impacts of weather and climate events.

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Title of abstract: Crisis communication and trust: on the long-term individual effects of a disaster on public trust in societal institutions

Abstract: In times of crisis, effective communication is central. The societal response to a crisis is set in motion via crisis communication channels directed at the public, spearheaded by key institutions like authorities, elected representatives, and the media. The success of this communication relies heavily on maintaining a high level of public trust in these societal institutions. Because, if people do not have confidence in the authorities, elected politicians, or the media who communicate to the public during a major crisis, great difficulties can arise in managing it. In this study, we use detailed individual-level administrative data of ca. 16,000 Swedish tourists who survived the 2004 Boxing Day Tsunami, matched

against other individuals in the Swedish population registry on several pre-tsunami characteristics, to isolate the effect of disaster exposure on measures of public trust in societal institutions – collected via a survey. The survey is administrated to 10,000 individuals (out of which 5000 were exposed), allowing for nuanced long-term measures of public trust in societal institutions and control variables, including exposure severity to the tsunami. This allows us to study the long-term effect of natural disaster exposure on public trust in societal institutions in a new way. In general, the tsunami victims have a lower trust in authorities and politicians, and their ability to handle crises almost 20 years after the disaster. They also assess the authorities' ability to handle other natural disasters negatively, but not their ability to handle other types of crises. Moreover, they also have less trust in evening newspapers/tabloids (and their crisis reporting) but not less trust in public service or morning papers.

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Title of abstract: Experiencing more and learning less

Abstract: Does previous hazard experience really improve awareness and adaptation? A "natural" flow is often assumed from previous hazard experience to high risk awareness, then to personal preparedness and, in the next step, to risk mitigation behaviour and/or adaptation. However, empirical studies have shown that the opposite can occur, as individuals with high risk perception still choose not to personally prepare themselves, adapt and/or move out of the most exposed areas. There are many reasons why at-risk people may not act on risk information. Elevated risk awareness does not always translate into adaptive actions because individuals may not have access to the necessary resources. These challenges also include a distrust of government, policies or decision-makers. For vulnerable communities, the message might not resonate with their lived reality or they are too preoccupied with daily needs. A central question is why people are still failing to act in an adaptive manner to reduce future losses even when there are ever richer risk information provided by ever more communication channels, such as websites, social media, mobile applications, television and print news. One answer is that the very question is misleading because it is based on the so-called "deficit model" that assumes a "knowledge-action gap" that can be overcome if only more and better information is provided to an ignorant public. Such assumptions are challenged by empirical data from Paris, France with two survey campaigns after a series of flood since 2016.

Poster presentations

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Title of abstract: A Comprehensive Review of Coastal Compound Flooding Literature

Abstract: Compound flooding, where the combination or successive occurrence of two or more flood drivers leads to an extreme impact, can greatly exacerbate the adverse consequences associated with flooding in coastal regions. This paper reviews the practices and trends in coastal compound flood research methodologies and applications, as well as synthesizes key findings at regional and global scales. Systematic review is employed to construct a literature database of 271 studies relevant to compound flood hazards in a coastal context. This review explores the types of compound flood events, their mechanistic processes, and synthesizes the definitions and terms exhibited throughout the literature. Considered in the review are six flood drivers (fluvial, pluvial, coastal, groundwater, damming/dam failure, and tsunami) and five precursor events and environmental conditions (soil moisture, snow, temp/heat, fire, and drought). Furthermore, this review summarizes the trends in research methodology, examines the wide range of study applications, and considers the influences of climate change and urban environments. Finally, this review highlights the knowledge gaps in compound flood research and discusses the implications of review findings on future practices. Our five recommendations for future compound flood research are to: 1) adopt consistent definitions, terminology, and approaches; 2) expand the geographic coverage of research; 3) pursue more inter-comparison projects; 4) develop modelling frameworks that better couple dynamic earth systems; and 5) design urban and coastal infrastructure with compound flooding in mind. We hope this review will help to enhance understanding of compound flooding, guide areas for future research focus, and close knowledge gaps.

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Title of abstract: Improved Decision-Making with Cyclone Forecast Products: A Dynamic Approach

Abstract: In recent years, the frequency and severity of natural hazards have increased, particularly affecting developing and least- developed nations. Notably, cyclones pose significant threats across Asia, bringing about destructive winds, heavy rainfall, and storm surges that compound the overall impact on affected regions. Since 2022, a methodical approach has been deployed to facilitate informed decision-making amidst multi-hazard scenarios, emphasizing early action to mitigate livelihood losses. This methodology uses the high-resolution forecast products (rainfall, wind gust), national and sub-national vulnerability index and lack of coping capacity from INFORMED Risk Index, and storm surge forecast from local met services which ultimately produces an impact map indicating the possible impact area to be alerted. The methodology's adaptability allows for the assignment of variable weights to different hazard components based on cyclone characteristics. For instance, in the case of Cyclone Mocha, greater emphasis was placed on wind gust forecasts over storm surges due to the relatively low magnitude of projected storm surges at landfall locations, thus enabling a more rational assessment for decision-making purposes. Case studies, including Cyclone Sitrang, Mocha, Hamoon, and Midhili, have demonstrated over 60% accuracy in identifying potential impact areas at administrative levels 1 and 2 with a 3-day lead time. Further refinement of the methodology through the incorporation of updated vulnerability and exposure data holds promises for enhancing both accuracy and lead time, thereby facilitating more informed decision-making processes.

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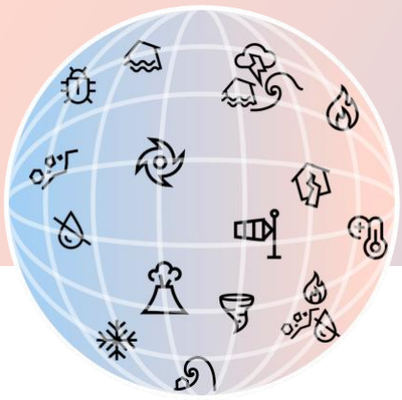
Title of abstract: Compounding Effects of Geo-Climatic Inundation Risks in the South Pacific Region: Towards Multihazard Decision Support Tools for Adaptive Resilience



Abstract: This presentation describes the application of interdisciplinary sector-based approaches to understanding and quantifying the compounding effects of multihazard geo-climatic inundation risks in Aotearoa New Zealand and the Southwest Pacific Islands. It draws on the findings from recent studies in this region which provide baseline quantifications of the impacts, damage and losses at varying scales – local, regional, national – to geophysical hazards such as earthquake- and volcanic- induced tsunamis, climate-induced sea-level rise, and extreme weather events such as tropical cyclones and associated river and coastal flooding.

Specific emphasis is made on examples from Aotearoa New Zealand, Cook Islands, Nauru, Republic of the Marshall Islands, Samoa, Tonga, Tuvalu and Vanuatu, that: 1) demonstrate the application and/or development of exposure and loss decision support tools and systems for a range of hazards (coastal storm and sea-level inundation, cyclone winds and flooding, tsunami); and 2) leverage the availability and integration of multiple information and software tools.

While the benefits of quantifying direct disaster damages and losses before, during and after an event is essential for resilience planning, key challenges in quantifying the flow-on, longer-term, socioeconomic impacts such as trauma, loss of livelihood, productivity and health impacts to name a few examples, are discussed in the context of research opportunities.

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Title of abstract: Modeling Sediment Dynamics in Seman River Basin: Implications for Water Resource Management in a Mediterranean Climate

Abstract: Hydrologic hazards, such as droughts and floods, significantly impact water resource availability and storage. In the Seman River Basin, situated in Albania within the Balkans region of Europe, these hazards pose significant challenges. This study employs modelling techniques to analyse sediment dynamics within the basin, focusing on the deposition and accumulation of fine sediments in reservoirs. Additionally, the study investigates the association between sedimentation processes and water supply deficits, particularly during periods of drought. The Mediterranean climate of the region adds complexity to these dynamics, necessitating a comprehensive understanding of sediment transport and storage mechanisms. Through the integration of hydrological modelling and climate data, this research offers insights into the interplay between hydrologic hazards and sedimentation processes in the Seman River Basin. The findings contribute to improved water resource management strategies tailored to the challenges posed by Mediterranean climates, enhancing resilience against the impacts of droughts and floods.

Keywords: sediments, reservoirs, droughts

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Title of abstract: Flash Flood Hazard: A Counterfactual Analysis for Germany

Abstract: Flash floods can arise from rapid runoff concentration in the landscape and are among the most destructive natural hazards. Managing their risks usually necessitates the application of extreme value statistics. However, the small temporal and spatial scale of flash floods poses a challenge as the requisite data for statistical methods is often unavailable or incomplete. Furthermore, the effects of climate change may compromise the robustness of extreme value statistics. To enhance our understanding of flash flood hazards in Germany, we present a novel „counterfactual“ scenario analysis. This approach considers alternative ways of how events could have unfolded. To identify worst-case scenarios is particularly

interesting for risk assessment. Accordingly, we assumed that historical rainfall events could have happened anywhere else in Germany: What would have happened if a particular rainfall event occurred in a different area? Would it result in a flash flood? To address these questions, we created a catalog of extreme rainfall events for the years 2001-2022. We then shifted the most extreme events across Germany and modeled the peak discharge for every realization (counterfactual peaks). This approach preserves the spatiotemporal event structure that significantly influences the overlapping scales of runoff processes and hence the hazard.

Our results reveal that, on average, the worst case counterfactual peaks would exceed the maximum original peak by a factor 5.3. Our study might help to help to identify flash flood prone areas and thereby reduce the element of surprise in disaster risk management. The method is transferable and could be a valuable asset, especially in data-scarce regions.

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Title of abstract: Joint changes in flood and drought hazards in Europe from 1950 to 2020

Abstract: Hydrological extremes are non-stationary, displaying long-term trends and natural oscillations. These changes in extremes can be driven by multiple factors including climatic (climate variability, climate change) and socio-economic (land use changes, water management changes) factors. There is evidence of an intensification of the water cycle linked to anthropogenic global warming. This may translate into an increase in flood and drought frequency and magnitude, albeit historical evidence shows pronounced regional variability. In this work, we analyze extreme high and low river flows across Europe for the period 1950-2020 with the aim to identify long-term trends in the occurrences of floods and droughts. The assessment is performed at an unprecedented resolution based on the Hydrological European REanalysis (HERA) streamflow dataset that has been generated with the spatially distributed physically based model LISFLOOD. We estimate return periods of both floods and droughts through non-stationary extreme value analysis. We apply an event coincident analysis (ECA) to capture potential changes in rapid transitions from drought to flood conditions, which can lead to compounding impacts. We assess joint changes in the magnitude and timing of both floods and droughts over the past 70 years. Our results reveal decadal variations in occurrences and magnitude of hydrological extremes. We also highlight regions that experienced similar or divergent trends in floods and droughts, providing precious insight for the understanding of past, present and future hydrological extremes across Europe and paving the way toward a more integrated assessment of flood and drought risks.

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Title of abstract: Indicators for urban vulnerability assessments: data availability and beyond

Abstract: In this study, we show how much data are available to measure urban vulnerability on the supranational (i.e., datasets spanning more than one country) scale. To do this, we create an ideal set of urban vulnerability indicators for six different hazards based the recently developed VulneraCity dataset and expert judgement. The expert knowledge comes from five of our co-authors, who have experience with the hazards and vulnerability assessments. They use the urban

vulnerability drivers from VulneraCity as a reference point, as it contains the most comprehensive collection of urban vulnerability drivers to date. These drivers are the underlying characteristics of cities and their citizens that determine how vulnerable they are to a hazard, based on an extensive literature review (3000+ articles). The drivers are converted into indicators by thinking of ways to measure – or operationalize – the drivers. We compare the ideal set of indicators with open-source urban data on the supranational level, which are collected from data-overview papers, own collections, and snowballing techniques and reviewed for urban relevance, timelines, and accessibility. This research should make researchers aware of the discrepancies between available and required data for vulnerability indicators, enabling them to better inform upcoming disaster risk assessment in the urban context. It could also reveal (spatial) gaps in data acquisition efforts for urban practitioners.

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Title of abstract: Global biases in hydro-geomorphic hazard research emerge from the scientific literature

Abstract: Floods, droughts, and rainfall-induced landslides are hydro-geomorphic hazards that affect millions of people every year. These hazards are therefore heavily researched topics with several hundred thousand articles published. The large number of published articles means identifying existing gaps is a challenge, especially regarding research specific to local risk conditions and impacts. How well does hydro-geomorphic hazard research cover heavily impacted regions, different hydro-climatic processes, or relevant socio-economic aspects? How often are multiple hazards studied together? In this work, we use natural language processing to search a database of 100 million abstracts for mentions of floods, droughts, and landslides. We use this information to create global gridded research densities for the three hazards based on all study locations from 293,156 abstracts. We then compare research density to environmental, socio-economic, and disaster impact data. The global distribution of research is influenced by human activity, national wealth, data availability, and population distribution. Countries that have been heavily impacted by hydro-geomorphic hazards in the past have a higher research density. However, this relationship strongly depends on country wealth. In low-income countries 100 times more people need to be affected before a comparable research density to high-income countries is reached. This disparity points to a lack of knowledge about exposure, vulnerability, and risk in several world regions, which needs to be addressed to reduce disaster impact and adapt to changing conditions in the future. We therefore conclude with guidance for which regions and hydro-climatic conditions an increased research focus on hydro-geomorphic hazards is most urgent.

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Title of abstract: Model based assessment of climate change impact on inland flood risk in coastal areas caused by compounding storm tide and precipitation events

Abstract: In addition to storm surges, inland flooding caused by intense rainfall is an increasing threat at coastal lowlands. Especially, the coincidence of both types of events poses great challenges to regional water boards. The evaluation of observed inland flood events at the German North Sea coast shows that mainly moderate storm series in combination with large-scale, heavy precipitation leads to an overload of inland drainage systems, whereas storm tides and

precipitation alone can be handled well. A pro-active risk management, however, requires risk-projections for the future. Therefore, we set up a model chain of a hydrological and a hydrodynamic ocean model, driven by the same climate simulations, in order to estimate future drainage system overloads. Evaluation of the simulations for the control period of two highly resolved climate models confirms that the models are able to reproduce the generation mechanism of such events. The combination of storm tides and precipitation leads to highest drainage system overloads, while moderate system overload are also caused by heavy rainfall events alone rather than by storm tides without precipitation. Scenario projections based on the climate models and two emission scenarios suggest that the intensity of compound events of rainfall and storm tides will increase consistently against the background of climate change for all investigated climate change projections, while simulated system overload is higher for RCP8.5 compared to RCP2.6 scenario. As for the past, future compound events will cause more potential damage compared to single extreme events. The model results indicate an increasing frequency and intensity of inland drainage system overloads along the North Sea coast if timely adaptation measures will not be taken.

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Title of abstract: Enhancing recoverability of the urban system in a multi-risk environment: A multi-criteria decision-making approach for identifying the minimum urban system

Abstract: Recovery planning is a critical aspect of promoting the resilient rebuilding of communities. This research develops and applies the concept of the 'minimum urban system' (MUS), representing the essential subset of physical assets within the urban system that must be preserved to ensure the continuation and effectiveness of the recovery efforts after a disaster in multi-risk environments. The MUS must be determined considering the relative socio-economic importance of the urban assets, their contribution to the whole urban system's performance, and their multi-hazard risk vulnerability. Our multi-criteria approach integrates the outcomes of the urban system analysis across three spatial scales (macro, meso, and micro), and multi-hazard risk assessment to identify the most crucial assets as the MUS.

In this research, we leverage participatory Fuzzy Cognitive Mapping and cartography and statistical data to identify essential urban functions and assets contributing to them. These assets' socio-economic importance and service capacity have been assessed through assigned indicators across three spatial scales. Afterward, the impact of multi-hazard risks, specifically consecutive earthquakes and floods, is evaluated, considering exposure and vulnerability interactions. For earthquakes, temporary shelter demand and the damaged state of important assets are estimated. Various temporary shelter options are explored for accommodating the population during recovery. The flood vulnerability of these accommodation options plus the important assets are then assessed. Ultimately, a multi-criteria decision-making approach is developed through a mathematical formulation. This approach considers factors such as the distance of temporary shelters from important assets, the capacity of t

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Title of abstract: COMPASS: towards climate and impacts attribution of complex extremes

Abstract: Weather extremes, such as heatwaves and floods, are increasing due to climate change. Attribution of the effect of global warming on weather extremes is a key challenge in climate research. In the EU-funded project COMPASS (COMPound extremes Attribution of climate change: towardS an operational Service), we aim to develop a methodological

framework for climate and impact attribution of various complex extremes that includes compound, sequential and cascading hazard events. Further advancing the attribution science is a crucial step towards the deployment of a European operational service.

While climate attribution for single-driver extremes has matured rapidly, the methods for complex extremes are still in their infancy. So far, single driver attribution studies fail to account for cases where the impact of an event is the result of the complex interplay of multiple physical drivers in combination with societal drivers. Climate attribution of complex extremes and their impacts is particularly challenging and has limited scientific benchmarks so far. Attribution of complex extremes to climate variability and change will help to better understand the complex interplay of physical and societal drivers that cause weather- related disasters and will promote societal preparedness and awareness for specific impacts of climate change.

This presentation will focus on the development of a global to local approach for hazard modelling that can characterize compound extremes with high accuracy. Hazard modelling will lay the foundation for the next steps of the attribution framework that include: weather type analysis of the climate conditions that give rise to complex extremes; detailed and up-to- date impact modelling; and novel strategies for the communication of results.

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Title of abstract: Amplified agricultural impacts from increasingly sequential heat extremes

Abstract: Climate change poses a significant threat to global food security, as increased frequency and magnitude of weather extremes can lead to harvest failures. Compound events, such as simultaneous heat and drought, have been identified as particularly detrimental to crop yields. This study focuses on the understudied impact of sequential heat extremes, examining their effects on soybean, maize, and wheat harvests in the United States and Europe over the past four decades.

Laboratory experiments suggest that crop exposure to spring heat may confer tolerance or enhance vulnerability to subsequent summer heat extremes. We introduce a statistical model that attributes yield losses to singular and compound weather conditions across seasons. We find that while hot springs contribute positively to crop yield, they also magnify yield losses due to summer heat by one-third compared to average spring conditions for US grown soybean and maize.

The heightened sensitivity leads to adverse impacts outweighing the benefits of hot springs when temperature anomalies exceed 3°C in the subsequent summer months.

Additionally, we explore future food system risks from sequential heat extremes using CMIP6 experiments, projecting a tenfold increase in the frequency of sequential heat extremes under high-emission scenarios. The compounding effect of these events is found to double associated agricultural losses, emphasizing the non-linear risks they pose to global food security, which can largely be avoided when limiting warming to 1.5°C globally. Moreover, our findings illustrate the importance of bridging detailed physiological insights from small-scale experiments with regional statistical analyses for effective adaptation planning.

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Title of abstract: Developing statistical downscaling methods to improve the simulation of compound drought-heatwave events

Abstract: Compound drought-heatwave events (CDHWs) amplify the adverse effects on ecosystems and socioeconomic systems comparing with individual droughts or hot extremes. Reliable projections of future CDHWs are the basis for the risk assessment, which can help making decisions aiming at building resilience to cope with CDHW risks. Recent studies have shown system biases exist in simulations of CDHWs from global and regional climate models due to unresolved/unrepresented physical processes and the multivariate bias corrections (MBCs) considering the dependence among multiple variables could improve the simulations of precipitation and temperature correlations, and frequencies or magnitudes of CDHWs in some cases, whereas there are still several studies reported no improvement of the MBCs. One the other side, comparing with large ensemble model simulations, Stochastic Weather Generators (SWGs) can enable the generation of a large number of CDHWs events with smaller computing resources. We identified Yangtze–Huaihe River Basin (YHRB) of China as the study area, for the western Pacific Subtropical High (WPSH) is usually located more to the north during a strong East Asia summer monsoon (EASM) year, leading to favorable conditions for CDHEs to occur in this area. We introduced a multi-site multivariable weather generator in the YHRB and preliminary results show that the SWG can realistically simulate distributions of temperature and precipitation at single sites, their temporal autocorrelation characteristics, spatial correlation patterns, Standardized Temperature Index (STI) and Standardized Precipitation Index (SPI). However, co-occurrence probabilities of high STI and low SPI, favoring the occurrence of CDHEs, were not well reproduced, resulting in serious underestimation of C

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Title of abstract: Language Models Uncover Natural Hazard Impacts

Abstract: Anthropogenic climate change, combined with climate variability, might significantly shift the frequency and magnitude of natural hazards in the next decades, with compound and cascading environmental and societal impacts. Present research on the effects of natural disasters is constrained by various factors, including an underestimation of the extent of impacts, a restricted geographical scope, and inadequate data source documentation. To address these gaps, we applied natural language processing techniques to build a comprehensive database of the natural hazard impacts documented since the 50s in the scientific literature. We mapped global research on climatological, hydrological, and meteorological extremes, such as droughts and heatwaves, and retrieved over 40 thousand full-text open-access papers

from ScienceDirect and Pubmed. A randomly selected sample of the documents was manually labeled according to their relevance to our task (i.e. if the study describes impacts from a natural hazard) and a classification model was trained to classify the remaining papers. Additionally, we developed an annotation framework designed to identify details concerning climate-related hazards within scientific publications. This framework includes categorizing information such as the date and location of the hazard, as well as its associated impacts. This work makes two significant contributions to the field of information extraction in natural hazards research: (i) it provides a corpus comprising 50 annotated open-access articles on the domain of natural hazards and (ii) a peer-reviewed global database documenting the impacts of natural hazards.

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Title of abstract: Current and future climatic drivers of low crop production years as treats to global food security

Abstract: Individual years of climate-driven extremely low global crop production can exert strong impacts on global food security. We use state-of-the-art global gridded process-based crop models from the GGCMI3b data base in conjunction with the corresponding ISIMIP climate model simulations to assess the climatic drivers of the lowest global crop production years for the four staple crops maize, wheat, soybean, and rice, and project their change under global warming. Our assessment captures the impacts of univariate climate extremes as well as multivariate and spatial compound events.

Low maize and soybean production years connect to heat and drought in the central USA while low rice production years relate to heat and drought in south-east Asia, highlighting the importance of multivariate events for these crops. Meanwhile, low wheat production years relate to spatially compounding heat in the northern mid-latitudes alongside central European drought, indicating a combined spatial-multivariate compound effect. Extremely low global crop production years become significantly more severe and frequent at 2 and 3 degrees of global warming, linked to the identified climate patterns and driven by increasing magnitude and frequency of extremely low wheat, soybean and rice production – maize production extremes remain fairly constant over time.

While individual years only contribute up to 5% to global low crop production years, regional impacts of climate extremes are more severe. In some regions such as southeast Europe, crop production in individual years can be less than half of the average production. This highlights the urgency to limit global warming to 2 degrees to reduce risk to crop-producing regions and the global food system.

Session 9: Artificial intelligence and machine learning for multi-risk assessment

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Title of abstract: Automated Classification of Atmospheric Circulation Types for Compound Flood Risk Assessment: CMIP6 Model Analysis Utilising a Deep Learning Ensemble

Abstract: The Großwetterlagen classification by Hess and Brezowsky is an established method for categorising the large-scale weather patterns across Europe. Previous studies found relations between the occurrence of certain Großwetterlagen and compound events. Compound flood events are among the most dangerous natural hazards because the simultaneous occurrence of extreme discharge and extreme storm surges can be much more devastating than their separate occurrence. It is, therefore, important to determine future changes in the frequency of those Großwetterlagen. The challenge is that the Großwetterlagen classification is a subjective classification which cannot easily be applied to large scale data sets of global climate models. In this study we present a deep learning ensemble for the automatic classification of Großwetterlagen that outperforms previous classification attempts. To assess future changes in the occurrence of Großwetterlagen, we used our ensemble of neural networks to classify the data of the scenarios SSP1-2.6, SSP3-7.0, and SSP5-8.5 for 31 CMIP6 models. Having a wide range of climate models reduces the uncertainty that is introduced by analysing only a single model. Additionally, we utilised daily data from the CMIP6 version of the Max Planck Institute Grand Ensemble to examine the influence of internal variability on the frequency of Cyclonic Westerly. The global climate models show a tendency for higher frequency of Cyclonic Westerly in the winter half-year, but a lower frequency during the summer half-year. Our results additionally show large variation among the models, which is likely due to their difficulty in accurately recreating weather systems.

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Title of abstract: Seasonal advancing heatwave prediction using machine learning approach

Abstract: Sweden has faced escalating heatwaves, triggering other natural hazards such as drought and causing negative health impacts. The formation of heatwaves is driven by a combination of atmospheric variables and land surface properties. This study aims to predict the occurrence of heatwave days during summer months in Sweden with a lead time ranging from 1 to 5 months using machine learning (ML) methods and remote sensing data. Five ML classifiers (Logistic Regression, Gaussian Naïve Bayes (NB), K-Nearest Neighbor (KNN), Random Forest, and Extreme Gradient Boosting (XGBoost)) were built utilizing 16 features obtained from Google Earth Engine for each month lead time and compared with evaluation metrics, accuracy and F1-score.

All models emerged effective for predicting heatwaves across 1-5 months lead times except for NB. XGBoost excelled at lead time of one month (F1-score = 0.63, accuracy = 0.81) and four months (F1-score = 0.54, accuracy = 0.79), while KNN performed best at 2, 3, and 5 months (F1-score = 0.63, 0.65, 0.49; accuracy = 0.77, 0.79, 0.78). By applying SHapley Additive exPlanations model interpretation technique, land features are important for longer prediction lead time compared to atmospheric features. Contributing factors to Swedish heatwaves included southerly/westerly winds, high temperature, high mean sea level pressure, low geopotential height, low precipitation, low evaporation, cropland, and flat terrain. These findings support the development of effective mitigation strategies for managing heatwave impacts in Sweden.

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Title of abstract: Spatial and Temporal Dynamics of Drought and Flood Events in Nigeria: A Machine Learning Approach

Abstract: Nigeria is highly susceptible to both drought and flooding, with devastating consequences for its economy, environment, and biodiversity. In 2022, flooding affected at least 2.8 million people in Nigeria, resulting in 6,123 death, and more than 2,500 injured. In Some areas, water levels reach the eaves of buildings. For instance, in 2022, flooding in Benin City displaced 64,473 people, injured 202, resulted in 148 deaths. By the end of October, more than 7.7 million people had been affected by the floods, and more than 2.1 million were registered as Internally Displaced People (IDP). According to UNICEF, Nigeria has an "extremely high risk" of the impacts of climate change. This study focuses on harnessing the power of machine learning (ML) to predict both droughts and floods, addressing the critical challenge of water resource management. The study explores the integration of remote sensing and satellite imagery to enhance spatial and temporal resolution for predicting drought and flood-prone areas. Machine learning models are trained using a combination of supervised and unsupervised learning techniques, with supervised models to predict both drought and flood occurrences based on historical patterns. Unsupervised learning methods, including clustering algorithms, assist in identifying hidden patterns and trends within the datasets, contributing to a more nuanced understanding of the complex interactions that lead to extreme weather events. Validation and evaluation of the machine learning models are conducted using historical data and a robust cross-validation framework to ensure generalizability. The developed models can integrate into decision support systems, offering stakeholders timely and accurate information to make informed decisions.

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Title of abstract: Assessing Groundwater Conflicts in Germany and the Effects of Droughts Using Artificial Intelligence and text-as-data

Abstract: Recent multi-year drought periods and competing user groups caused conflicts and highlighted risks concerning the quantity and quality of groundwater resources in Central Europe. To better understand these groundwater-related conflicts, several case studies have been conducted prominently in regions with an extended history of water scarcity. Yet, there is limited research on the emergence of groundwater-related conflicts in Central Europe and the role of recent drought events in shaping them. Here, we study spatio-temporal patterns of groundwater-related conflicts in Germany since 2000. Specifically, we investigate: (i) How are groundwater-related conflicts characterized, (ii) which influential stakeholders are shaping these conflicts? (iii) what are the spatio-temporal patterns of these conflicts, and (iv) how do drought events and different socio- economic factors influence their occurrence? We use machine learning and natural language processing tools on more than one million newspaper articles to develop a spatio-temporal database of conflicts. Also, we extract and categorize involved stakeholders using a named entity recognition algorithm. Then, we use statistical modeling to link the occurrences of groundwater conflicts with drought. Our study reveals the growing diversity of involved sectors and the geographical spread of groundwater-related conflicts in Germany. Also, our results shed light on the role of the recent drought events' influence on the risk of conflicts. Our findings contribute significantly to assessing the evolving landscape of groundwater-related conflicts in Germany and the underlying effects of droughts. The proposed method highlights how artificial intelligence can enable large- scale assessment of environmental conflicts using text data.

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Title of abstract: Multi-hazard exposure of different income categories in Europe in a changing climate

Abstract: Human-induced greenhouse gas emissions are the primary cause of rising global temperatures and alterations in the frequency, intensity, and extent of extreme climate events. Climate change is changing the distribution of climate risks, which arise from the interaction between hazards and the vulnerability and exposure of populations. While future climate risk is influenced by climatic conditions, it is also shaped by changes in vulnerability and exposure driven by different development pathways. Differences in vulnerability result partially from inequalities related to economic conditions like wealth or income. In this study, we built a European 1km-gridded dataset of disposable income consistent with the Shared Socioeconomic Pathways using an innovative machine learning methodology. This dataset was used to examine how different income groups are exposed to multiple hazards (heatwaves, river flooding, and coastal flooding) under various warming scenarios. The projected exposure was then decomposed to isolate the spatial changes attributable to development pathways and the changes linked to warming scenarios. Considering the diversity of climatic zones and socioeconomic structures among European countries, we employed unsupervised machine learning algorithms to cluster countries based on the evolution of inequality of exposition faced by the various income groups. Our findings reveal persistent inequalities that are likely to persist throughout the century under different scenarios. These insights highlight the need for producing socioeconomic scenarios that more effectively address equity issues. They can also contribute to advancing the climate justice agenda.

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Title of abstract: Exploring the World of Multi-Hazard Susceptibility Mapping With Deep Learning

Abstract: A crucial component of disaster preparedness is the development of a multi-hazard susceptibility map, which plays a vital role in comprehensive risk assessment, resource allocation, land use planning, emergency management, community preparedness, and decision-making. Recently deep learning methods have been showing potential to map susceptibility at a finer resolution. While prior research has predominantly focused on advanced single-hazard or simplified multi-hazard susceptibility mapping, an approach to explore multi-hazard susceptibility mapping using deep learning methods and explainable AI's remains lacking to date. Addressing this gap, our research employs an ensemble Convolutional Neural Networks, to develop a multi-hazard susceptibility map. Leveraging diverse datasets and the MYRIAD-HESA framework, our analysis considers a range of hazards and their interactions, offering a more integrated view of the complex risk landscape faced by communities. Using Japan as a case study, the resulting susceptibility map serves as a valuable tool for informing land use and urban planning, resilient infrastructure development, and identification of suitable locations for critical facilities. Furthermore, it supports emergency management by facilitating resource prioritization, coordination, evacuation planning, and community awareness. This research contributes to evidence-based decision-making, policy development, and global disaster preparedness efforts.

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Title of abstract: A Machine Learning approach to support multi-risk assessment and climate adaptation planning in the Veneto coastal area

Abstract: Global climate is experiencing an unprecedented increase of temperature, leading to the occurrence of many extreme events worldwide. Coastal areas are particularly vulnerable to climate change (CC) impacts, due the high population density, interconnected economic activities and the presence of fragile habitats and ecosystems. Interactions between multiple hazards, acting at different spatio-temporal scales, can amplify the effects on dynamic vulnerability and exposure patterns. An integrated approach is crucial to assess impacts, considering the relationships among all risk-factors (hazard, exposure, and vulnerability) at the land-sea interface. Accordingly, Machine Learning (ML) algorithms offer a new path to tackle the analysis of these multi-risk events, due to their ability to integrate great volumes of heterogenous data and model non-linear relations between multiple factors. A two-step ML approach was developed to estimate the cumulative number of future impacts caused by extreme climate events along the Veneto coastal municipalities. At first, the model learns the relationships of atmospheric and marine hazards against impacts recorded in the Veneto region during 2009-2019 timeframe. Consequently, the second step aims at estimating the effect of future CC scenarios on coastal multi-risks for the Veneto region. Different CC scenarios (i.e., RCP2.6, 4.5, 8.5) have been integrated into the developed ML model to assess coastal impacts until year 2100. The results show a gradual increase in expected annual impacts, mainly driven by the combination of the analysed hazards, for all scenarios, with the RCP8.5 scenario being the worst observed. These outputs will support to the definition of disaster risk management pathways for the Veneto pilot within the MYRIAD project.

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Title of abstract: A conceptual framework for an AI driven multi-hazard risk and resilience climate service

Abstract: The increasing complexity and severity of climate-related hazards call for a transformative approach in risk assessment and resilience planning, both within the European Union and on a global scale. Conventional methods, largely dependent on static models, are proving to be insufficient as they fail to adequately represent the dynamic nature and intricate feedback loops of climate hazards and risks. This shortcoming hinders the understanding of climate events across short, medium, and long-term scales under the influence of climate change, compromising the utility of climate services. In response to these challenges, this abstract sets the foundation for our research towards a novel conceptual framework for an AI-driven multi-hazard risk and resilience climate service.

This initiative stems from a thorough review of existing practices and advancements, which includes: (i) an examination of the use of artificial intelligence (AI) and machine learning (ML) in multi-hazard risk assessment, (ii) an analysis of the opportunities and and challenges in integrating traditional and AI-driven methodologies in climate services, and (iii) the development of cutting-edge AI-based methods for enhancing multi-hazard risk frameworks, as undertaken in the Myriad project.

Our research serves as a crucial step towards the development and testing of a comprehensive climate service prototype, addressing various hazards and resilience strategies, catering to the needs of diverse stakeholders including regional authorities, private sector entities, and individual consumers.

This research is part of the MSCA project EXPEDITE aimed at exploring opportunities for developing a risk and resilience climate service based on artificial intelligence.

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Title of abstract: Explainable and Responsible Artificial Intelligence for Disaster Risk Management

Abstract: The increasing threat of disasters and their devastating impacts on communities and economies highlight the urgent need for effective strategic disaster risk management (DRM). While Artificial Intelligence (AI) holds promise in improving DRM through enhanced decision-making, its lack of explainability has spurred a demand for Explainable AI (XAI). Additionally, the rapid advancements in generative AI necessitate responsible AI (RAI) within DRM, particularly considering the emergence of deepfake data and information. Proper utilization and implementation of XAI can significantly contribute to this responsibility as well.

This study explores and delineates XAI and its connections with RAI. Furthermore, to comprehend the current state of XAI application in DRM, our analysis presents achievements and challenges in this domain. This study addresses research questions, identifies hazard types, risk components, and AI/XAI methods, shedding light on key challenges. Notably, we observed a significant increase in the use of XAI techniques for DRM in 2022 and 2023, highlighting the growing need for explainability.

Insights and recommendations for improving the explainability, responsibility, and effectiveness of XAI and RAI in DRM will be provided. These include the necessity for XAI and RAI methods in multi-hazard risk analysis, integration of XAI in early warning systems and digital twins, and the need for responsible AI methods in DRM from a general perspective. This study serves as a roadmap for both researchers and practitioners, elucidating the intricate interplay between Explainable AI, Responsible AI, and DRM. Further, it showcases the potential of emerging AI techniques for multi-hazard and disaster risk management.

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Title of abstract: Anticipating and Understanding Humanitarian Crisis with Explainable Artificial Intelligence

Abstract: Global disaster risks and their subsequent impacts are becoming increasingly crucial to assess, given escalating climate change and socio-economic disparities. Addressing this challenge requires a multi-risk framework capable of forecasting crises from various hazards and considering risk interactions. Our study exploits a comprehensive dataset, updated monthly at the subnational level across over a hundred countries. This dataset includes indicators of food insecurity, conflict, displacement, fatalities, and natural hazards. We apply explainable artificial intelligence (XAI) methods, such as SHAP and LIME, to decipher the complex relationships driving humanitarian crises. Our predictive models estimate the number of 'people in need' for different lead times, revealing complex, time-sensitive patterns through machine learning algorithms. Our analysis uncovers that the influence of drivers can significantly vary based on the definition of 'people in need', highlighting the existence of different mechanisms and the diverse impacts of natural hazards. This study offers a nuanced approach to multi- risk modelling, enabling the identification of the varied dimensions of humanitarian crises to tailor responses to the multifaceted needs of affected populations. Improving crisis anticipation tools will also help preventing accumulation of new and consequent cyclical shocks that undermine sustainable development as well as arduously earned progress in disaster risk reduction and climate change adaptation.

Poster presentations

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Title of abstract: Machine learning approaches for multi-risk assessment of river water quality under global and local changes: a case study in the Veneto Region, Italy

Abstract: Water quality plays a pivotal role in shaping the ecosystem's health and directly/indirectly influencing water-use sectors.

However, the interplay between extreme climate events and anthropogenic activities has the potential to create synergistic effects that significantly impact the dynamics of water quality. This study introduces a novel approach employing machine learning techniques to unravel the intricate interplay between extreme climate events, anthropogenic activities, and river water quality. Compound hot-dry and alternating wet-dry extreme events are analyzed alongside anthropogenic activities (i.e., anthropogenic land-use and population pressures), exposures and vulnerabilities of the river networks and drainage basins. We explore the synergistic impacts on key water quality elements and ecological status through the development of water quality multi-risk machine learning models that assimilate complex and dynamic interactions to unveil the vulnerabilities of river systems in the face of dynamic climatic and human-induced changes. Additionally, focused on the nexus of future trends of climate change and socio-economic development, the research applies a multidisciplinary approach, using climate models, projections on land use/land cover and population changes, as well as nature-based solutions and adaptation measures to create multi-risk scenarios for water quality. This approach provides a comprehensive framework for assessing the cumulative impacts, anticipating potential risks, and informing adaptive management strategies, contributing to a deeper understanding of the challenges posed by the intersection of climate change and socio-economic development and offering practical insights for water resource management and climate change adaptation.

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Title of abstract: Deep learning based super-resolution of hazard maps

Abstract: High-resolution hazard maps are needed for more effective disaster risk management. Producing such maps directly with physics-based models remains computationally prohibitive at the global scale. Here we demonstrate a deep learning (DL)-based model that fuses low-spatial-resolution flood inundation grids with high-resolution terrain grids to generate a high-resolution flood hazard map. The model is trained using a large synthetic dataset of high-resolution flood simulations with diverse domains and boundaries generated from open data and a physics-based model. To evaluate the model, we compare traditional algorithm-based methods for resolution enhancement and the proposed DL-based model. Preliminary results show the DL-based model achieves higher accuracy and faster speeds than traditional methods, being able to reproduce sub-grid hydraulics from the expensive high-resolution physics-based model. While transferability remains challenging, early results suggest the model has good performance in similar regimes. While this study focuses

on flood hazard mapping, the demonstrated potential of deep learning-based super-resolution techniques suggests similar opportunities for multi-hazards, increasing the lead time of impact-based forecasts and providing under-served communities access to high-resolution hazard maps.

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Title of abstract: Global Building Profiling: Unveiling Insights through Advanced Machine Learning

Abstract: Over the past decade, significant strides have been made in the field of Machine Learning (ML), leading to widespread adoption across diverse domains. This presentation showcases an ongoing project that extends the application of advanced ML techniques beyond predicting building characteristics globally. Our project harnesses an in-house developed global exposure database, constructed exclusively from open data sources such as OpenStreetMap and the Global Human Settlement Layer, to aid in the risk assessment of natural calamities. The database aims to individually describe every building on Earth, facilitating the estimation of building characteristics and vulnerability. This, in turn, enables high-resolution damage and loss assessments during natural catastrophes like earthquakes and floods, offering vital support for disaster response and resilience measures. Despite the project's innovative approach, the reliance on open data introduces challenges related to data completeness, with some areas exhibiting comprehensive mapping while others lack sufficient information. Our primary goal is to bridge this gap between advanced ML techniques and the open exposure database, addressing the completeness issue and advancing the accuracy and coverage of building characteristic estimations. By integrating multi-hazard risk assessment into our ML-driven framework, we aspire to improve disaster response strategies and enhance the overall resilience of vulnerable communities.

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Title of abstract: AI (Artificial Intelligence)-Driven Flood Extent Detection and Monitoring via RiverSnap, a Citizen Science Initiative

Abstract: RiverSnap progresses an innovative citizen science program that uses the capabilities of smartphones, transforming them into versatile river monitoring devices. This cost-effective approach utilizes strategically positioned stainless-steel smartphone mounts along rivers, allowing participants to effortlessly snap individual photos of the river's conditions using their smartphones. These photos are seamlessly uploaded to a centralized database for analysis, enabling the evaluation of long-term river and ecosystem changes. Behind the simple strategy of RiverSnap, we have developed a transformer-based convolutional neural network (CNN) that cannot only estimate river parameters (e.g., water surface, water level) but also monitor natural hazards like floods and droughts. The model's outputs (i.e., river lines and flood extent areas) are cross-referenced to ensure accuracy with various references, including fixed targets within river scenes or water lines derived from authoritative maps. By comparing these references with the CNN model's predictions, we can efficiently and locally detect flooding, droughts, or normal river conditions. We can also determine the extent of any current flood at each station. RiverSnap's AI monitoring system effectively showcased its capabilities during a severe flood in Niedersachsen, Northern Germany, using images from two stations in Hannover to deliver precise and timely river information. Experimental results showed that the detected water lines in the station's area gradually rose above the

reference river line from December 21, 2023, to January 3, 2024. This upward trend accurately reflected the increasing severity of the flood, further confirmed by the expanding flood extent areas during the same timeframe.

Author(s): Katharina Horn; V.-Prof. Dr. Stenka Vulova; Hanyu Li; Prof. Dr. Birgit Kleinschmit;

Affiliation: Technical University Berlin, Geoinformation in Environmental Planning Lab

Title of abstract: Modelling Current and Future Forest Fire Susceptibility in North-East Germany

Abstract: Preventing and fighting forest fires has been a constant challenge in Germany in recent decades. Forest fires alter forest structure and composition, threaten people's livelihoods in proximity to forests, and lead to economic losses, as well as soil erosion and desertification (Bowman et al. 2020; Pereira et al. 2021). Climate change and drought events, paired with anthropogenic activities, have substantially magnified the intensity and frequency of forest fires (Chicas & Østergaard Nielsen 2022). It is crucial to identify the conditions that cause the emergence and spread of forest fires to improve prevention and management (Ambadan et al. 2020).

In Germany, the federal state of Brandenburg has been particularly affected by forest fires in recent years (Gnilke & Sanders 2020). Here, we apply Random Forest machine learning algorithm to model current and future forest fire susceptibility in Brandenburg using a set of topographic, climatic, anthropogenic, soil, and vegetation predictor variables. We modeled forest fire susceptibility at a spatial resolution of 50 meters for current (2014-2022) and future scenarios (2081-2100) considering different shared socioeconomic pathways (SSP3.70 and SSP5.85). To our knowledge, only few studies have analyzed current and future forest fire susceptibility at a high spatial resolution so far. The model results underscore the importance of anthropogenic parameters, such as proximity to urban settlements or railways, and vegetation parameters, such as the percentage of broadleaf forest, in modeling forest fire susceptibility on a regional level. This study will allow forest managers to better identify areas of Brandenburg which are most susceptible to forest fires, enhancing warning systems and prevention measures.

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Affiliation: (1) Euro-Mediterranean Center on Climate Change (CMCC) Ca'Foscari University of Venice (UNIVE); (2) University School for Advanced Studies of Pavia (IUSS); (3) Center for Climate Change and Transformation, Eurac Research;

Title of abstract: Assessing multi-hazard hot and dry-related events through impact chains and machine learning in the Adige River Basin, Italy

Abstract: Climate change is predicted to increase the frequency, intensity and duration of hot and dry events in the Adige River Basin area. These conditions can cause widespread impacts on vegetation, ecosystems and water quality highlighting the need for further understanding of cascading and compounding hot and dry events. Compounding reduced river discharge and heatwaves can lead to higher pollutant concentrations and low dissolved oxygen along the river, algal blooms and salt intrusion at the estuary, which can impact crop yields and natural vegetation. This study aims to apply the Multi-Hazard methodology developed for the Myriad-EU project to analyze spatio-temporal footprints of climate change-induced hot and dry events in the Adige River basin in the last thirty years (1991-2021). The identification and assessment of the spatiotemporal patterns of drought occurrences and their associated risks have been carried out through unsupervised machine-learning techniques. The methodology follows a similar approach described by Claassen et al. (2023). Firstly, impact chains were developed to identify main drivers, hazard combinations and potential cascading impacts across systems and sectors. Secondly, percentile analysis and DBSCAN clustering techniques were used to identify

extreme climate events and single-hazard clusters from climate indicators. Finally, single hazard clusters were combined to analyze compound events, considering their spatial and temporal overlaps. Overall, this study contributes to a better understanding of hot and dry dynamics through the application of machine learning techniques thus enhancing drought risk assessment and management strategies.

Session 10: Storylines and narratives for multi-hazard, multi-risk decision-making

Author(s): Gabriele Messori[1]; Maria Rusca[2] ; Giuliano Di Baldassarre[1]

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Title of abstract: Socio-environmental storylines for multi-risk decision making

Abstract: In the Anthropocene, the characteristics and outcomes of "natural" hazards are increasingly shaped by humans, through a multifaceted interplay of socio-political and environmental factors. This can lead to the same event having highly differentiated consequences for different societal groups, and to cascading and inter-sectoral impacts. This complexity can only be effectively addressed through a multi-risk decision framework. Developing such a framework is complex, and not all decision-making actors may have the expertise or resources to achieve this. Here, we present an approach to develop decision-relevant socio-environmental storylines. These investigate the relation between the genesis of impactful events, accumulation and distribution of risk and risk cascades, and consequences across different societal groups. In doing so, they provide an impact-focused vision of future social-environmental risks, beyond what is achievable within conventional disciplinary boundaries. The aim is to provide concrete and actionable information, accessible to a wide range of decision-making actors who may be operating in resource-constrained environments. The approach is flexible and applicable to a wide range of events. We provide a concrete example in the form of a storyline for compound drought in Southern Africa.

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Title of abstract: Exploring social vulnerability through narratives: A mixed-methods approach to develop storylines of vulnerability for heat and flood related risk in Austria

Abstract: Climate change interacts with a multitude of socioeconomic characteristics, for example, income, age, and employment, determining individual vulnerability and coping capacities. However, existing impact assessments of climate risk commonly focus on aggregate levels, leaving blind spots with respect to within-country distributional effects. Adhering to the concept of intersectionality, this study examines differential vulnerabilities and factors determining heterogeneities on a household level in the context of heat and flood related risks in Austria.

To this end, we apply a mixed-methods approach to create narratives and storylines, integrating findings from a comprehensive literature review, stakeholder workshops, semi-structured interviews, and a multivariate statistical analysis. By exploring expert's perceptions and framings around vulnerability, we identify and highlight the complex

interrelationships between drivers of social vulnerability and the distribution across society for heat and flood related risk respectively. The knowledge generated is then developed into storylines and further contextualized by insights from a K-modes clustering algorithm that is based on geocoded socioeconomic data and climate impact data on a 1kmx1km scale.

Through this integrated and participatory approach, three comprehensive storylines are developed per climate risk. The storylines i) contribute to a more effective communication of social vulnerability to stakeholders working on risk management, ii) allow for a more nuanced representation of society in climate impact assessments, and iii) inform the development of just and targeted adaptation measures and pathways for the equitable distribution of adaptation benefits.

Author(s): Gordon Woo

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Title of abstract: Downward counterfactual generation of Storylines

Abstract: A downward counterfactual is a thought about the past where things turned for the worse. Originally used in social psychology, this terminology was applied to the analysis of extreme risks by Woo (2019). Downward counterfactuals subsequently have been developed as a framework for building climate storylines by Ciullo et al. (2021). Downward counterfactuals of notable historical events constitute a rich resource for generating narratives of the future. Merz et al. (2021) have pointed out that when exploring the possibility space of extreme floods, biases of wishful thinking should be avoided by purposefully constructing downward counterfactuals. The insights gained from downward counterfactuals apply to all natural hazards, including volcanic unrest (Aspinall and Woo, 2019). Starting from a library of historical events, downward counterfactual generation of storylines provides an effective way of discovering physically plausible multi-risk compound events, which might be considered surprising otherwise, especially under a changing climate. Salient examples will be given. The Derna, Libya, flood disaster of 11 September 2023 is a recent example of a severe loss event, associated with climate change; Storm Daniel was a Mediterranean cyclone that had caused extreme rainfall in Greece. The severe loss might have been anticipated beforehand through downward counterfactual analysis. Had the dams built in the 1970s existed in 1959, they would have been breached by the flood of that year. As shown by images of Derna, visualisation of downward counterfactuals would help comprehend the scale of potential losses associated with storylines. Such visualisation is facilitated by recent advances in Generative AI. Examples of such illustrations will be given.

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Title of abstract: Towards a storyline-based, ontologically structured approach for multi-risk assessment of urban areas

Abstract: The concept of risk storylines refers to a defined, plausible combination of events, their consequences and the factors possibly affecting these elements, as well as the physical, socio-ecological and functional elements at risk (Shepherd et al. 2018; March et al. 1991, Sillmann et al. 2021). We propose a storyline-based approach as a methodology for the multi-risk assessment of urban environments, by including multiple hazards, with their possible interactions, and all the exposed urban assets with the objective of evaluating the socio-economic impacts. As structured graphical representation of a risk storyline we employ impact chains, which provide a conceptual representation of risk intuitive and consistent with most recent IPCC and UNDRR indications and also convey information on the (possibly) causal relationships between events and their impacts on the analyzed context. The representation of impact chains through virtual knowledge

graphs and ontologies ensure that even complex risk-storylines can be efficiently managed and interacted with using semantic database technologies. Multi-risk processes can be therefore considered in a consistent framework for different hazards, i.e., meteorological, hydrological, geohazards, environmental, societal hazards, etc. (UNDRR-ISC 2021), with a careful balance between narrative, semantic and episodic description, aimed at improving the awareness of the addressed risks within an actionable framework which foster active convergence between Disaster Risk Reduction and Climate Change Adaptation. Two applications of the proposed approach developed within the framework of the projects RETURN (extended partnership, Italian funded) and PARATUS (EC funded) are presented and discussed.

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Title of abstract: Storylines of drought-flood events

Abstract: Cascading events of floods after droughts are complex hydrosocial disasters. In the PerfectSTORM project ('STOrylines of futuRe extreMes'), we investigate the processes behind drought-flood events to provide the understanding needed to prevent major disasters in the future. Using a mixed-methods approach, we analysed storylines and narratives in two case studies and globally. Hydro-climatic data analysis of 8255 catchments revealed drought-induced shifts in rainfall-runoff relationships, increasing AND decreasing flood risk. Document analysis of 192 reported drought-flood events showed that these multi-hazards caused more impacts than single hazards. In the Horn of Africa, these impacts intensified when the events compounded with poverty, conflict, and political instability resulting in cascading vulnerabilities. Our 39 storytelling sessions (213 participants) in Kitui, Kenya, showed how positive and negative drought-flood interactions changed over time. Heavy rainfall after drought positively contributes to harvests and recharging water storage, but since the 1950s impacts changed from disease outbreaks and famine to landscape changes (erosion) and economic effects. In contrast, our 70 storytelling sessions in Iquitos, Peru, revealed that communities there rely heavily on the seasonal fluctuation in river levels. They are impacted by anomalies in timing and extent of dry and wet seasons, posing a threat to their livelihoods. Anticipation of these anomalies is important for both individual and institutional preparedness. These diverse narratives offer unique perspectives on the spatio-temporal interactions between drought and flood risks. Our next step is to use them in interactive storytelling workshops with stakeholders and communities to imagine different futures.

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Title of abstract: Navigating climate risk in humanitarian action: The potential of storyline approaches

Abstract: The humanitarian community has a long history of attempting to reduce the human impact of extreme weather and climate events. Over the past decade there has been an increasing shift towards using climate science to better anticipate climate impacts on vulnerable communities and hence guide humanitarian planning and responses. However, large uncertainties, climate and non-climate, and complex compounding risks pose significant challenges to integrating climate information into humanitarian planning.

Storylines offer the potential to help this community navigate these complexities and uncertainties. The IPCC AR6 WG1 defines storylines as "a way of making sense of a situation or a series of events through the construction of a set of

explanatory elements" and they "can be used to describe plural, conditional possible futures or explanations of a current situation, in contrast to single, definitive futures or explanations".

As such storylines related approaches are valuable for the humanitarian sector as they offer the potential to provide robust and valuable understanding of risk, as well as supporting the development of effective interventions.

Storylines do not remove the underlying uncertainty, however, they do help to shift the questions asked from "what is going to happen", to "what would unfold if this storyline occurred". This shift can improve understanding of climate risk in complex contexts and connect with decision-making processes more effectively than presentations of aggregate uncertainty ranges. We explore the potential value of storylines for climate risk management within the humanitarian sector, we present practical examples of effectively applying them to estimate and describe systemic climate-related risks, especially in vulnerable regions.

Author(s): Jasmina Schmidt

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Title of abstract: Disaster narratives in emergency services: Tools for crisis and disaster governance

Abstract: This presentation explores the role of narratives in shaping our understanding of disasters and crises and their impact on organizational responses within the context of disaster governance. Narratives facilitate the interpretation of actions, events, and objects in our surroundings. Focusing particularly on disaster narratives, this study delves into their significance in the collective memory of emergency organizations and their influence on responses to future crises, thereby contributing to disaster preparedness and prevention. Qualitative social research methods, including interviews and focus group discussions, were employed to investigate the perspectives of road maintenance services and organizations involved in forest fire control. The case studies examined organizations relying on weather information for anticipating and responding to future weather events. The study's findings highlight two crucial dimensions of narratives: the content of what is considered significant enough to be recounted and the manner in which these events are narrated. Distinct plotlines are identified as instrumental tools for categorizing different narratives. The framing and contextualization of events emerge as influential factors shaping future actions and decision-making processes. Narratives that emphasize renewal and learning are shown to promote proactive measures and enhance preparedness for future extreme weather events. Furthermore, the paper analyses narratives both before and after the Ahr valley flood event in Germany in 2021. This analysis underscores how crises can disrupt sense-making processes and collectively shape explanations.

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Title of abstract: Storylines for (future) impact assessment: Hurricane Sandy's compound flood impacts on New York City

Abstract: Our understanding of the effects of high impact weather events to society is limited to their rare occurrences. Climate change adds extra challenges to future impact estimation as multiple climate drivers and hazards will likely be altered. In this context, storylines offer a non-probabilistic way of quantifying high impact events under different assumptions and of understanding their mechanisms. Our study presents storylines of Hurricane Sandy (2012) to assess compound coastal flooding on the critical infrastructure of New York City under various scenarios. These scenarios include

the effects of climate change, such as changes in the storm and on sea level rise, and internal climate variability, which accounts for variations in storm intensity and location. Our findings suggest that the flood volumes and impacts on critical infrastructure are directly linked to the predominant flood hazards identified in each storyline, such as storm surge and local precipitation. Furthermore, our multiple scenarios show that sea level rise is likely to amplify flood volume and impact mainly via higher storm surges, while increased precipitation due to internal climate variability might also substantially increase flooding and its impacts. This study highlights the importance of building a set of relevant scenarios and integrating them into a modeling framework for future impact assessment. Such an approach allows for understanding complex meteorological events, the multiple hazards involved, and the resultant societal impacts.

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Title of abstract: Storylines approach to Multi-hazard Disaster Risk Management in Volcanic Islands: Lessons from the Canary Islands

Abstract: Integrating a multi-hazard approach into disaster risk management for volcanic islands, especially those reliant on tourism, introduces layers of complexity. These scenarios are characterized by intricate interactions among various hazards, demanding extensive data collection and significant resources for continuous monitoring, emergency response, and resilient recovery. Moreover, understanding that the impacts and decision-making processes often transcend sectoral and island boundaries, requires a systemic risk approach to identify and reconcile conflicting risks and interests. Ultimately, isolation and high economic dependence on tourism accentuates the need for robust and agile risk management strategies to protect lives, but also preserve the economic lifeline of these islands.

In this research, we employ a Storyline approach to chronicle the evolving preparedness of the volcanic Canary Islands in response to volcanic-related multi-hazards. Our study encompasses a twenty-year timeline, extending from the intense seismic swarm in Tenerife in 2004, through the significant oceanic eruption near El Hierro in 2011, and culminating with on-going risks subsequent to the volcanic eruption of Tajogaite on La Palma in 2021. This timeline serves as a narrative framework to capture the dynamic direct and indirect risks faced by the archipelago's in the context of volcanic multi-hazard scenarios. In addition, the inclusion of the preparation, mitigation, response, and recovery stages of the DRR cycle provides a structured lens of the adaptation and resilience-building efforts of the region. This storyline enables us to identify patterns, strengths, and gaps in the archipelago's approach to managing multi-hazard scenarios, offering valuable insights into the dynamic and complex

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Title of abstract: Retrospective narrative of climatic events in a wine cooperative system

Abstract: Wine cooperative systems are composed by several winegrowers who vinify their production collectively in a cellar. While the vulnerability of grapevines to climatic hazards has been studied, the vulnerability of wine cooperative systems has not.

However, the physical impact of hazards on grapevines inevitably disrupts both farms and wineries. In a context of climate change, the accumulation of hazards during a single crop year is becoming common. Despite the emergence of conceptual

frameworks for multi-hazard situations, there are no case studies relating the chains of climatic events and impacts in these systems.

How can a retropective narrative of an agricultural campaign disrupted by several climatic hazards mets help to understand the construction of impacts and identify key points of vulnerability ?

We conducted a post-hoc study of a wine cooperative in the south of France, affected in 2021 by a spring frost followed by a rainy spell during the harvest. We used a triangulation of discourses from interviews with the cooperative's managers, a documentary analysis and a quantitative survey of the cooperative's members to retrace the sequence of events and associated decisions.

This process, highlighted the complexity of decision-making in a context of limited information for cooperative managers. In trying to reduce the potential impact of a first event, they reduced their ability to respond to a second risk. It is with this temporal hindsight that we are able to identify the effects of compensation or aggravation of the damage linked to the decisions taken. The reconstruction of the story shows the importance of multi-scale adjustment decisions in the construction of impacts. It can also serve as a basis for identifying collective adaptation strategies.

Poster presentations

Author(s): Luke J. Harrington

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Title of abstract: Maximising the value of observations to understand future drought risk: evidence from Aotearoa New Zealand

Abstract: To understand the risks associated with climate extremes in a warming world, one of the most powerful sources of information comes from observational data associated with past events. Yet, we know the relative rarity of historical weather events can be effectively random and heavily influenced by multiple sources of internal variability. In this study, we demonstrate a statistical framework to quantify the relative rarity of past meteorological drought events around Aotearoa, exploring an extensive range of drought onset periods, spatial footprints, and event durations. Using several case studies, we show which regions are statistically overdue for a record-breaking meteorological drought, which past events were statistically exceptional across multiple regions, and suggest pathways to quantify worst-plausible events under current and future warming scenarios at the local scale.

Author(s): Hayley J. Fowler[1]; Colin Manning[1]; James Carruthers[1]; Elizabeth J. Kendon[2]; Selma Guerreiro[1]; Jen L. Catto[3]; Steven C. Chan[4]; Phil G. Sansom[2]; Daniel Bannister[5];

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Title of abstract: Storylines of future UK winter compound wind and rainfall extremes

Abstract: We show by conditioning on large-scale circulation dynamics that average and maximum monthly UK cold-season precipitation have scaled in line with expected thermodynamic scaling, with a significant upward trend from 1980 resulting from change to observed mean temperature. We can explain this observed intensification using results from a 12-member ensemble of local convection-permitting 2.2 km climate projections over the UK and Ireland – UKCP Local. We

quantify the probability of an extra-tropical cyclone (ETC) producing an extremely severe wind footprint and rainfall footprint within the same storm using a wind severity index (WSI) and rain severity index (RSI). We find an increase in frequency of winter ETCs that produce extreme WSI and RSI for 2060-2081, RCP8.5, compared to 1981-2000. These compound extremes are 3.6 times more likely by 2060, mainly driven by increased rainfall intensities, pointing to a predominantly thermodynamic driver. However, future winds also increase alongside a strengthened and southward displacement of the jet stream, leading to a dynamically-enhanced temperature increase. This intensifies rainfall in line with Clausius-Clapeyron, and wind speeds from additional latent heating causing cyclone intensification. We find the land area experiencing compound wind and rainfall extremes will increase. These are highest to the north of a cyclone centre where both warm and cold fronts occur in proximity, likely from rainfall from the warm conveyor belt falling into zones of high wind within the cold conveyor belt, and a consequence of increased convective activity near to cold fronts. These findings can be used to build storylines, further quantifying uncertainty of response by sampling additional climate models, to help guide climate adaptation.

Author(s): Cees Van Westen[1]; Iqra Naz, Funda Atun[1]; Silvia Cocuccioni[2]; Massimiliano Pittore[2];

Affiliation: (1) University of Twente; (2) EURAC, Italy;

Title of abstract: Multi-Risk Impact Chains: a new way of characterizing complex disaster events

Abstract: Impact chains are conceptual models of climate and disaster risks developed to streamline the analysis of climate-related impacts. They have been used primarily as graphical representations of complex events, and they tend to soon become too complex for many decision-makers, who often refer to them as “spaghetti monsters”. In this presentation we propose a new approach to Multi-Risk Impact Chains, which are tree-like graphical representations of complex multi-hazard and compound events, and how these create cascading impacts in different sectors. Central in this approach is the differentiation between triggers, drivers, hazardous events, and impacts, which are represented on a user-adjustable time scale. The graphical representation is the basis for a database structure where these components are stored as entities, with corresponding interrelationships (e.g. triggering, contributing to, causing, impacting). The system is represented hierarchically along a timeline, with triggers and drivers on the top level, hazardous events in the middle, and impacts in the lower section, which can be subdivided in sectors, following the PDNA approach. Triggers and hazardous events are characterized by their type, frequency, magnitude/intensity, onset time, and duration. Impacts are characterized by their type, severity (in absolute or relative manner), duration and recovery. Impacts can be caused by hazardous events, or by other impacts. Independent, cascading, trigger-coupled, pre-conditioned, consecutive and compound events are also considered in space and time. The impacts from different sectors can be combined into an overall resilience curve using multi-criteria evaluation, with the impacts from different sectors as input, and analyzed per time

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Title of abstract: Multi-hazard risk storylines in the MYRIAD-EU project

Abstract: We present HORIZON 2020 MYRIAD-EU (Multi-hazard and sYstemic framework for enhancing Risk-Informed mAnagement and Decision-making in the EU) project research on the development of Storylines to aid understanding of

the complexities of sectoral interdependencies and decision-making processes in multi-hazard and multi-risk contexts. This research is drawn from cross-sector, pilot-based themes that highlight specific sectors and their interdependencies.

Storylines currently being developed for the MYRIAD-EU Pilot areas aim for deeper understanding of social and environmental systems, through exploration of both past and plausible future multi-hazard risk events. Multi-hazard, multi-risk event-based storyline development is centred around a series of guiding questions that consider the pre-condition of the system, hazards and their interrelationships, direct and indirect impacts, sectors and their potential interdependencies, short and long-term responses, as well as any underlying assumptions that may influence decision-making. The process of addressing these questions enables stakeholders to explore past risk management decisions and any lessons learnt, identify causal relationships, and better inform future planning across sectors.

While the end goal is a qualitative storyline comprising a series of exploitable narratives; the process of storyline development is of equal value. Storylines developed in a collaborative environment serve as a facilitation tool for stakeholder engagement and communication to support knowledge exchange across the science, policy, and practice domains. Proactive facilitation of improved understanding of stakeholder needs with respect to multi-hazard risk management is a further outcome.

Session 11: Demonstration of tools and services

Author(s): Scott Williams; Sirkku Juhola; Alexandra Malmström;

Affiliation: University of Helsinki;

Title of abstract: Building an Integrated Decision Support System for Climate Change Adaptation: An Urban Digital Twin of Helsinki, Finland

Abstract: Adapting to climate change is one of the great governance challenges of our time. Efficient adaptation requires cross-sectoral cooperation and breaking barriers between expert stakeholders that are often entrenched in planning processes. Stakeholders need access to common sources of information that allow them to have a shared understanding of the risks and possible responses to climate change hazards. Urban digital twins (UDTs), which are digital representations of urban spaces, are one remedy to these challenges. The Helsinki UDT, currently under construction, aims to connect expert stakeholders both with each other and the most up-to-date climate information and models available in order to aid in urban planning. The Helsinki UDT incorporates information about the built, natural, and social environments with custom-designed heat and flood models in order to accurately assess the risks the city faces from these climate hazards. Our research group are currently working on incorporating urban climate projections and possible adaptation scenarios into the UDT, so stakeholders can better grasp what the future of their city may look like. In this session, I will describe the conceptual framing of the Helsinki UDT as a common source of information, how it can serve to connect disparate groups of stakeholders, and how it can aid in climate change adaptation decision-making. There will be a practical demonstration of the current state of the UDT and a discussion of how it will progress in the future. This session is relevant for all people interested in digital tools/visualizations for climate planning, methods of integrating geographic data sources, and how a common digital platform can break down barriers between stakeholders.

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Title of abstract: RiskScape: A multi-risk assessment software suite

Abstract: RiskScape is an open-source software with a flexible modelling engine for multi-hazard risk analysis. In this session we present the RiskScape suite comprising a command line-based engine and web-based platform for model operation and sharing. The RiskScape engine implements user-defined risk quantification workflows as 'model pipelines'. We will present model pipeline steps and functions that analyse hazard, exposure, and vulnerability data across different spatio-temporal domains using geoprocessing and spatial sampling operations. Steps and functions are presented for deterministic and probabilistic risk model workflows, using multi-hazard examples from New Zealand and Southest Pacific Island countries.

RiskScape advances modelling software for multi-hazard risk analysis through several implementation features. The RiskScape engine operates model pipelines independent of system prescribed model input data classifications or standards. Multiple hazard types, metric intensities, and temporal occurrence information is geometry processed and sampled to create coverage data of simultaneous or sequenced multi-hazard events at object-exposure locations. Escalating multi-hazard event impacts are then determined for object-exposures using scripted conditional or nested statements that apply vulnerability models in a logical sequence of temporal hazard and impact occurrence. These model features, supported by open geospatial consortium standard geospatial data files and operations, expedite RiskScape for modelling multi-hazard risk at any geographical location or scale.

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Title of abstract: Demonstrating Multi-Hazard Risk Assessment Tools through MYRIAD-EU: A Journey Through Software Interplay and Challenges

Abstract: In the evolving field of multi-hazard risk assessment, understanding and comparing various software tools is crucial. The presentation will present our approach to reviewing and demonstrating a range of pivotal tools, including CLIMADA, RIESGOS, NARSIS, HAZUS, and RISKSCAPE, as investigated in the MYRIAD-EU project. We focus on these tools' interactions, functionalities, and the need for standardized plug and play processes in multi-hazard risk software.

A core finding of our research is the lack of a "one size fits all" solution in multi-hazard risk assessment. Each tool offers distinct advantages, particularly in addressing dependent and independent hazard scenarios (preconditioned vs.

multivariate vs. spatially compounding vs. temporally compounding). The duration of hazards, current and future timestep scenarios, alongside exposure and risk metrics, emerge as key factors influencing potential multi-risk assessments.

Our demonstration will include a detailed presentation of the MYRIAD-EU European scale dataset, showcasing an overlapping multi-hazard exposure at risk tool, the vulnerability database tool and the risk scenario software prototype for the EU, shedding light on the complexities in various risk assessment methods, from multiple hazards through to multi-risk. Both quantitative and qualitative (companion abstract) software tools are needed.

We'll also delve into a practical case study from the Danube and Canary Islands regions, discussing the requirements involved in managing a complex multi-risk scenarios, including necessary inputs and outputs in a software setting. Our aim is to not only demonstrate the capabilities of the MYRIAD-EU tools but also to identify areas for improvement, standardisation and potential integration between tools.

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Title of abstract: FloodAdapt - Empowering communities to make informed decisions on flood risk reduction strategies

Abstract: The increasing frequency and repercussions of compound flooding in urban and coastal communities call for climate-adaptative urban planning. To assess the interplay between intensified precipitation and storm surge with and without adaptation strategies, complex models are needed that have high computational costs, making these models impractical as management tools to develop effective climate-resilience strategies. FloodAdapt is an open-source compound flooding decision support tool which is easy-to-use and accessible for decision makers and practitioners. It is built upon a rapid physics-based flood hazard and a fast impact model that reduces computational costs and complexity. FloodAdapt allows its users to understand the flood risk within their community under differing future projections like sea level rise, urban development or population growth. Interventions such as flood walls or urban green infrastructure can be evaluated based on their effectiveness in reducing flood impacts, and their economic benefits over time. Aside from monetary impact assessment, FloodAdapt highlights social vulnerability within neighborhoods and underscores the most vulnerable groups among them. A comprehensive user interface enables interaction and "What-if" scenario development. Model results are visualized in an interactive map, supported by info-metrics, which facilitate rapid model output evaluation. Co-creation with the U.S. Department of Homeland Security and the city of Charleston, South Carolina have yielded valuable end-user perspectives. These insights have led to a flexible and feature-rich design that can be tailored to community needs. This presentation will introduce FloodAdapt and showcase the benefits to researchers, practitioners, policy makers, and stakeholders.

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Title of abstract: A Demonstration of an Integrated Multi-Hazard Analysis in Conflict Settings Platform in Myanmar

Abstract: The IFRC Global Report 2020, "Come Heat or High Water ," indicates a 35% increase in extreme weather and climate-related disasters since the 1990s, causing over 410,000 deaths. Inadequate data, poor collection, and inequality contribute to underestimating the impact. Better trend analysis is essential for understanding the interaction between climate change and its impact on vulnerable communities. The Red Cross Red Crescent (RCRC) faces challenge of responding to the compounded impact of conflicts, climate, and environmental crises on vulnerable communities. Particularly in conflict zones such as Burkina Faso, Myanmar, and Lebanon, addressing multi-hazard risks and impacts

requires a more integrated approach to Climate Change and Conflict-related data in decision-making. In response to these challenges, a collaboration between ICRC WatHab and 510, an initiative of the Netherlands Red Cross, has yielded a transformative platform. The tool empowers ICRC WatHab to personalize interventions, independence and efficiency in addressing the evolving challenges in humanitarian contexts. The foundation of this platform development exists of user-insights collected via co-design sessions and focus group discussions. These sessions explored the use of climate data in day-to-day activities within the ICRC WatHab department, addressing challenges through a user-centric approach. Key insights, such as the need for a "Multi-hazard tool" to provide a holistic view of risks in an area, guided the platform's development. This tool seamlessly combines quantitative insights, presenting both risk data and operational information. It equips country teams with a comprehensive understanding of various layers of information crucial for their decision-making processes.

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Title of abstract: A digital Bento box for natural disaster, climate and multi-risk data

Abstract: In our fast-paced world, finding the right information became a crucial and challenging task in many sectors, especially when talking about natural and manmade disasters and their interconnected risks. There are various open-data and proprietary data platforms for end users in the web when in need for risk data for relief, research or just for the public interest. However, most of these platforms are either limited to just one peril or are in scope to assess the holistic needs of risk communication and decision making both for single and multi-hazard. In this presentation, we will take a deep dive into the search for disaster risk information and present a potential solution to fulfill the data needs of today's multi-risk world.

At Risklayer, we have been constantly working on a web platform to both communicate the impact of on-going hazardous disasters as well as a tool to quickly showcase long-term and short-term risks. This system is populated both by automatic algorithms using state-of-the-art modelling as well as curated data inputs, like assessments of historic and future disasters and risks, from disaster risk scientists. In contrast to many other platforms, which either focus on events or on certain aspects of risk or hazards of a specific peril, our goal is to provide a holistic web interface to combine different perils and a variety of impact metrics together. In addition, the platform functions as a host of various long-term data to provide a pathway for data-driven decision support to also provide a better understanding of multi-hazard scenarios within the MYRIAD framework.

We want to foster the discussion and development of the contemporary demands for a true natural disaster and multi-risk data and risk communication web platform.

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Title of abstract: Disaster Risk Gateway: a crowdsourced catalogue of multi-hazard risk assessment and management frameworks, methods, models and tools

Abstract: In recent years there has been a progression of multi-hazard risk assessment and management emerging approaches across several initiatives. To strengthen collaboration between projects, disciplines, sectors and communities MYRIAD-EU has developed Disaster Risk Gateway, a wiki platform for discovering and sharing existing frameworks, methods, models and tools ('approaches') for understanding, assessing and managing multi-hazard risk. This resource is a key output of the MYRIAD-EU Diagnosis work package, establishing a common baseline of multi-hazard risk assessment and management approaches. To develop the wiki, we identified the use cases within the project consortium and undertook a scoping study of existing approaches from review papers and knowledge within the consortium. The scoping work highlighted the challenges of terminology and cataloguing the range of qualitative, semi-quantitative and quantitative approaches in a wiki environment. In this first iteration of the wiki, we adopt a simple structure under two themes: Multi-hazard Risk Assessment and Multi-hazard Risk Management, recognising that some of the examples in the wiki overlap both themes. Each wiki entry provides an overview of the approach, together with technical considerations and links to the sources. In addition, we set out a series of referenced definitions, using wherever possible established glossaries. We held a collaborative online editing event (wiki-thon), with the ambition that Disaster Risk Gateway will become a resource that is used and updated by the wider risk management community. We present the benefits and challenges of the crowd-sourcing approach, potential further development of Disaster Risk Gateway and opportunities for the knowledge generated to be applied across disciplines.

Session 12: Nature-based Solutions for disaster risk reduction

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Title of abstract: Unravelling stakeholder narratives on nature-based solutions for hydro-meteorological risk reduction

Abstract: This study investigates stakeholder perspectives on Nature-Based Solutions (NBS) for flood risk management in Southeast and Central Europe. NBS, a transformative approach in hydro-meteorological risk management, aligns human activities with natural processes, offering benefits like biodiversity conservation and improved community well-being. Despite their potential, a gap exists between theoretical promises and realised outcomes of NBS, primarily due to socio-economic barriers and stakeholders' varied interpretations. The research employs a combined approach of Q-methodology (N = 103) and narrative analysis to identify four ideal-typical narratives among stakeholders: the optimist, sceptic, reformist, and pragmatist. Employing Q-methodology and narrative analysis, this research explores stakeholders' views at five river basin sites in Bulgaria, Poland, Croatia, and Serbia, regions with limited NBS implementation yet facing increased climate change risks. The findings reveal four distinct narratives: Optimists, who highlight NBS's multifunctional benefits; Sceptics, concerned about the lack of empirical evidence and practical viability of NBS; Reformists, advocating for systemic improvements and transparent processes; and Pragmatists, focusing on tangible benefits and cost-effectiveness. These narratives reflect diverse concerns and priorities, from financial feasibility to environmental preservation. The study aims to guide the design of contextually appropriate NBS strategies. It emphasises holistic stakeholder engagement as crucial for successful NBS implementation, advocating for an approach that accommodates diverse viewpoints.

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Title of abstract: How can Multiple Criteria Decision Analysis support the evaluation of Nature-based Solutions?

Abstract: Evaluating the performance of Nature-based Solutions (NbS) is paramount to make sure they become more widespread and accepted by multiple stakeholders, but complex. The available literature on NbS provides various approaches to evaluate their performance. However, they all use different terminology (e.g., variable, indicator, criterion, constraint) making it difficult for a practitioner to navigate this domain and select the most suitable set of evaluation parameters for their NbS project. Therefore, this study provides a harmonized framework to assess NbS performance. This was achieved via a Multiple Criteria Decision

Analysis approach inspired by Value-Focused Thinking (VFT). VFT is a way of approaching complex decision-making that emphasizes the need to identify the values that stakeholders have to solve a decision problem. We related these values directly to what the stakeholders involved in NbS projects aim to achieve, which were expressed as objectives to be either maximized or minimized. Objectives were then clustered in groups of relevance, leading to hierarchies that allow to visually group them. The last step of the VFT approach we used involved the operationalization of the objectives, meaning the definition of how each objective can be measured using criteria.

We developed a framework to evaluate NbS on their performance with four domains (environmental, technical, social, and economic), 14 categories, 59 objectives, and more than 100 criteria. According to the desired target of the evaluation, a practitioner can now choose the domain(s), categories, objectives, and criteria that best fit their type of NbS project and stakeholders' interests. The application of this framework to a case study in the Zambezi river basin in Zambia will be discussed.

Poster presentation

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Title of abstract: Evaluating the Potential of Nature-Based Solution for Disaster Risk Reduction and Climate Adaptation Pathways in Coastal Areas

Abstract: NBS have increasingly been embedded in policies for climate change adaptation (CCA) and disaster risk reduction (DRR).

The European Green deal promotes the integration of NBS through a new narrative involving biodiversity, Ecosystem Services (ES), and their potential for transformative pathways. The selection of suitable NBS should be based on their ability to reduce the magnitude, duration, or frequency of climate hazards considering their effectiveness under present and future conditions.

However, empirical evidence on NBS performance is lacking – especially for coastal environments where there is limited site-specific evidence, and there are no internationally recognized NBS standards. REST-COAST aims to address these issues by demonstrating that upscaled coastal restoration can provide a low carbon solution to CCA and DRR. This work supports reaching this objective by conducting a systematic review to expand the evidence-base for NBS implementation through identifying performance indicators. It could be noted that NBS performance is most frequently evaluated based on environmental indicators; e.g. vegetation, carbon sequestration, sedimentation, nutrients. The challenges related to the design and development of risk scenarios that explicitly include NBS simulations as transformative pathways can be addressed by incorporating the NBS performance indicators and using new data technologies. To do so, a conceptual risk framework for the Venice lagoon that will integrate the NBS performance indicators with climate and NBS intervention scenarios to evaluate risk reduction through ES provisioning. This framework will provide the basis for a Bayesian Network for risk modelling, as well as the co-development of adaptation pathways for the Venice Lagoon.

Session 13: Recent developments in multi-hazard early-warming systems

Author(s): Maryam Rokhideh

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Title of abstract: Towards Achieving the Panacea of Effective Multi-Hazard Warning Systems for All

Abstract: Warning systems have evolved significantly across Europe, especially in recent decades as capabilities and technologies have advanced monitoring, forecasting, and the diversity of communication tools. However, technology has also generated a number of new uncertainties and risks, particularly with regards to how people act and respond to receiving a warning, as seen by the 2021 devasting floods in Germany that killed over 184 people. While the EU has mandated advanced public warning systems via mobile communications, progress in each member state has been mixed. Currently 24 out of 27 member states are operating or testing a public warning system and only 15 member states have cell broadcasting capabilities. Whilst the focus remains on expanding mobile communication systems, there is an exigent need to consider inclusive and multichannel warnings that empower individuals to take the most appropriate actions possible. This is further complicated by events that are compounding, cascading, or multi-hazard. The growing complexity of risks present new challenges in communicating and managing warnings to all users. The EU-funded project 'The HuT' brings together the human and technology nexus to better understand how to design, develop, and operationalise multi-hazard warning systems. Using case studies within the HuT project, this paper explores how to generate effective multi-

hazard warnings across a range of hazards by examining the decision-making processes, various scales involved, and multi-directionality of communicating warnings. By examining different case studies, we aim to establish what successful multi-hazard warning systems may look like in the European context.

Author(s): Michele Calvello

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Title of abstract: Standard protocol for evaluating warning systems

Abstract: The contribution addresses, from a conceptual point of view, the complex issue of evaluating the performance of warning systems that are operating over large areas to cope with the risk posed by extreme weather events. In a perfect warning chain, the warning received by the end user would contain precise and accurate information that perfectly met their need, contributed by each of the many players in the chain; in real warning chains, information, and hence value, are always lost as well as gained at each link in the chain (https://link.springer.com/book/10.1007/978-3-030-98989-7). The protocol is structured as a three-part evaluation process: 1) description of the system; 2) assessment of criticalities during high impact events; 3) routine assessment of daily operations. For each part, the protocol prescribes a set of must-do. This study is being carried out within the Horizon Europe project "The HuT: The Human-Tech Nexus - Building a Safe Haven to cope with Climate Extremes" (https://thehut-nexus.eu/). The protocol has been developed considering two case studies, and will be further put to test during the remaining part of the project. Through this action, detailed information from many different warning systems will be collected and used for a comparative study between warning systems operating, in different areas of the world, for different weather and climate related risks.

Session 14: Systemic risk-assessing, modeling, coping

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Title of abstract: The Global Production Ecosystem as a connector of global systemic crises

Abstract: The growing interconnection of socio-ecological systems and the intensification of global stresses have multiplied the frequency and spread of shocks in the economy. Understanding the associated systemic risks is key for building a sustainable, resilient society but is made difficult by the complex and cross-scale relationships at play.

Drawing on the Global Production Ecosystem (GPE) framework and a recently developed database, we here unpack the architecture of modern global shocks and assess cross-scale propagation dynamics. First, we provide a typology of ways the GPE interact with global crises in terms of buffering, amplifying, or connecting crises. Second, we trace the successive dynamic phases of each shock and establish how they are transferred, absorbed, and linked together to create systemic

crises across space, time, and sectors of society. Finally, we emphasize the contribution and vulnerability of the GPE to the shocks and highlight examples of disparities in impacts between high- and low-income countries.

Our results highlight how the configuration of biosphere components inherited from colonization defines the way socio-ecological shocks emerge and propagate. We therefore call for greater attention to how injustices frame plural and just futures and suggest that leverage points are not only a strategy for building resilience, but also a means of emancipation against the perpetuation of colonial inequalities.

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Title of abstract: Scenarios-based modeling of the economic impacts of weather-geopolitical coupled extreme events on the global food web: a case study of the Russian-Ukraine war and the 2022 summer heatwaves

Abstract: Coupled extreme weather and geopolitical events will exert unprecedented shocks on the global food web and the global supply chain in general, especially when conflict regions are major breadbaskets. These types of shocks have not yet been explored, and the likelihood of their recurrence is increasing. For example, following Russia's invasion of Ukraine, it is likely that conflicts will arise in real time between NATO and Russia, China and Taiwan, the US and Russia, and the US and China. Extreme weather events have been shown to increase in magnitude and frequency, impacting crop growth and productivity. There is a likelihood that these events will occur side by side, exerting a new type of shock on the global food web. To better understand the behavior of these events, we model the impact of the war between Russia and Ukraine and the summer 2022 heat wave on the global food market as coupled events. We consider scenarios such as the start of the invasion, the peak of the war, Ukraine's fightback, sanctions against Russia, refugee crises across Europe, and heatwaves in the summer of 2022. Using data from the United States Department of Agriculture (USDA), Statista, and Acclimate production value losses, we show that the agricultural sectors of southern European countries such as France and Italy are more vulnerable to the Russian-Ukrainian war, although they are less affected by the refugee crisis compared to northern European countries. In general, sub-Saharan Africa is most affected by the conflict due to its weak economy and heavy dependence on imports from conflict regions. Financial support for the governments of this region (sub-Saharan Africa) can contribute to economic recovery.

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Title of abstract: Socio-economic impacts of multi-hazards in Scandinavia: A case study of the 2018 heat-drought-fire event

Abstract: This study first maps the historical occurrence of multi-hazards, illustrating the spatial distribution of compound heat-drought-fire events within the Scandinavian region. According to historical data, around 12% of the forestry areas located along the northern Norwegian-Swedish border and southwestern part of Norway are exposed to drought, fire, and heat events. Then, to better understand the cross-sectoral and cross-regional effects of these compound events, we further analyze the event of 2018 which was featured with extreme heat, drought and forest fire in the Scandinavia region. We use a macroeconomic model, GRACE (Asbjørn et al., 2018), to address the socioeconomic implications of the compound event of 2018 and the resulting responses in a global context. Integrating the climate information and risk measures of compound events, we highlight significant and negative direct impacts on industry productions in the region's agriculture, forestry, and energy sectors. We find varying and wide-spreading socioeconomic impacts across sectors and

regions, particularly in Europe. These 2018 multi-hazard disturbances had ripple effects, shifting market equilibriums and affecting global trade patterns. The consequences include reduced manufacturing outputs, reduction in labour inputs and enhanced domestic prices for consumer goods within the region. The compound event of 2018 also notably affected the trade of forestry goods because of Scandinavia's vital role in the international wood market. This led to a moderate yet widespread effect on GDP losses, affecting not only the Scandinavian region but also trading patterns, particularly in Europe.

Author(s): Chakraborty, L.; Motlaghzadeh, K.; Jahangir, M.S.; Henstra, D.; Thistlethwaite, J.; Andrews, S.; Pulatsu, B.; Malomo, D.; Spinney, J.;

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Title of abstract: Assessing distributive environmental injustices and socio-spatial heterogeneity to seismic risk in the built environment of Ottawa and Montreal

Abstract: This study explores spatially heterogeneous relationships between seismic risk and neighbourhood demographic, racial/ethnic, and socioeconomic indicators in the built environment of Ottawa and Montreal. The study uses data from Canada's Probabilistic Seismic Risk Model and the 2021 population census. The seismic risk index scores represent a community's relative risk considering annual average loss of life, economic loss, and social vulnerability. Two deprivation indices - economic insecurity and neighbourhood instability - were spatially clustered with seismic risk index scores for all census dissemination areas, following a bivariate local indicator of social association approach, to unveil "hotspot" areas with high probabilistic seismic risk that were spatially associated with high socioeconomic deprivation in neighbours. Using the multiscale geographically weighted regression results, we mapped the extent of local relationships between concerned variables and socioeconomic inequalities to seismic risk. The multivariate statistical and geospatial analysis confirmed that a large proportion of seniors, living alone persons, lone-parent families, unemployed persons, low-income populations, private dwellings constructed before 1961, recent immigrants, and neighbourhood instability were consistently overrepresented in seismic risk zones of the study area. The results have revealed spatially varying relationships between seismic risk and socioeconomic characteristics, providing empirical evidence of disproportionate risk exposure of vulnerable populations and built environment characteristics. It intends to support planning and emergency management activities in hotspot zones. The results are helpful for risk-based prioritization and resource allocation for mitigation.

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Title of abstract: Modelling the influence of risk perception on the impacts of droughts and floods

Abstract: Numerous socio-hydrological models have been proposed to represent the complex interplays between society and hydroclimatic extremes. Yet, it is still unclear how different risk perceptions can influence the implementation of adaptation actions and the consequent impacts of multiple extremes over time. Here we present a new system-dynamics model to simulate the interplay between water management, droughts, floods, and society. The model accounts for four stylized types of societies based on idealized scenarios of risk perception and management responses: risk neglecting, risk controlling, risk downplaying, and risk monitoring. We perform synthetic experiments to investigate how the co-existence of communities with different risk behaviors can affect the implementation of adaptation measures and the consequent

changes in drought and flood losses. Our findings show that the homogenous presence of social groups with diverse risk attitudes leads to higher drought and flood losses due to the unsustainable water use of risk-neglecting and risk-downplaying groups. Finally, our results highlight that societies characterized by high homogeneity in risk attitudes tend to implement less collective measures, opting instead for individual measures by specific social groups. Our study emphasizes the importance of including the interplays between different risk perception behaviors and the occurrence of multiple hydroclimatic extremes in current socio-hydrological models for improving water risk management strategies

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Title of abstract: Systemic risks to port and countries due to maritime chokepoint disruptions

Abstract: A large share of global trade is transported through a set of narrow maritime corridors, so-called maritime chokepoints. Recent disruptions, such as, the Suez blockage in 2021, the Panama Canal drought in 2023/2024 and the Houthi rebel attacks in 2023/2024 showcased how disruptions to these chokepoints can disrupt trade and have large economic implications far beyond its localised impacts. In this study, we analyse the systemic risk of maritime chokepoint disruptions and the economic implications for ports and countries that depend upon them. We categorize the likelihood of occurrence of various types of risk (i.e., piracy, geopolitical conflict, climate extremes, and ship blockages) as well as the implications of such disruptions in terms of transport delays, rerouting costs and trade flow disruptions. We identify which ports and countries are most at-risk to face maritime chokepoint disruptions and the economic costs these countries may experience. These results help country authorities and various actors in the freight sector to better prepare for such low-probability but high-impact events, for instance by developing adequate emergency/contingency strategies to cope with such disruptions. Moreover, our results have useful applications to the financial sector, in particular re-insurance companies, to price such systemic risks into their financial products.

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Title of abstract: Enhancing Systemic Resilience of Interdependent UK Infrastructure: A System-of-Systems Approach

Abstract: UK infrastructure is threatened by increasingly frequent and intense extreme weather events as our climate changes. Dependencies between infrastructure networks compound these challenges, potentially amplifying the consequences as failures propagate. Storm Henk, on January 2nd, brought damaging winds and rain across southern and central England and Wales, leading to power outages and transport disruption [1]. Past studies have mainly assessed the resilience of individual sectors, overlooking comprehensive assessment of systemic resilience [2]. This paper presents an open-source modelling framework taking a system-of-systems approach [3] to stress-test interdependent UK infrastructure's resilience against extreme weather events. The framework models network services across electricity, telecoms, transport and water, connected to buildings and communities. The model simulates asset disruptions using fragility curves and event hazard maps, then propagates failures, labelling elements both directly affected and indirectly disrupted. Economic impacts are quantified as direct damage to assets and indirect loss of services. This paper aims to: provide insights into interdependent network vulnerabilities; offer actionable recommendations to enhance systemic resilience against extreme hazard events; and provide standard protocols by integrating data and tools onto the DAFNI platform.

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Title of abstract: Analyzing Tourism, Disaster Risk and Climate Change Data at the Sub-national Scale

Abstract: Presented are key findings and methodologies on multi-hazard and multi-risk assessment at a European scale, with a specific focus on the tourism sector. Tourism is vital to national economies and to the livelihoods of those communities in tourist destinations. The tourism sector is particularly vulnerable to hazards and the impacts of climate change, while at the same time tourism greenhouse gas emissions are a major contributor to climate change. The analyzed data provides a comprehensive stocktake for the resilience of the tourism sector through indicators that track key connections between disaster risk from a multi-hazard perspective, climate change, and the tourism sector's vulnerability to disruptions in other sectors, such as food & agriculture, transportation, energy, water, health and finance. The study integrates global datasets, emphasizing exposure metrics for population, buildings, and infrastructure. A significant effort has been directed towards gathering datasets relevant to the tourism sector, including publicly available data on tourism indicators, GDP, and population movements, providing insights into seasonal tourism trends. This data is complemented by information from OpenStreetMap, detailing locations of hotels, restaurants and other tourist sites. Over 40 metrics are analyzed at the sub-national NUTS 2 and NUTS 3 levels, providing a framework to assess the tourism sector's progress in climate and disaster resilience at the sub-national level. Several case studies provide detailed insights into more granular data for applying the multi-hazard methodologies developed in the MYRIAD-EU project. The data and analyses act as a basis for a tourism resilience observatory to inform tourism policy-makers, industry actors and further scientific research.

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Title of abstract: Assessing transboundary and intersectoral spillovers of multiple natural hazards in the Danube Region using a large-scale macroeconomic agent-based model

Abstract: The potential for systemic risks arising from interconnected social, technical, and economic systems is becoming increasingly evident as climate change leads to more frequent and severe natural hazards and multi-hazard events (e.g., compound and cascading hazards) that can lead to unforeseen consequences on various levels. We present a large-scale macroeconomic agent-based model (ABM) designed to trace the spread of indirect losses caused by natural hazards across different regions and sectors. Using the Danube Region as a case study, we simulate economic and social ripple effects resulting from direct physical damages (i.e., loss and damage of capital stock) caused by various hazard scenarios, such as compound flooding, consecutive floods and droughts, and compound flooding and earthquakes. Our ABM is designed to

capture micro-level behaviours and agent heterogeneity in terms of adjustment in response to direct damages both on the supply and demand sides of goods and labour markets, e.g., supply chain disruptions and reduction of production capacities. The ABM is calibrated on the NUTS-2 regional scale and incorporates dozens of industries. Using macroeconomic aggregates and a risk ratio metric comparing direct and indirect exposures, we quantify industries, regions and population subgroups most severely affected by indirect impacts on a short- to medium-term based on their positions within a wider economic network. We demonstrate that ABMs can be utilized to conduct participatory investigations of cascading risks that extend beyond individual impacts and encompass risk proliferation across both sectorial and regional boundaries. Our approach reveals latent vulnerabilities within economic networks that may pose potential risks, despite not being immediately apparent.

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Title of abstract: Integrating Broad and Deep Research: A Multi-Stressors Framework for Translating Across Scales and Disciplines

Abstract: Risk research is often limited by disciplinary approaches and the analysis of a single sector or scale despite the increased interactions between hazards in the Anthropocene. These limitations lead to inequitable policy advice and misguided outcomes. Moreover, hazard interactions involve feedback mechanisms that multiply impacts and losses. The Anthropocene demands research that is simultaneously broad and deep. Recent attention to multiple stressors, coupled hazards, and systemic risks foregrounds the need for multidimensional approaches to risk, but research still lacks full integration. Here, we provide a broad and deep framework that embraces the complexity of such integration using a translator. This translator takes the form of agent-based modelling that connects mixed methods, societal sectors, and analytical scales. This innovative approach explicitly treats informational transfers and dialogues with different disciplines. We test this framework in a transdisciplinary and codesigned risk assessment in Brazil, examining the contributions of urbanisation, behaviour, and socioeconomic vulnerability to health risks. The results include a quantitative risk assessment, qualitative thematic analysis and generative segregation patterns. These findings reveal marked differences in exposure and vulnerability across social classes during the COVID-19 pandemic. This framework thus successfully overcomes disciplinary siloing, accounts for cross-sectoral losses and tracks feedback mechanisms between environmental and social factors. These innovations may be easily transferred to other types of risks and are vital for promoting evidence-based and context-sensitive policies that are essential for fairer and more effective adaptation.

Poster presentation

Author(s): Heidi Kreibich

Affiliation: GFZ German Research Centre for Geosciences

Title of abstract: How can socio-hydrological data from paired hydrological extreme events enhance our knowledge of human-water systems?

Abstract: Damage caused by hydrological extremes is increasing in many regions of the world. A better understanding of the causes of the increasing damage is essential for effective flood and drought risk management. However, there is a lack

of empirical data on the processes in complex human-water systems. As part of the IAHS Panta Rhei Initiative, a dataset was compiled containing socio-hydrological data from paired events, i.e. two floods or two droughts that occurred in the same area. The 45 paired events cover a wide range of socio-economic and hydro-climatic conditions. The dataset is unique in that it covers both floods and droughts in terms of the number of cases and the amount of qualitative and quantitative socio-hydrological data. The advantages of the dataset are that it enables comparative analyses across all paired events and allows detailed context-and site-specific analyses in the individual study areas. An initial analysis of the dataset found that risk management typically reduces the damage from floods and droughts, but has difficulty reducing the damage from unprecedented events (Kreibich et al. 2022). The presentation will show various in-depth results to inspire further analyses with the aim to help solve one of the twenty-three unsolved problems in hydrology, namely "How can we extract information from available data on human-water systems to support the development of socio-hydrological models and conceptualisations?" (Blöschl et al. 2019).

Literatur

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Title of abstract: Investigating multi-perspective interactions on groundwater extraction and evaluating its related risk in Taiwan by Bayesian network modeling

Abstract: Agricultural water demand accounts for the largest part of the total water consumption in Taiwan, as in many other countries. Due to the great water demand, groundwater becomes an alternative water resource for agriculture irrigation if there is no sufficient surface water supply, but the over-exploitation of groundwater also leads to problems such as groundwater depletion and land subsidence. In Taiwan, the latter may increase the flood risk and pose an adverse impact on the infrastructures like Taiwan High Speed Rail, and extreme weather events and frequent drought events increase the water stress, which worsens the situation in the recent years.

Agricultural groundwater extraction in Taiwan is affected by various factors such as surface water availability and quantity, farmers' crop selections influenced by agriculture policies, etc. There are strong interactions among decisions of different stakeholders, including farmers, agencies related to surface and ground water management and agencies responsible for agriculture and food. To evaluate the associated risks induced by over-exploitation of groundwater, multi-perspective interactions should be considered. In this study, Yunlin County, located in central Taiwan, is selected as the study area because of the severe land subsidence. A Bayesian network is constructed to model the complex interactions among stakeholders relevant to groundwater extraction and management and evaluate the related risks, including the further land subsidence potential. The Bayesian network may also facilitate discussions and formulate strategies for sustainable agricultural water and risk management with the aid of its intuitive and transparent structure.

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Title of abstract: Can Open Social Datasets Effectively Calibrate Socio-Hydrological Flood Risk Models?

Abstract: Sociohydrology is an interdisciplinary field that explores the complex interactions between society and water systems. Quantitative sociohydrological models featuring Human-Flood Interactions have focused on elucidating the influence of floods on the society and the feedbacks connecting the societal response back to the flood system. In order to quantify the systemic processes, a combination of expert knowledge (literature) and empirical data from private households and companies have been used to calibrate the sociohydrological models (1, 2). Attributes from the Human-Flood System including flood intensity, settlement density, awareness, preparedness, and flood impact are represented by the model. Among these, we largely depend on empirical field surveys to collect representative data on flood risk awareness and preparedness. In this study, we aim to assess the utility of large open datasets characterizing public attention (Google Trends and Twitter posts) to quantify risk awareness and preparedness in the flood-exposed regions, before the onset of a flood event. The usability of the datasets will be validated against empirical data from flood events (3) and applied to calibrate socio-hydrological model based on selected flood events from the Panta Rhei benchmark dataset: socio-hydrological data of paired events of floods and droughts (4).

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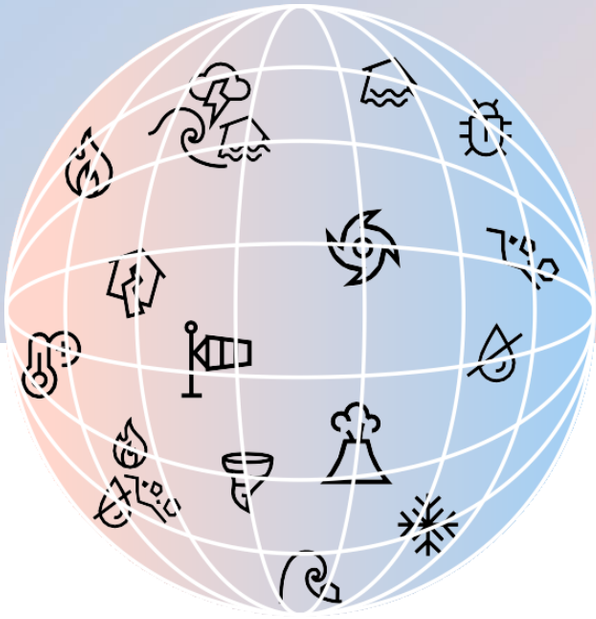

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