Fire Weather Index: from high resolution climatology to Climate Change impact study

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Contents

- Context
- Building a high resolution 1958-2008 FWI climatology
  - Dataset and methods
  - Observed trends
  - FWI reanalysis vs fire statistics
- Impact of Climate Change on fire meteorological danger
  - Climate model, scenarios and downscaling method
  - Future trends (2040, 2060 and 2090)
- Conclusions and further work
Fire meteo indices provide efficient guidance tools for prevention and early warning of forest fires. These indices are only based on meteorological input data.

The underlying approach is to exploit meteorological information as fully as possible to model the soil water content, biomass condition and fire danger.

Fire meteorological danger is estimated by Météo-France at national level through the use of Fire Weather Index (FWI).

FWI is a numeric rating of fire intensity. FWI system consists of six components that account for the effects of fuel moisture and wind on fire behavior. Calculation of the components is based on consecutive daily observations of temperature, relative humidity, wind speed, and 24-hour rainfall.

This kind of products can also be used for climatological purpose.
Operational context

- FWI national maps are produced twice daily and available for Civil Protection on a specific website.
- Fire risk level is assessed at regional level.
- Spatial resolution : 2.5 km
- Input data : Arome mesoscale weather forecast model and hourly high resolution rainfall analysis.
- Rainfall data are produced by merging rain gauge and rainfall radar data
A study on the potential extension of forest areas prone to forest fires commissioned jointly by the Ministry of Agriculture, the Ministry of Ecology and the Ministry of the Interior.

This study was carried out by ONF (National Forest Office), IFN (National Forest Inventory) and Météo-France - in charge of FWI reanalysis and FWI forecast (2040 / 2060).

Increasing trend in terms of fire frequency or fire severity is difficult to assess by using Civil Protection databases. Fire events databases are usually incomplete and inhomogeneous. Moreover this approach mainly identifies the anthropogenic effect (due to changes in human activities and soil occupation) rather than climate change impact.

Fire meteorological danger trend can be studied through FWI reanalysis on a long period. In order to assess a long-term trend FWI has been recomputed on a 50 year period by Météo-France. Safran model has been used to derive a 50-year hydrometeorological reanalysis, running from 1958 to 2008 (Vidal 2009). FWI was modeled at daily time step on a 8km regular grid.

Producing a high resolution FWI climatology allow us to downscale climate change scenarios. The Quantile-Quantile correction method was applied on a 8km grid.

1958-2008 Fire Weather Index climatology

Observed trends
A strong interannual variability
Four years stand out on this chart
Unsurprisingly we can identify the most severe drought events in France
+22% between 1961-1989 and 1989-2008 periods
High resolution FWI climatology
Mean seasonal FWI over France (June-July-August period)

- Mean seasonal FWI calculated during summer increased all over French area.
- At regional level the highest increases in FWI were in Corsica, mediterranean area and on montainous areas.

1961-1980 period

1989-2008 period
The number of days with FWI > 20

- We also studied the total number of daily FWI above a threshold (20, 40 and 60). This is a consistent indicator in order to characterize an increase in global meteorological fire danger.

1961-1980 period

1989-2008 period
FWI linear trend over France on 1958-2008 period

- Linear trend of Fire Weather Index (year-1) on 1958-2008 period.
- Black dots indicate grid cell with statistical significance (Mann-Kendall test with 95% threshold)

Annual period

Summer period
..and a strong correlation between FWI and fire statistics

- On this chart we can notice a clear relationship between annual mean FWI and fire statistics (total number of fires) at national level.
Potential impact of climate change on fire meteorological danger:

Predicting FWI trend with climate change scenarios
**Methodology**

- **Climate model**: French ARPEGE-Climat V4 model
- **Emission scenarios**: A2, A1B and B1
- **Use of raw model outputs**
- **Use of Quantile-Quantile correction method on FWI daily values and downscaling at 8 km resolution**

Quantile-quantile approach for winter mean temperature in Paris. Correction method applied for each statistical threshold.
Annual FWI anomaly
(with Q/Q correction method and downscaling)

A1B scenario
A2 scenario
B1 scenario

2040
2060
2090
### Annual FWI anomaly (with Q/Q correction method and downscaling)

<table>
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<th>Scenario d'émission</th>
<th>2040</th>
<th>2060</th>
<th>2090</th>
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<td>A1B</td>
<td>0.848</td>
<td>2.5806</td>
<td>3.5815</td>
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<tr>
<td>A2</td>
<td>0.58</td>
<td>2.636</td>
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<td>B1</td>
<td>0.575</td>
<td>0.782</td>
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<table>
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Impact of climate change on the number of days with high fire risk (FWI > 40)

- From 1.8 to 10.1 days / year with FWI > 40
- 500 M€ are dedicated each year to forest fire fighting resources
- Additional 100 M€ could be spent per year in 2060 due to Climate Change

1961-1980 reference period

2060 – A1B scenario
<table>
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<th>Number of days with FWI&gt;40</th>
<th>Number of days with FWI&gt;60</th>
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<td>Référence 1989-2008</td>
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Conclusion

- Trends are very clear also in terms of total number of daily FWI above a threshold. In many French regions the annual number of days with FWI> 20 show an increase from 10 days up to 50 days locally.
- The surface of the metropolitan area concerned by at least one day every year with FWI> 20 doubled between the period 1961-1980 and the period 1989-2008. The trend is similar to the threshold 40.
- The use of Météo-France climate model suggests a similar increasing trend for FWI in 2040. A 30% increase (reference period:1961-2000) is predicted for three different emissions scenarios (A1B, A2 and B1). Interannual variability should also increase and leads to meteorological conditions which has never been observed yet.
- We predict a strong increase in fire meteorological danger in 2060. A 75% increase (reference period:1961-2000) is predicted for A1B and A2 emissions scenarios.
- Typical Mediterranean meteorological fire danger conditions could be observed all over the French area. Year 2003 could be considered as a consistent reference for 2060.
Final integration of results
Meteorological conditions x forest sensitivity index
Test mapping of forest potentially vulnerable to summer fires in 2040-2060
Only summer fires are taken into account.
Modelling assumptions: No changes in species at the horizons considered.
Average sensitivity index by forest stands has been estimated by considering biogeographical regions, elevation, soil types, exposures, slopes, ranges of pubescent oak, etc…
The potential sensitivity is expressed only in areas that have in 2040 or 2060 conditions equivalent to those of the Mediterranean area (based on FWI).
Index of sensitivity of vegetation to summer forest fires in the meteorological danger conditions of the reference period (1989-2008)
national map of areas potentially susceptible to forest fires

Index of sensitivity of vegetation to summer forest fires in the meteorological danger conditions of the modeling 2040

1
2
3
4
national map of areas potentially susceptible to forest fires

Index of sensitivity of vegetation to summer forest fires in the meteorological danger conditions of the modeling 2060
Thank you for your attention!

July 27, 2003: Néron Mountain near the city of Grenoble. This fire will last nearly one month.