# Extreme Wildfire Events Data Hub for Improved Decision Making

# D3.1 Protocols for data collection on Extreme Wildfire Events

**Union Civil Protection Mechanism (UCPM) call Knowledge for Action in Prevention & Preparedness, UCPM-2023-KAPP-PREP, Project number: 101140363**

---

**Work package:** WP3 - Extreme wildfire data gathering

**Lead beneficiary:** Catalan Fire and Rescue Service (CFRS)

**Contributing beneficiary:** Pau Costa Foundation (PCF)

---

Funded by the European Union

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union. The European Union cannot be held responsible for them.

| Document history | | | |
|---|---|---|---|
| **Version** | **Date** | **Modifications** | **Source** |
| D_v.1 | 16/04/2024 | First draft | CFRS |
| R_v.1 | 23/04/2024 | Review | WUR, PCF |
| F_v.1 | 29/04/2024 | Final version | CFRS |

*April 2024*


| Lead beneficiary | Contributing beneficiary |
|---|---|
| Catalan Fire and Rescue Service (CFRS): | Pau Costa Foundation (PCF): |
| **Castellnou**, Marc | **Guarque**, Pau |
| **Nebot**, Edgar | |
| **Arilla**, Etel | |
| **Bachfisher**, Mercedes | |
| **Castellarnau**, Xavier | |
| **Castellvi**, Jordi | |
| **Cespedes**, Jose | |
| **Estivill**, Laia | |
| **Ferragut**, Aniol | |
| **Larrañaga**, Asier | |
| **Miralles**, Marta | |
| **Pagès**, Jordi | |
| **Pallàs**, Pepe | |
| **Rosell**, Martí | |
| **Ruiz**, Borja | |



**Quote as:** Castellnou, M., Nebot, E., Arilla, E., Bachfisher, M., Castellarnau, X., Castellvi, J., Cespedes, J., Estivill, L., Ferragut, A., Larrañaga, A., Miralles, M., Pagès, J., Pallàs, P., Rosell, M., Ruiz, B., Guarque, P. (2024). *Protocols for data collection on Extreme Wildfire Events*. Extreme Wildfire Events Data Hub for Improved Decision Making (EWED).

# Table of contents

# List of figures



# List of tables

# List of acronyms

| | |
|---|---|
| ABL | Atmospheric Boundary Layer |
| AFAN | Advanced Fire Analysis Network |
| AGL | altitude Above Ground Level |
| CFRS | Catalan Fire and Rescue Service |
| CONAF | COrporación NAcional Forestal, Chile |
| COST | European Cooperation in Science and Technology |
| DC | Drought Code |
| EFFIS | European Forest Fire Information System |
| EGIF | Equipo de Gestión de Incendios Forestales |
| EWE | Extreme Wildfire Event |
| EWED | Extreme Wildfire Events Data Hub for Improved Decision Making |
| FA | Fire Analyst |
| FFMC | Fine Fuel Moisture Content |
| FIRE-RES | Innovative technologies and socio-ecological-economic solutions for FIRE-RESilient territories in Europe |
| FWI | Fire Weather Index |
| GIS | Geographic Information System |
| GRAF | GRup d'Actuacions Forestals, Bombers de la Generalitat de Catalunya |
| LCL | Lifting Condensation Level |
| MODIS | MODerate resolution Imaging Spectroradiometer |
| MSL | altitude above Mean Sea Level |
| NERO | European Network on Extreme fiRe behaviOr |
| NOA | National Observatory of Athens |
| PCF | Pau Costa Foundation |
| ROS | Rate Of Spread |
| VIIRS | Visible Infrared Imaging Radiometer Suite |

# Executive summary

The last decade has seen an increase in the frequency and intensity of Extreme Wildfire Events (EWEs) in Europe and around the world [4]. This leads to situations of uncertainty for both civilians and emergency responders, who find their ability to respond to these situations diminished. To reduce this uncertainty, it is essential to generate knowledge and create understanding of these phenomena, especially at the level of fire-atmosphere interaction.

The primary objective of the EWED project is to **collect data on these phenomena, to study and analyse their causes, and to simulate their consequences in a detailed and accurate manner.** This is done with the intention of improving the existing knowledge and ultimately the response capacity of European fire services. To achieve this objective, the project proposes a novel methodology for the analysis of EWEs, initiated by the CFRS. This methodology allows for the acquisition of in-depth knowledge of these processes on a global scale.

This protocol focuses mainly on **the collection of data on the vertical profile of the atmosphere, but also on fire behaviour data, smoke plume characteristics and wildfire properties**. This dataset must be homogeneous so that it can be included in the Open Data Portal that will be created by the EWED project, to become a pioneering global database for wildfire analysis.

For the elaboration of this document, we have used the experience gained in the implementation of this methodology by GRAF (CFRS) since the wildfire season of 2021, implemented during wildfires in Catalonia, as well as some parts of Spain and during the wildfire season of 2023 in Chile. It has been complemented by the lessons learnt from the Catalonia workshop of the EWED project, which defined the data needed for the study of EWEs and the format of the data to be collected.

# Introduction

‘Protocols for data collection’ is a document that summarises how and what data should be collected from EWEs so that they can be uploaded to the Open Data Portal and thus be used to increase the knowledge about these events in order to improve the response of European emergency systems to extreme wildfire events. This Deliverable 3.1 Protocols for Data Collection belongs to WP 3. Extreme Wildfire Data Gathering, which aims to **collect data on fire behaviour, fire-atmosphere interaction and assessment of smoke plume types and their evolution.**

The main objective of the EWED project is to **create a novel open platform to collect EWE data from different European countries and to improve the knowledge, understanding and capacity to respond to these wildfires**. In this Open Data Portal (Task 3.3), data collected during wildfire events can be uploaded and through models and algorithms will provide analysis and monitoring of wildfires in real time, facilitating strategic decision-making.

These collected data, to be uploaded to the Open Data Portal, must be consistent among all project partners, as well as by external agents collaborating on this project. This data homogenisation should allow the design of a simple Open Data Portal and database structure, facilitate the use of simulation models and algorithms, and give scientific credibility to the results of the project. In addition, it is necessary to standardise this data collection and compile it in this document, since it represents a new methodology in the field of wildfires, especially with the use of radiosondes to obtain data on the vertical profile of the atmosphere during EWEs **[2]**.

To collect all this information, the present document is divided into three distinct sections:

- **Section 2** presents a preliminary descriptive account of the rationale behind the collection of these data and the specific variables of interest in the study of EWEs.
- **Section 3-4** contains technical information regarding the standardisation of data collection formats and instructions for gathering data from both fire and ground characteristics, as well as from the atmosphere.
- **Section 5** describes the experiences of CFRS in the use of radiosondes in wildfires and the Catalonia workshop of the EWED project (EWED Catalonia Workshop), which served as a demonstration pilot where the foundations of the Open Data Portal were discussed, and the main characteristics of the data collection were defined.

This document addresses the question of what data are essential for the study of EWEs and in what format they should be collected. However, it does not define where and when these data should be collected. Answering this question requires a certain level of knowledge and analytical capacity based on the expertise of those responsible for data collection.

The Appendices details the data collection procedures using the Windsond software to obtain the vertical profile of the atmosphere from radiosondes and the APP SmokeMeter to calculate the height of the smoke plume.

In conclusion, the main objectives of this document are:

- Ensure that all professionals who work in wildland fires gather data about EWEs using the same methodology and data format.
- Facilitate the use of these data gathered from the Open Data Portal by researchers and decision-maker in wildfire emergency situations.

**Disclaimer:** The use of these tools is just a suggestion, any tools can be used as long as the format of the data obtained is consistent with protocols in this document. CFRS has been using Windsond radiosondes for the past three wildfire seasons due to their suitability for collecting atmospheric data in wildfires. One advantage is that they can be used to collect data on small variations (such as inversions and changes in rising speed, for example) that would not be possible with larger radiosondes. Additionally, their lightweight construction reduces potential risks associated with aerial operations. Another advantage is the reduced price point, as well as their possibility to bee recovered and reused, which makes it a more cost-effective solution. Moreover, the data gathered using the Windsond software and radiosondes is useful for the analysis of pyroconvection processes. Finally, it is a European product that offers reliable customer service in case of technical issues or improvement needs.

# 1

# 1. Background

Since 2016, there has been a significant increase in the number of large fires on a global scale that do not respond to the expected fire behaviour previously observed. Wildfires such as Fort McMurray (Canada), the 2017 fire season in Chile, Pedrógão Grande (Portugal), California (2017, 2018, 2020, 2021), Australia (2019-2020), Greece and Turkey (2021) or the recent fires in Canada and Greece in 2023, are some examples of wildfires behaving well above what is considered normal fires, with fire behaviour parameters and processes that allows to classify them as extreme wildfire events (EWEs). **[7]**

*Table 1. Wildfire events classification based on fire behaviour and capacity of control. Reference: **[7]**.*

| | Fire Category | Real Time Measurable Behavior Parameters: FLI* (kWm$^{-1}$) | ROS (m/min) | FL (m) | Real Time Observable Manifestations of EFB: PyroCb | Downdrafts | Spotting Activity | Spotting Distance (m) | Type of Fire and Capacity of Control * |
|---|---|---|---|---|---|---|---|---|---|
| *Normal Fires* | 1 | <500 | <5 [a]<br><15 [b] | <1.5 | Absent | Absent | Absent | 0 | Surface fire<br>Fairly easy |
| *Normal Fires* | 2 | 500–2000 | <15 [a]<br><30 [b] | <2.5 | Absent | Absent | Low | <100 | Surface fire<br>Moderately difficult |
| *Normal Fires* | 3 | 2000–4000 | <20 [c]<br><50 [d] | 2.5–3.5 | Absent | Absent | High | ≥100 | Surface fire, torching possible<br>Very difficult |
| *Normal Fires* | 4 | 4000–10,000 | <50 [c]<br><100 [d] | 3.5–10 | Unlikely | In some localized cases | Prolific | 500–1000 | Surface fire, crowning likely depending on vegetation type and stand structure<br>Extremely difficult |
| *Extreme Wildfire Events* | 5 | 10,000–30,000 | <150 [c]<br><250 [d] | 10–50 | Possible | Present | Prolific | >1000 | Crown fire, either wind- or plume-driven<br>Spotting plays a relevant role in fire growth<br>Possible fire breaching across an extended obstacle to local spread<br>Chaotic and unpredictable fire spread<br>Virtually impossible |
| *Extreme Wildfire Events* | 6 | 30,000–100,000 | <300 | 50–100 | Probable | Present | Massive Spotting | >2000 | Plume-driven, highly turbulent fire<br>Chaotic and unpredictable fire spread<br>Spotting, including long distance, plays a relevant role in fire growth<br>Possible fire breaching across an extended obstacle to local spread Impossible |
| *Extreme Wildfire Events* | 7 | >100,000 (possible) | >300 (possible) | >100 (possible) | Present | Present | Massive Spotting | >5000 | Plume-driven, highly turbulent fire<br>Area-wide ignition and firestorm development non-organized flame fronts because of extreme turbulence/vorticity and massive spotting Impossible |

Note: [a] Forest and shrubland; [b] grassland; [c] forest; [d] shrubland and grassland; *FLI classes 1–4 follow the classification by Alexander and Lanoville [125].

In the deliverable 1.1 of the FIRE-RES project **[4]**, the concept of EWE is defined as 'wildfires with large-scale complex interactions between fire and atmosphere generating pyroconvective behaviour, coupling processes that result in fast, intense, uncertain and rapidly changing fire behaviour, that exceeds the technical limits of control. Moreover, in some moments, the observed fire behaviour exceeds the expected one, overwhelming the decision-making capabilities of the emergency system'.

Since that time, on a global scale, there has been a situation of uncertainty regarding EWEs, in which neither the conditions of the scenario nor the response capacity of the firefighting operations have been known **[5]**, represented in the uncertainty matrix in Figure 1. This fact endangers both society and emergency systems involved in wildfire extinction. Currently, there is a lack of comprehensive understanding of the pyroconvection process when the fire interacts with the atmosphere. The EWED project aims to increase the knowledge about these extreme wildfire events in order to adapt the response of the firefighting systems and enhance the certainty of strategic decision-making.

| | | Scenario: Known | Scenario: Unknown |
|---|---|---|---|
| Emergency response system | Known | Known scenario. Safety protocols and predictability work. | Uncertain scenario but operational response is known and predictable. Black swans would not be detected. The scenario must be changed. |
| Emergency response system | Unknown | Known scenario but uncertain operational response. Tactics should be modified to develop certain scenarios. | Uncertain situation. The evolution of the scenario is not known nor is the operational response. Situation must be reconsidered. |

*Figure 1. Uncertainty matrix based on scenario and response capacity. Reference: **[5]**.*

To identify and describe this fire-atmosphere interaction, data collection during wildfires is needed to provide empirical data on these processes. To do this, it is essential that the collection of these data (both from radiosondes, graphical files, and other relevant data) be continuous throughout the incident, allowing the evolution of the fire to be studied and the potential for the occurrence of the pyroconvection phenomenon to be defined. It is of vital importance, as this phenomenon can have a direct impact on the fire behaviour on the surface, such as an increase in the rate of spread (ROS), or a sudden change of direction. It is important to know these characteristics to be able to answer some questions:

— Are surface characteristics driving the spread of the fire?

— Or is it the atmosphere?

The understanding of this information will allow the emergency systems to reduce uncertainty about the short-term evolution of the fire, and to identify future risk situations. It will also make it possible to establish a strategy that adjusts to the evolution of the fire according to the observed conditions.

The EWED project focuses mainly on collecting data on the conditions of the vertical profile of the atmosphere, following the methodology initiated in Catalonia by the Catalan Fire and Rescue Service (CFRS), through its GRAF units (wildfire specialists), during the 2021 wildfire season **[2]**. In addition, data were also collected that same year using radiosondes in the Sierra Bermeja wildfires (Spain) and during the Chilean fire season in 2023.

The CFRS team that was collecting data in Chile was part of the 'Forest Fire Analysis and Research Cell' (led by Jordi Pagès and Jordi García) of the Equipo de Gestión de Incendios Forestales (EGIF). EGIF was a programme for the exchange of knowledge and working methodologies at international level sponsored by the COrporación NAcional Forestal de Chile (CONAF) and carried out by the Pau Costa Foundation (PCF) during the 2022 and 2023 fire seasons.

The three wildfire seasons in which radiosondes have been used to obtain data on atmospheric conditions, have allowed CFRS to identify the necessary characteristics of both radiosondes and launches to obtain reliable data. Besides, the experience in more than 20 years of wildfire analysis, with the collection of field data and fire reconstructions, together with this collection of data from the vertical profile of the atmosphere, have allowed CFRS to develop this protocol for collecting data of EWEs, which will ensure that this data will fit into the Open Data Portal needs.

There are other projects running in parallel that also address EWEs:

— **FIRE-RES project** (Innovative technologies and socio-ecological-economic solutions for FIRE-RESilient territories in Europe, **FIRE-RES Website**) is a 4 years project that aims to develop innovations related to the 4 pillars of the project: EWE process/behaviour drivers (fuel in the ecosystem in t/ha, atmosphere, energy emission in kW/t); emergency and fire management; landscape and economy; and governance, society, communication and risk awareness. During the first workshops of the project, the framework was established, identifying current challenges, lessons learnt and EWE cases. The results can be found **D1.1 Transfer of lessons learnt on EWEs to key stakeholders.** In addition, inputs for atmospheric data analysis using new knowledge and expertise on EWEs have been identified. D1.2. will include the results of this work and will be available on the project website.

— **NERO** is the European **N**etwork on **E**xtreme fi**R**e behavi**O**r (**NERO Website**). The COST Action is led by the National Observatory of Athens (NOA) and aims to cultivate a European culture that fosters effective cross-boundary sharing of expert knowledge, including data and tools. NERO aims to bridge the gap between scientific findings and practical application, advocating for efficient science-based wildfire management. The overarching goal of NERO is to create and coordinate an international network that brings together wildfire scientists and practitioners to address the challenge of understanding and predicting extreme fire behaviour.

# 2

# 2. Data collection specifications

Wildfires are complex and dynamic phenomena influenced by a significant number of variables. This section defines the most suitable wildfires in which to collect data for research on EWEs, as well as for running the models and algorithms developed throughout the project. Additionally, the key variables are outlined, along with instructions for their collection.

Utilising these methods as a foundation will ensure the homogeneity of the collected data and make it easier for project partners and external collaborators to gather them with the same standards.

## 2.1. Wildfires of interest

The wildfires targeted for data collection are those that have convective behaviours on the surface, that is, those in which the smoke plume is convective or has the potential to become convective. These wildfires, under atmospheric conditions that allow it, may have the capacity to start pyroconvection processes, with updraft and downdraft currents, which will have a direct impact on the fire behaviour on the surface, and may develop into an EWE.

Meaning, it is crucial to monitor the daily meteorological situation, both at surface and atmospheric level. It is a must to pay attention to those days with high temperatures, low humidity and with little moisture recovery at night, and with moderate winds. These conditions significantly increase fuel availability, empowering the fire with a heightened capacity to release energy.

## 2.2. Atmospheric vertical profile

Collecting data on the vertical profile of the atmosphere is essential to understand if there is a potential for interaction between the fire and the atmosphere, and to study the nature of this interaction. There are several considerations that need to be taken into account to ensure that the data collected meets the needs of the models and algorithms and are useful for EWE analysis.

### 2.2.1. Vertical profile of the atmosphere influenced by the wildfire

Launching of radiosondes within wildfire smoke plumes enables the collection of data from the vertical profile of the atmosphere that is being modified by the wildfire. This includes meteorological data from inside the smoke plume, such as temperature, humidity, wind speed and direction, etc. Also, radiosondes gather data such as position and altitude, facilitating the calculation of the vertical speed of the radiosonde, which can be used to study the updraft and downdraft currents of the smoke plume.

To acquire a comprehensive understanding of the atmospheric vertical profile, it is important to launch radiosondes **frequently**, especially when **notable changes in fire behaviour** are observed, and from different parts of the wildfire. This frequency will allow enable the identification of changes in the atmosphere conditions and predict changes in surface fire behaviour due to the fire – atmosphere interaction. It is also interesting to launch radiosondes at times when **weather changes are expected**, as it provides knowledge on how these changes affect the vertical profile of the atmosphere influenced by wildfire.

The data collected on the vertical profile of the atmosphere during wildfires varies considerably depending on where the radiosonde is launched. When launched from the tail of the wildfire, it is common to obtain data on the characteristics of the entire smoke plume, as the radiosonde is suctioned by the indraft. Launching from the head of the wildfire, due to the proximity to the fire front, high temperatures are recorded, mostly within a few tens of metres, which is useful, among other things, for measuring the intensity of the fire front. Finally, launching from the flanks also gives good results if lateral rotors pull the radiosonde toward the core of the plume.


*Figure 2. The launching position of a radiosonde in a wildfire. A: from the back of the fire, B: from the flanks, C: from the head of the fire. Reference: CFRS.*

### 2.2.2. Vertical profile of the atmosphere outside the wildfire influence

It is important to launch a radiosonde outside the fire smoke plume and far from its influence within the same hour, named **control radiosonde**. The aim of this launch is to gather the data that will allow us to compare if the wildfire is modifying the atmospheric structure. Additionally, it provides information about the vertical profile of the atmosphere in an area unaffected by the fire. The launching of the radiosonde control validates the atmospheric models forecasts with the on-field data, and defines if they can be considered as a reliable source that day.

Whenever possible, it is important to launch this control radiosonde before reaching the wildfire and outside its influence to ensure that the vertical profile data of the atmosphere are not altered by the fire. It is also important to launch control radiosondes frequently during a prolonged event to ensure a good understanding of the evolution of the vertical profile of the atmosphere outside fire influence. Ideally, **no more than 1 hour should elapse between smoke plume and control radiosonde launches.**

During the Catalonia Workshop, the idea was raised to use the descent profile data of the radiosonde whenever it falls outside the fire influence area to collect this data. However, whenever possible, it is recommended that the control radiosonde be launched outside of the wildfire. This ensures that data is collected throughout the entire ascent (sometimes the *radiolink* is lost during the fall of the radiosonde) and that the data is not altered by the fire.

### 2.2.3. Conditions in launching position

In order to select the launching site, it is important to know how the fire behaves. It is key to have conducted an analysis of the fire or to be in continuous contact with those monitoring the fire assessment **[3]**. This ensures that the chosen launch site is safe and provides valuable data.

To be useful for EWE analysis, the launch of the radiosondes must be accompanied by a description of the wildfire scenario and wildfire behaviour at the launching site at the time and the location description. This contextual information is crucial for interpreting the data collected and understanding how the wildfire dynamics may influence the atmospheric conditions observed.

It is necessary to record the exact **position of the radiosonde launch** (using UTM coordinates), which can be extracted from the Windsond software (see *Appendix 1*), as well as its **position relative to the fire** (head, flanks, back, or control radiosonde) and the **position of the fire front**. Also, the exact **time of launch** for each of the radiosondes used.

The characteristics of the plume should be described, especially its **colour** and the presence or absence of **rotors**. It is important to **record a video** of the launch of each radiosonde, showing its trajectory and the fire behaviour at that moment. This footage enables the correlation of the obtained vertical profile of the atmosphere with the observed fire behaviour, helping to identify if it follows the expected pattern. Ideally, the video should show the moment of launch until the radiosonde is being sucked by the indraft of the smoke plume and it disappears from the field of vision.

In addition to recording the launch of the radiosonde, it is important to gather information on the fire behaviour in launching location (more information in section *2.4.2 Fire behaviour*):

- Flame length
- Type of fire front
- Exact location of the fire front
- Relative position to the fire (head, flanks, tail)
- Spotting (presence or not and distance)
- Torching (presence or not and percentage)
- Approximate measurements of the depth and width of the fire front (if there are aerial resources that can be consulted, their information about this data can be of great use).

## 2.3. Smoke plume data

The characteristics of the smoke plume are related to the pyroconvective phenomena occurring in the fire and provide relevant information for the study of EWEs. Therefore, it is essential to collect data on the smoke plume throughout the wildfire.

### 2.3.1. Smoke plume height

Knowing the structure of the vertical profile of the atmosphere, is important to obtain data on the height at which the maximum limit of the smoke plume is located. This information helps predict potential changes in wildfire behaviour the surface. For example, it allows one to determine if the plume has reached the Atmospheric Boundary Layer (ABL) limit or if it is near to the Lifting Condensation Level (LCL), which could lead to a moist pyroconvection process.

This data can be obtained from the **SmokeMeter** APP, which has an intuitive user interface and calculates the height of the smoke plume in an easy way. A detailed explanation of how this application works is given in *Appendix 2*. The APP can be downloaded from the following link: **SmokeMeter - Apps on Google Play**

It is important to save the image used by the APP (by taking a screenshot when height is taken) and to record the time it was taken. In this way, the evolution of the wildfire plume can be identified and tracked clearly.

### 2.3.2. Smoke plume evolution

The graphic documents of the smoke plume, both images and videos, help identify phenomena that are occurring in the wildfire, and relate them to the fire behaviour. In addition, if these are carried out frequently as the fire progresses, it is possible to get a clear idea of its evolution.

Although the aerial images taken by the aerial resources supporting the fire-fighting operations also provide interesting information, images taken from the ground are more useful for identifying the different pyro convective processes and prototypes.

When taking a photo or video of the smoke plume, you should consider what you want to show, whether it is the whole plume or an interesting part of the plume that is relevant to the study of the convective phenomenon. A complete image of the smoke plume will be more useful for the Open Data Portal. The images should have the following characteristics:

- If possible, the **entire smoke plume** should be visible, from the ground to the highest point.
- A **horizontal image or video** is preferable (as long as the previous point is guaranteed), as it allows a better appreciation of how the plume behaves when it reaches its limit (it expands laterally).
- It is necessary to **save the time of the shot** and identify it in the file name. This makes it possible to identify the evolution of the fire. It is easy to find this information in the metadata of the image/video. There are mobile applications that help to collect this data in the image (Timestamp or Conota, i.e.).
- Indicate where the image or video was taken in realtion to the wildfire.

*Figure 3. Examples of ideal images of wildfire smoke plumes. Reference: CFRS.*

However, it may also be interesting to capture an image or video of a specific area of the smoke plume, i.e. a change of conditions in one of the areas of the plume, side rotors, detail of spotting under the smoke plume, etc. In this case, it is vitally important that, as in the previous case, the time of the shot is identified in the file name, and the position with respect to the fire from which it was taken.

Another way to capture the evolution of the smoke plume, which does not have to be done by the radiosonde team, is to make or collect (from other crew members, i.e.) **time-lapse video footage** of the smoke plume evolving over a long period of time. This will be very helpful in fire analysis if the file includes the time it was taken and the length of the recording.

## 2.4. Wildfire evolution

In addition to understanding the vertical profile of the atmosphere and the changes caused by the wildfire, it is also important to collect data on the evolution of the burning area and the fire behaviour at the surface. This section defines the main data to be collected.

### 2.4.1. Fire perimeters

To get a clear picture of the evolution of the fire, it is valuable to draw hourly perimeters. They aid in determining other variables such as the rate of spread or the number of hectares burnt per hour. There are different methods to obtain them, which can be used together. Regardless of the method used, it is important to follow these specifications for generating the data:

- Whenever possible, the fire perimeter of each hour should be drawn up (isochrones like **hourly perimeters**).
- The different isochrones should be drawn as a **polygon**, not as a line.
- The field in the perimeter file that contains the time information must be of **type *Date***, not numeric.
- **Include as much detail as possible** (useful for calculating ROS and burn rate, i.e.).

The most detailed method is to use the current positions of the various members of the fire-fighting system in the fire, based on the geolocation of their radios (both vehicles and personnel). These positions are recorded and can be viewed live if the operation's management system allows it, facilitating real-time perimeter mapping. An alternative method for drawing hourly perimeters is to use aerial imagery that is georeferenced and available throughout the duration of the wildfire.

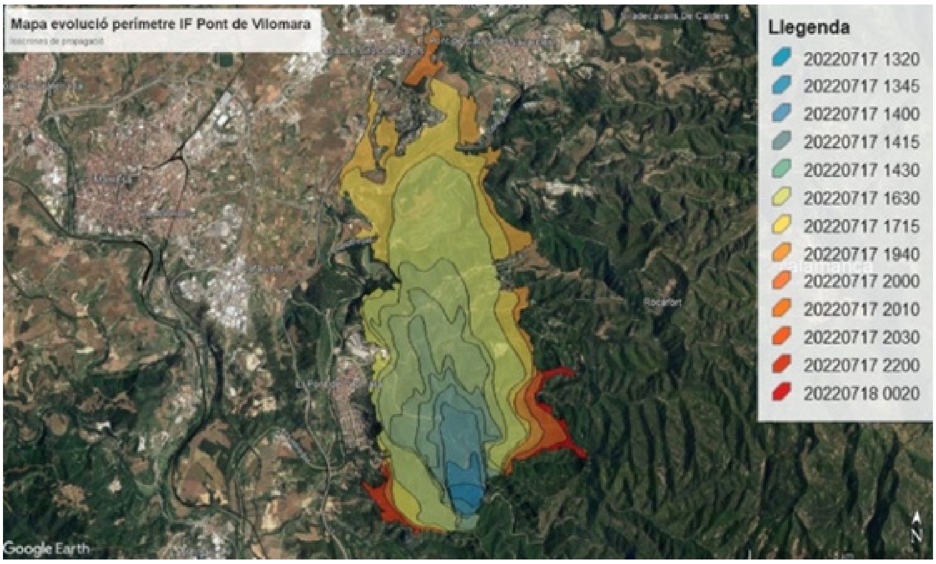



*Figure 4. Fire perimeter evolution of the Pont de Vilomara wildfire (Catalonia, 2022). Reference: CFRS.*

### 2.4.2. Fire behaviour

Understanding the characteristics of the fire behaviour observed at the surface is essential in correlating the vertical profile of the atmosphere with potential changes in the fire. There is some data that is relatively easy to collect and that provides a lot of useful information for running the various models and algorithms. Some of these are the same fire behaviour data to be collected in the radiosonde launch zone (section *2.2.3 Conditions in launching location*), but on a global scale of the wildfire.

- Flame length (m): mean and maximum
- Rate of spread (m/h): mean and maximum
- Burn ratio (ha/h): mean and maximum
- Spotting (m): mean and maximum distance
- Torching (%): presence or not and surface percentage

## 2.5. Wildfire scenario

Knowing the landscape and fuel conditions at the time of the wildfire allows the correlation of situations between different wildfires, which can help to predict EWE behaviour and situations. It is therefore important that these are accurately recorded.

One of these is the **fuel availability**, both live and dead. On the one hand, it is necessary to know what type of dead fuel is available, categorised as 1h, 10h, 100h or 1000h. This information can be obtained in the field from the same wildfire being studied or from recent wildfires. It can also be adjusted based on the meteorological conditions of previous hours, especially relative humidity. On the other hand, the condition of the live fuel can be obtained by knowing the drought situation of the area on fire. This gives us an idea of the water stress of the live vegetation and its availability to burn.

Data should be collected about the **weather conditions** at the time of the fire and for the preceding days, as they have influence on the fire behaviour. Variables such as temperature, relative humidity, dew point, wind speed, and wind direction are necessary for a thorough analysis. The **synoptic situation** in the fire area should also be determined to provide context for general weather conditions.

**Forest structure** plays an important role in the development of wildfires. Hence, it is important to collect this information from the area affected by the fire, using both fuel model maps and forest maps of the region. This will help determine the **fuel load** in the fire area and identify critical points for fire spread.

# 3

# 3. Data standards

The previous section defined the different variables needed to study EWEs and to run the models and algorithms of the Open Data Portal. This section describes the format and technical requirements of these data to meet the standards of the database and be used in the subsequent EWE analysis.

## 3.1. Data from wildfire conditions

As mentioned above, it is important to relate the wildfire conditions to the atmospheric conditions. Table 2 shows the format and units of the different variables to be collected of these fire conditions, together with the key observations for their collection discussed in section 2.

*Table 2. Format and units from wildfire conditions variables.*

| Variable | Format / units | Observations |
|---|---|---|
| Burn ratio | Hectares per hour (ha/h) | From hourly perimeters. Mean and maximum. |
| Depth of the front | Metres (m) | Calculated from aerial video or georeferenced picture. Measured at the radiosondes launching moment. |
| Width of the front | Metres (m) | Calculated from aerial video or georeferenced picture. Measured at the radiosondes launching moment. |
| Hourly fire perimeter | Shapefile (.shp), Keyhole Markup Language (.kml). **CRS: WGS84** | Important: must be **polygon** features. Hour field must be ***Date*** type. |
| Rate of spread (ROS) | Metres per hour (m/h) | Gather both mean and maximum ROS observed. |
| Smoke plume height | Metres (m) | Important: save the image of the smoke plume. |
| Smoke plume image | .jpg archive | With the current hour the picture was taken and relative location to the wildfire. |
| Smoke plume video | .mp4 archive | With the current hour the record was taken and relative location to the wildfire. |

## 3.2. Data from radiosondes launching position

There are other data associated with radiosonde launches that do not provide information on the vertical profile of the atmosphere, but are also important for the analysis of EWEs.

*Table 3. Format and units from radiosondes launching variables.*

| Variable | Format / units | Observations |
|---|---|---|
| Date and hour of launching | DDMM - hhmm | Important to gather the exact time of launching. Given by the radiosonde. |
| Fire front location | UTM coordinates | As accurate as possible at launching moment. May be taken by hourly perimeters. |
| Launch position (GPS) | UTM coordinates | Information about launch location of the radiosonde. Given by the radiosonde. |
| Launch position relative to the wildfire | - Back<br>- Flanks<br>- Head<br>- Control | As detailed as possible. |

## 3.3. Data from atmosphere conditions

These variables should be gathered from the surface level and also along the vertical profile of the atmosphere, from the surface to upper atmosphere.

*Table 4. Format and units from atmosphere conditions variables.*

| Variable | Format / units | Observations |
|---|---|---|
| Altitude | Metres (m) | Radiosondes measures above sea level (MSL) and above ground level (AGL). |
| Atmospheric pressure | Pascals (Pa) | Gathered from both radiosondes and surface barometers/ meteorological stations. |
| Dew point temperature | Degrees celsius (ºC) | Gathered both from radiosondes and surface thermo-hygrometers/meteorological stations. |
| Relative humidity | Percentage (%) | Gathered from both radiosondes and surface hygrometers/ meteorological stations. |
| Temperature | Degrees celsius (ºC) | Gathered from both radiosondes and surface thermometers/meteorological stations. |
| Vertical speed | Metres per second (m/s) | Gathered from radiosondes. |
| Wind direction | Degrees (º) | Gathered from both radiosondes and surface anemometer/ meteorological stations. |
| Wind gusts | Metres per second (m/s) | Gathered from both radiosondes and surface anemometer/ meteorological stations. |

# 4

# 4. Data collection tools

Sections 2 and 3 of the document describe the data to be collected in a wildfire and their format to be entered into the Open Data Portal, ensuring the homogeneity of the data. Section 4 defines some of the tools that can be used for these purposes.

## 4.1. Atmospheric vertical profiles

Data on the vertical profile of the atmosphere can be acquired from both models and real measurements, which can be atmospheric sounding realised by meteorological stations or atmospheric radiosondes launched in wildfires. The information from the models is useful to analyse and know the forecast for the next few hours, while the radiosondes are useful to know the reality of the atmosphere at a given time in the field. In addition, radiosondes, when launched into a burning area, allow data to be collected for analysis of the fire-atmosphere interaction.

### 4.1.1. Atmospheric radiosondes

*Figure 5. Radiosondes launching equipment. Reference: Windsond.*

The radiosondes that provide the most relevant information are those launched in the fire area (either inside the plume or as a control radiosonde), since they allow the gathering of information that neither models nor meteorological station radiosondes show.

Some characteristics of these instruments are described below. The materials needed, the execution and the technical procedure of the launches are described in detail in Appendix 1 Methodology of data collection with radiosondes in wildfires.

As said in the Background section, the first time radiosondes were launched in wildfires smoke plumes was during the fire season of 2021 in Catalonia **[2]**. Despite there being some other technologies to gather data about their characteristics, such as Doppler Lidar and Doppler Radar **[1][6]**, the decision to use the radiosondes is due to two main reasons. Firstly, the high cost of Radar and Lidar technologies, much higher than the price of radiosondes. Secondly, although Radar and Lidar tools offer detailed information of the plume, especially in the identification of the vertical currents within the plume, they do not capture meteorological data, such as relative humidity or wind speeds, which are crucial for the investigation of the EWE. That might be solved using radiosondes in helicopters or drones, but these are only useful to gather data of the environment, not inside the plume. Also, this option does not allow obtaining data on the vertical speed inside the smoke plume, which is a very important fact in the research of EWEs.

In addition to these two considerations, radiosondes launched from the ground have other characteristics that make them useful for analysing wildfires plumes. They are light and do not require large equipment, which is why it facilitates the movement of the launching team working inside the wildfire. The procedure for launching and controlling the radiosonde is also relatively simple, and the software used is intuitive, which makes it easier to read the data. The export format of the data allows us to work very easily with a wide range of products. It is also important to note that depending on weather and terrain characteristics and launch management, the radiosondes can be recovered and reused.

In the FIRE-RES project key inputs have been identified for atmospheric data analysis using new knowledge and expertise on EWEs and the results can be consulted in D1.4, available in the project website section **FIRE-RES, deliverables and reports**. It also includes some considerations about the currently available tools for monitoring EWEs and the most appropriate to do so.

To know the vertical profile of the current atmosphere, data from current radiosonde soundings are also available from several European observatories, which typically launch at least two soundings per day. This information is often presented in skew-T plots and is updated to the last launch of each station. While the coverage of this data may not be highly detailed due to the limited number of stations in different countries, it provides reliable and real data that offers insights into general atmospheric conditions. The following website brings together most of the measurements done in Europe: [Meteociel, Europe radiosondages]

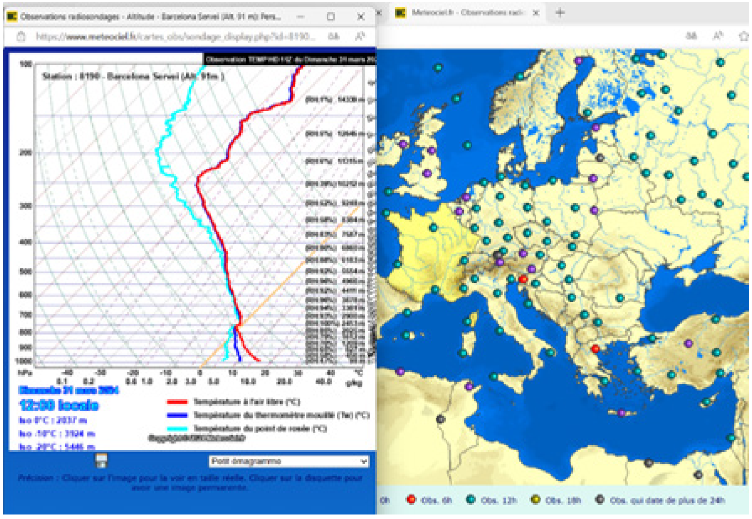


*Figure 6. Meteociel radiosondages interface with radiosonde stations and data example.*

### 4.1.2. Atmosphere vertical profile models

Although meteorological models of the vertical profile of the atmosphere, under certain conditions, and especially below the ABL top, they provide data that in some cases do not correspond to reality, they are useful for knowing the conditions to be expected during the day. As explained above, this is why it is important to launch control radiosondes to verify the information from these models.

Using these models, it is possible to predict the conditions that will affect the wildfire and identify windows of high EWE risk. Some websites that contain this data include skew-T graphs. These graphs are relatively easy to read for all types of users and contain a wealth of information. In the following websites, atmospheric vertical profile data can be consulted selecting both the model and the forecast location:

- Windy
- Tropical Tidbits
- Pivotal Weather

## 4.2. Surface conditions

Surface weather data can be obtained both in the field by the fire responders themselves and from the national network of weather stations. The first ones usually provide information on the environment affected by the wildfire, while the weather stations collect more general data describing the general situation. The most reliable variables are:

- Temperature (ºC)
- Dew point (ºC)
- Relative humidity (%)
- Wind gusts (m/s)
- Wind direction (degrees)

In addition, some surface fire behaviour data can be collected in the field, both at the radiosonde launch site and in other parts of the wildfire. One of the most used variables to understand fire behaviour in wildfires is **flame length (m)**, which is calculated by measuring the distance from the base of the flame to the top of the flame. It should not be confused with flame height, which is the distance of the highest part of the flame from the ground. This is important because if the wind speed is moderate to high, the heat value of the flame (as well as its length) will be very high even if the flame height is low.

It is essential to collect data on the average flame length throughout the fire and at the different points (head and flanks), as well as the maximum flame length recorded.

In order to run the Open Data Portal models and algorithms, it is also necessary to collect data on the **width and depth of the fire front (m)**. Georeferenced imagery taken by aerial fire-fighting resources can be useful for this purpose. This information enables an understanding of the total surface area burning at a specific time, which can be correlated to the amount of heat emitted by the fire. This heat emission, referred to as the mass flux, is a crucial variable in comprehending pyroconvection processes.


*Figure 7. Left: Definition of flame length. Reference: The Emergency Program (TEP). Right: Definition of the width and depth of the fire front on a Sentinel 2 image from the Avila wildfire (August 2021, Spain). Reference: SentinelHub.*

In addition to the need for the images to be georeferenced, as this is the only way to calculate these variables using geographic information systems (GIS), it is also necessary to identify the time at which the images were taken and include this information to the file name.

From the hourly calculated fire perimeters, the **burn rate (ha/h)** can be calculated, enabling the quantification of the impact of the fire runs. Additionally, the **rate of spread (ROS, m/h)**, can be obtained by the isochrones definition. For this reason, it is necessary to draw the isochrones as accurately as possible.

## 4.3. Fuel availability and fire risk indices

Various nationally developed fire risk and drought analysis indices can be used to determine fuel availability and fire risk. However, in order to homogenise the data in the project, it would be necessary for this information to come from the same source and in the same format. For this reason, the use of the **EFFIS platform** of the European Union's Copernicus Earth observation and monitoring programme is recommended for the collection of data on fuel availability and fire risk indices.

This programme offers two noteworthy applications. One is the Current Viewer Situation Viewer (**EFFIS - Wildfire Current Situation**), which provides access to various risk indices on a global scale, such as the Fire Weather Index (FWI), Drought Code (DC), Fine Fuel Moisture Content (FFMC) among others, as well as anomaly data for these indices. It also provides graphical representation of the evolution of these indices over the last few days. It also includes data on human settlements, protected natural areas, Corine Land Cover and forest fuel map, as well as access to MODIS and VIIRS hotspots. It also allows data to be searched for specific dates, which is useful for ex-post analysis of wildfires.

The other application is the Wildfire Risk Viewer (**EFFIS - Fire Risk Viewer**), which provides access to visualisation and download of wildfire risk, hazard and vulnerability data for European countries.

# 5

# 5. Lessons learnt from data collection process

The following are the principal lessons learnt and recommendations for enhancing the data collection process in EWEs, which have been derived from the utilisation of this methodology for data collection in wildfires since 2021 by CFRS, and from insights shared by project partners.

## 5.1. Previous experiences

As described in the Background section, this methodology for collecting data about the vertical profile of the atmosphere in wildfires was initiated in Catalonia during the 2021 fire season by the CFRS, specifically by the GRAF units (specialised group in wildfires). During these three years, in addition to wildfires in Catalonia, it has also been used in other areas of Spain and during the 2023 Chile fire season.

*Figure 8. Pictures from the launch of the radiosondes in Catalonia. Reference: CFRS.*

From 12 to 14 March 2024, partners of the EWED project and some external collaborators, participated in a workshop on using radiosondes to collect real-time data during wildfires. The workshop was held in Manresa, Catalonia. The main activity of the workshop was, during a prescribed burn in Can Feliu 2, Cardona, the practice of radiosonde launching and the subsequent processing of the collected data. This practice was done in a prescribed burn to simulate fire-like smoke plumes and observe the type of data that can be collected.

*Figure 9. Launch of radiosondes by project partners during the Catalonia Workshop at Can Feliu 2 PB. Reference: PCF.*

Additionally, participants identified key points for the joint design of the Open Data Portal, involving both wildfire professionals and researchers, ensuring that it is practitioners' friendly. The methods and data needed to feed the Open Data Portal were also discussed, as well as the testing of the protocol document for the deployment of atmospheric radiosondes in wildfires.

*Figure 10. Discussion on the use and operation of radiosondes during the Catalonia workshop at Manresa fire station. Reference: PCF.*

## 5.2. Lessons learnt and recommendations

From the experience gained in the use of this methodology during these three years, together with the exchange and practical exercise in the Catalonia workshop, some recommendations have been derived to ensure a useful data collection, especially in relation to the use of radiosondes.

It is important to analyse how the fire will behave in order to decide on the most suitable launching site. It is also important to keep an eye on possible changes in behaviour by continuously analysing the situation. Before launching a radiosonde, it is key to know how the fire is behaving and approximate how it will behave in the next few moments to decide where to launch. It is therefore important to have fire analyst capacities either directly by the team or through the support of an analysis team.

The radiosonde's launch location, both in wildfires and prescribed burning, has a direct impact on the collected data **[2]**. That is an aspect that must be considered since this location is also related to the security considerations to be assessed. It will be necessary to always evaluate the assumable risk, safety, and situational awareness frequently, avoiding that the deployment of the launching equipment and the preparation of the radiosondes does not distract from the risk awareness, the conditions of the environment and its evolution.

It is not the purpose of this document to go into the capabilities and skills that are recommended for a Fire Analyst (FA) or a FA team. More information can be found in the AFAN project deliverable: Guidelines of fire analyst competencies and skills **[3]** (core competencies which enable the FA or the FA team to provide support at a wildfire incident). This guide outlines the competencies needed in a generic and harmonised way by describing shared organisational needs and commonalities grouping them in 6 areas: the impact of meteorology on fire behaviour (MET), fire position (POS), fire behaviour (BEH) and fire spread patterns (PAT), Tactical Planning (TP), Strategy and sCenario Awareness (SCA). It also gives examples of tasks for each of them.

If the wildfire event remains active during the late afternoon, it is important to carry out a radiosonde launch around **sunset**. The data collected by this radiosonde will allow us to know if the structure of the atmosphere is prone to EWE at night. Thus, these data will be useful to predict and identify the possible expected nocturnal behaviours of the fire and will facilitate decision-making and strategy definition.

It is also interesting to do **multiple radiosondes launches**, that is, to launch more than one radiosonde at a time and location, if the conditions of the fire and the equipment allow so within the smoke plume, the different radiosondes do not follow the same path, and the atmosphere conditions can be different at different points in the smoke plume. So, this allows us to get more detailed data on the conditions of the smoke plume and therefore a better simulation. The more data we have about the plume, the closer the model will be to reality.

Below the ABL, radiosondes provide valuable information because models are usually not completely accurate in this area, especially in the case of wildfires, which cause changes in this layer. Above the ABL, data from meteorological models are reliable in most cases. This consideration implies that when launching and monitoring radiosondes, it is necessary to understand when the radiosonde can be lowered, since the information collected is already useful. Knowing when to lower the radiosonde depends on several factors, but there are some points that can help to make the decision.

Therefore, it is necessary for the radiosonde to reach the top of the ABL and, if possible, continue to ascend at least until some metres above expected LCL in daily models. It is therefore important to know the vertical profile of the atmosphere forecasted for that day and location. It is also valuable to know how to identify turbulence in the data in order to read it correctly and avoid false conclusions, normally presented as erratic changes in data. To identify this top ABL height, some situations can be considered in the data graphs:

- Relative humidity tends to a maximum, and then starts to decrease.
- There is a significant decrease in vertical velocity. These radiosondes normally ascend at about 2-3 m/s. Velocities below this range could be considered a slow ascent.

It is important to know how to recognise these changes in the graphs of launched sondes, and it is useful to have an idea of when the radiosonde can be cut off. It should also be remembered that it is necessary to monitor the radiosonde properly to plan its landing location well and to make it easier to recover, although the situation does not always allow it.

# 6

# 6. Conclusions

This document establishes clear and uniform standards for data collection during wildfire events. These standards ensure that all fire professionals collecting data can use the same methodology and data format, regardless of the project partner or the country where the wildfire occurs.

By standardising data collection, access to valuable information for researchers and decision-makers in wildfire emergency situations is facilitated. The availability of consistent data in the resulting Open Data Portal from the EWED project will enable effective analysis and real-time monitoring of wildfires, thus enhancing strategic response capacity.

Furthermore, providing an open platform for data collection and sharing on EWEs, this document promotes advancement in research and knowledge generation about extreme wildfires. The collected data not only support operational decision-making but also supports the development of models and algorithms that enhance understanding of these events.

In addition to project partners, this document is also designed to guide all people that work in wildfire suppression wishing to contribute to the Open Data Portal. This ensures that collected data meet the portal's needs and promotes broader and more effective collaboration in extreme wildfire research.

In summary, this document establishes a robust framework for data collection and standardisation during extreme wildfire events, with the ultimate goal of improving response to these events and advancing scientific knowledge about them.

# 7

# 7. References


**[1]** Aydell, T. B., & Clements, C. B. (2021). Mobile Ka-Band Polarimetric Doppler Radar Observations of Wildfire Smoke Plumes. Monthly Weather Review, 149(5), 1247-1264. https://doi.org/10.1175/MWR-D-20-0198.1

**[2]** Castellnou, M., Bachfischer, M., Miralles, M., Ruiz, B., Stoof, C. R., & Vilà-Guerau de Arellano, J. (2022). Pyroconvection classification based on atmospheric vertical profiling correlation with extreme fire spread observations. Journal of Geophysical Research: Atmospheres, 127, e2022JD036920. https://doi.org/10.1029/2022JD036920

**[3]** Castellnou, M.; Miralles, M.; Nebot, E., Estivill, L. *Guidelines of fire analyst competencies and skills*. AFAN Project (2021).

**[4]** Castellnou, M., Nebot, E., Estivill, L., Miralles, M., Rosell, M., Valor, T., Casals, P., Duane, A., Piqué, M., Górriz-Mifsud, E., Coll, L., Serra, M., Plana, E., Colaço, C., Sequeira, C., Skulska, I., Moran, P. (2022). *FIRE-RES Transfer of Lessons Learned on Extreme wildfire Events to key stakeholders.* Deliverable D1.1 FIRE-RES project. 119 pages.

**[5]** Castellnou, M., Prat-Guitart, N., Arilla, E. et al. (2019). *Empowering strategic decision-making for wildfire management: avoiding the fear trap and creating a resilient landscape.* Fire Ecology 15, 31. https://doi.org/10.1186/s42408-019-0048-6

**[6]** Lareau Neil P., Clements Craig B., Kochanski Adam, Aydell Taylor, Hudak Andrew T., McCarley T. Ryan, Ottmar Roger. (2024). *Observations of a rotating pyroconvective plume.* International Journal of Wildland Fire 33, WF23045. https://doi.org/10.1071/WF23045

**[7]** Tedim, Fantina & Leone, Vittorio & Amraoui, Malik & Bouillon, Christophe & Coughlan, Michael & Delogu, Giuseppe & Id, † & Fernandes, Paulo & Ferreira, & Mccaffrey, Sarah & McGee, T. & Parente, Joana & Paton, Douglas & Pereira, Mário & Ribeiro, Luis & Viegas, Domingos & Xanthopoulos, Gavriil. (2018). *Defining Extreme Wildfire Events: Difficulties, Challenges, and Impacts.* Fire. 1. 9. https://doi.org/10.3390/fire1010009

# *Appendix*

# 1

# 1. Methodology of data collection with radiosondes in wildfires

This document describes the detailed steps to carry out a radiosonde launch using Windsond radiosondes.

Windsond has a user's manual in English with details on how to use the radiosondes. It can be found on the following web page: https://files.sparvembedded.com/windsond_manual_2.1.pdf

However, some points are expanded below, images are added and the procedure to be followed with all the equipment is detailed. Some of the images and points included in this document also come from this manual, where the reference is indicated.

At the end of this document there is a summary/checklist with the steps (without explanation or images) to quickly review the tasks to be performed.

## Data to be collected

The data that can be obtained are the following:

- Wind speed and direction at different atmospheric levels.
- Temperature and relative humidity.
- Radiosonde altitude.
- Ascending velocity.
- Receiver-radiosonde distance.
- % of signal reception.
- Dew point.
- Atmospheric pressure.
- Radiosonde trajectory, GPS position.

## Equipment

The necessary equipment to carry out launches are shown in the following images:




*Radiosondes materials: (A) Radiosondes, balloons, antenna, battery chargers. Reference: https://sparvembedded.com/products/windsond . (B) Helium bottles. Example: Dräger 6 litres. Reference: Botella Dräger de acero 6L | Prolaboral. (C) Receiver and cable. Reference: https://sparvembedded.com/products/windsond.*

The brands identified in this section need not necessarily be the ones shown, as long as the alternatives have equivalent performance.

### Elements of the radiosonde equipment:

- Radiosondes
- Balloons
- Batteries 75mAh
- Ground station:
    - Antennas (long and short individual station)
    - Radio receiver
    - PC connection cable
    - Battery Charger
- Helium cylinder/tank with pressure reducer

Detail of the technical specifications of the radiosondes can be found on the Windsond's website: https://sparvembedded.com/products/windsond

Additional elements that facilitate the launching and movement/preparation of the Ground Station:

- Operational vehicle.
- Laptop or Tablet (must have Windows system).
- Inverter to connect to the vehicle or battery that allows continuous charging of the computer.
- Radios.
- Repairing material for the radiosondes: thread, cups, duct tape, etc.
- Internet connection.
- Box for all the materials.

## General data collection process

For the collection of vertical atmospheric profile data using radiosondes, some steps must be followed to ensure a successful launch. These are described below:

1. The decision of the launching location should be based on the situation foreseen for the day and the fire conditions and be made as close as possible to the appropriate time for release.

2. Checking of the elements of the equipment and verification that the batteries are charged.

3. Steps for the preparation and launching.

    a) Preparation of the Ground Station
    b) Radiosonde activation
    c) Radiosonde stabilisation process
    d) Launching
    e) Radiosonde flight and data reception
    f) Remote monitoring of the radiosonde
    g) Cutting of the thread that connects the radiosonde to the balloon
    h) Radiosonde landing on the terrain

It is important to obtain data from outside the fire or prescribed burn area of influence to compare with those obtained from the smoke plume. To do so, it is possible to launch a radiosonde, before or after the main radiosonde launch on a separate location in case of the wildfire or before the prescribed burn. It is also possible to rely on the data during the descent of the radiosonde as long as it is far enough away from the fire or prescribed burn. However, it is only recommended if the control launch is not possible. Using the falling radiosonde to obtain environmental data may not be useful for obtaining this data if the radiosonde does not leave the area of influence and it is possible that the radiolink connection may be lost, preventing data collection.

**4.** Radiosonde recovery.

The data is available on the Ground Station from the initial moment of the launch, as long as the radiolink is sufficient. However, the recovery of the radiosonde allows it to be reused for other launches. If we assume that we start from the moment the radiosonde has touched the ground:

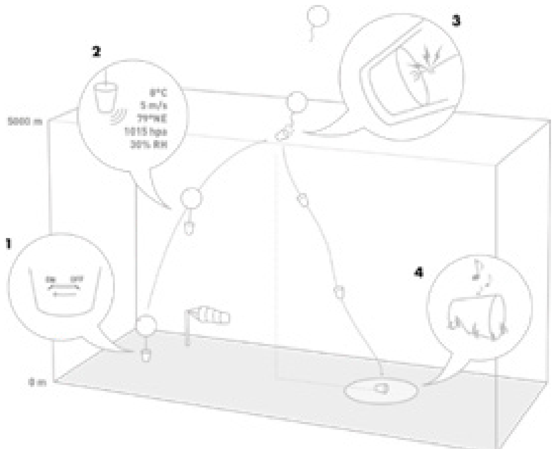
1. Initial location of the landing location through the remote device.

2. Moving to the landing location of the radiosonde.

3. Connections with the radiosonde in trying to be as close as possible to adjust the initial location.

4. Radiosonde recovery.

The steps for points 3 and 4 of *General data collection* process are detailed below:




*Radiosonde launching steps. Reference: Windsond.*

## Launching location selection

One of the key points of launching of the radiosondes is the determination of the launching zone. It will be necessary to always evaluate the assumable risk, safety, and situational awareness at all times, avoiding that the deployment of the Ground Station and the preparation of the radiosondes does not distract from the risk awareness, the conditions of the environment and its evolution.

## Launching team (people)

Although it is not essential, it is recommended to have two people carrying out the launch. The binomial ensures greater situational awareness. In the case of using a vehicle, having a team formed of 2 people allows one of them to be one person in the vehicle checking the connection, data reception, etc., while the other person can move around to look for a more suitable launching point (indraft point, open area, etc.).

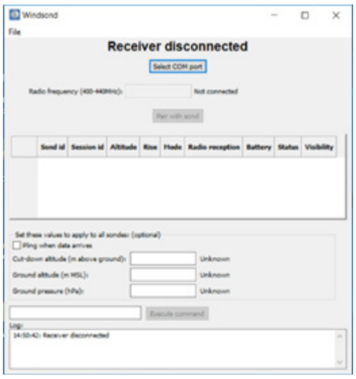
# Radiosonde launching steps

### A. Ground station setup

#### 1. Turn on the computer/table and start the Windsond software

- **Power supply:** Ensure power supply with an inverter connected to the car or with an external battery.
- **Internet connection:** Check internet connection.

#### 2. Open WINDSOND software

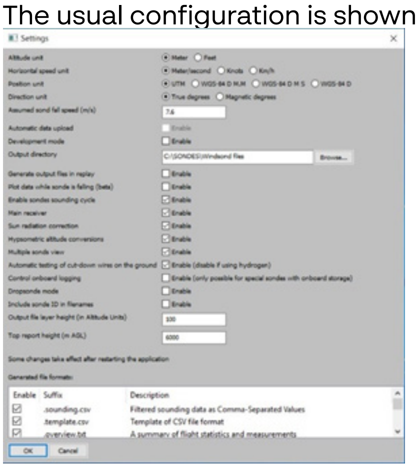



#### 3. Check that the configuration is correct ("Settings"): go to File > Settings tab.

The program must be left open to receive the radiosonde data. A specific window will be opened for each radiosonde, but the general management is done from the general view.

- The application window indicates *"Windsond"* on the cover.
- Each radiosonde's window indicates the code of the radiosonde on the upper part of the panel.

The usual configuration is shown in the picture below:




Activate ***Multiple sonds view: Enable***

Change the ***'Top report height (m AGL)'*** if necessary.

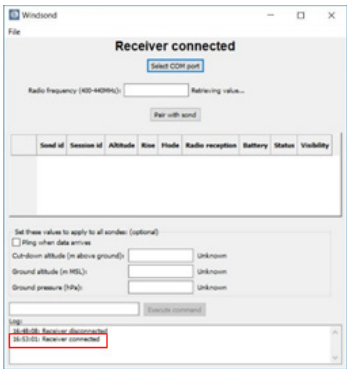
### 4. Connect receiver and antennas

4.1. Connect the 2 antennas to the receiver, and the receiver to the computer using the USB output cable.

4.2. Connect the USB cable from the receiver to the computer. A green led lights up.

4.3. Press the switch on button of the receiver to turn it on. We now have 2 green LEDs on.

4.4. Check that the connection between Windsond and the receiver is correct:




## B. Radiosondes preparation

### 1. Take the radiosonde out of the cup:

Be careful! Avoid touching the radiosonde, it is the most sensitive part of the device.

### 2. Connect the charged battery

Connect the battery to the plate (it is not necessary to put the Velcro, as long as it is sufficiently separated from the resistor). Remember! The connection has a specific position that allows it to connect! It is better to have verified if the batteries are correctly charged before (see final point of this section).

If the battery is fully charged it will show 4.1-4.2 V battery voltage. The fully discharged voltage is 3.3 V. Therefore, the radiosonde will be attenuated to this voltage level.

[Reference: *https://files.sparvembedded.com/windsond_manual_2.1.pdf*]

### 3. Identify the radiosonde

On the inside of the cup and on the plate, there is a number on a white label that allows the radiosonde to be identified.

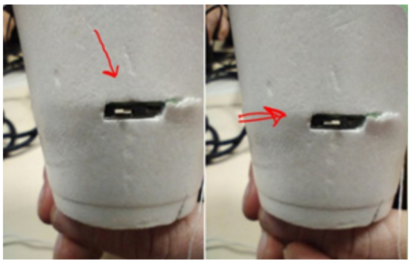
**4. Make sure that the knot of the thread is outside of the cup.**

This avoids that when the thread is cut ('cut-down' action), the knot obstructs the hole on the lid of the cup and the balloon and the radiosonde does not separate. In this case, we would lose the radiosonde until the balloon is deflated or falls in an uncontrolled place.

**5. Stretch the antennay**

The antenna is a white filament that comes out of the lower part of the cup and is normally kept folded on one side of the cup when packaged in the original pac-king. It is important to make sure that it is well stretched and unfolded.

**6. Switch-on the radiosonde**



Move the side button. When the radiosonde is switched-on, it makes a sound and the white led inside the radiosonde li-ghts-up making a flash of light that can be seen located on the base plate inside the radiosonde:

***Checking charged batteries:***

It is better to have checked the batteries prior to launch. But at this moment, they can also be checked using the battery char-ger. If the led that indicated the charge is green, the battery is charged. If it is red, the battery is discharged and is charging at that moment.

They are charged with the adapter-charger via USB to any computer/charger.

According to the manufacturer, the batteries last 2-4 hours (Radiosonde – Windsond - FAQ | Sparv Embedded) but we have found that they do not last 3 hours when they have been charged many times.
According to the Windsond manual, 30 minutes is sufficient for a full charge.

**7. Checking of sounds**

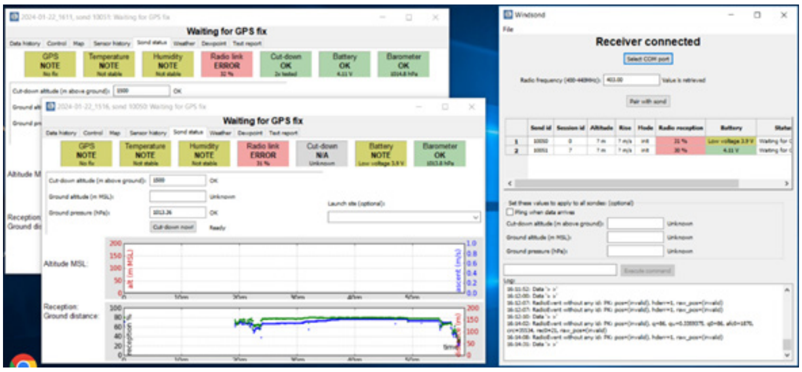
7.1. An initial sound of two deep tones at start-up. If this does not happen, the battery charge is too low, even for low altitude measurements.

7.2. A lower sound than the first one that will stop every few seconds, indicates that it is not yet ready for launching. Before the radiosonde can be launched, it has to acquire a GPS signal and contact the ground station software.

7.3. Between thirty seconds and two minutes, the radiosonde emits a series of ascending beeps and then emits two short beeps, followed by high-pitched beeps every few seconds. This means that the radiosonde is ready to launch at any moment.

## 8. Check radiosondes and antenna receiver connection

Once the radiosonde is connected (step 6) a new window opens automatically on the computer screen:




There will be as many windows opened as activated radiosondes. In the previous image there are two actives radiosondes (left part of the image). These appear in the list of the Windsond software (right part of the image).

Before initiating the radiosonde launch it is necessary to check the following:

1. Check the number of the radiosondes (in red)
2. All the variables that measure parameters must be in green (in green)
3. Battery status. Wait a while, if the status does not improve and is not good enough, change the battery. **Minimum 3.9V (low voltage)**, anything below this value means, the battery must be replaced (in blue)
4. *Radiolink* over 70%

The *radiolink* assumes that the radiosonde starts less than 5 metres from the receiver antenna. According to the manufacturer, in more distant starting positions it works just as well, but the system will complain of low reception. Also according to the manufacturer, this is normal.


## 9. Inflate the balloon with 30l of helium

If a lot of data is to be collected and analysed, it is advisable to always use the same type of ballon, to give equality in the way they are taken.

The balloon is inflated with the helium recipient using the pressure reducer. Be careful to place the balloon well-adjusted to the outlet of the pressure reducer to avoid losing gas.

**Inflate the balloon to a diameter of approx. 50 cm**

The standard party balloons are a bit too small and give a low speed of ascent. The big party balloons work well, but they need to be about 30 cm high. They need to have about 30 l of helium. (the bottles labelled *"balloon heli"* are low purity and somewhat less efficient) [Reference: *Radiosonde – Windsond - FAQ | Sparv Embedded*].

| Balloon weight (g) | Diameter (cm) | Circumference (cm) | Volume (liters) | Rise speed (m/s) | Recommended for |
|---|---|---|---|---|---|
| 9 | 40 | 123 | 30 | 2 | < 5 000 m |
| 17 | 54 | 143 | 83 | 2 | 5000 – 8000 m |

*Examples of ascending velocities for different balloons and gas content.*
*Reference: https://files.sparvembedded.com/Windsond_sounding_guide_v5.pdf .*

**Tip:** you can use a pre-linked string loop to measure the circumference, or you can simply estimate the diameter. The amount of gas is not exact, but if there is too much gas, it can cause the balloon to dive before reaching the target altitude, and too little gas will slow the rising speed, causing the radiosonde to move too far away.

[Reference: *https://files.sparvembedded.com/Windsond_sounding_guide_v5.pdf*]

For reference, a balloon of 9 grams of diameter inflated to 40 cm or circumference of 123cm gives a volume of 30l and a lift of 2m/s$^2$.

In case of using helium for party balloons, it should be considered that these have a low purity which implies that the lift force is lower.

The balloon will expand as it ascends, since air pressure decreases with altitude. At 5500 m altitude the pressure is reduced by half and the balloon has twice the volume. Over-inflating the balloon can cause it to collapse before the maximum altitude. The 9-gram balloon can hold about 80 l before it drops.

## 10. Tying the radiosonde to the balloon

It is necessary to leave a minimum length of **5m of thread between the balloon and the radiosonde.**

## 11. Positioning the radiosonde and antennas

The antennas with long cable can be placed on the top of the vehicle because they have magnets that allow it.

In order to guarantee the transmission, it is necessary to:

- Keep the antenna as straight and vertical as possible.
- The antennas must be at the same level or below the level of the radiosonde, so that there is plenty of *radiolink*, and no gaps in between to ensure constant *Radiolink*. Without *Radiolink* no data is received.

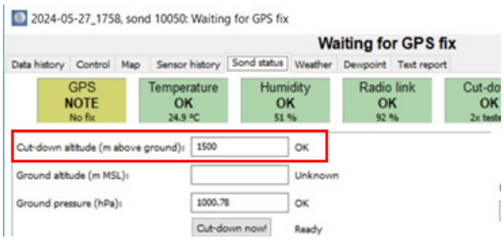
When the radiosonde goes up, it searches for the receiver at the last known frequency for 5 seconds. If the receiver is not found, the radiosonde starts to alternate between a predefined frequency (434.00 MHz) and the last known frequency. At the first start of a new radiosonde or when the radiosonde recognises a new frequency, a window with the radiosonde information and buttons will automatically appear.

If this does not happen, press the *"Pair with sonde"* program button until a window for the new radiosonde appears:


The transmission speed and configuration are also communicated to the radiosonde. This allows us to have several systems in the same area. However, it should be noted that this procedure implies that any radiosonde can be transferred to a new receiver if the previous receiver is not connected when the radiosonde is started.

### 12. Check that the automatic height selected is the one you need

Select ***Sond status > Cut-down altitude.*** The value can be entered manually to adjust it to what we need. This value can also be modified once the radiosonde is launched, during the flight.



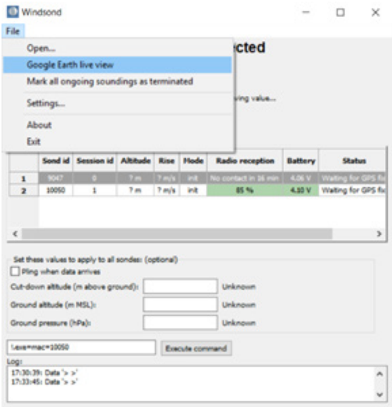

If we do not change it and we want it to reach a higher elevation than the one indicated, when it arrives at the one marked, the resistance will automatically cut the thread and the radiosonde will land, and we will have no data from this point on. By default, this elevation is 1.500m above ground level (AGL).

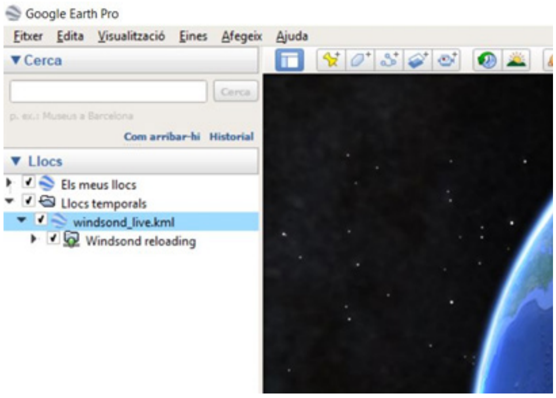
By default, the first air pressure reading after activation is assumed to be the ground level pressure and the first GPS signal reading is the elevation of the ground above sea level. These two figures are then used to calculate all the altitudes of the radiosonde above sea level (MSL) and above ground level (AGL). These figures can be overridden by the user by setting two fields *'Ground altitude'* and *'Ground pressure'* in the *'Sound status'* tab. This can be modified both before and after the sounding.

GPS altitude readings can be incorrect, even by hundreds of metres. For this reason, all altitudes after the initial altitude are calculated from the known elevation and ground air pressure.

### 13. Open Google Earth viewer (if it has not been done before)

- We must have it open for all the radiosondes. It is the visualisation of the information than Windsond software is receiving.
- It allow us to see the trajectory that the radiosonde is following.
- If it does not open automatically, it opens from ***Windsond > File > Google Earth live view:***




### 14. Radiosonde launching

It is advisable and practical to carry out the launch between two people but is not essential.

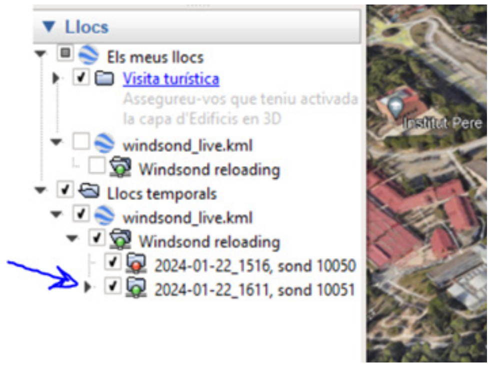
***Example:***

- ***Radiosonde operator:*** takes the radiosonde and moves to the launching area/point.
- ***Receiving equipment operator:*** is normally located in the vehicle, in the co-pilot position in the car, and is the one with the computer. [If there is a tablet, their position can be mobile and be with the radiosonde at the launching point].
- ***Radiosonde operator:*** communicates (voice or radio) that she/he is at the indicated location.
- ***Receiving equipment operator:*** checks that the reception is correct (all indicators in green), if not, waits or gives indications to the radiosonde operator to look for a better location, come to change the battery, etc. If everything is correct, give the OK for launching.
- ***Radiosonde operator:*** when releasing the balloon, it is necessary to do it smoothly, so that the radiosonde does not receive a strong pull and breaks the two wires of the resistor. It is recommended to hold the thread of the radiosonde over the cup until the thread between the radiosonde and the drop is stretched and to let it go slowly in order to avoid the strong pull.

It is needed to take a video or photo of the launching, to identify the fire behaviour and the track that radiosonde is following.

## 15. Google Earth monitoring

First, we need to **check that we visualise the radiosonde correctly.** A layer per radiosonde with its code will be displayed. Once the radiosonde is launched, in Google Earth it should appear with the green light on, it means that the data (*radiolink*) are well received.




But sometimes the connection can be momentarily lost between the radiosonde and the ground station and Google Earth does not indicate it. Therefore, it is always necessary to follow what the Windsond software of each radiosonde tells us from the corresponding windows.

If we lose connection to the radiosonde, we will see the next warning (in red):

Corrective options:

a) **Check the connection between the antennas and the receiver** in case they have been disconnected during the movement of the vehicle or due to other reasons.


b) **Improve the position of the antennas with respect to the radiosonde:** you can try to move the vehicle to find a new location with as few obstacles as possible between the radiosonde and the antennas.

c) **Be patient... sometimes it takes a while for the *radiolink* to become ready.**

The *radiolink* exceeds 10 km in open terrain and has sometimes operated at 50-100 km depending on the manufacturer, using the omnidirectional antennas. Be careful because if there are obstacles in the line of sight between the radiosonde and the receiver (such as trees or buildings) the *radiolink* can be interrupted.

Unless the program reports a loss of connection, the data connection is fully functional, with no data corruption, regardless of the reception indicator. When the radiosonde is within a few metres of the receiver at the starting point, normal reception is between 85-95%. During the flight, the number will quickly drop to 30-50% as the distance increases. A lower reception, below 20%, indicates that the connection may soon be lost. Make sure the receiver antenna is well positioned and check the automatic cut-down altitude.

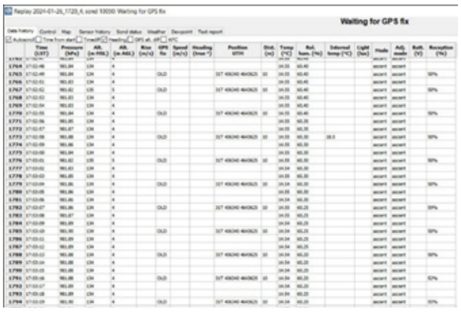
When the radiosonde falls to ground, the connection is usually cut because of the obstacles on the ground. When the radiosonde is recovered again, the reception returns to about 100-400m.

For a good radiosonde recovery, it is important to ensure a good data connection when the radiosonde is at the top of the ascent so that it marks a good landing location on the Google Earth visualisation.

## 16. Data monitoring

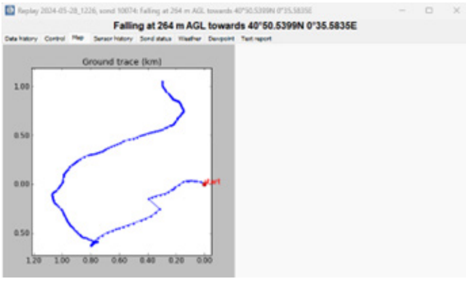
From the moment the radiosonde is switched-on, data is continuously recorded on the computer. When the radiosonde is linked, the data are continuously recorded on the computer. These data can be visualised through the next tabs:

**1. Data history:** through this tab you can visualise all the incoming data and the geographic coordinates:

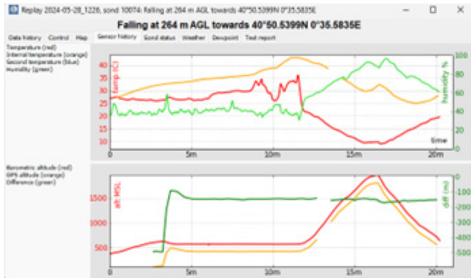



**2. Control:** this tab allows to control technical specifications of the radiosonde, and control its modes .

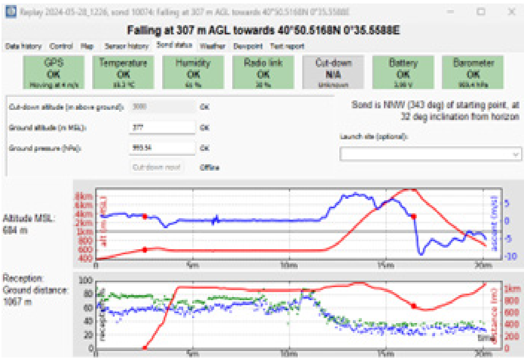

**3. Map**



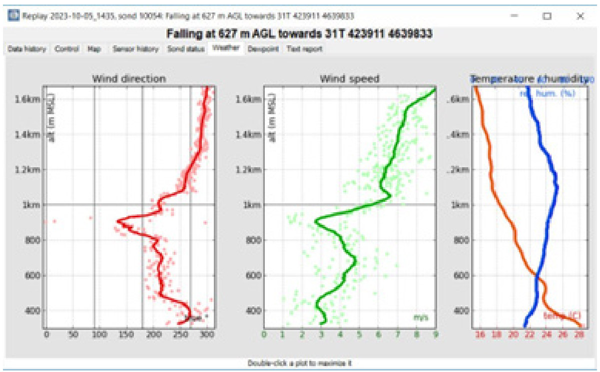

**4. Sensor history**



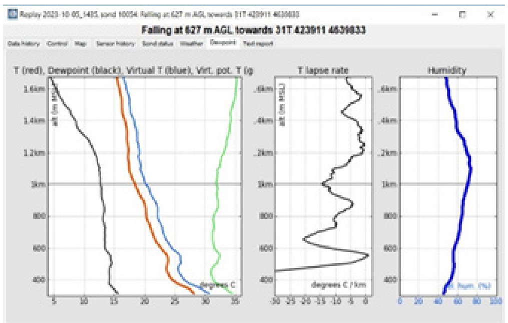

**5. Sound Status**




**6. Weather:** this tab shows graphs with wind direction, wind speed and temperature/humidity. The measured values are shown as dots and the average values are shown with black lines. The grey grid lines mark them every 1000 m of altitude above sea level (MSL). In the wind direction graph, there is a grey line every 90 degrees. Missing data due to loss or lack of reception are shown as larger spaces between the points.



**7.** **Dew Point**

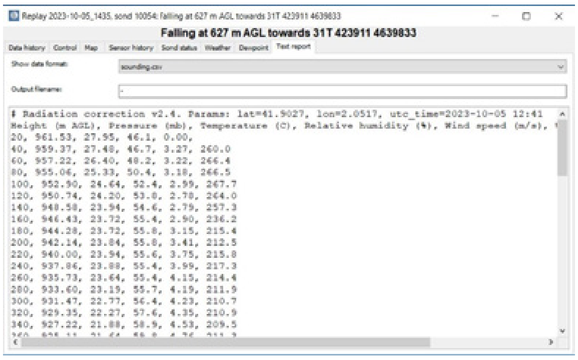



**8.** **Text report:**

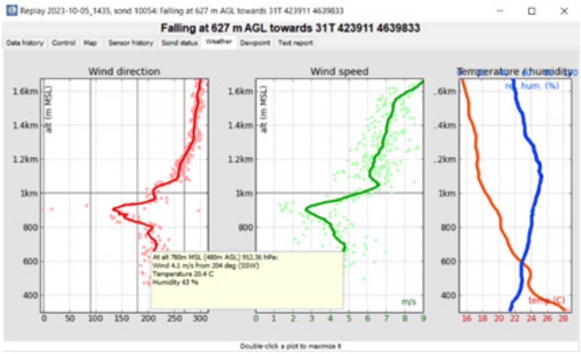
Abbreviations:

— AGL = altitude Above Ground Level

— MSL = altitude above Mean Sea Level



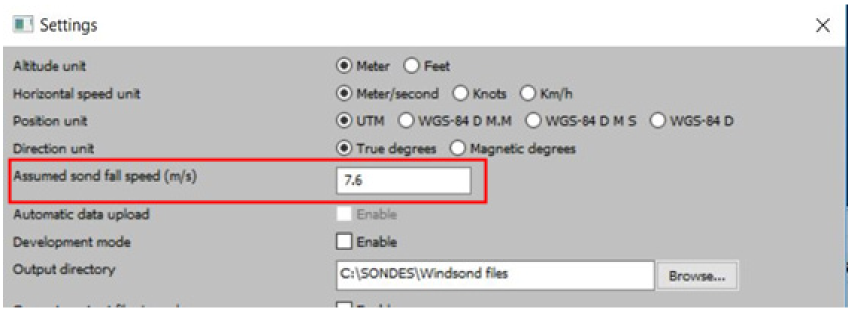

**9.** **Google Earth**


Those tabs that have graphs allow you to see the data on them. Just place the mouse over the point you want to know and a green box with the data appears.

## 17. Landing point and cut-down height selection

During the flight, the Windsond software predicts the landing location based on the ascending speed, the wind conditions, and the predicted descending velocity. The predictions are given after the radiosonde ascends above 60m AGL. The landing site is predicted when *'cut-down now!'* is clicked at the moment when the corresponding icon appears in the Google Earth view, with and accuracy generally better than 50m. The accuracy depends mainly on predicting the correct fall-down velocity (configured in the Windsond menu: *File > Settings*).



Landing site predictions are also provided in Google Earth for some higher *cut-down altitudes* and for the current established altitude. These predictions will be maintained at higher altitudes. However, as the wind is likely to change at higher altitudes, it is important to be aware of how they change over time.

There are two ways to cut-down the radiosonde and make it land to the ground:

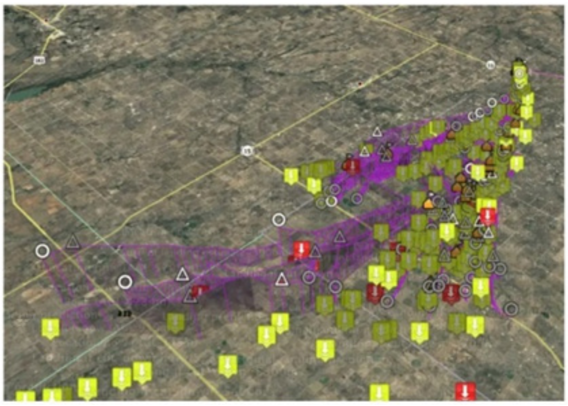
1. Automatically when it arrives at the height determined in the program.

2. Manual *'Cut-down now!'*. This button can be accessed from two points: the *'Sound status'* tab or the *'Control'* tab.

When this option is selected, the resistor inside the radiosonde, on the plate, becomes incandescent and cuts thread. At high altitudes it would be possible that, due to the temperature, the resistor would not be able to cut the thread, but normally it works correctly.

But the most accurate way to bring the radiosonde to the ground is to do it manually using the Google Earth visualisation and pushing the *'cut-down!'* button when the landing icon that is shown on the Google Earth map reaches a location of our interest.

To select the correct height, go to the Google Earth visualisation. Remember that it is possible to have several radiosondes flying at the same time, each one with its own prediction.



*Visualisation with Google Earth of the trajectory and landing prediction of different radiosondes.*

*Reference: https://sparvembedded.com/products/windsond/many-sondes.*

## 18. Radiosonde recovery

Before starting the recovery process, it is important to note the UTMs indicated by the program in the *Data history* tab, at the last available record. These UTMs can be used to locate the radiosonde if the program fails, the computer is disconnected or any other situation that interrupts the process. These UTMs can be introduced in any GPS application and help us to locate the radiosonde.

The format of the geographic coordinates will be the one we have selected in *File>Settings* (see point details of the steps to be taken for the field launch).

When the radiosonde is on land, it has three ways to save energy and extend the duration of the battery to help facilitate recovery. The modes are as follows:

**1. FIND ME** (*'On ground, beeping'*): plays a few tons (first increasing, then decreasing the tons) and blinks every 5 seconds. It sends GPS reports every 4 seconds. After **45 minutes**, it switches to SLOW FIND ME

**2. SLOW FIND ME** (*'On ground, sometimes beeping'*): plays tons and blinks every 15 seconds. GPS reports every 4 seconds. After **3 hours**, it switches to POWERSAVE.

**3. POWERSAVE** (*'On ground, silent'*): Does not blinks or reproduce sounds. It sends a short signal every 15 seconds and waits for a response from the receiver. It sends a complete GPS position once every 2 minutes.

We can choose before or during the flight which mode to enter when landing (*'Behavior at landing'*) from the *Control tab*:

**1. POWERSAVE** (*'On ground, silent'*): does not blinks or reproduce sounds. It sends a short signal every 15 seconds and waits for a response from the receiver. It sends complete GPS positions once every 2 minutes.

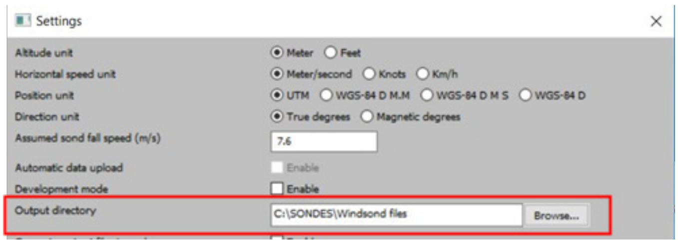
**2. 'Beacon at once':** if the radiosonde is to be recovered in a few hours, the sound played in this position makes it easier to find the radiosonde.

**3. 'Power-save':** if the radiosonde is to be recovered in a couple of days, click this battery saving mode. When the ground station is brought to the location next to the radiosonde, the receiver will *'wake-up'* the radiosonde to the FIND ME mode once the *radiolink* is restored. This occurs at about 200-1000m from the radiosonde.

The operating mode of the radiosonde can be viewed in the *'Data history'* tab, *'Mode'* column.

## 19. Data received by the radiosonde storage and its management

The data are collected independently if the radiosonde is recovered or not. They will be stored in the folder indicated in *Files > Settings > Output directory:*




To collect and transfer the data for analysis:

1. Close the window corresponding to the radiosonde.

2. It is recommended to have a shortcut to this folder on the radiosonde computer desktop.

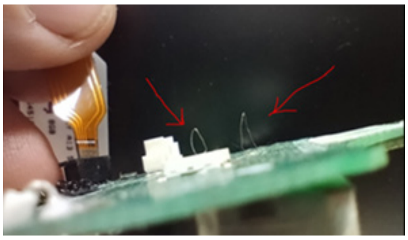
3. In the folder you will see several files. The files have the code of the radiosonde and the date and time of launching. No need to say that all the files that have the same date and time are from the same launch and this helps to locate them when different launches have been made during the same day.

4. Once all data is gathered, follow *Data management* steps to upload them to the Data repository.

## Maintenance and repair of the radiosondes

**Replacement of the thread:** If it is necessary to tie the thread again to the radiosonde. The thread must be passed through the resistance. The thread must enter through the hole in the lid of the cup of the radiosonde, pass through the two rings of the resistor (see picture) that is on the plate, inside the cup, and come out again through the same hole in the cover of the radiosonde.

It is necessary to check that the knot is on the outside of the lid so that when the thread is cut with the resistor, the knotdoes not prevent the rediosonde from falling and keeps it attached to the balloon.



**Battery recharging:** the discharged batteries must be recharged again before the next launch. It takes a minimum of 30 min. approx. per battery to be fully charged when the batteries are new.

**Replacement of material:** balloon, helium, etc.

## Final summary/Check-List

### Before leaving headquarters:

| | |
|---|---|
| | Availability of the equipment. |
| | Batteries charged. |
| | Enough radiosondes with thread. |
| | Helium bottle filled and ready. |
| | Charged computer (not essential if we have an inverter or external battery). |

### Arrival at the launching location:

| | |
|---|---|
| | Working conditions (safety, situational awareness). |
| | Data reception conditions (GPS availability, coverage, etc.). |

### Before releasing the radiosonde:

| | |
|---|---|
| | GROUND STATION ASSEMBLY |
| | Power-on the computer. |
| | Check mobile network. |

| | |
|---|---|
| | Check GPS availability. |
| | Install the elements properly: 1. Attach the antennas to the receiver<br>2. Connect receiver to PC |
| | Receiver connected correctly (2 green lights). |
| | Ground station connected, this is the Windsond program installed and working on the computer. |
| | Check that the configuration is correct (especially if it is the first time, otherwise it will be saved from the previous launch). |
| | RADIOSONDES ASSEMBLY |
| | Take the radiosondes out of the radiosonde cup. |
| | Connect the charged battery. |
| | Note/identify the radiosonde number. |
| | Check that the thread is outside the cover. |
| | Stretch the antenna. |
| | Attach the radiosonde to the balloon. |
| | RADIOSONDE – GROUND STATION LINK (previous to the launching) |
| | Check that all the parameters of the radiosonde are in green at the ground station (Windsond software on the computer or tablet). |
| | Verify the sounds of the radiosonde. |
| | Inflate the balloon with helium and attach it to the radiosonde. |
| | Position radiosondes and antennas correctly. |
| | Verify the automatic elevation *'Cut-down!'* (Windsond application). |
| | Open Google Earth Viewer. |
| | When all the parameters are in green (Windsond program), release the radiosonde. |
| | MONITORING THE FLYING RADIOSONDE |
| | Monitoring of the data collected through the graphs. |
| | Selection of the radiosonde landing area using Google Earth, the landing prediction and the parameters of the Windsond graphics program. |
| | Radiosonde size ('Cut-down now!') |
| | Registration of the UTMs of the landing location. |
| | Radiosonde recovery. |

### Maintenance of the radiosondes:

| | |
|---|---|
| | Battery recharge (30 min per battery) |
| | Replacement of the threads. |
| | Repairing of broken radiosondes. |
| | Refill the helium bottles (if it is necessary). |

## References


Windsond Manual 2.1: https://files.sparvembedded.com/windsond_manual_2.1.pdf



*Authors:*

***UT GRAF (Bombers - CFRS)***


*Date:*

***16th of April 2024***

# *Appendix*

# 2

# 2. Methodology of smoke plume height with *SmokeMeter* APP

**SmokeMeter APP** is an application that has been specifically designed to accurately estimate the smoke plume height. This tool complements atmospheric profile data acquired with the radiosondes, improving our understanding of the fire-atmosphere feedback. The application is easy to operate on the field, and works worldwide, over short, medium and long distances (more than 15km).

To get the data, the app needs some inputs:

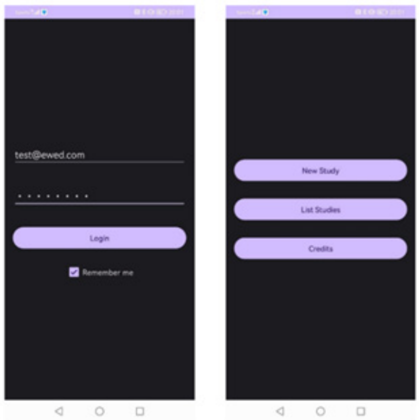
- Observer data (automatic)
- Fire data (marking a location on the map)
- Angle (shooting a photo with the phone)

And with these inputs, the app provides some outputs:

- Distance to the fire (metres)
- Some plume height (metres)
- Save records with all data (time, coordinates, description, title, ...)

## Data gather with the APP

The **SmokeMeter** APP has a user-friendly interface, which allows to get the data in a few simple steps:




### 1. Download and install the app

Only available with the Android operating system. It can be download using this link: SmokeMeter - Apps on Google Play

### 2. Log in

To use the APP, you will need a user and password. More advanced versions will include an option for automatic login. At this time, to obtain your account, you have to write to *smokemeter.help@gmail.com* and request it.

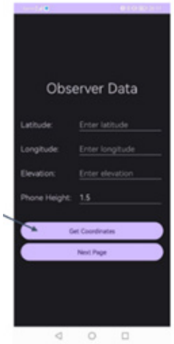
### 3. Home screen

Once logged in, the home screen will be displayed. Three options are available:

- New Study: perform a measurement and record it
- List studies: view the registered data
- Credits

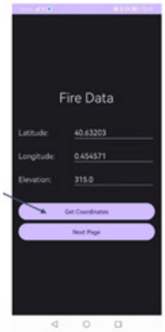
## 4. New study

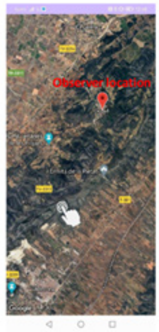
To create a new column height measurement, select the New Study option from the home screen. From here, you will need to fill in the required information in each of the windows that appear.




**1. Observer data:** is the data on the observer's location. You will need to **enable location** and **allow access to the device's location**. There are two options to get this location:

- **Get coordinates** – automatic calculation according to the current location
- **Manual data input:**
  - Latitude (decimal degrees)
  - Longitude (decimal degrees)
  - Elevation (metres)
  - Phone height (metres)



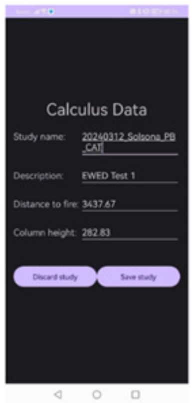

**2. Fire data:** is the location of the **smoke plume base**. There are also two options to get this data:

- **Get coordinates – automatic calculation according to the current location**
- **Manual data input:**
  - Latitude (decimal degrees)
  - Longitude (decimal degrees)
  - Elevation (metres)



**3. Get column angle:** With the data collected in the previous points, the height of the column is obtained in this step. It allows us to take photos and record videos.

- **Get angle (recommended):** with your arm outstretched, tilt your phone (not your arm) until the line shown on the screen is at the top of the column.
- **Manual data input:** angle (decimal degree).




**4. Save study:** With the above three screens filled in, the desired information has been obtained. The next section is the one that stores the data obtained.

The name and description of the study can be changed in this section. The height of the smoke plume and the distance from the wildfire are also displayed in the same screen.

In the Study name field, for better homogeneity, it is proposed to use the following format:

- Date: *yyyymmdd* +
- Short identifying name +
- Wildfire or prescribed burn (*W/PB*) +
- 3 first letters of the country (*NOR, GRE, NET, CAT, etc.*)
- *Exemples: 20210724_StCQ_W_CAT* or *20240228_Orista_PB_CAT*

It is also important to **save the image** used for the angle calculation. At this moment, the APP does not save this file, so it is necessary to collect this image.

5. **List studies**

This window provides access to basic information on the various studies carried out by the user. It provides data such as the name of the study, the description, the distance from the observer to the fire, the height of the plume, the date and time of the measurement.

It is not currently possible to automatically download this data in .csv format via the APP. Work is underway to improve implementation in this area.

6. **Credits**

This section contains information about the main developers of SmokeMeter APP.

Note: At the time of writing this document, the application is under development, so some of these steps and functionalities may change over time.

*Authors:*

***UT GRAF (Bombers - CFRS)***

*Date:*

***16th of April 2024***

EWED