

From fire danger to fire activity forecast

Francesca Di Giuseppe

Fire forecast Lead

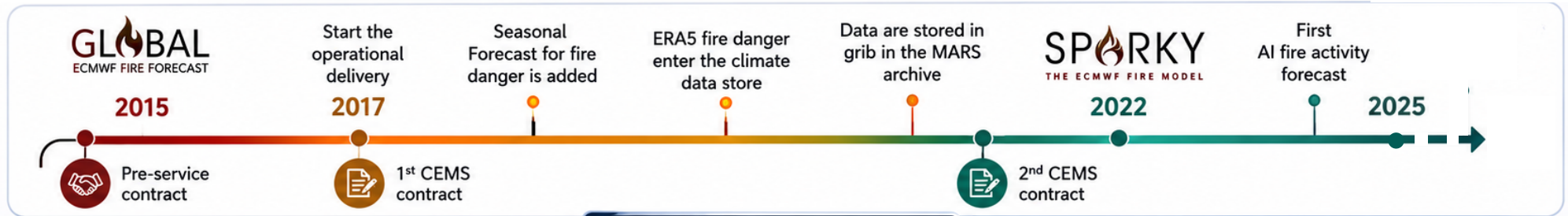
Francesca.DiGiuseppe@ecmwf.int

Contributions from Joe McNorton

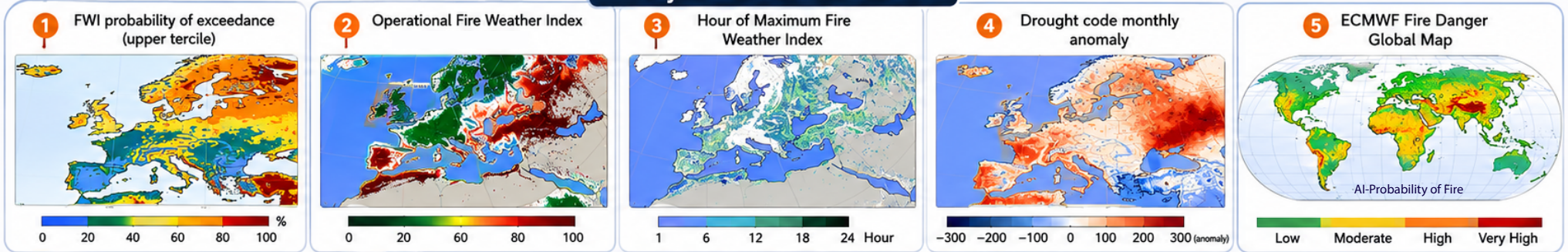
SPARKY
THE ECMWF FIRE MODEL



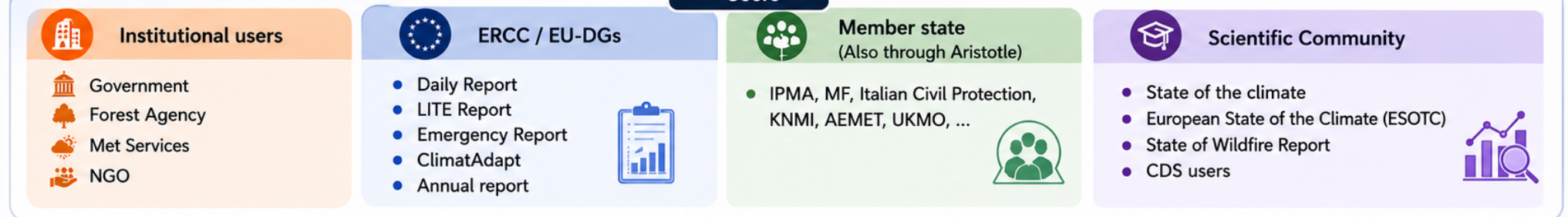
10 Years of Fire at ECMWF with Copernicus



Key Fire & Weather Datasets



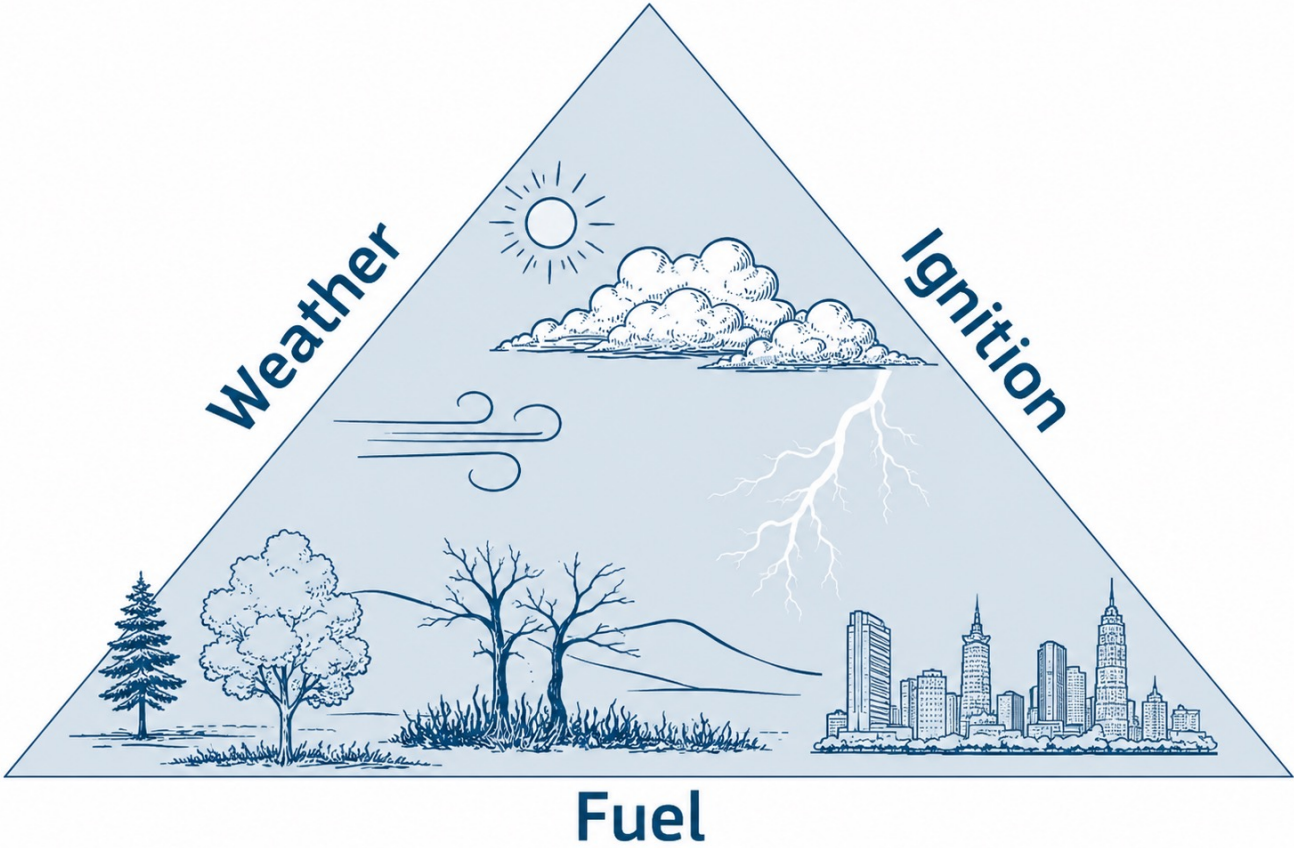
Users



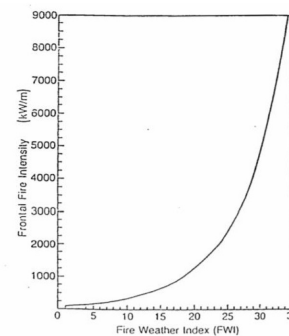
Fire forecast based on fire weather indices

From days to seasonal prediction

The fire triangle



Example of Fire danger index “meaning” (FWI)

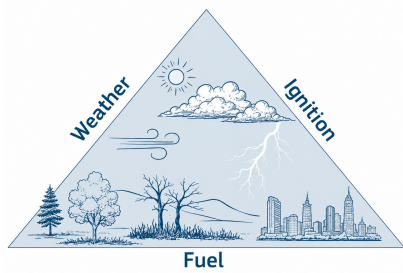


Fire Danger Ratings give you an indication of the consequences of a fire, if one was to start. The higher the fire danger, the more dangerous the conditions.

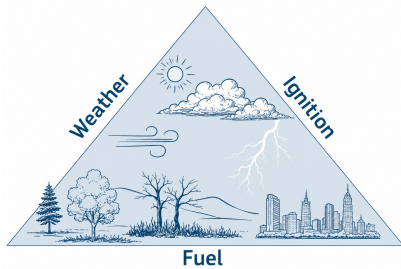
However it does not say if a fire has been ignited

Alexander, M.E.; De Groot, W.J. 1988. Fire behavior in jack pine stands as related to the Canadian Forest Fire Weather Index System. Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. Poster with text.
Quintilio, D.; Fahnestock, G.R.; Dubé, D.E. 1977. Fire behavior in upland jack pine: the Darwin Lake Project. Canadian Forest Service, Northern Forestry Centre, Edmonton, AB. Information Report NOR-X-174.

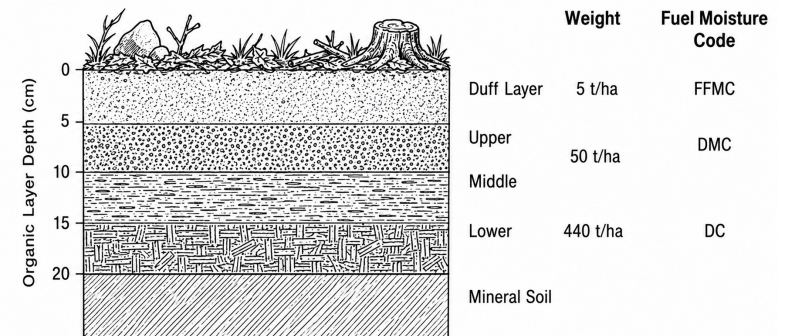
Assumptions and simplifications of the fire weather indices



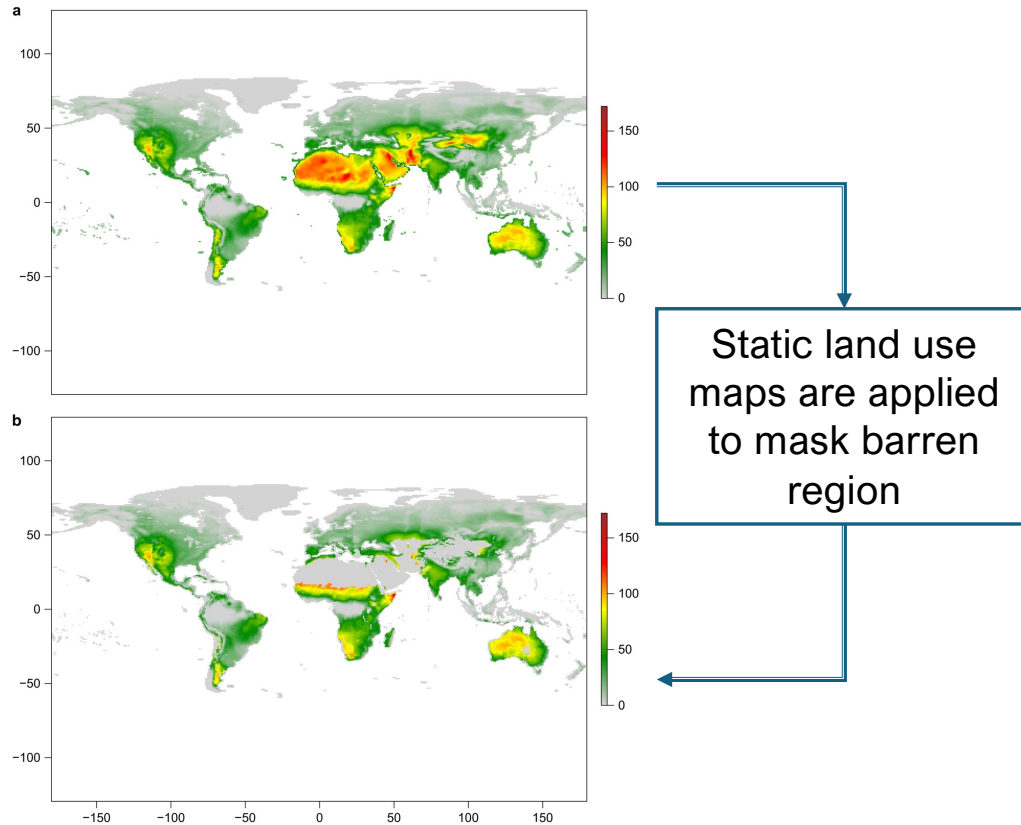
Fuel is imbedded into the equations which are calibrated for a specific fuel type (Boreal forest)



Ignition is not considered



Fire Danger forecast relies on weather anomalies and does not consider fuel availability



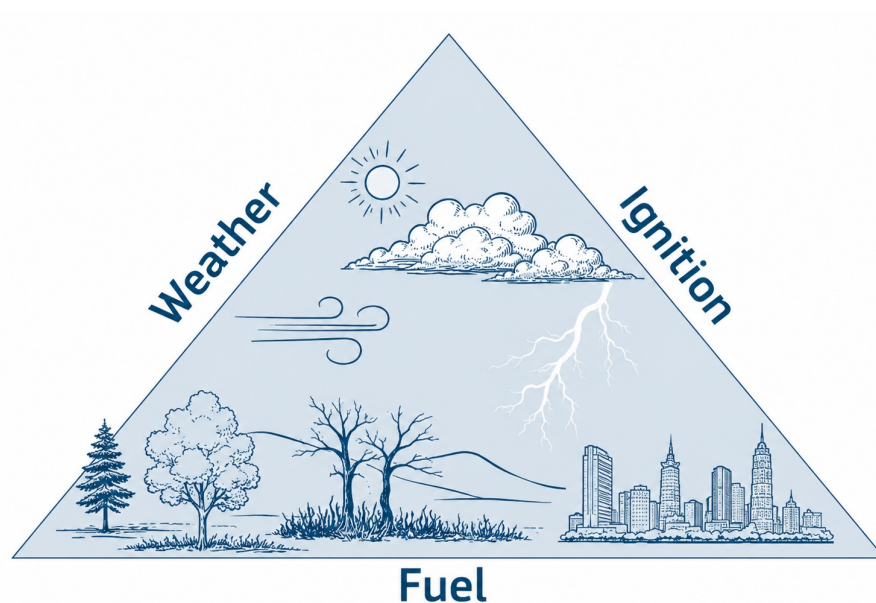
Fire weather indices are calculated from daily temperature, relative humidity, wind speed and rainfall . Not accounting for fuel leads to unrealistic results when applied globally.

Over deserts, for example, fire danger is usually very high because of the dry conditions, but fires are impeded by the lack of biomass to burn. Static maps are usually applied to mask out barren areas.

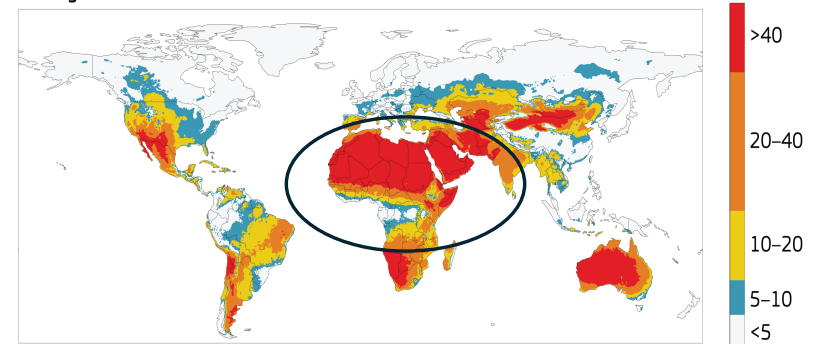
Figure from Vitolo, C., Di Giuseppe, F., Krzeminski, B. *et al.* A 1980–2018 global fire danger re-analysis dataset for the Canadian Fire Weather Indices. *Sci Data* 6, 190032 (2019).

Can we move from abstract concepts like FWI to metrics with meaning:

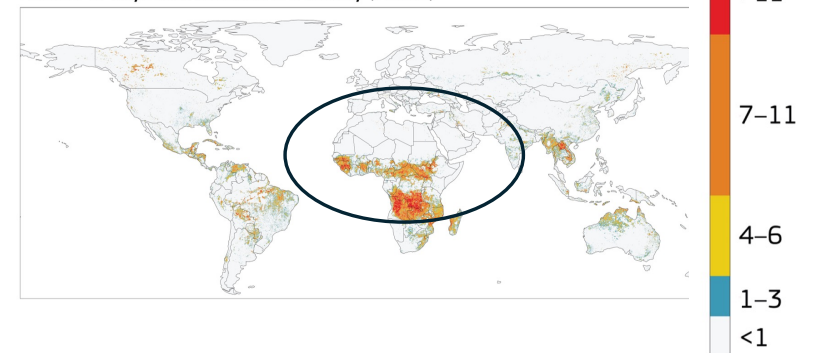
On a given day what is the probability that a fire will occurring in each area?



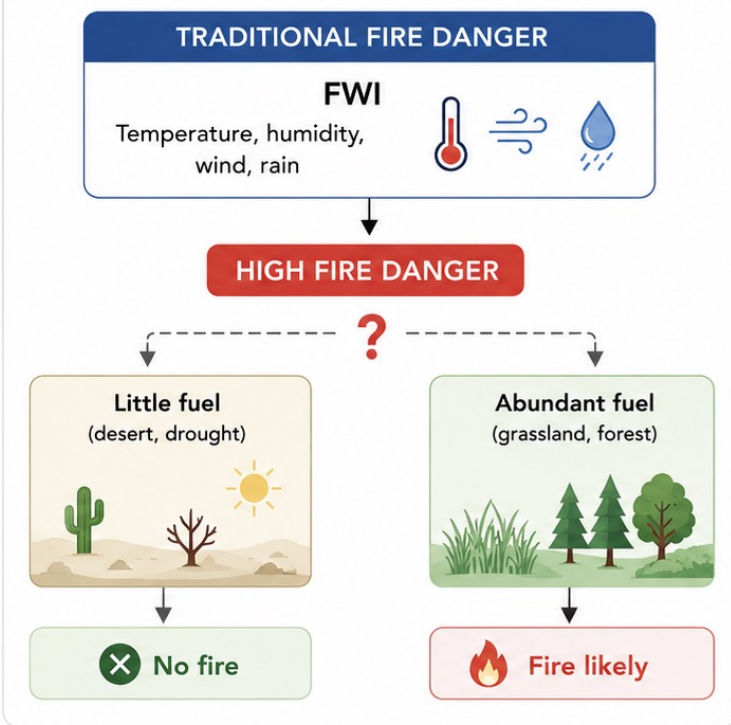
Average Fire Weather Index



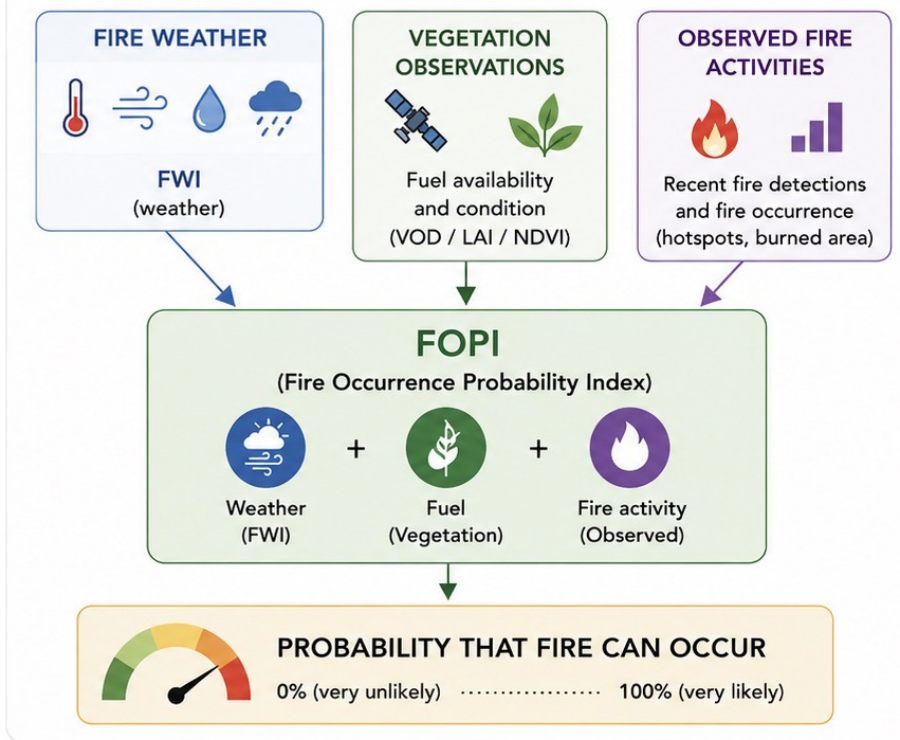
Number of days with recorded fire activity (MODIS)



WHY WEATHER ALONE IS NOT ENOUGH TO PREDICT FIRE OCCURRENCE



THE FOPI CONCEPT



FWI answers:
"Could a fire spread?"

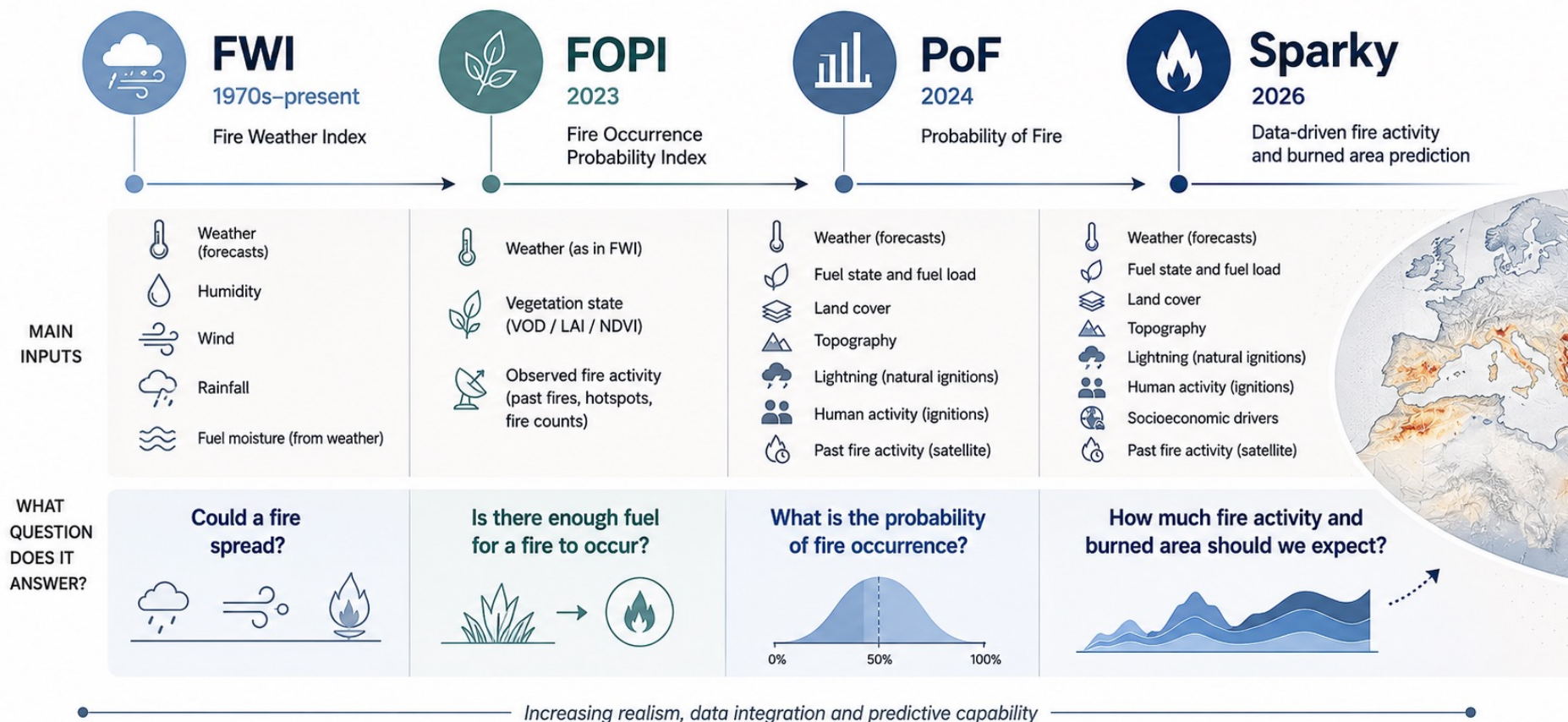


FOPI answers:
"Is there enough fuel available for a fire to occur?"

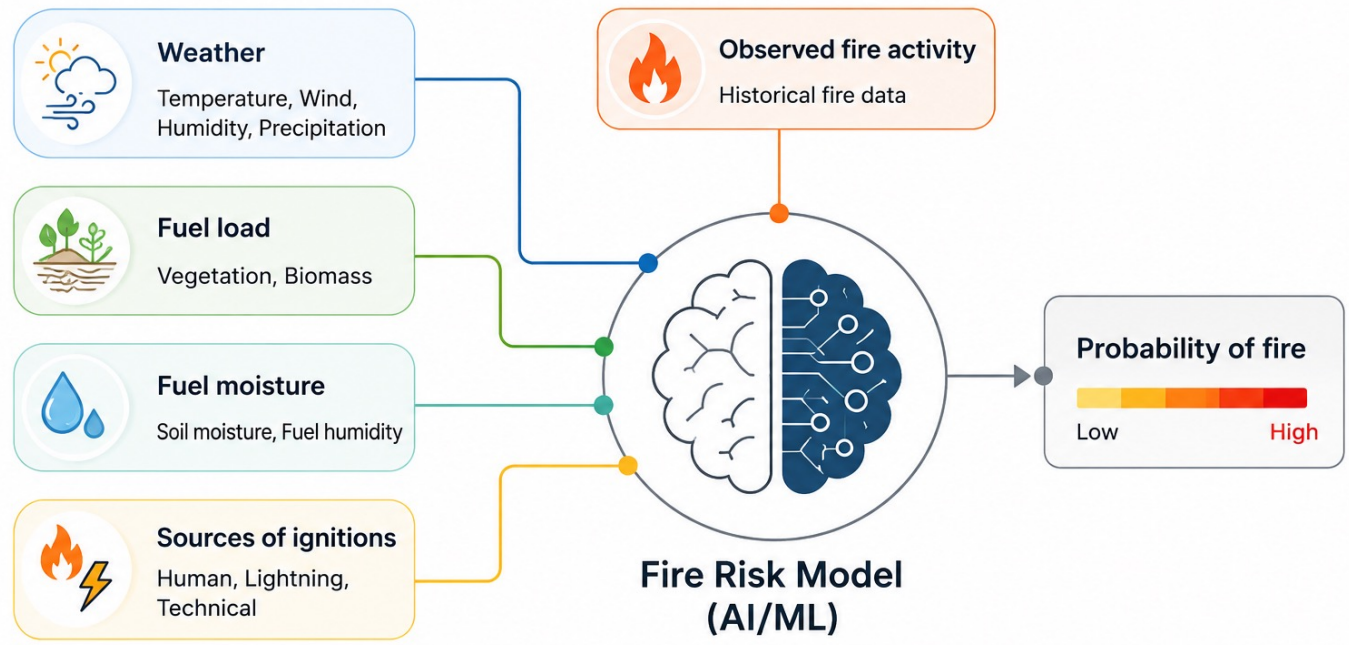
F. Di Giuseppe: Accounting for fuel in fire danger forecast: the fire occurrence probability index (FOPI), *Env. Res. Letters* (2023)

Evolution of ECMWF fire prediction systems

From weather-based fire danger to data-driven fire activity and burned area prediction



SPARKY-Probability of fire

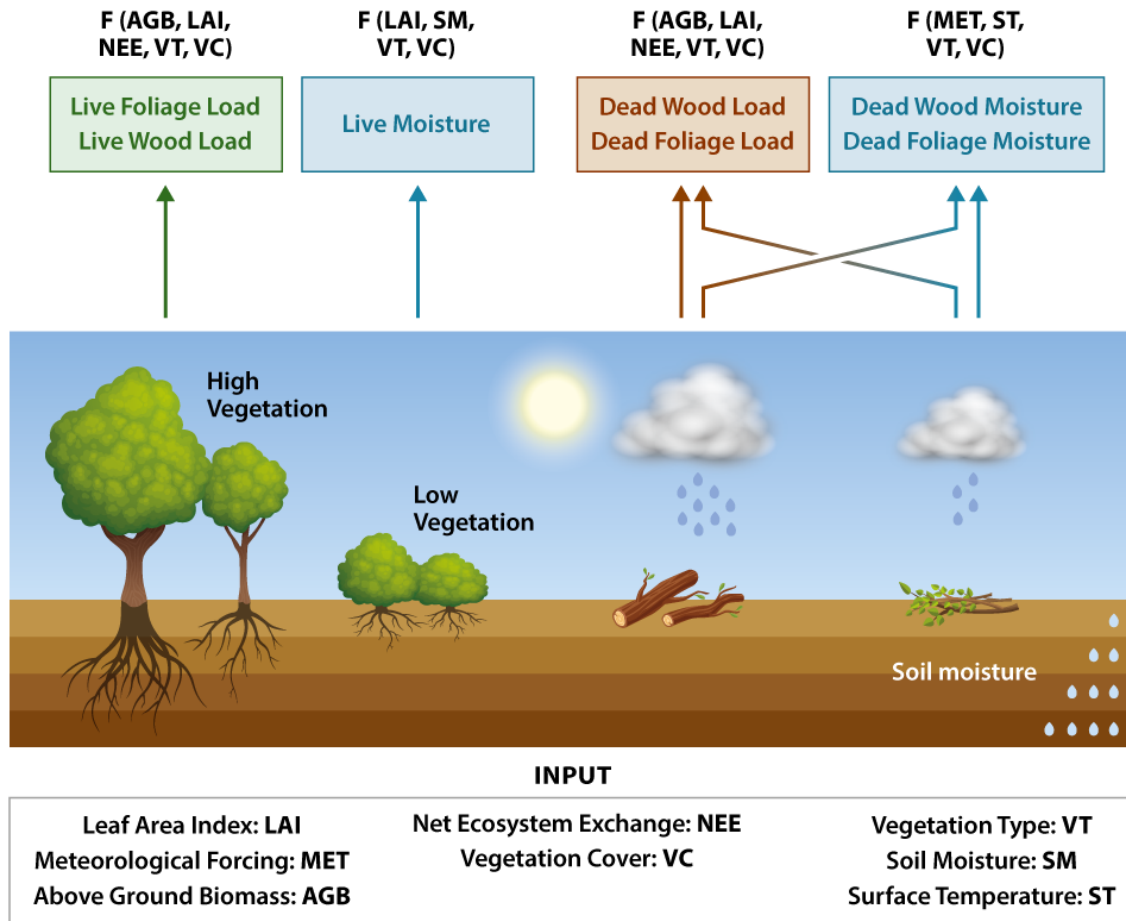


How do you achieve the skill of the PoF? With a lot of data

2m Temperature	Weather	Daily	ERA5-Land	Muñoz-Sabater et al. 2021
2m Dewpoint Temperature	Weather	Daily	ERA5-Land	Muñoz-Sabater et al. 2021
10m Wind Speed	Weather	Daily	ERA5-Land	Muñoz-Sabater et al. 2021
Precipitation	Weather	Daily	ERA5-Land	Muñoz-Sabater et al. 2021
Live Leaf Fuel Load	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Live Wood Fuel Load	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Dead Foliage Fuel Load	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Dead Wood Fuel Load	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Live Fuel Moisture Content	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Dead Foliage Moisture Content	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Dead Wood Moisture Content	Fuel	Daily	Fuel Model	McNorton et al. 2024a
Vegetation Optical Depth	Fuel	Monthly	Satellite (SMOS)	Wigneron et al. 2021
Low Vegetation LAI	Fuel	Monthly	Satellite (multi-sensor)	Boussetta and Balsamo, 2021
High Vegetation LAI	Fuel	Monthly	Satellite (multi-sensor)	Boussetta and Balsamo, 2021
Type of Vegetation	Ignition	Fixed	ECLand	Boussetta et al. 2021
Urban Fraction	Ignition	Fixed	ECLand	McNorton et al. 2023
Orography	Ignition	Fixed	ECLand	Boussetta et al. 2021
Lightning	Ignition	Daily	ERA5	Hersbach et al. 2020
Population Density	Ignition	Fixed	Gridded Population of the World (GPW) v4 – SEDAC (2020, 2.5 arcmin to 9km)	Center for International Earth Science Information Network – CIESIN
Road Density	Ignition	Fixed	Global Roads Inventory Dataset – 2018	Meijer et al. 2018

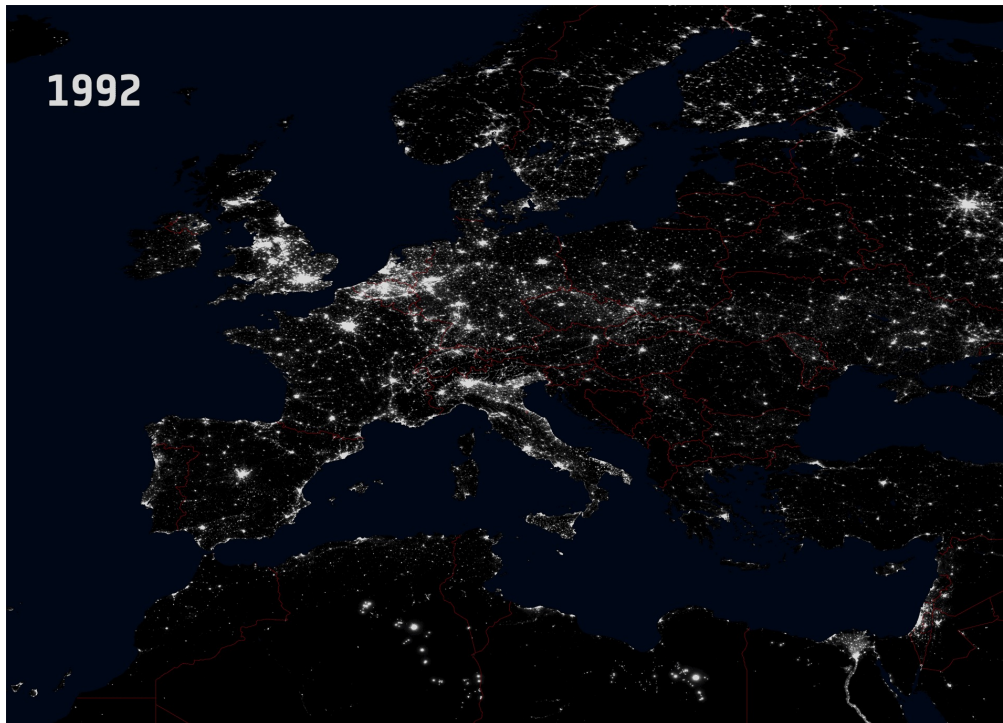
SPARKY-Fuel

Daily
~9 km
Global
Dataset



Beyond Weather and Fuel

To integrate the socioeconomic controls on fire behaviour we source novel datasets that whilst suffering from latency and temporal frequency issues represent the spatial extent of human influenced burning.

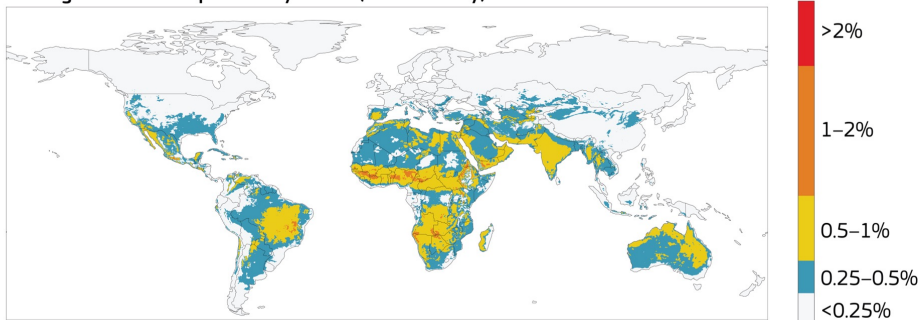


Variable	Category	Variable	Category
Live Leaf Load	Fuel	Precipitation	Weather
Live Wood Load	Fuel	2m Temperature	Weather
Dead Foliage Load	Fuel	2m Dewpoint Temperature	Weather
Dead Wood Load	Fuel	10m Wind Speed	Weather
Dead Foliage Moisture	Fuel	Type of High Vegetation	Fuel/Ign
Dead Wood Moisture	Fuel	Type of Low Vegetation	Fuel/Ign
Live Fuel Moisture	Fuel	Urban Cover	Ignition
Low Vegetation LAI	Fuel	Lightning Intensity	Ignition
High Vegetation LAI	Fuel	Population Density	Ignition
High Vegetation Cover	Fuel	Total Road Length	Ignition
Low Vegetation Cover	Fuel	Orography	-

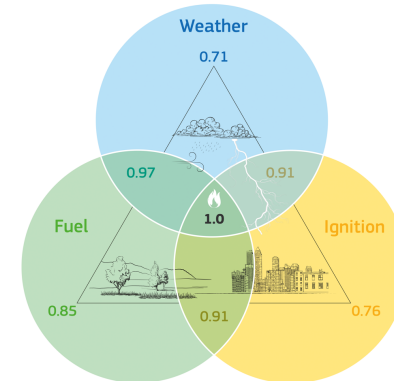
And many more...

Using weather data alone this is not possible.

Average data-driven probability of fire (weather only)



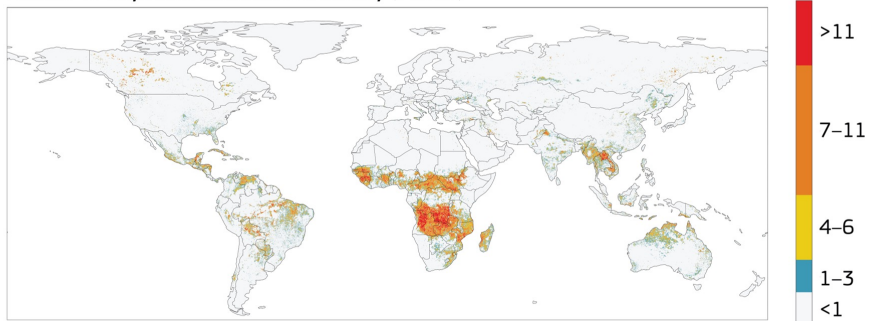
Quality of the fire predictive model



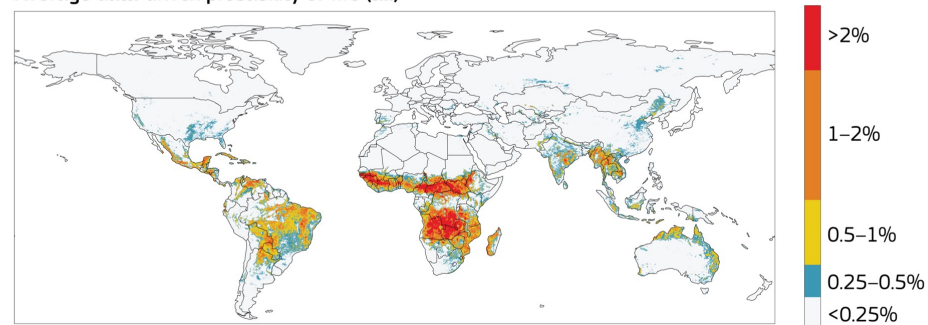
Di Giuseppe et al Nature Comm 2025

But with more data it is...

Number of days with recorded fire activity (MODIS)



Average data-driven probability of fire (all)



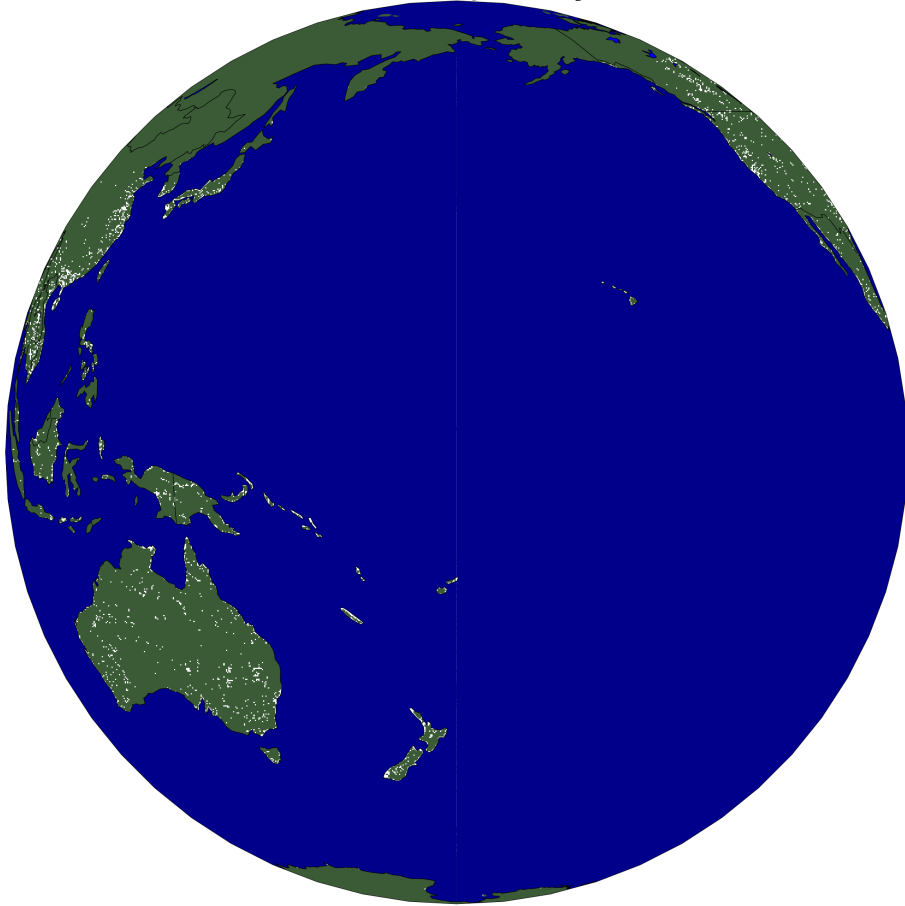
© ECMWF June 3, 2026

SPARKY- probability of Fire

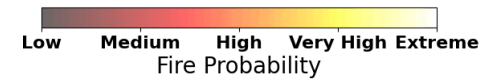
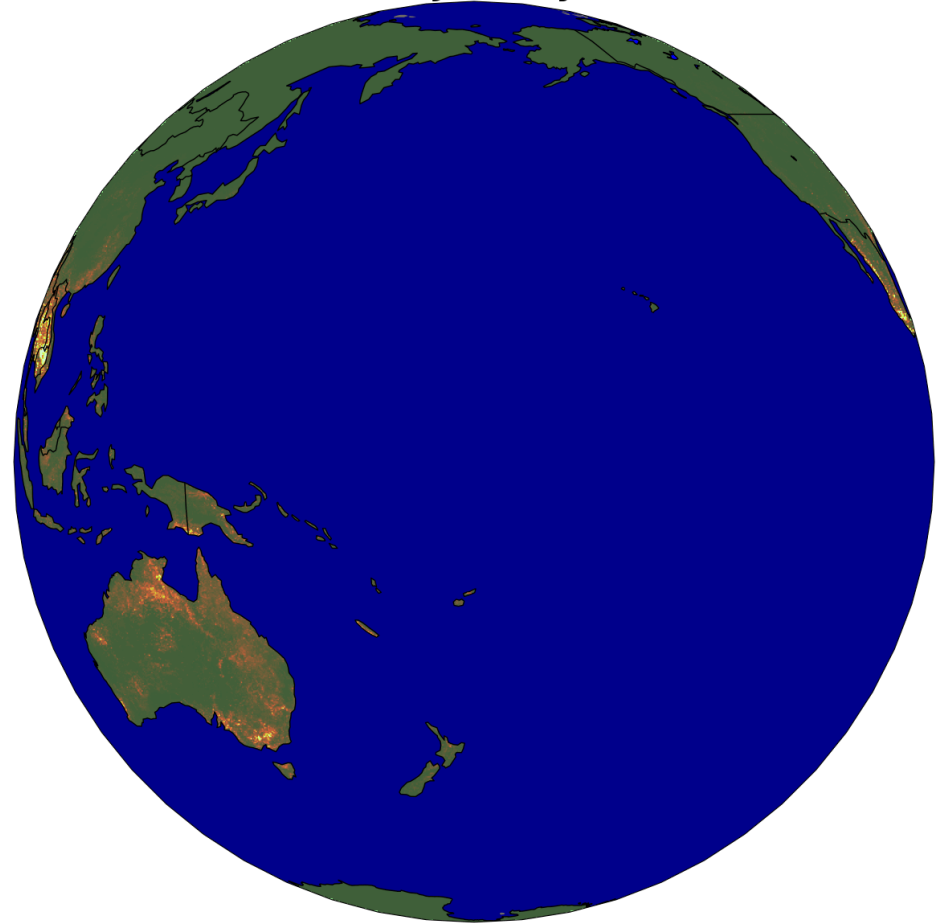
1. The **Global Probability of Fire (PoF)** has been running in real time at **ECMWF** since 2023.
2. The model combines **numerical weather predictions, land surface models, and satellite observations.**
3. PoF is based on an **Extreme Gradient Boosting (XGBoost)** algorithm using a **probabilistic classifier.**
4. It is trained on active fire detections from **MODIS, VIIRS, GOES-E, Meteosat, and Himawari** satellites.
5. The model produces a **daily 10-day forecast** at **9 km** and **1 km** resolution globally.

Advantages of a data-driven fire forecast

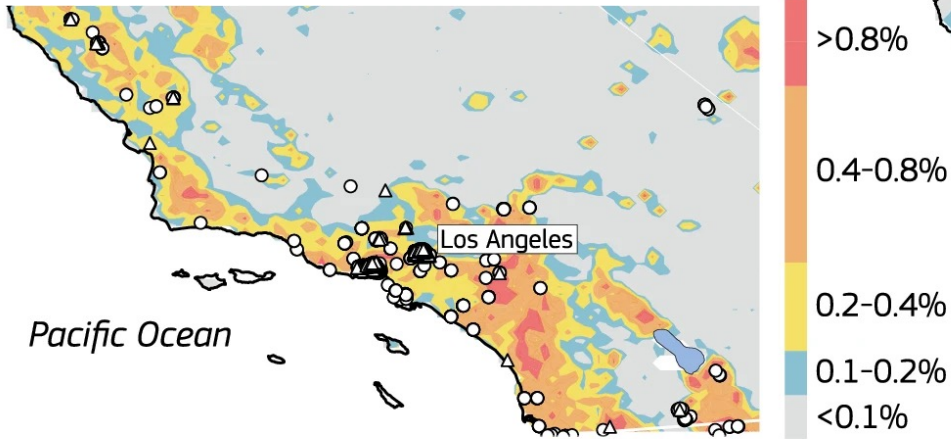
Observed Fires for January 01, 2024



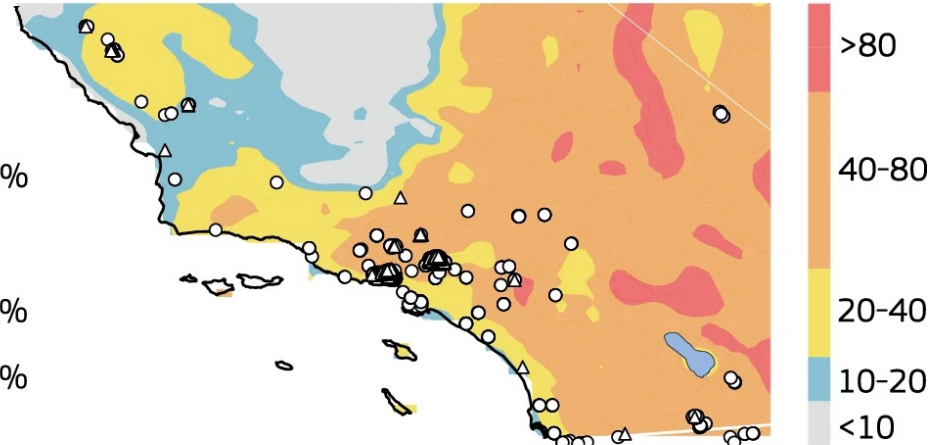
Forecast for January 01, 2024



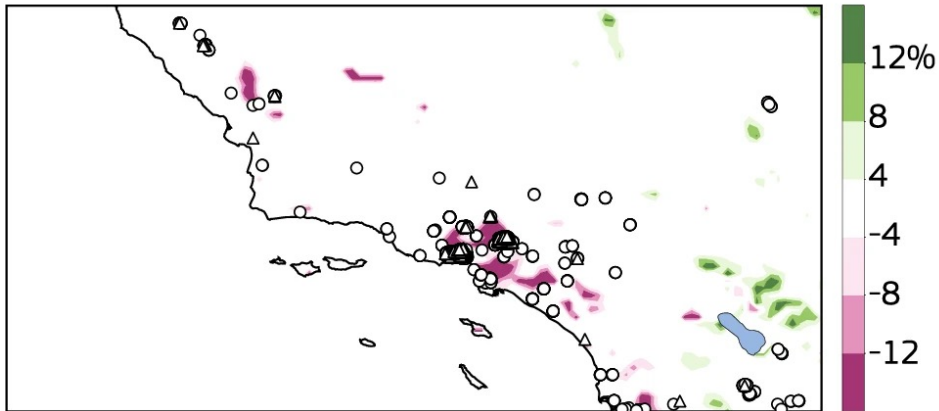
Sparky - PoF



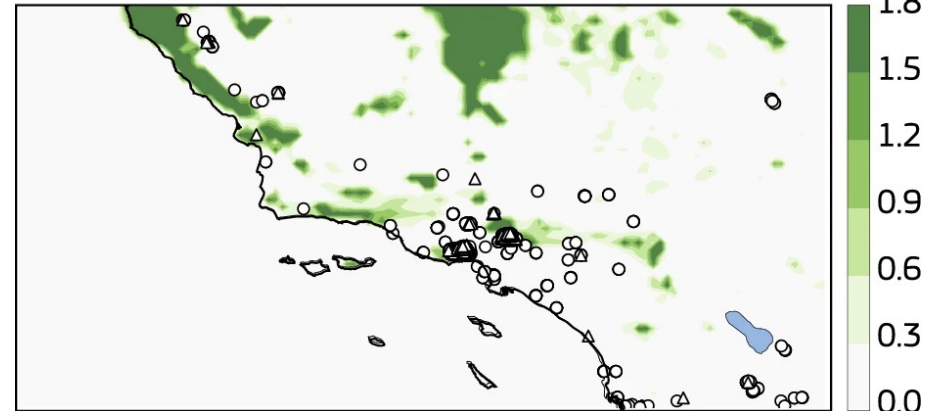
Fire Weather Index (ECMWF/EFFIS)



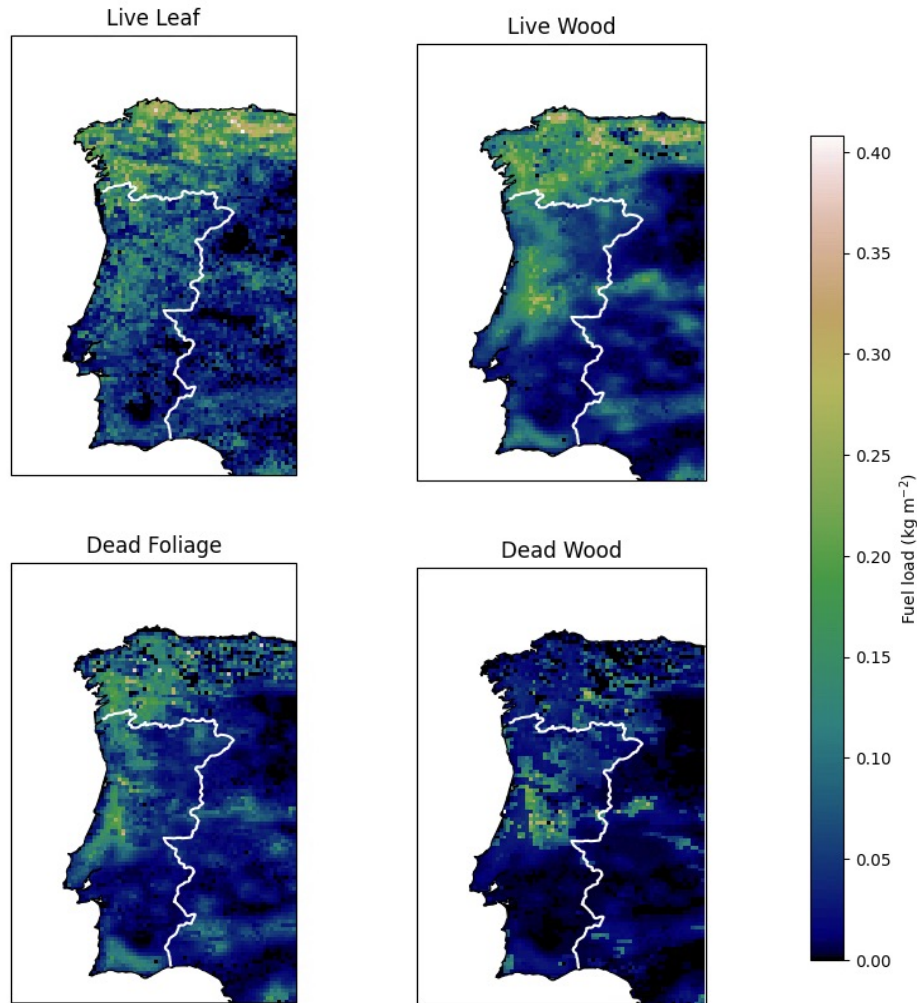
Dead Fuel Moisture Content Anomaly 7-1-2025



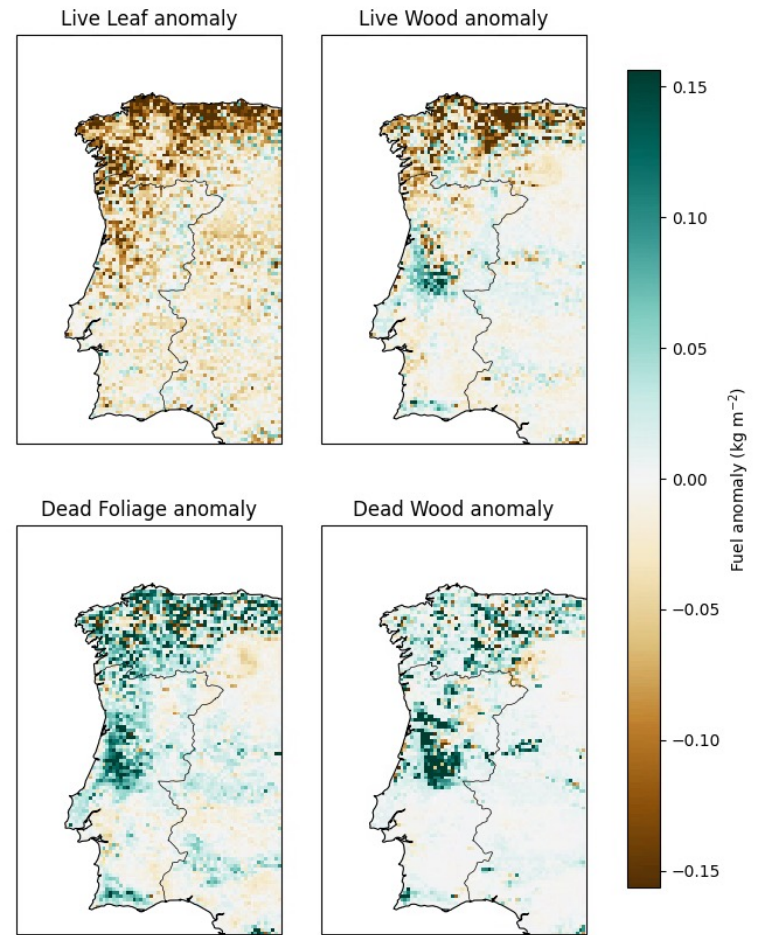
Total Fuel Load (kg m²) 7-1-2025



A case study for Portugal

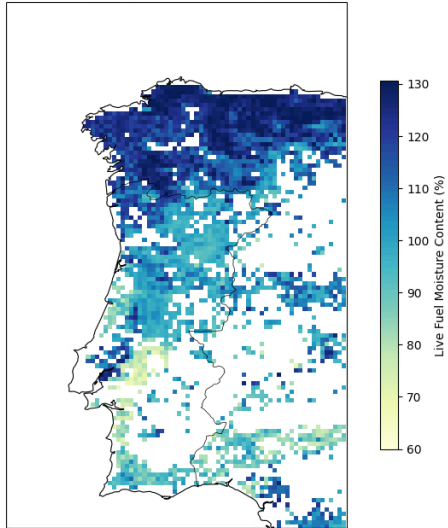


Fuel anomalies (2025 – August climatology)

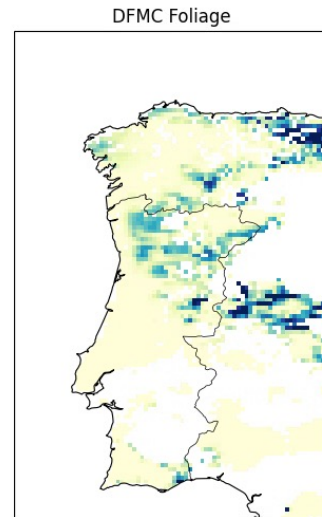


A case study for Portugal

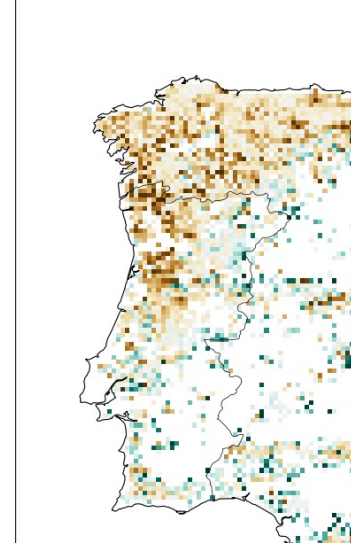
LFMC over Portugal (LLE > 0.1 mask) - 15 Aug 2025



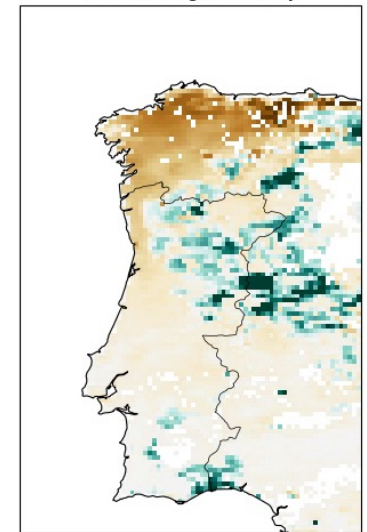
DFMC masked by fuel load (DFO > 0.1) - 15 Aug 2025



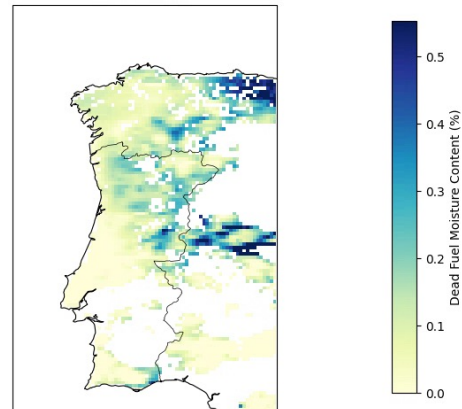
LFMC anomaly (2025 - climatology) - masked by LLE > 0.05



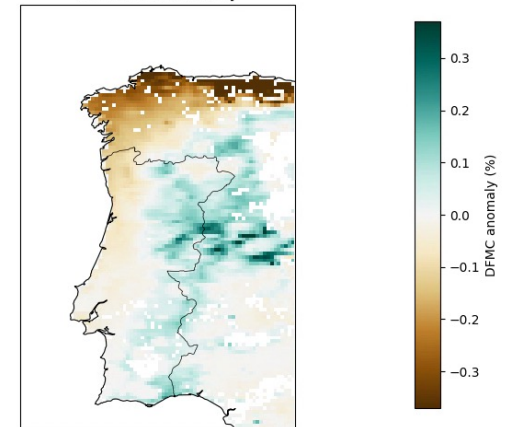
DFMC Foliage anomaly



DFMC Wood

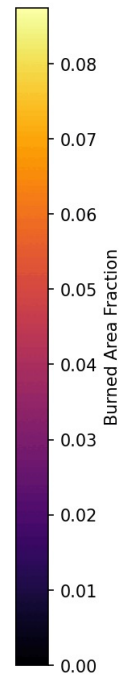
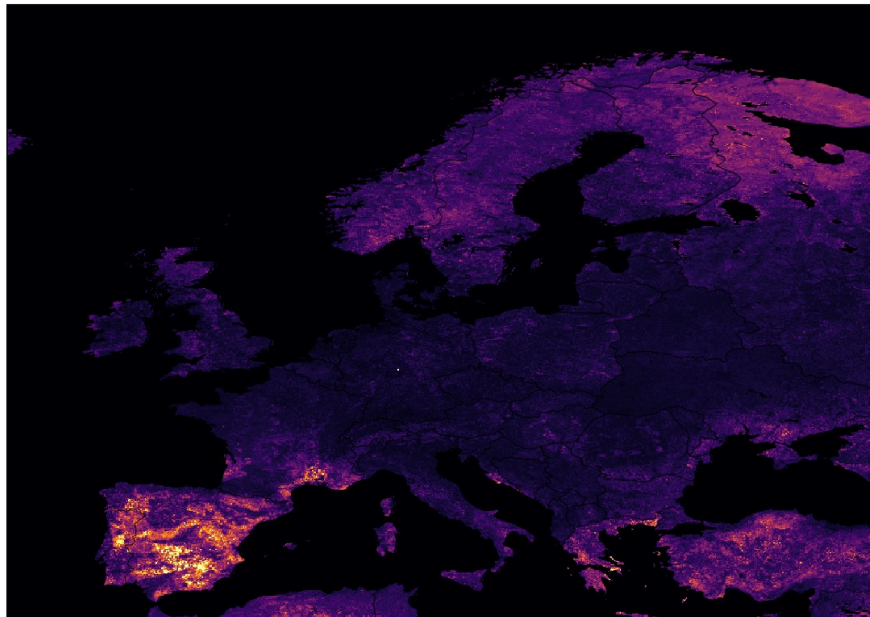


DFMC Wood anomaly

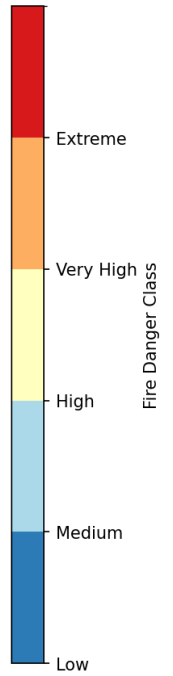
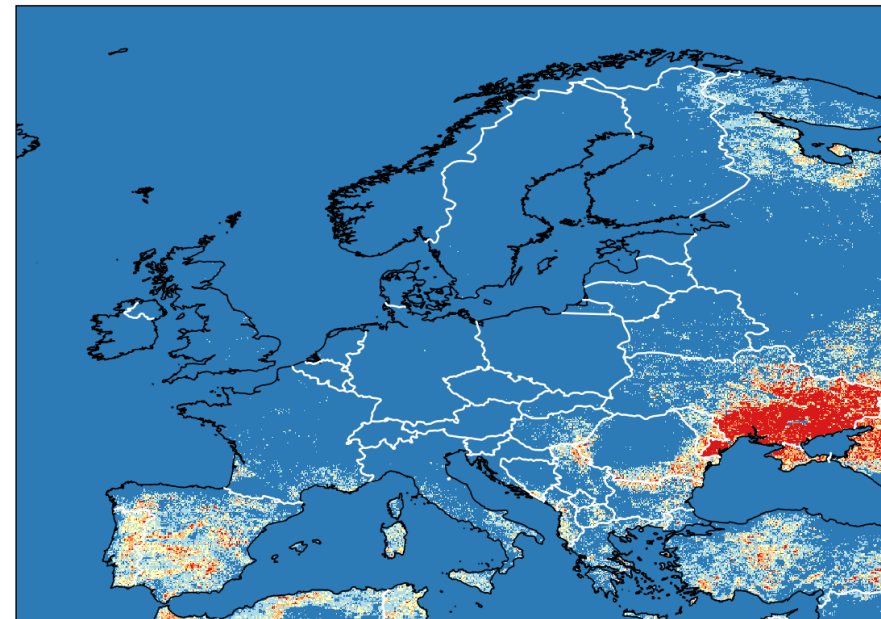


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Predicted Burned Area Fraction
2025-08-06

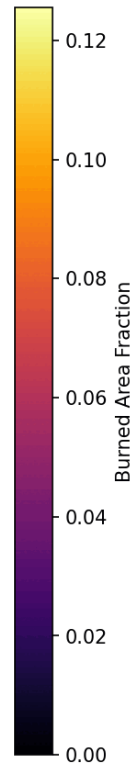
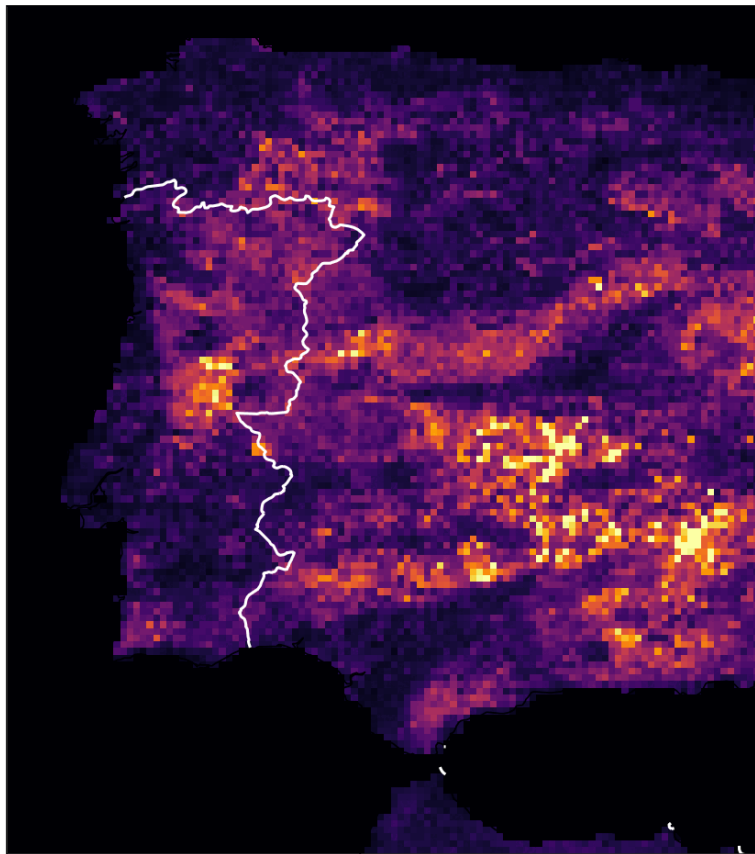


Fire Danger Classification
2025-08-06

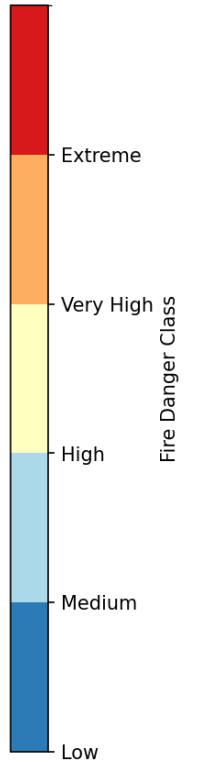
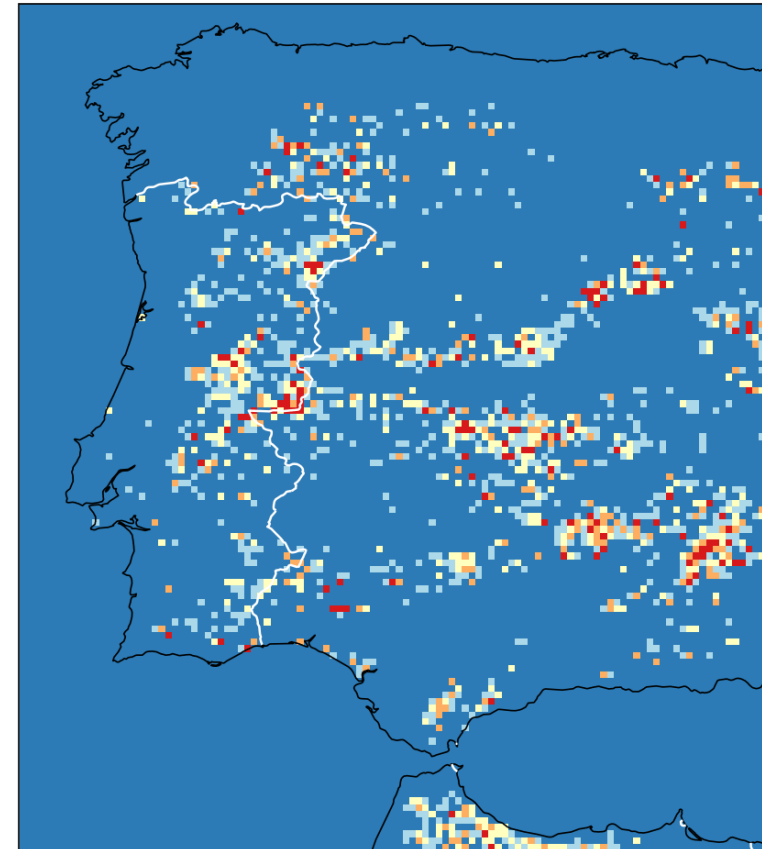


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Predicted Burned Area Fraction
2025-08-06

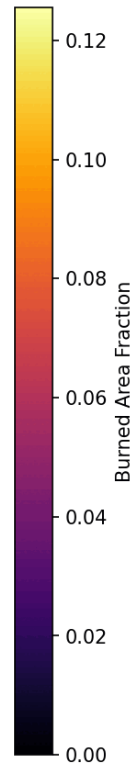
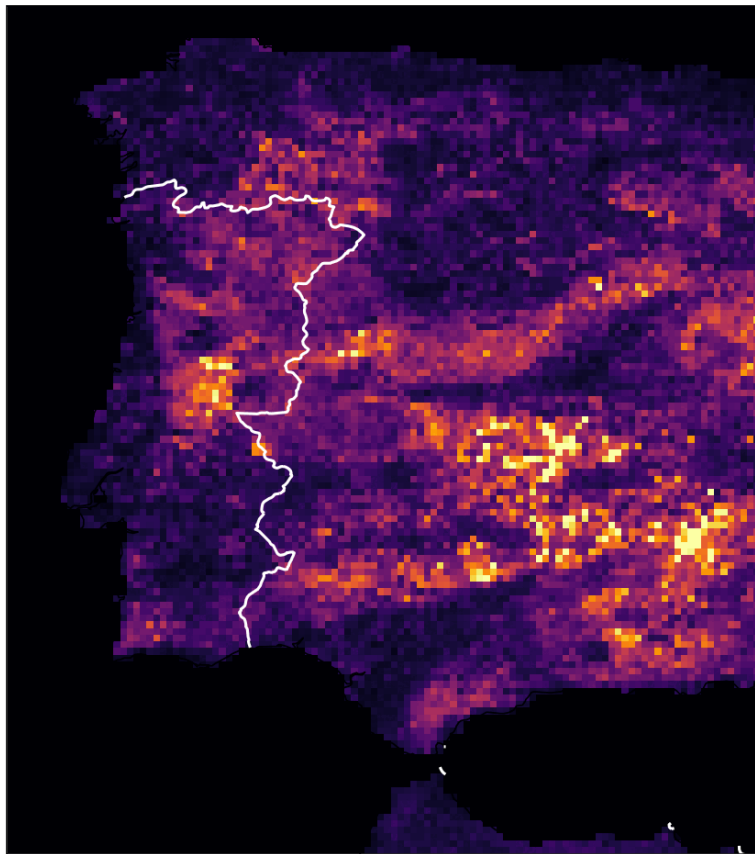


Fire Danger Classification
2025-08-06

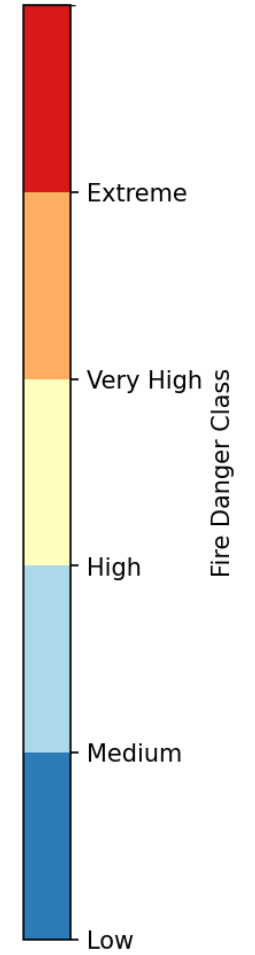
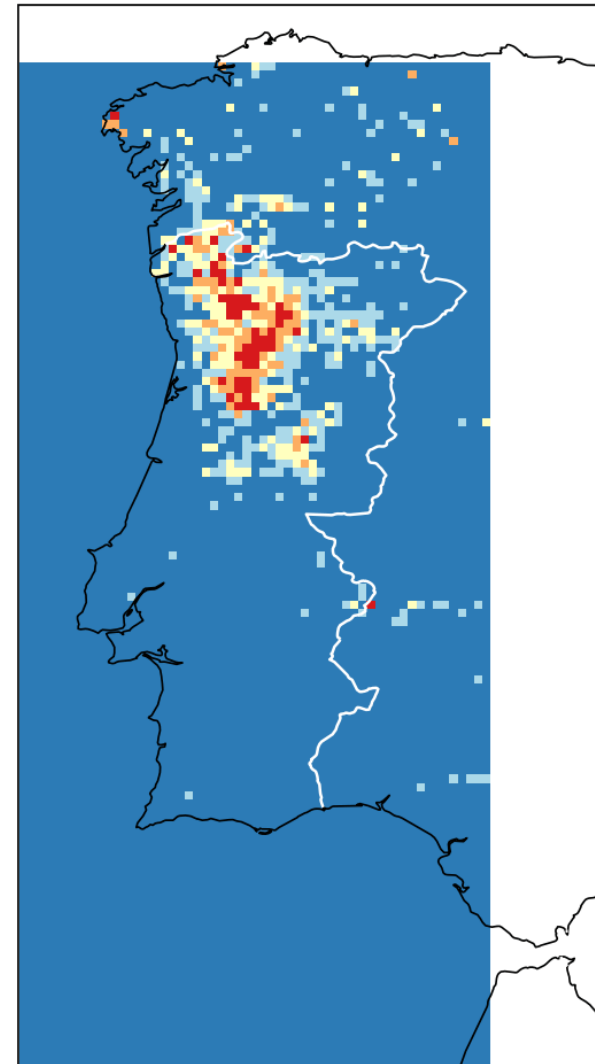


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Predicted Burned Area Fraction
2025-08-06



Fire Danger Classification
2025-08-06



Currently Available Products

- Global Sparky-PoF 1km/9km
- Sparky-Fuel
- Sparky-BA (if a fire occurs, how big?)
- Sparky-FRP (if a fire occurs how intense?)

Possible Products for Future/Collaboration

- Sparky-Evolution
- Sparky-RoS

PoF Toolbox: Democratizing Fire Risk Modelling

Reproducible notebooks for
building local PoF models with your
own data





www.ecmwf.int