

AI for the Earth System

Matthew Chantry

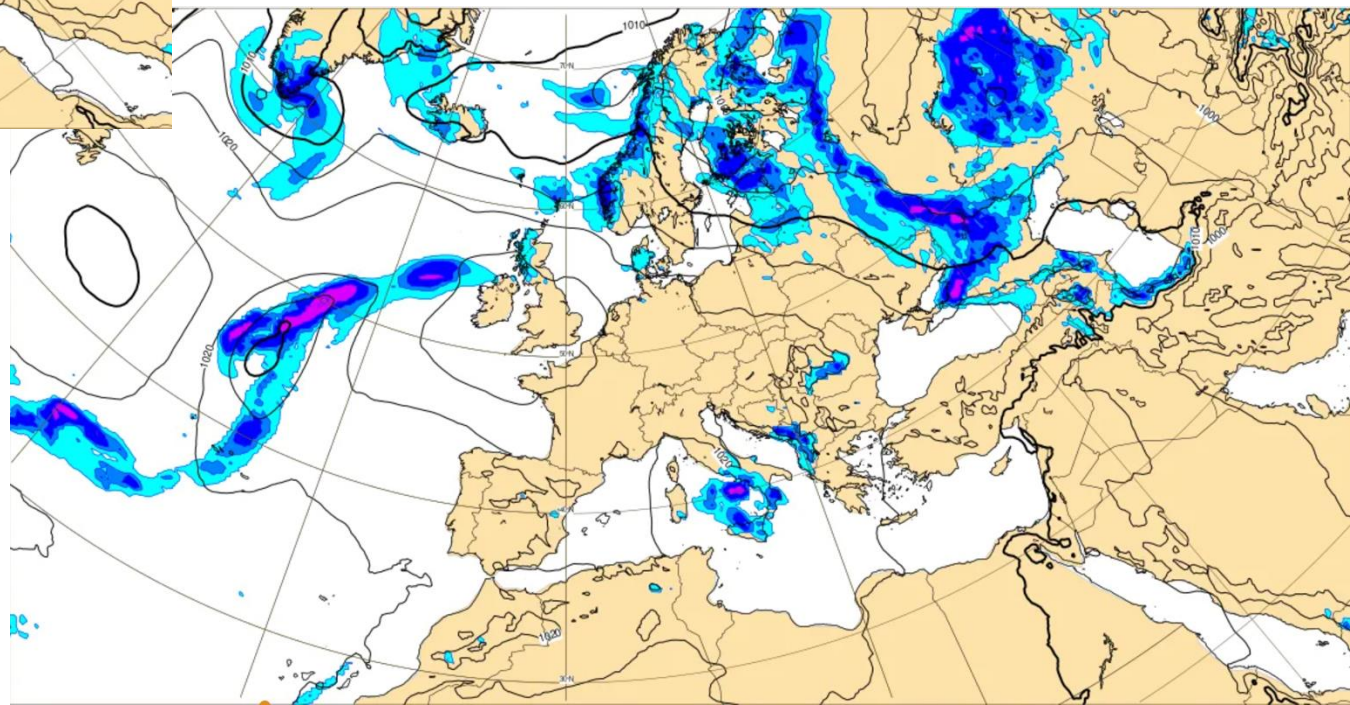
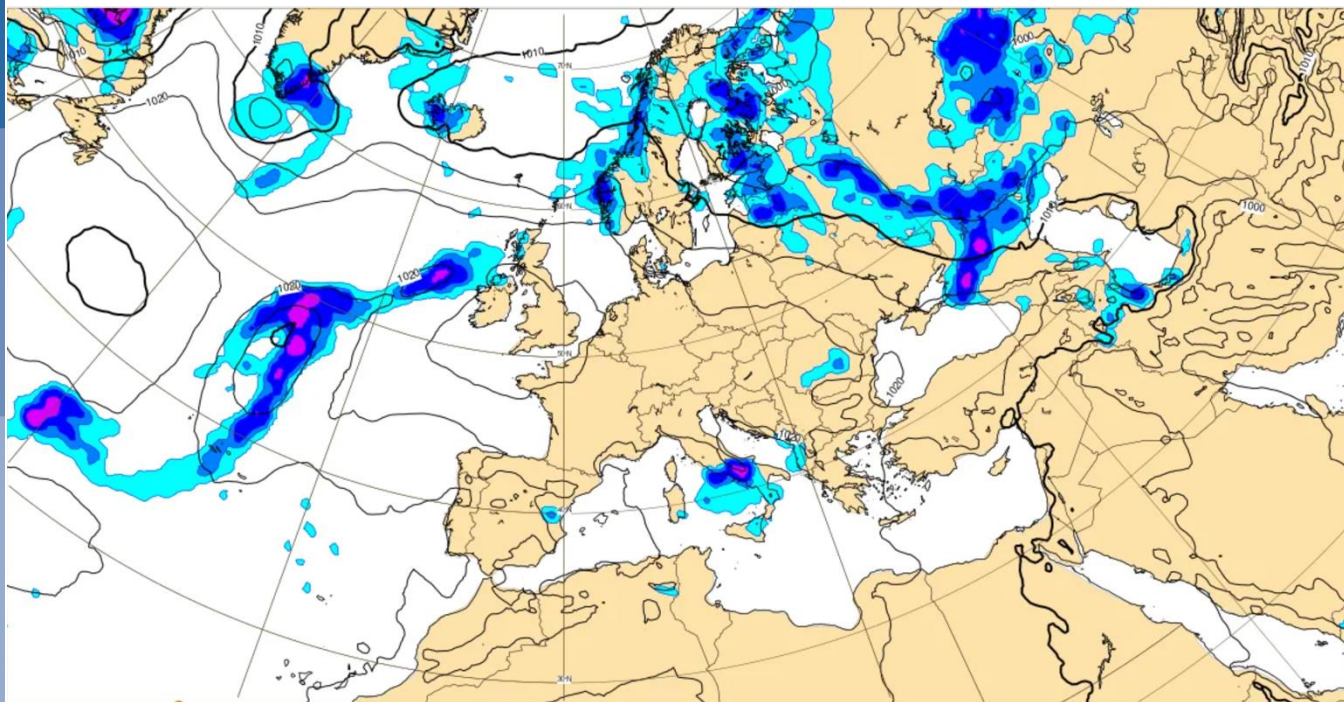
Strategic Lead for Machine Learning

European Centre for Medium-Range Weather Forecasts

matthew.chantry@ecmwf.int



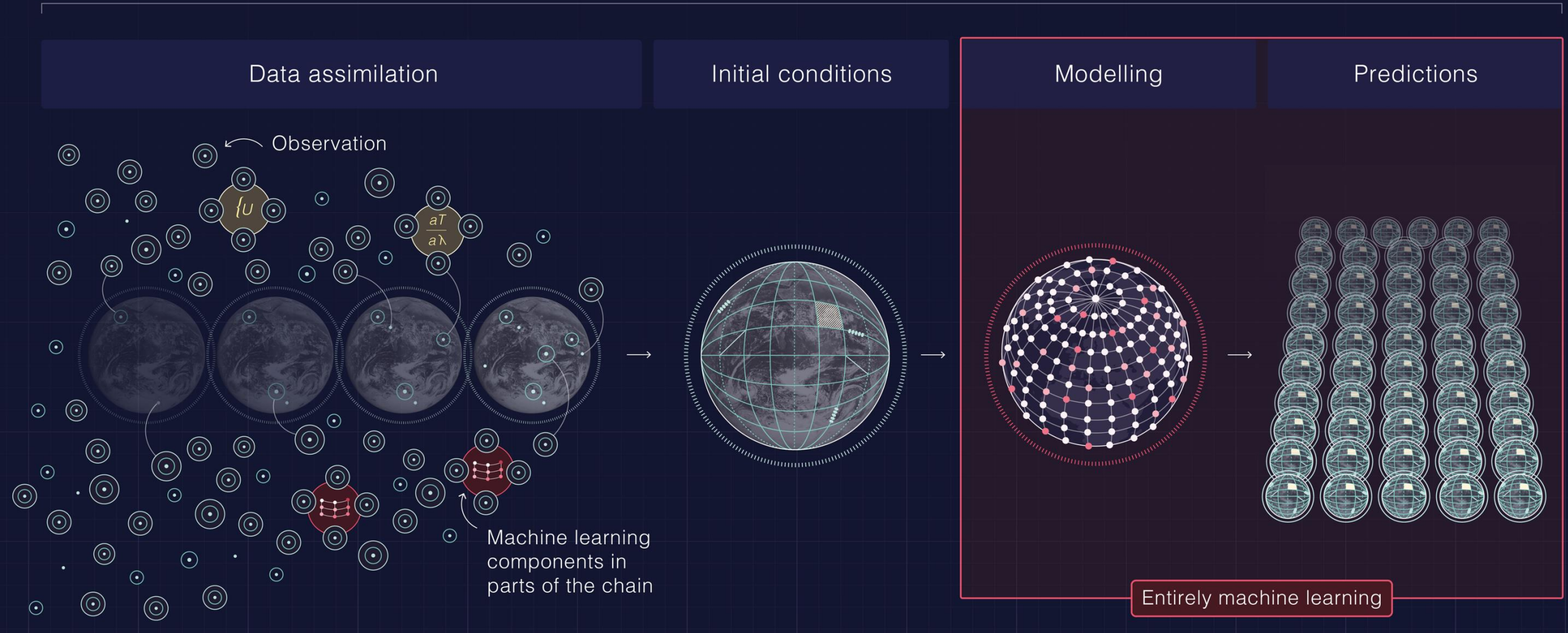
AI weather Turing test – which is AI, which is physics-based

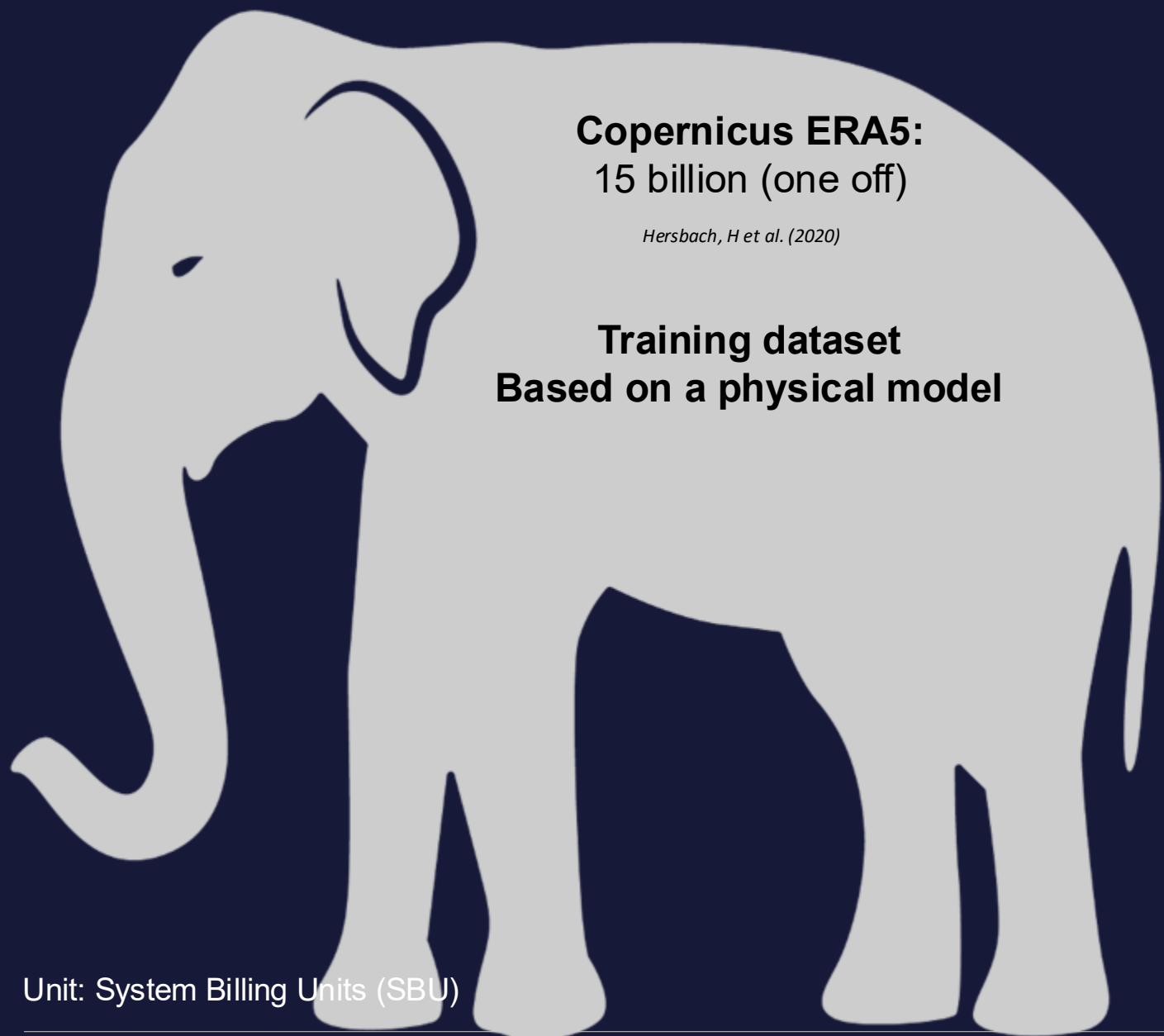


ARTIFICIAL INTELLIGENCE FORECASTING SYSTEM (AIFS)

Machine learning is used in entire segments of the chain, and will continue to be integrated.

Weather forecasting chain



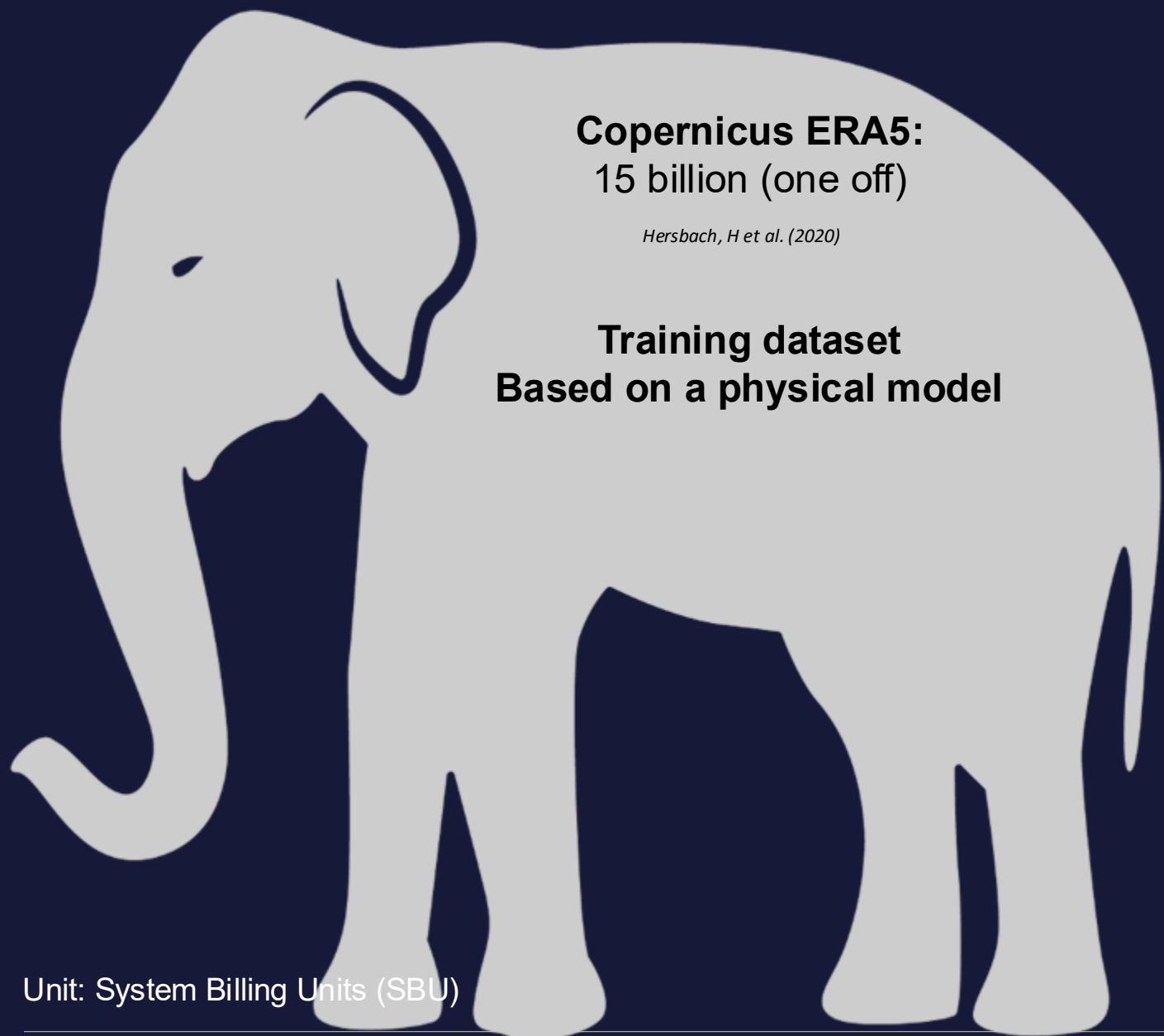


Copernicus ERA5:
15 billion (one off)

Hersbach, H et al. (2020)

Training dataset
Based on a physical model

Unit: System Billing Units (SBU)

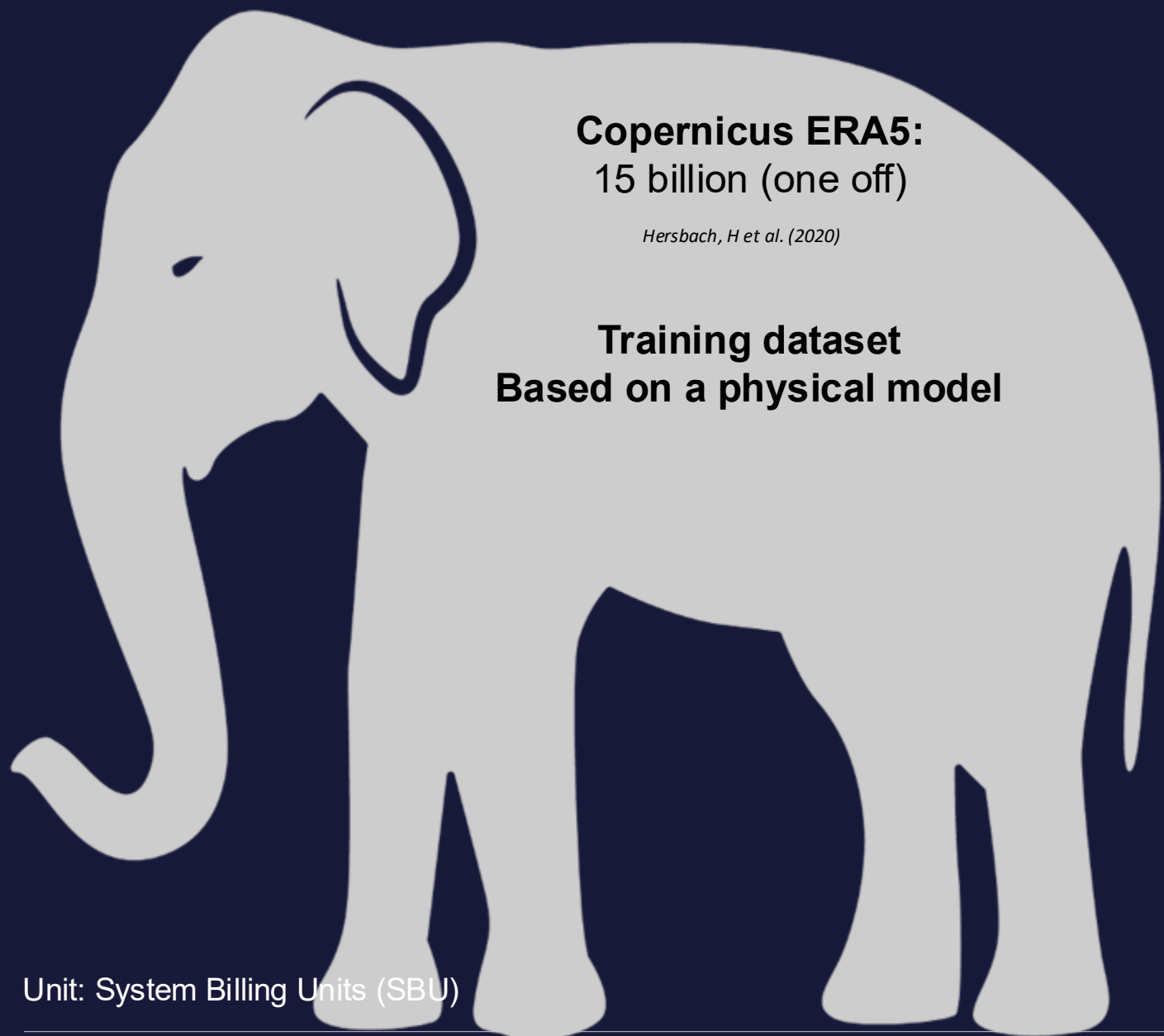


Copernicus ERA5:
15 billion (one off)

Hersbach, H et al. (2020)

Training dataset
Based on a physical model

Unit: System Billing Units (SBU)



Copernicus ERA5:
15 billion (one off)

Hersbach, H et al. (2020)

Training dataset
Based on a physical model

Unit: System Billing Units (SBU)

180 000
per forecast

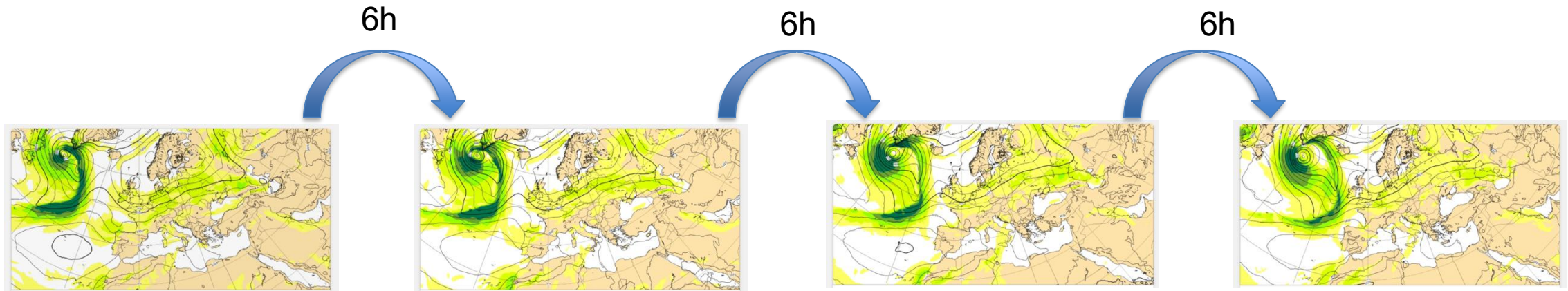
0.3
per forecast

~1000x
reduction in
energy
Forecast time
reduced from
~30minutes to
~3minutes



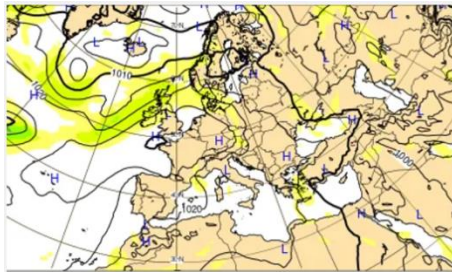
Weather Forecasts –Data Driven?

The model learns from ca. 40 years of ECMWF's ERA5 re-analysis data, stepping 6hours into the future



The forecast is then autoregressively stepping 6h into the future $x_n = f(x_{n-1}) \dots$

AIFS – operational forecasting with AI

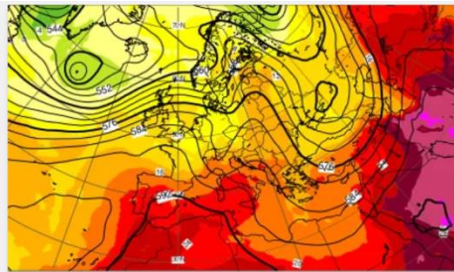


Latest forecast

AIFS Single: Mean sea level pressure and 850 hPa wind speed

Wind speeds near the surface are roughly proportional to the distance between isobars so closely packed isobars mean strong surface winds...

[jupyter](#) [github](#) [launch](#) [binder](#) [Open in Colab](#)

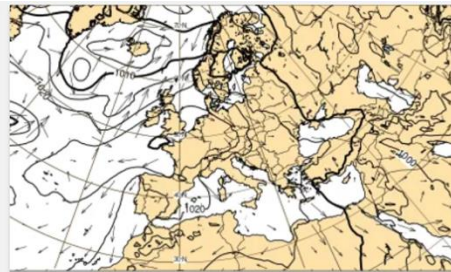


Latest forecast

AIFS Single: 500 hPa geopotential height and 850 hPa temperature

The 850 hPa level is usually just above the boundary layer and at this level the day-night variation in temperature is generally negligible...

[jupyter](#) [github](#) [launch](#) [binder](#) [Open in Colab](#)

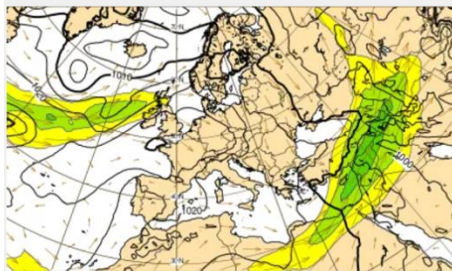


Latest forecast

AIFS Single: 100 m wind and mean sea level pressure

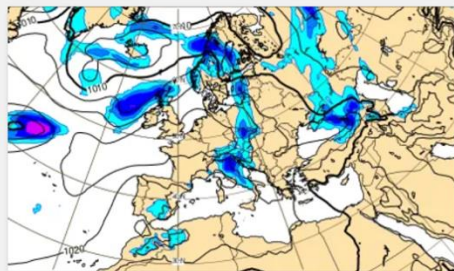
These charts show surface pressure patterns. Areas of high pressure (anticyclones) are usually associated with settled weather...

[jupyter](#) [github](#) [launch](#) [binder](#) [Open in Colab](#)



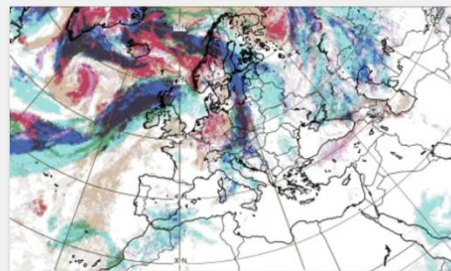
Latest forecast

AIFS Single: Mean sea level pressure and 200 hPa wind



Latest forecast

AIFS Single: Rain and mean sea level pressure

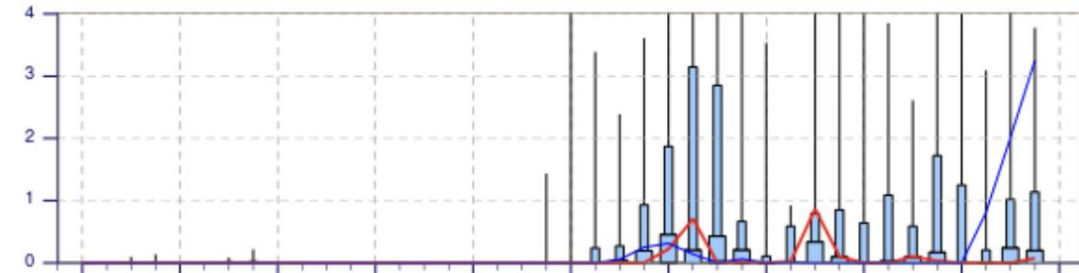


Latest forecast

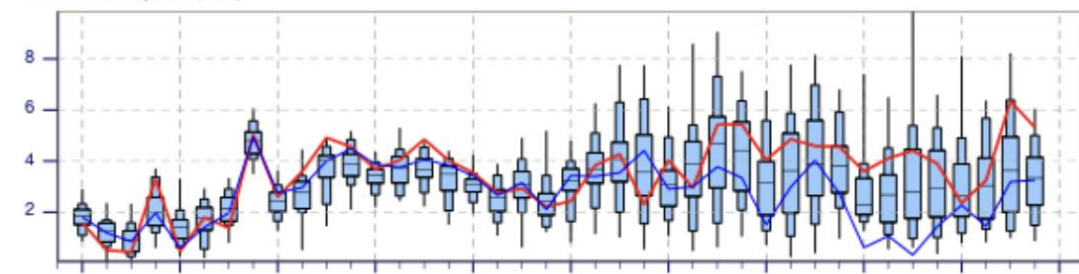
AIFS Single: Total cloud cover

This display helps with the recognition of clouds of

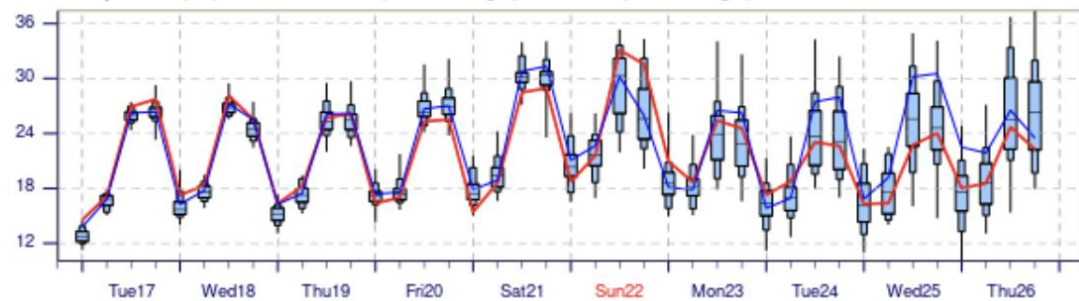
Total Precipitation (mm/6h)



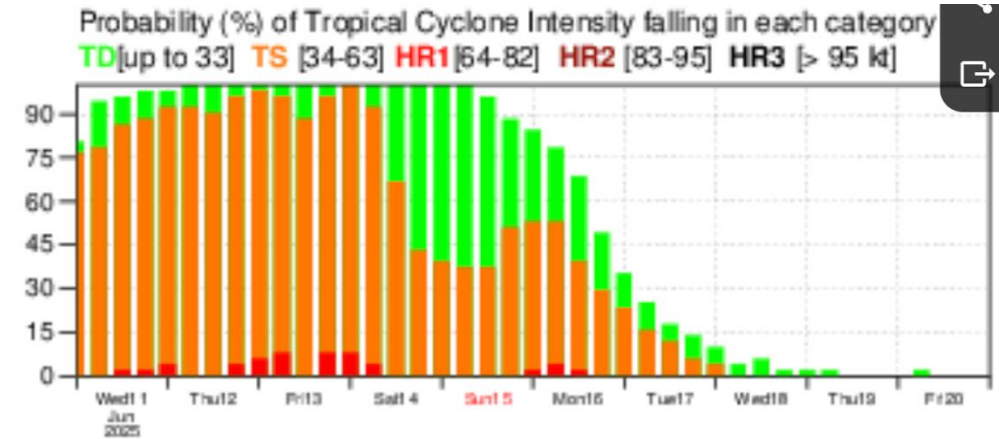
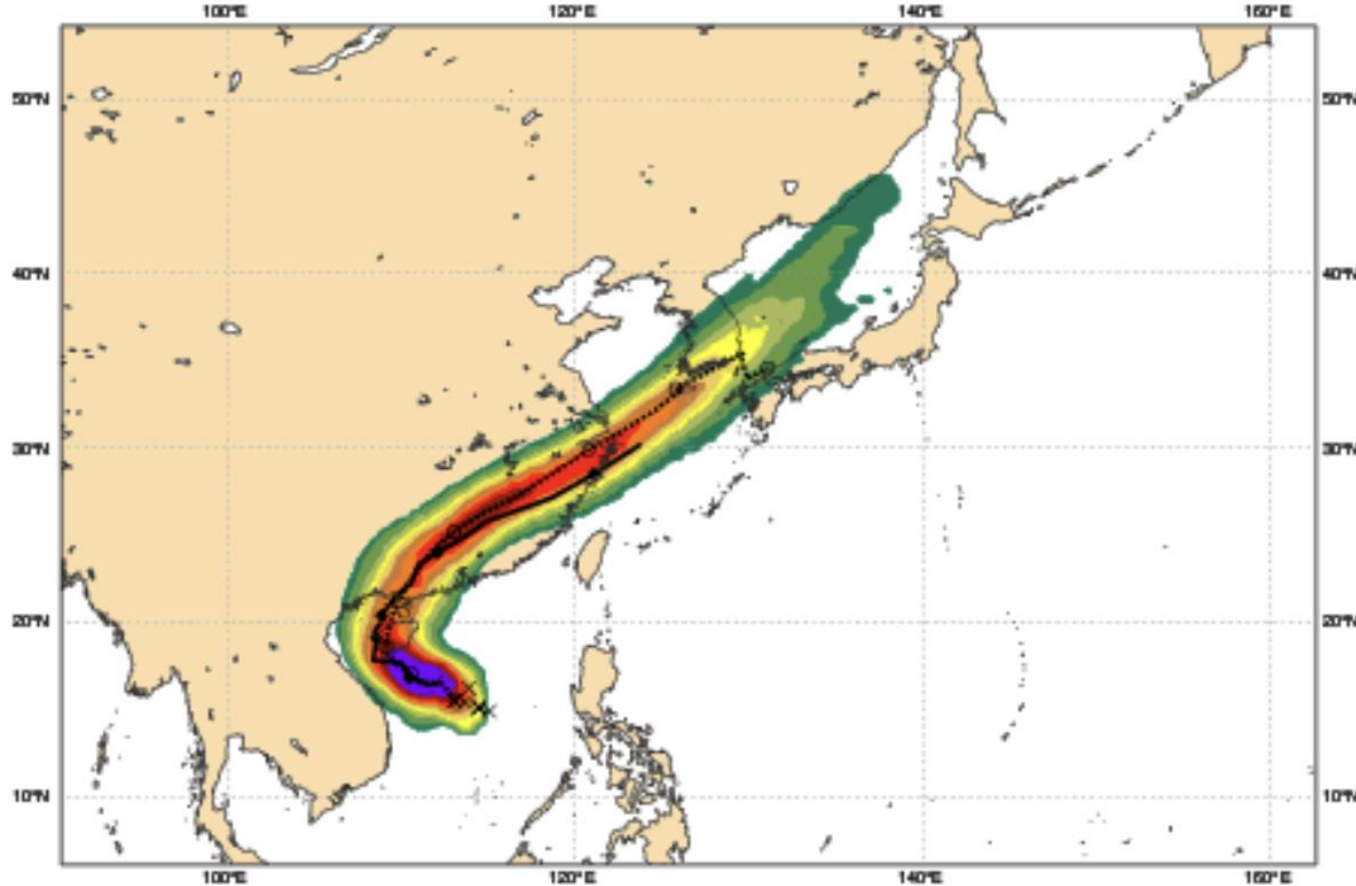
10m Wind Speed (m/s)



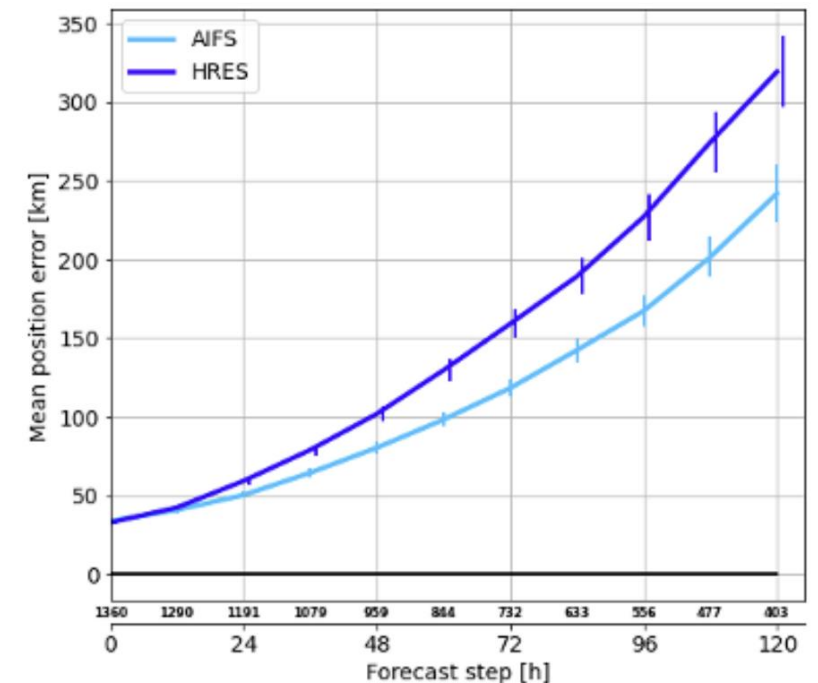
2m Temperature(°C) reduced to 20 m (Station height) from 60m (Model height)



Ensembles – key for reliable decision making



AI allows larger and more reliable ensembles
AI systems more accurate for a range of tasks



Anemoi

Open-source ML software framework for earth system modelling. Underpins AIFS, DestinE AI activities and more activities across Europe.

Open recipes for training the AIFS and open models.

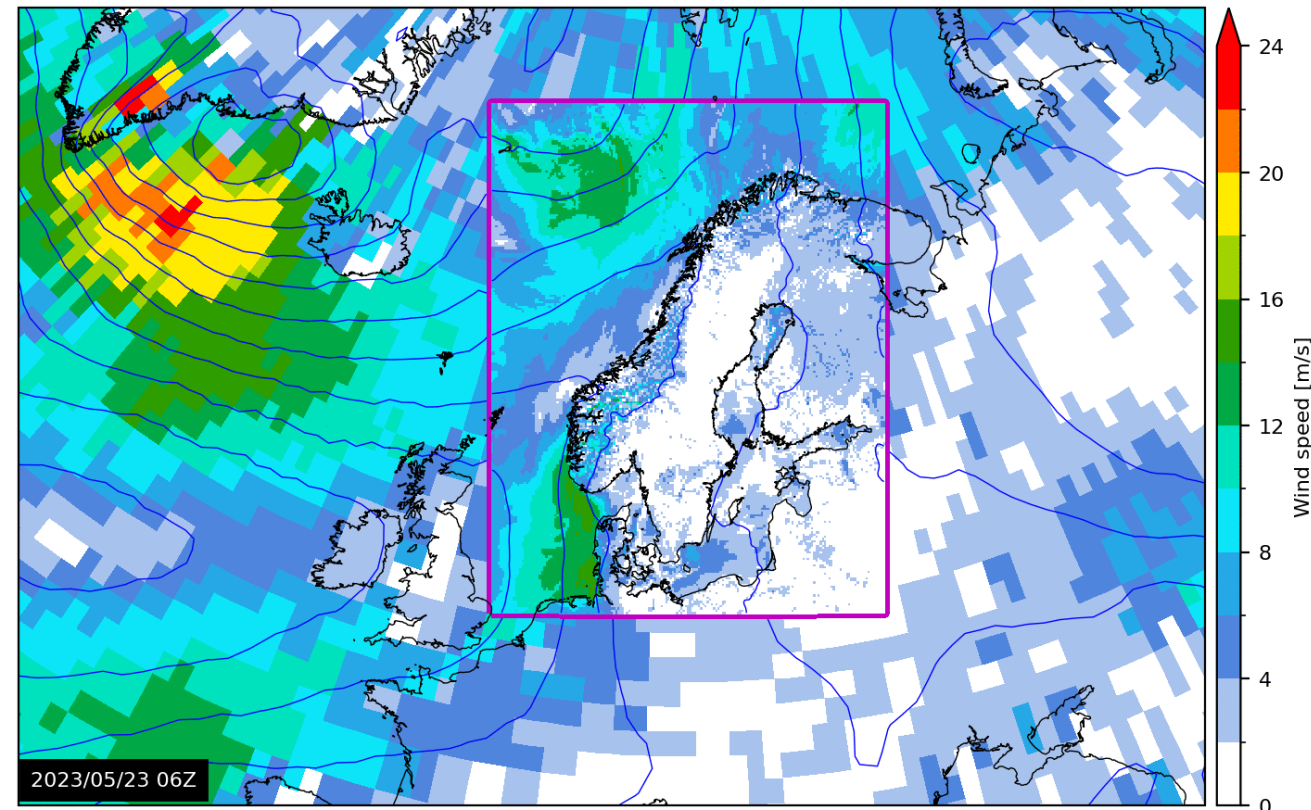
Developed and used by meteorological centers across Europe.

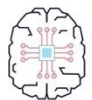
AEMET, DWD, FMI, GeoSphere, KNMI, MET Norway, Meteo Swiss, Meteo France, RMI, & ECMWF



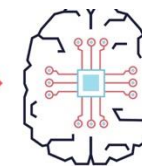
Pooling of resources without resulting in a single forecasting model.

Anemoi in action: developing weather model for the Nordics

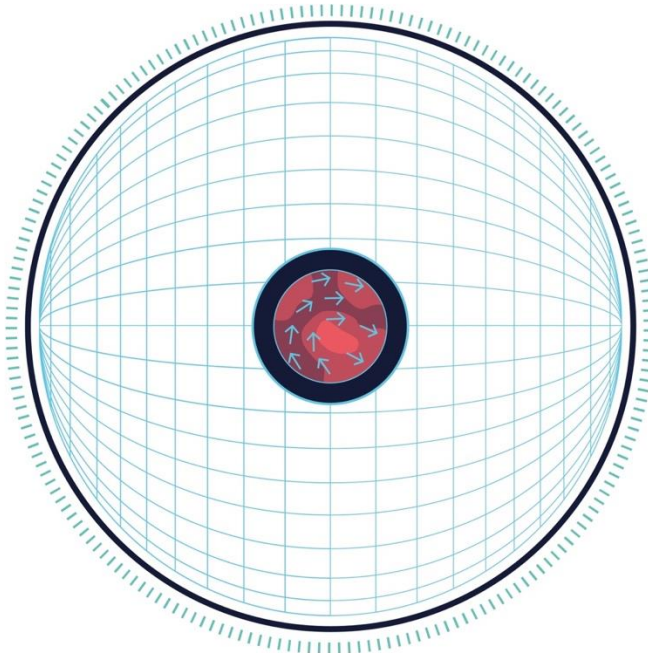




EXPANDING TOWARDS AN EARTH-SYSTEM AI MODEL WITH DESTINE



ATMOSPHERIC COMPONENT



FORECASTING THE WEATHER
(ECMWF'S AIFS)



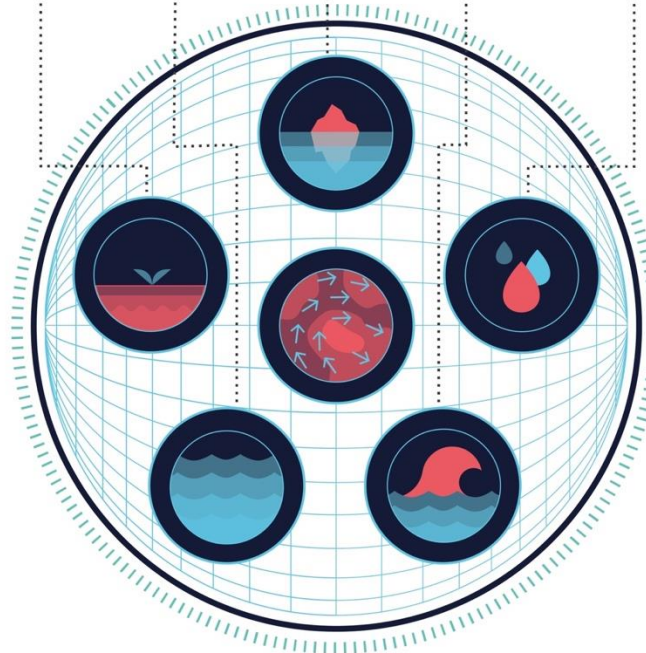
LAND

OCEAN

SEA-ICE

WAVE

HYDROLOGY

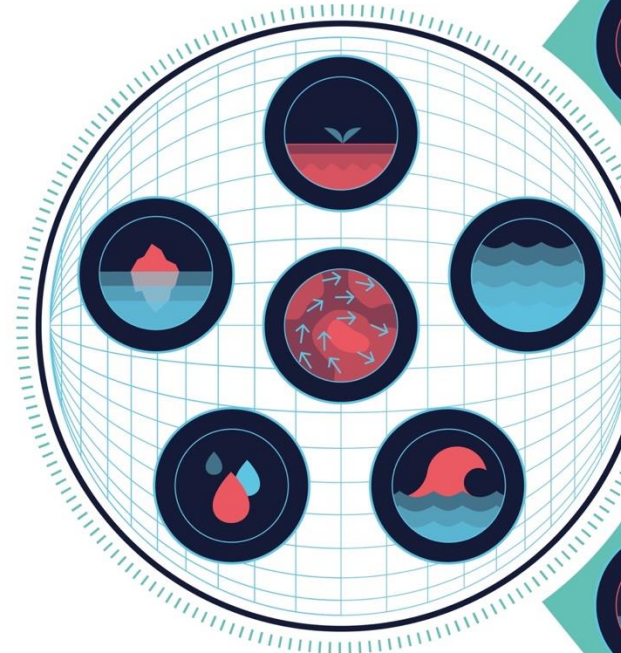


FOR WEATHER
EXTREMES

FOR CLIMATE
PROJECTIONS

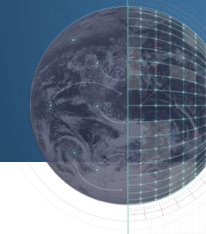


IMPACT SECTORS

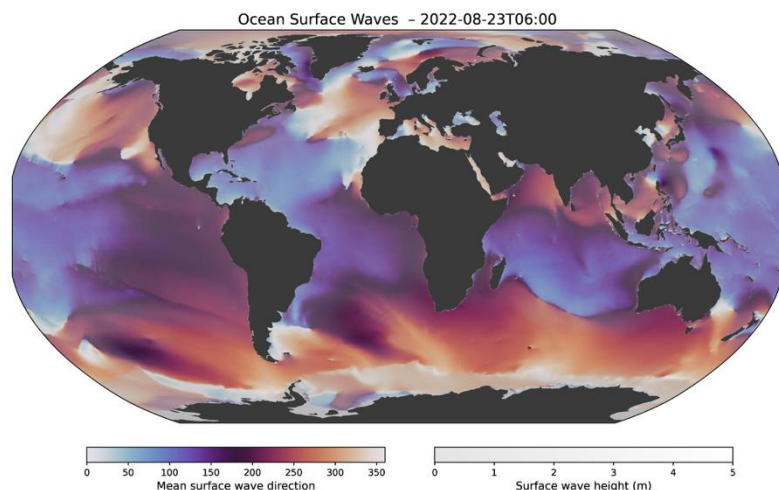


DEMONSTRATORS FOR
IMPACT SECTORS

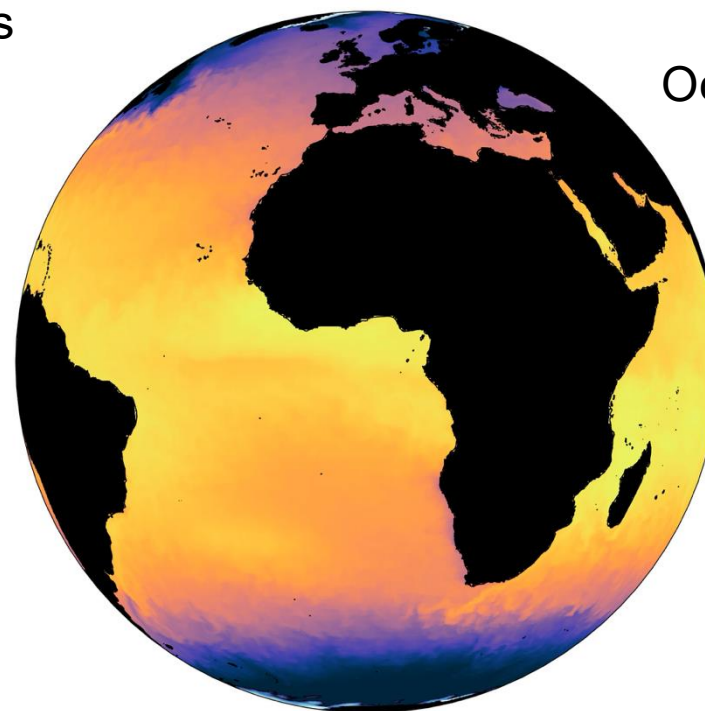




Status: First prototypes across the Earth System

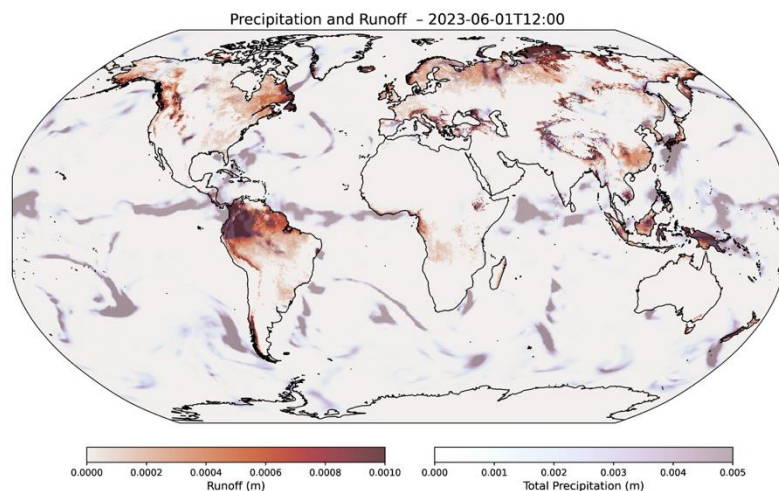


Waves



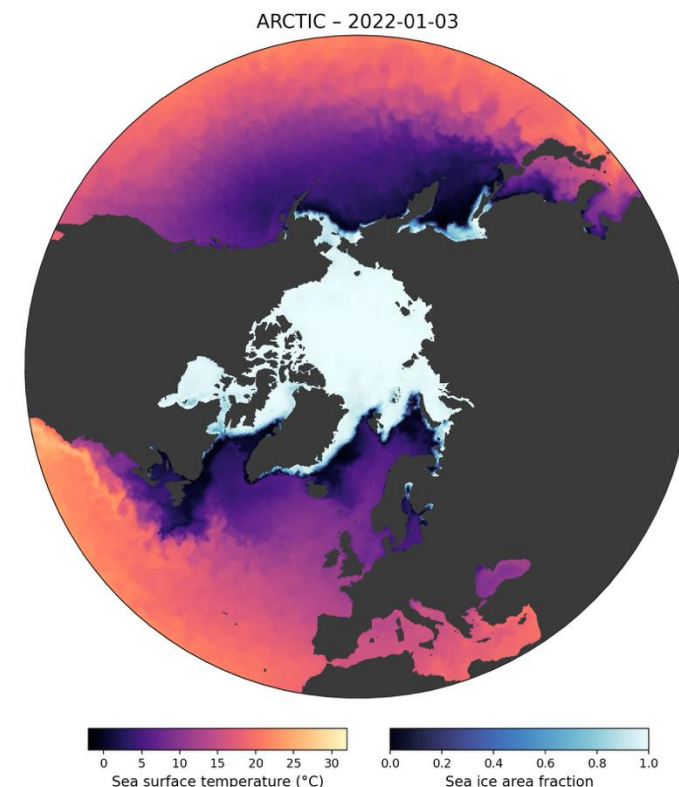
Ocean

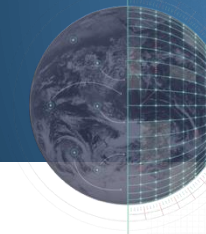
Sea ice



Land

Prototypes due
Q4 2025

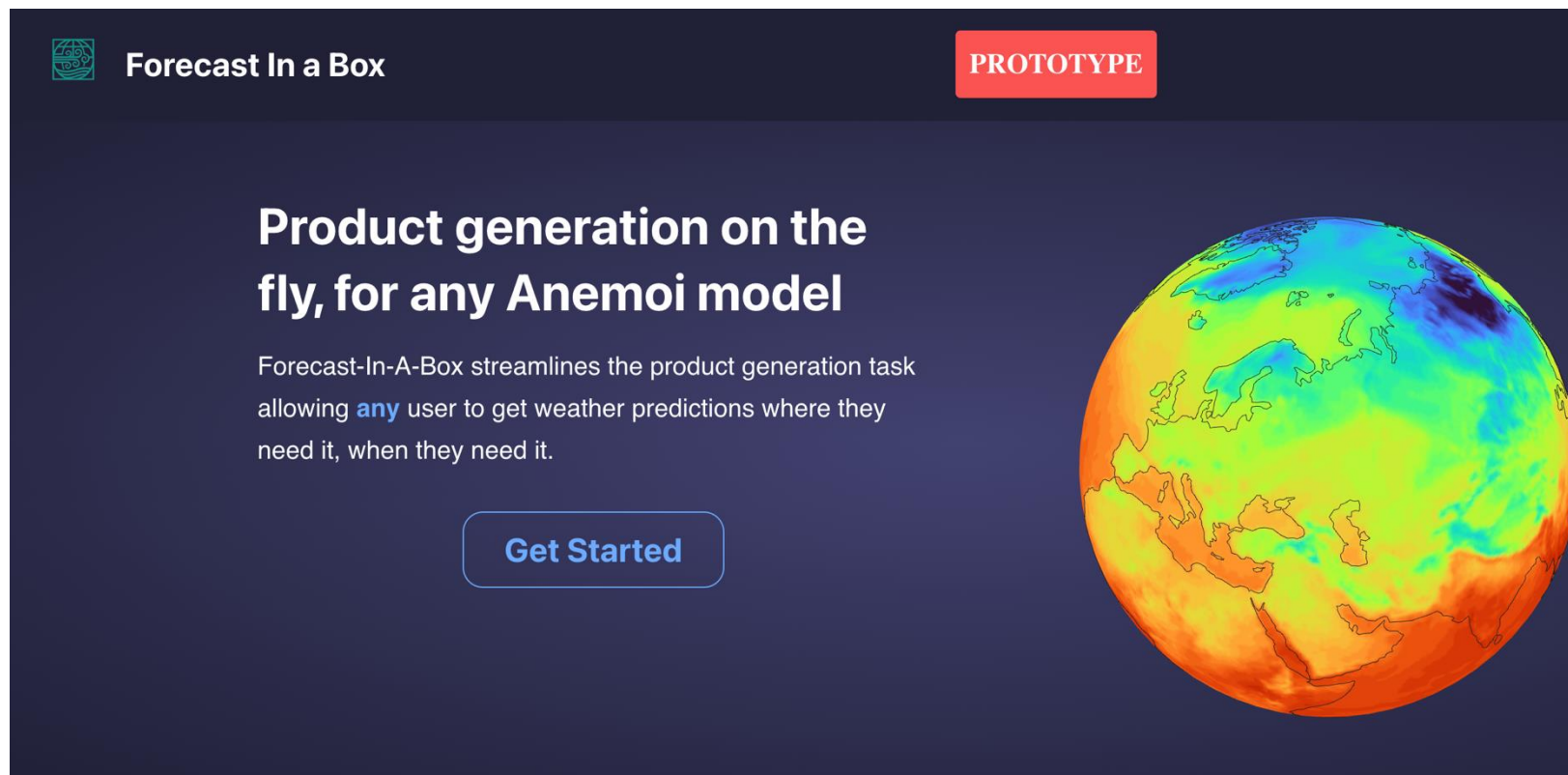




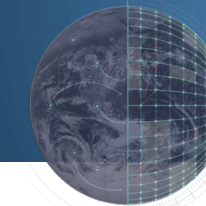
Enhanced interactivity – forecast in a box



Leverage low cost to empower decision makers to run custom forecasts – present or historical



Prototype due Q4 2025



Enhanced interactivity – chatbot for weather and climate

NEWS

Development Seed to create a climate and weather chatbot in DestinE

2 April 2025



The specialised geospatial data engineering provider **Development Seed** has been selected in the call opened by the European Centre for Medium-Range Weather Forecasts (ECMWF) to develop a climate and weather chatbot in the framework of the Destination Earth (DestinE) initiative of the EU Commission.

Ease interaction with weather and climate data for policy makers.

Answers rooted in Destination Earth simulations

Demonstrator ready in 2026

Summary

- AI-based forecasting already operational at ECMWF.
 - Models and data fully open.
- Development of these systems happening in coordination across Europe with National Meteorological Centres.
 - Anemoi lowers barrier to entry developing AI forecasting systems.
- Within Destination Earth developing prototypes and demonstrators for:
 - Earth system representation.
 - Enhanced interactivity.
 - Deployment in phase 3.