Operational Forecasting Assistance for Forest and Vegetation Fires at Météo France

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Meteorological assistance to help prevent and fight wildfires has existed in France for a long time. In 2023, following an exceptionally busy 2022 wildfire season over the French territory, this service was stepped up significantly. This article briefly presents a few aspects of the current wildfire system implemented at Météo France as of 2024.

A brief history

Meteorological assistance for forest fires began in France in the 1960s. To ensure the protection of Mediterranean forests, which are particularly vulnerable to wildfires, there has been close collaboration for several decades between Civil Protection, the National Forestry Office (ONF) and Météo France (previously known as the National Meteorological Service). Initially tested on a single department (the French administrative unit) with a meteorological fire danger map and a text bulletin, the scope of the fire assistance provided was gradually extended to the entire French Mediterranean area in 1979. To create a wildfire forecast, the forecaster assesses and examines "fire" indices. Fire indices have evolved considerably over the years as a result of research and feedback from various forest fire-fighting services (Civil Protection and ONF).

Prior to 1987, a single fire index was used to determine the risk of wildfire. This single index combined modelled vegetation dryness with forecast wind (called the "Thornthwaite reserve") [1].

Thereafter, three new fire indices were developed: one qualifying the overall level of fire risk, another indicating fire *outbreak potential* and the last estimating fire propagation speed (South-East Propagation Index, pronounced “Ipse” in French). From 1995 onwards, the *Canadian Forest Fire Weather Index* (FWI, “IFM” in French) [2] also began to be incorporated into wildfire modelling work. Since then, weather forecaster and firefighter experience and expertise, combined with these advances in numerical weather prediction have contributed to notable improvements in the quality and reliability of fire indices and the spatial resolution of fire forecasting.

The French firefighting doctrine

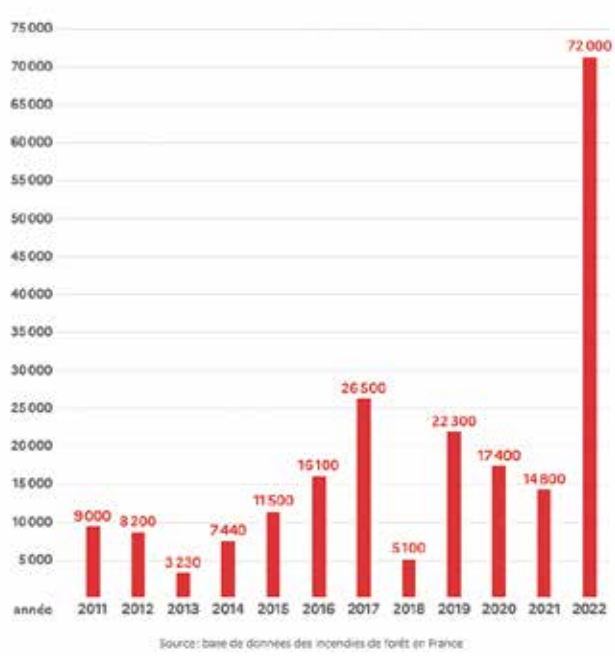
The Civil Protection forest fire-fighting doctrine advises that any wildfire must be attended and targeted within 10 minutes in order to prevent the fire spreading across an area of 1 hectare (10,000 m^2) and becoming uncontrollable. This theory is based on the predicted time needed to successfully mobilise land and air fire-fighting resources, however the operational danger of the fire is often also closely linked to the day's weather conditions.

2022: An exceptional year with wildfires in France and Europe

The end of 2021 into early 2022 saw a period of low rainfall, followed by particularly hot weather in April and May 2022. The subsequent summer of 2022 was dry and very hot, with successive heatwaves. As a result, the vegetation was particularly dry during the summer season, creating conditions highly conducive to the development of fire and leading to exceptional wildfire activity.

A total of 19,711 fires were recorded in 2022 in France burning a surface area of 72,000 hectares of forests, natural areas and crops **(Figure 1)**. This made 2022 a historic year for wildfires, not only in terms of the ecological toll the wildfire had on the environment, but also in terms of the resources that were deployed to protect the human population and control these fires. Of particular note in 2022 was the number of large scale fires and their distribution across the whole of mainland France.

A total of 90 departments recorded a significant wildfire events in 2022. During 2022 97% of fires in France were treated by fire-fighting resources before they exceeded 5 hectares, successfully achieving the goal set out in the French fire-fighting doctrine.



▲ *Figure 1: Area burnt over 11 years in France (hectares)*

Today the risk of forest fires provides concern not just for the Mediterranean region but for Europe as a whole. The total area of land in Europe affected by wildfire was more than 780,000 hectares, confirming the extraordinary intensity of this 2022 year's fires. In Spain alone, almost 10,000 fires destroyed 265,000 hectares, while in Portugal, 10,000 fires destroyed more than 110,000 hectares.

As a result of the significant wildfire activity in 2022, the French government has increased supporting resources available for fire-fighting and in response Météo France have now implemented the following:

- Increased Météo France's operational support to the French Civil Protection Service
- Introduction of a wildfire prevention tool to inform the general public of wildfires and raise the awareness of the danger of forest fires: called “Forest Weather” [3].

Using meteorology to help forecast fire danger

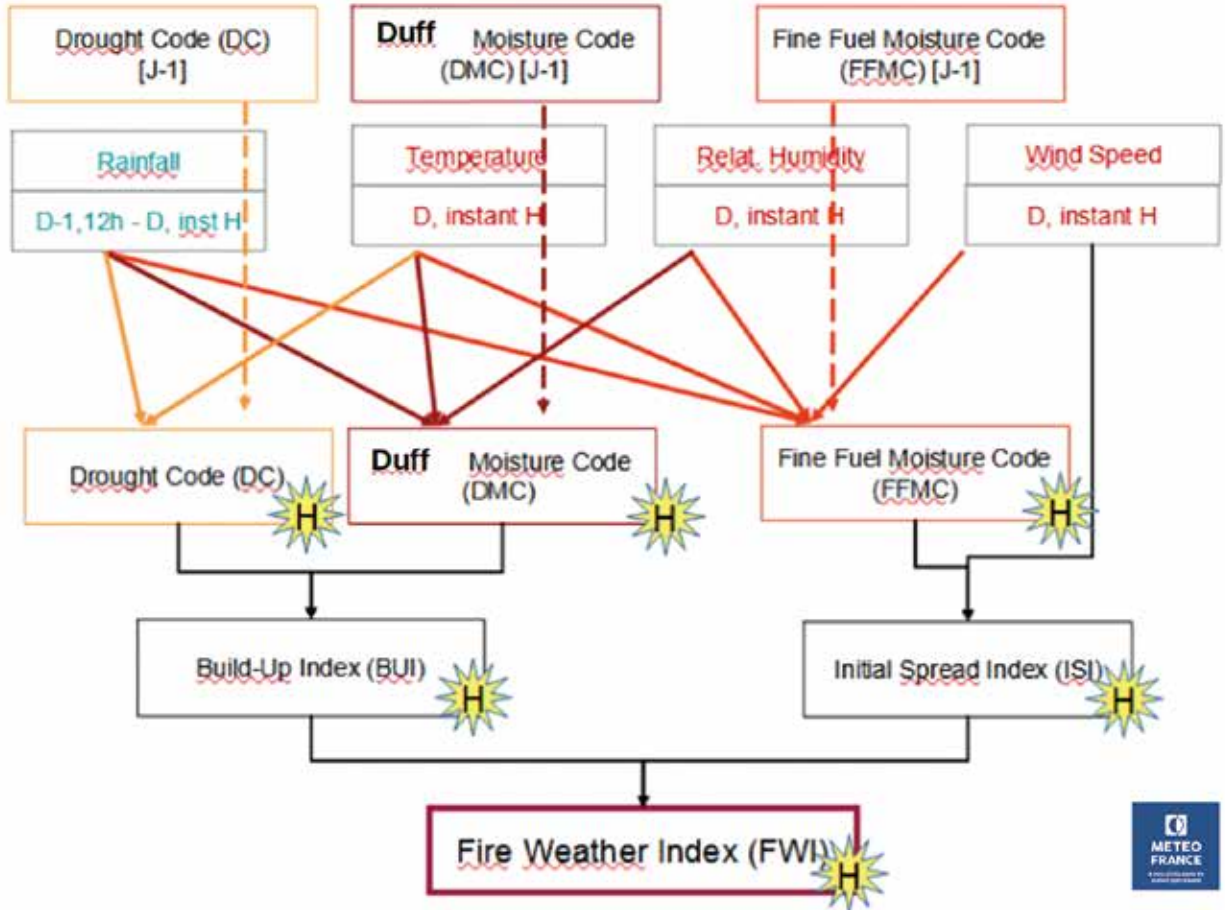
Forecasting the level of "forest fire danger” can be achieved by assessing the dryness of the living vegetation at the time together with the expected meteorological conditions.

Various specific indices have been developed to help forecast wildfire. The historical Canadian method [2] provides indices valid at 12 UTC. Météo France has adapted this model to calculate them at hourly time steps, over a range from 08 to 18 UTC. These hourly indices make it possible for the forecaster to estimate the timing of maximum wildfire risk during the day. These are known as ‘MAX indices’ (IFMx, IEPx, etc). This approach allows the forecaster to better define the danger timings for events occurring before or after 12 UTC.

To determine the level of dryness of living vegetation, a ‘*Vegetation Drought Sensitivity Index*’ (NSV2) is used. This index combines the ‘*Humus Index*’ (called IH or DMC) and the ‘*Drought Index*’ (called IS or DC) **(Figure 2)**. This NSV2 index is close to the Canadian “Build-up Index” (BUI, called ICD in French), but has been adapted to include the characteristics of French forests. In some regions actual field observations of vegetation dryness can be carried out by forestry agents which are then fed into modelling to ground truth and improve the NSV2 index for these areas.

DMC / DC	0-300	300-350	350-400	400-450	450-500	500-600	600-650	650-700	700-750	750-1000	>1000
0-20											
20-50											
50-70											
70-110											
110-170											
170-200											
200-250											
>250											

▲ *Figure 2: Showing how the ‘Humus Index’ (DMC, columns) and ‘Drought Index’ (DC, rows) are combined to provide the ‘Vegetation Drought Sensitivity Index’ (NSV2).*



▲ *Figure 3: Components of the IFMx (FWI) System. Calculation of the components "H" is based on consecutive hourly data.*

Once the living vegetation drought has been validated, the forecaster studies the day's weather conditions, assessing:

- Working Wind: the average wind direction, strength and gusts
- Temperature
- Air Humidity
- Expected Rainfall
- Cloud Cover

The forecaster assesses the variation of these parameters over the day, focusing on the most sensitive time slot, and studies their impact on various fire indices, in particular the '*Fire Weather Index*' (IFMx, FWI) which is used to determine the meteorological fire danger level **(Figure 3)**.

Like the NSV2, the *'Fire Weather Index'* is also corrected for vegetation conditions in France to create the *'Integrated Danger'* as studies have shown that this index is affected by significant biases in the case of light or severe drought in living vegetation. In turn the *'Meteorological forest fire danger'* is determined and expressed on a scale of 6 levels, from Low to Extreme (the Extreme level being possible only after expert consideration, **Figure 4**).

This information is supplemented by a *'Danger Index for dead vegetation*' (IEPx) it is a combination of the 'Fine Fuel Moisture Code' (FFMC, ICL in French) and the 'working wind' parameter. This index is used to characterise the danger of fires breaking out and spreading **(Figure 5)**. It is used

NSV2	IFMx		10		30		50		80	
		F	10	F	30	F	50	L	80	M
		F	10	L	30	L	40	M	60	S
		F	10	L	30	M	50	S	80	T
		L	10	L	30	M	50	S	80	T
		L	10	M	30	S	50	S	80	T

▲ *Figure 4: 'Integrated danger' is a combination of 'Vegetation Drought Sensitivity' (NSV2) and 'Fire Weather Index' (IFMx, FWI). The scale is Low (F), Light (L), Moderate (M), Severe (S), Very Severe (T). An Extreme class is possible for critical drought situations.*

Wind / FFMC	< 80	80 – 85	85 – 89	89 – 93	93 – 96	96 – 97	> 97
0 – 5 m/s							
5 – 10 m/s							
10 – 15 m/s							
> 15 m/s							

▲ *Figure 5: Scale of IEPx, from level 1 (blue) to level 6 (purple).*

to estimate the possibility of fire "outbreaks". It is particularly relevant for crop and low vegetation (grass) fires, and outside the summer season.

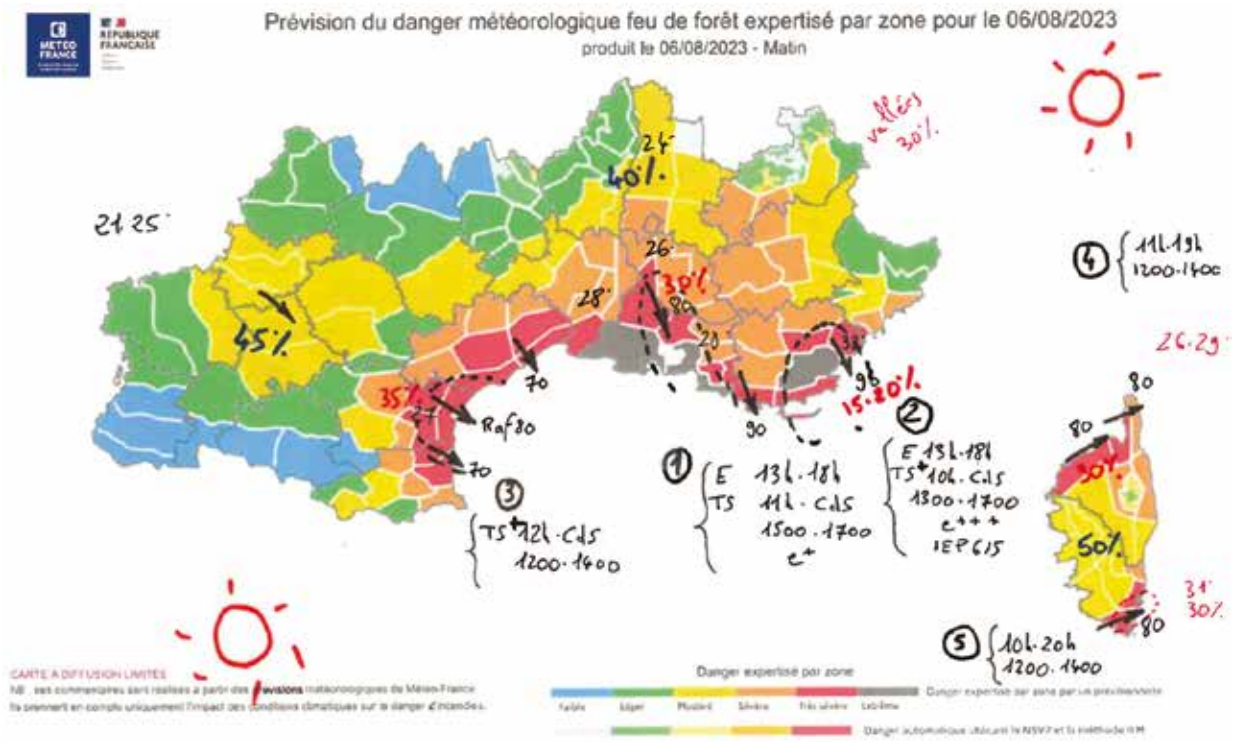
These products are then combined to form the wildfire advice and guidance production provided to the Civil Protection below **(Figure 6)**.

Operational support

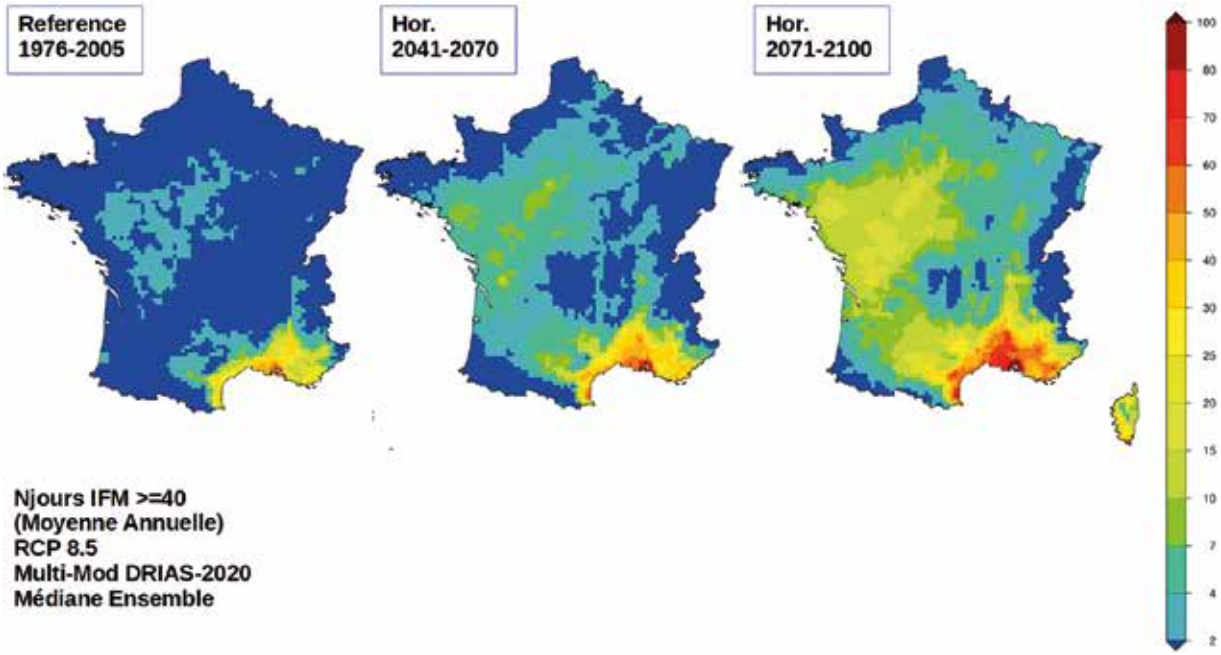
Since 2023, Météo France has provided wildfire forecasting assistance to the whole French territory. In terms of Civil Protection, a national coordination centre for fire-fighting resources has been set up in Nîmes in the south of the country. It operates daily between June and September. A forecaster is seconded to the Centre where they provide the meteorological fire danger assessed on a national scale for the current day (D), the following day (D+1) and gives a trend in the evolution of these dangers from D+2 to D+7, depending on the weather scenario forecast.

The forecaster responds in real time to Civil Protection requests. The system has been strengthened in the south-west of France and is predominantly modelled on the historic one in place in the Mediterranean area with local fire-fighting authorities. It is at this regional level that the most accurate forecasts are provided (for sub-departmental sensitivity areas), thanks to forecasters who are particularly experienced in this type of hazard. This system should be extended to the other French regions in the coming years.

Outside the summer season, wildfire forecasters provide basic national forecasts on a weekly basis to the civil protection authorities. In addition, other Météo France forecasters provide the ERCC with fire weather hazard data as part of the ARISTOTLE project [4].



▲ *Figure 6: Example of production provided to Civil Protection. Morning "annotated" map of the assessed "meteorological forest fire" danger and relevant weather parameters/fire indices valid for the Day, 06/08/2023.*



▲ *Figure 7: Maps of annual average number of days with IFM □40 for RCP8.5, by time horizon, Ensemble Median [6].*

Effects of climate change and provisional conclusion

Global warming, combined with changes in forest vegetation as fuels, will have very tangible effects on forest fires in France [5]:

The following affects are expected in the future in response to these changes:

- Intensification: an 80% increase in the land areas burnt by wildfire by 2050
- Geographical extension: almost 50% of moorland and woodland in mainland France will be at high risk of wildfire by 2050
- Temporal extension: the wildfire risk period will be three times longer (from June to October) and contribute to more winter or spring fires
- an increase in the number of vegetation and farmland fires, including in peri-urban areas

Global warming is predicted to cause more fires than ever before **(Figure 7)**. Three of the biggest fires that hit France in the last 40 years occurred in 2021 and 2022. In its sixth assessment report, the Intergovernmental Panel on Climate Change (IPCC) warns of an increase in the probability of "catastrophic forest fires" of between 30% and 60% by the end of the century. Furthermore, these extraordinary fires pose public health problems. In this context, the assistance of Météo France will be essential.

Glossary:

(French acronym between brackets)

FFMC (ICL):

The Fine Fuel Moisture Code is a numeric rating of the moisture content of litter and other cured fine fuels. This code is an indicator of the relative ease of ignition and the flammability of fine fuel.

DMC (IH):

The Duff Moisture Code is a numeric rating of the average moisture content of loosely compacted organic layers of moderate depth. This code gives an indication of fuel consumption in moderate duff layers and medium-size woody material.

DC (IS):

The Drought Code is a numeric rating of the average moisture content of deep, compact organic layers. This code is a useful indicator of seasonal drought effects on forest fuels and the amount of smouldering in deep duff layers and large logs.

ISI (~IEP):

The Initial Spread Index is a numeric rating of the expected rate of fire spread. It is based on wind

speed and FFMC. Like the rest of the FWI system components, ISI does not take fuel type into account. Actual spread rates vary between fuel types at the same ISI.

BUI (ICD, ~NSV2):

The Buildup Index is a numeric rating of the total amount of fuel available for combustion. It is based on the DMC and the DC. The BUI is generally less than twice the DMC value, and moisture in the DMC layer is expected to help prevent burning in material deeper down in the available fuel.

FWI (IFM):

The Fire Weather Index is a numeric rating of fire intensity. It is based on the ISI and the BUI, and is used as a general index of fire danger throughout the forested areas of Canada [7].

[1] **Thornthwaite C. W., 1948.** *An Approach toward a Rational Classification of Climate*. Geographical Review 58, 55-94.

[2] **Van Wagner C.E., 1987.** É*laboration et structure de la méthode canadienne de l'Indice Forêt-Météo*. Service canadien des forêts, Administration centrale, Ottawa (Ontario). Rapport technique de foresterie 35F. 34 p.

[3] "The European Forecaster", Newsletter of the WGCEF N°28, September 2023. http://www.euroforecaster.org/gpeasy/gpEasy_CMS/Archive

[4] http://aristotle.ingv.it/

[5] *Lutte contre les feux de forêt: protéger les populations, les biens et l'environnement*. Dossier de Presse 2023. available at https://www.interieur.gouv.fr/sites/minint/files/medias/documents/2023-04/DP_Feux_foret_10EP_HD.pdf

[6] DRIAS les futurs du climat, https://www.drias-climat.fr/.

[7] https://cwfis.cfs.nrcan.gc.ca/background/summary/fwi