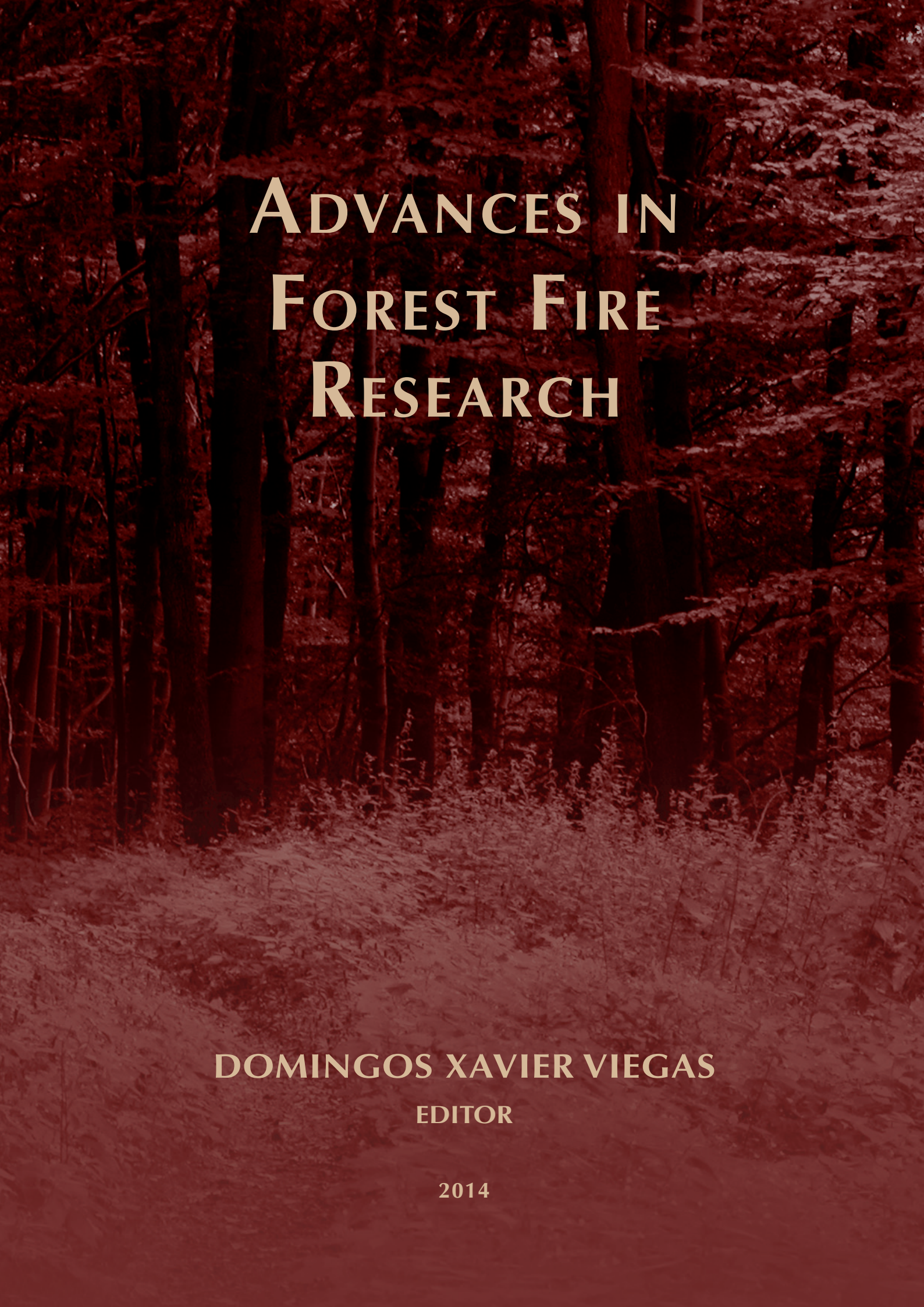

Advances in Forest Fire Research

DOMINGOS XAVIER VIEGAS

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A new calibration for Fire Weather Index in Spain (AEMET)

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Abstract
The Fire Weather Index (FWI) is an index based on meteorology. The system consists of six components and it depends on weather variables taken each day at 12 UTC (or forecasted for 12 UTC): temperature, relative humidity, wind speed and rain during the previous 24 hours. FWI is an accumulative index, that is, subindexes values for a day D are used for the calculation of the final index the following day D+1. The procedures for the calculation for Iberian Peninsula and Balearic Islands were initialized by AEMET in 2008 March, being executed daily without interruption since then. Canarias Islands procedures are being executed since 2013 May. Procedures include analysis for day D and forecasts for day D+1, D+2 and D+3 in a 0.5ºx0.5º horizontal resolution grid cells with data provided by the HIRLAM numerical weather prediction model.
FWI values calculated for a determinate localization have no meaning for themselves. It's necessary to make a correspondence between the danger classes and those FWI values in order to calibrate it. For this, five danger classes split has been calculated only from a climatological point of view. Each class or risk level corresponds with a range of values of FWI between different percentiles. Thus, fire low risk corresponds with FWI values below its percentile 40; moderate risk with FWI values between percentile 40 and 65; high risk between percentile 65 and 85; very high risk between percentile 85 and 95 and extreme fire risk above its percentile 95. In the calculation of the different percentiles, a data period from May 2008 until December 2013 has been used. This period will be updated with most recent values according to the month pass.

***Keywords**: FWI, fire risk, danger classes, calibration, validation*

1. Introduction

The purpose of the Fire Weather Index (FWI) system, based on the Canadian system, is to account for the effects of weather on forest fuels and forest fires. The system consists of six components: three primary subindexes representing fuel moisture and following daily changes in the moisture contents of three classes of forest fuel with different drying rates, two intermediate subindexes representing rate of spread and fuel consumption, and a final index representing fire intensity as energy output rate per unit length of fire front.
The three primary subindexes are, according to *Van Wagner, C.E., (1987)* :

- Fine Fuel Moisture Code (FFMC), which represents the moisture content of litter and other cured fine fuels in a forest stand, in a layer of dry weight about 0.25 kg/m^2.
- Duff Moisture Code (DMC), which represents the moisture content of loosely compacted, decomposing organic matter weighing about 5 kg/m^2 when dry.
- Drought Code (DC), which represents a deep layer of compact organic matter weighing perhaps 25 kg/m^2 when dry.

Those three primary subindexes plus wind are combined in pair to produce the two intermediate subindexes, ISI and BUI. Final index, FWI, is formed by a combination of the two intermediate subindexes. According to *Van Wagner, C.E., (1987)* :

- Initial Spread Index (ISI), a combination of wind and the FFMC that represents rate of spread alone without the influence of variable quantities of fuel.
- Buildup Index (BUI), a combination of the DMC and the DC that represents the total fuel available to the spreading fire.

- Fire Weather Index (FWI), a combination of the ISI and the BUI that represents the intensity of the spreading fire as energy output rate per unit length of fire front.

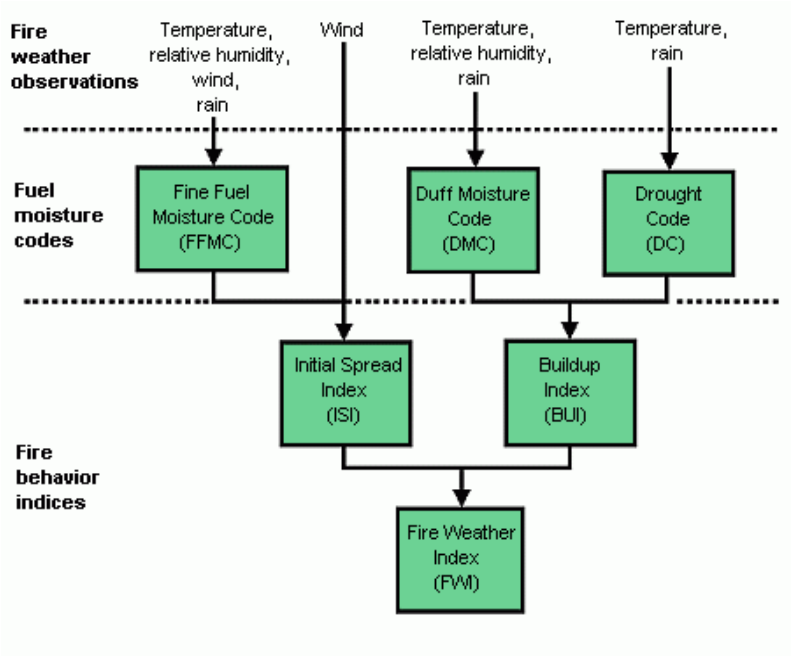

Figure 1. FWI system components.

The system depends on weather variables taken each day at noon Universal Time Coordinated UTC (or forecasted for 12 UTC): temperature, relative humidity, wind speed and 24 hours-precipitation values. FWI is an accumulative index, that is, subindexes values for a day D are used for the calculation of the final index the following day D+1. Moreover, in order to guarantee the estimations stability, calculations must be initialized in a high rain period, when fine fuel moisture content is maximum.
Two different procedures are used in AEMET in order to calculate the FWI system components: *Iberian Peninsula and Balearic Islands* on the one hand and *Canary Islands* on the other hand.
Procedures for the calculation for *Iberian Peninsula and Balearic Islands* were initialized by AEMET in 2008 March, being executed daily without interruption since then. Procedures include analysis for day D and forecasts for day D+1(H+24), D+2(H+48) and D+3(H+72) in a 0.05ºx0.05º horizontal resolution grid cells for D+1 and 0.16ºx0.16º horizontal resolution grid cells for D+2 and D+3. Meteorological data are provided by the HIRLAM numerical weather prediction model. *Canary Islands* procedures are being executed since 2013 May. Procedures include analysis for day D and forecasts for day D(H+12), D+1(H+36) and D+2(H+60) in a 0.05ºx0.05º horizontal resolution grid cells for D and D+1 and 0.16ºx0.16º horizontal resolution grid cells for D+2. Meteorological data are provided by the HIRLAM numerical weather prediction model.

Examples of weather variables provided by HIRLAM:

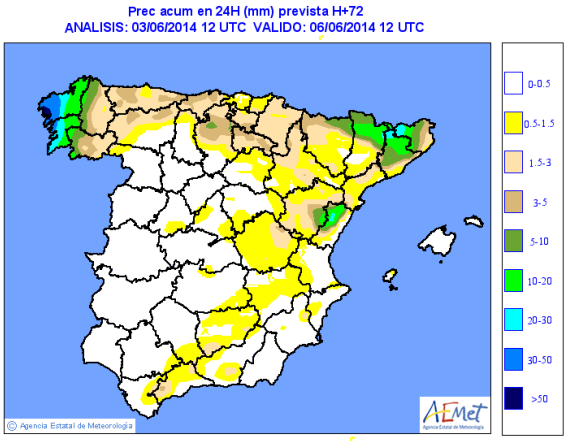

Figure 2. Precipitation during the previous 24 hours

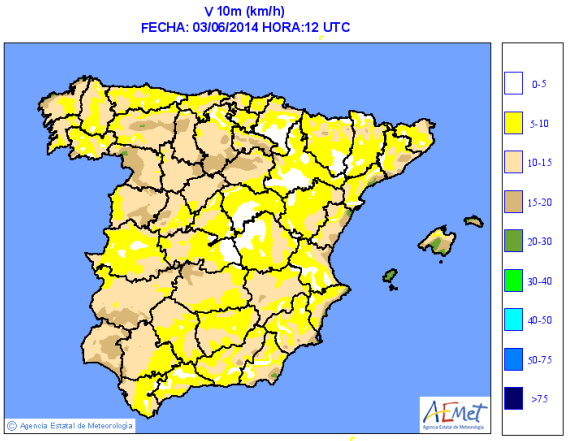

Figure 3. 10 m wind speed

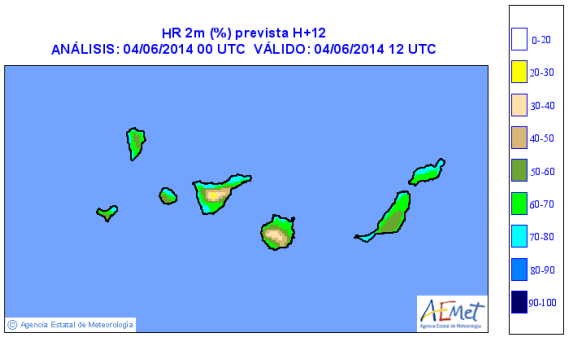

Figure 4 –2m Temperature

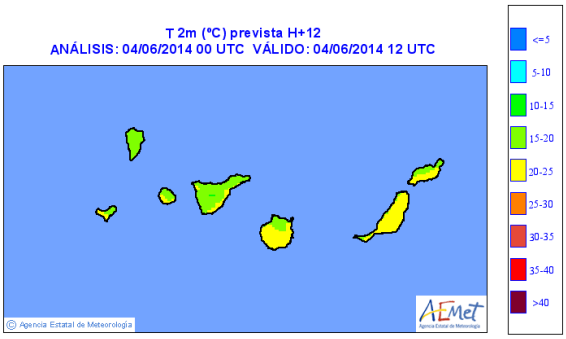

Figure 5. 2m Relative Humidity

Examples of subindexes for Iberian Peninsula/Balearic Islands and Canary Islands:

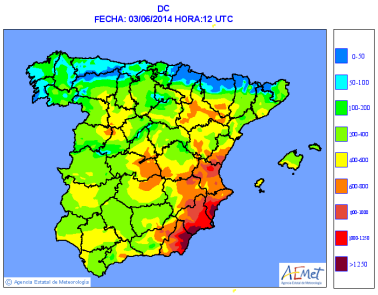

Figure 6 –Drought Code (DC)

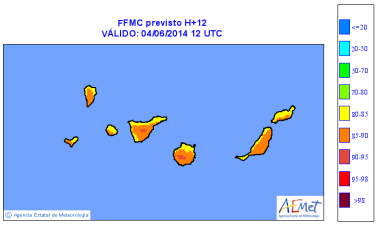

Figure 7 –Fine Fuel Moisture Code(FFMC)

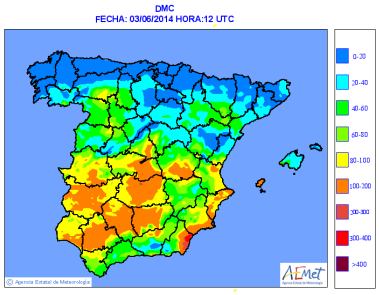

Figure 8 –Duff Moisture Code (DMC)

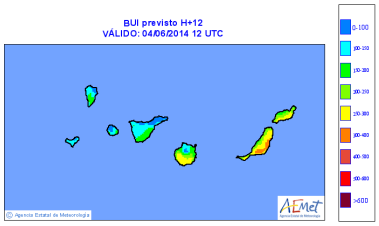

Figure 9 –Buildup Index (BUI)

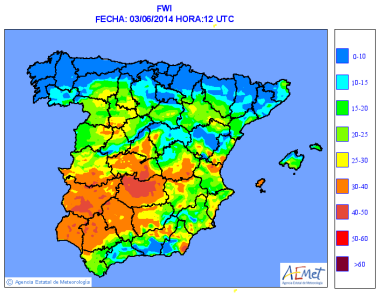

Figure 10–Fire Weather Index(FWI)

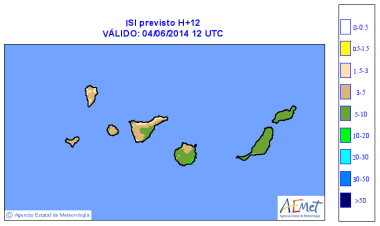

Figure 11 –Initial Spread Index(ISI)

2. Methods

FWI values calculated for a determinate localization have no meaning for themselves. It's necessary to make a correspondence between the danger classes and those FWI values. Furthermore, non meteorological factors such as type, quantity and fuel distribution must be taken in account when assigning danger classes in the different areas. In order to represent a range of climatological conditions, FWI values are calculated using daily weather data provided by the numerical weather prediction model HIRLAM during several years. Cutoff values for the different danger classes are calculated from the value at different percentiles.

2.1. Old calibration Peninsula and Balearic Islands.

Five danger classes have been established in AEMET: low, moderate, high, very high and extreme fire risk level. Until 2013, according to that division, FWI had been calibrated for the location of a set of observatories and automatic meteorological stations by setting four threshold values for delimitating those five danger classes. From those four threshold values, by interpolating, a file with the four threshold values in every grid point was generated. Fire risk level is calculated by comparing, in every grid point, FWI daily value with the corresponding four threshold values for that grid cell. That calibration has been carried out by starting off FWI values at meteorological stations and historical records of burned area of fires surrounding those stations. A 10 years period (1997-2006) only with months between June and October was considered.

2.2. New calibration Peninsula and Balearic Islands.

However, as we have considered that the fire risk level provided should only take into account meteorological and climatological factors, it's necessary to try another different calibration according to the above requirements. For this, five danger classes division has been calculated only from a climatological point of view. Each class or risk level corresponds with a range of values of FWI between different percentiles. Thus, fire low risk corresponds with FWI values below its percentile 40; moderate risk with FWI values between percentile 40 and 65; high risk between percentile 65 and 85; very high risk between percentile 85 and 95 and extreme fire risk above its percentile 95. In the calculation of the different percentiles, a daily data period from May 2008 until December 2013 has been used by using weather data provided by the numerical weather prediction model HIRLAM. This period will be updated with most recent values according to the month pass.

FWI values have been separated in two different periods; from May to October, and from November to April. Thresholds obtained for May-October period have been generated from FWI series values ranging from April to November during 2008-2013, thus, 8 months. In the other hand, thresholds generated for November-April period have been calculated from the whole FWI values series(2008-2013).

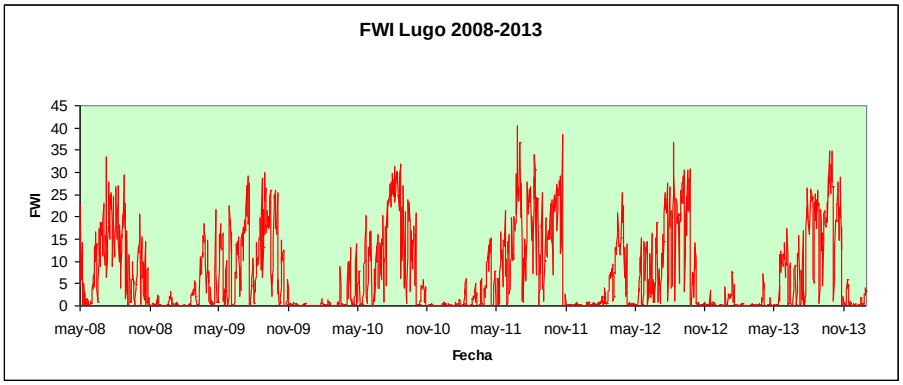

Figure 12. FWI values from January 2009 to December 2013

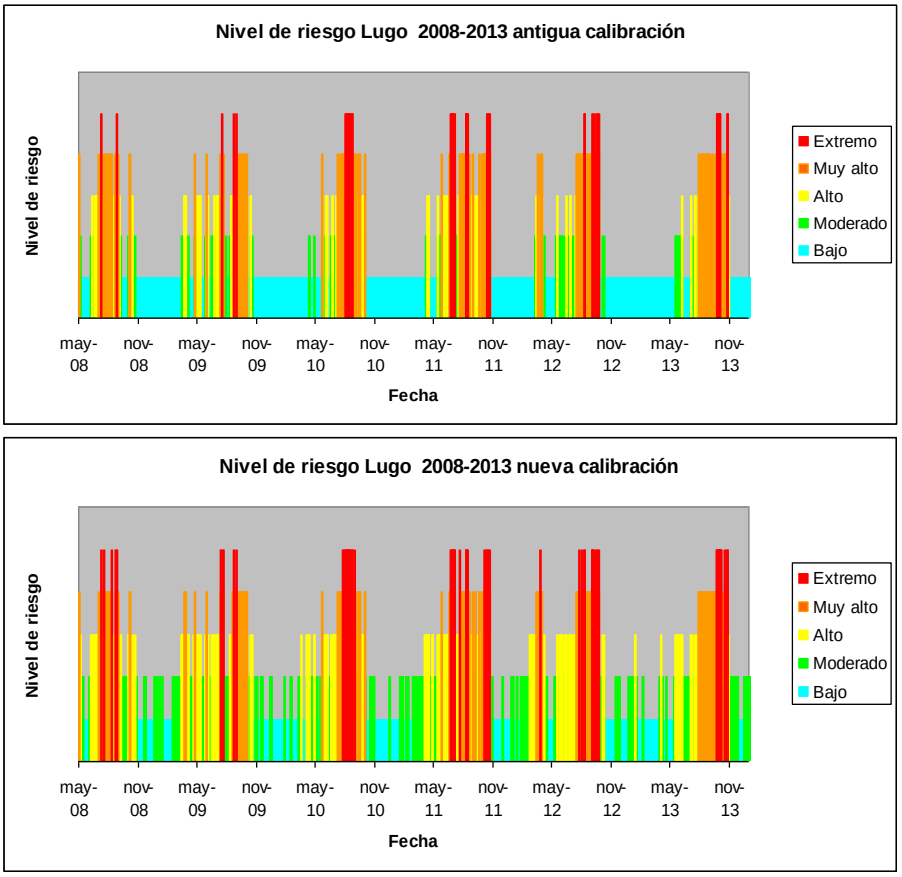

Figure 13. Risk levels January 2009 to December 2013(old calibration-top/new calibration-bottom)

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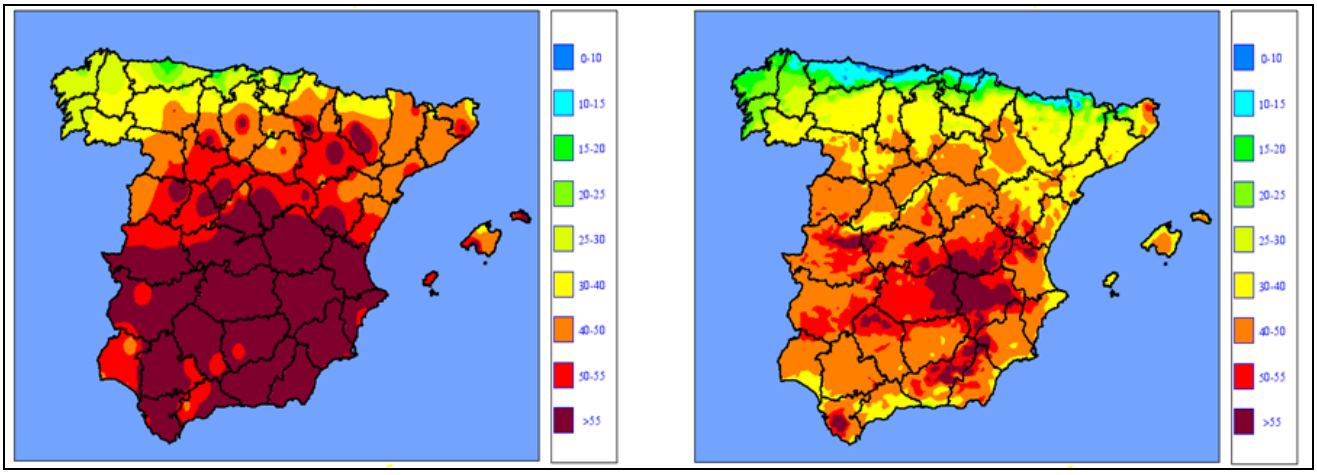

Figure 14. Percentile 95 FWI values. Old Calibration (left / New Calibration(right).

2.3. **Old calibration Canary Islands.**

Unlike the old calibration previous to 2014 calculate in Peninsula and Balearic Islands, Canary Islands calibration has always been calculated taking into account only meteorological and climatological factors. Again, five danger classes have been established: low, moderate, high, very high and extreme fire risk level. Each class or risk level corresponds with a range of values of FWI between different percentiles. Thus, fire low risk corresponds with FWI values below its percentile 40; moderate risk with FWI values between percentile 40 and 65; high risk between percentile 65 and 85; very high risk between percentile 85 and 95 and extreme fire risk above its percentile 95. In the calculation of the different percentiles, a daily data period from March 2009 until February 2011 has been used by using weather data provided by the numerical weather prediction model HIRLAM.

2.4. **New calibration Canary Islands.**

The only different with the old calibration is the extension of the period from January 2009 to December 2013. Due to the special characteristic of the Canary Islands climate, FWI values used for percentile calculation and the threshold generation are ranging for the whole year.
This period will be updated with most recent values according to the month pass.

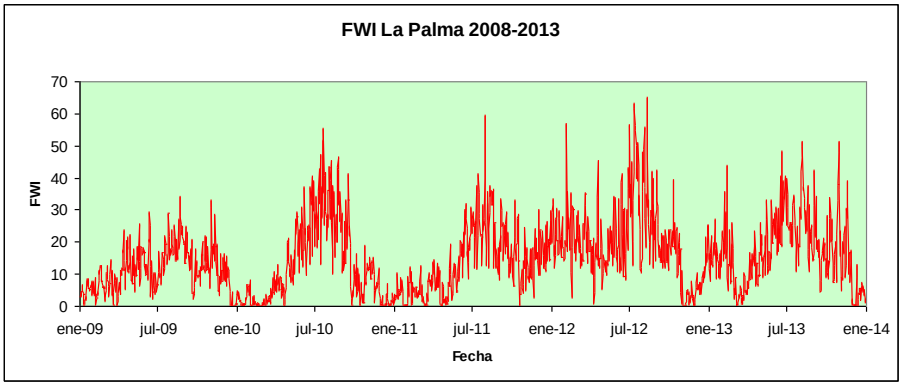

Figure 15– FWI values from January 2009 to December 2013

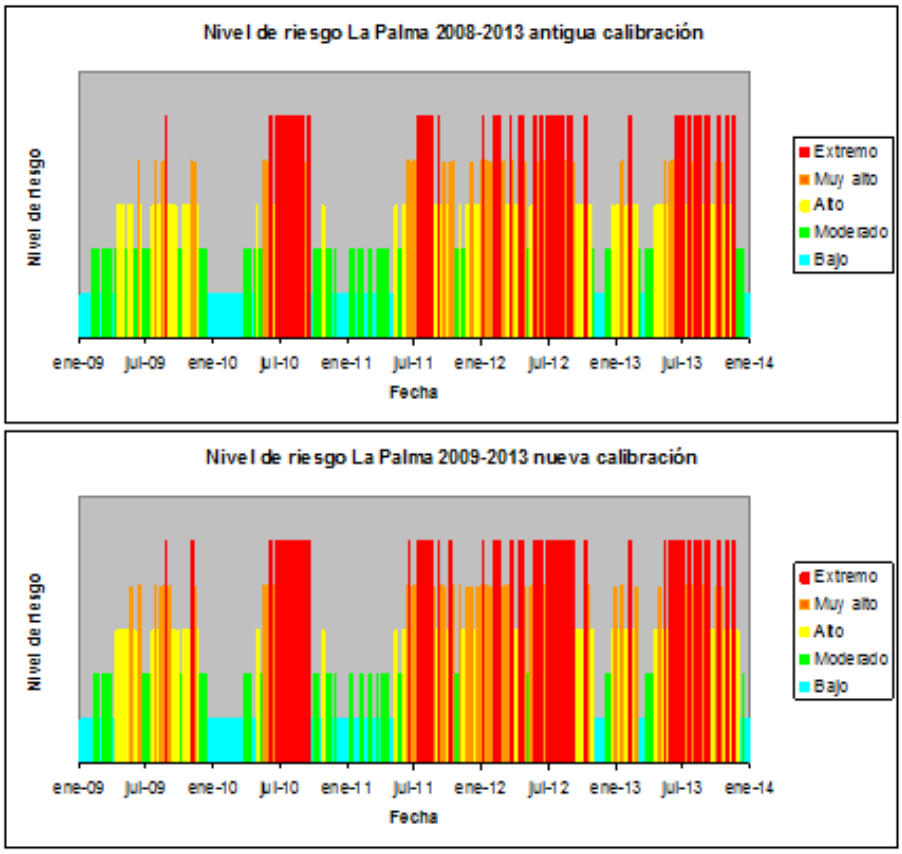

Figure 16. Risk levels January 2009 to December 2013(old calibration-top/new calibration-bottom).

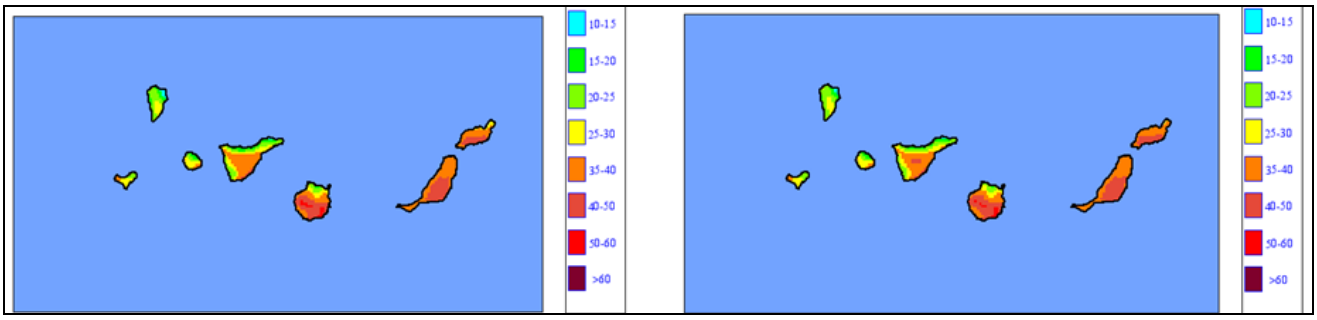

Figure 17- Percentile 95 FWI values. Old Calibration (left)/ New Calibration(right).

3. Results.

3.1. Iberian Peninsula and Balearic Islands.

Fire occurrences during 2010 year have been used in order to validate the new calibration behaviour, taking only into account those ones with burned area greater than 5 hectares, what makes us to have 230 fires spread all over the Iberian Peninsula and Balearic Islands.

For each fire coordinates, FWI value in the nearest grid point has been calculated. Then, two risk levels have been associated to that FWI value, one calculated with the old calibration, and another one calculated with the new calibration. Thresholds obtained for May-October period have been generated from FWI series values ranging from April to November during 2008-2013, thus, 8 months. In the other hand, thresholds generated for November-April period have been calculated from the whole FWI values series (2008-2013). In figures 18 and 19 results are presented by comparing the two different

calibrations for the whole 2010 year. As we can see, the risk level associated to each fire with the new calibration appears, in most of the fires, in a higher danger class.

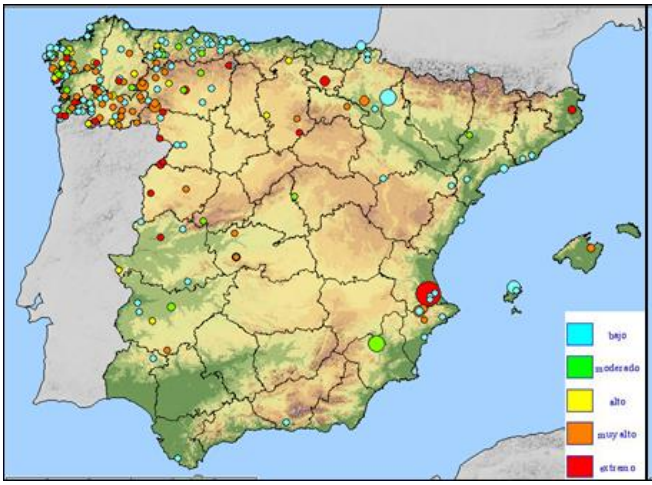

Figure 18. Fire risk level during 2010 old calibration

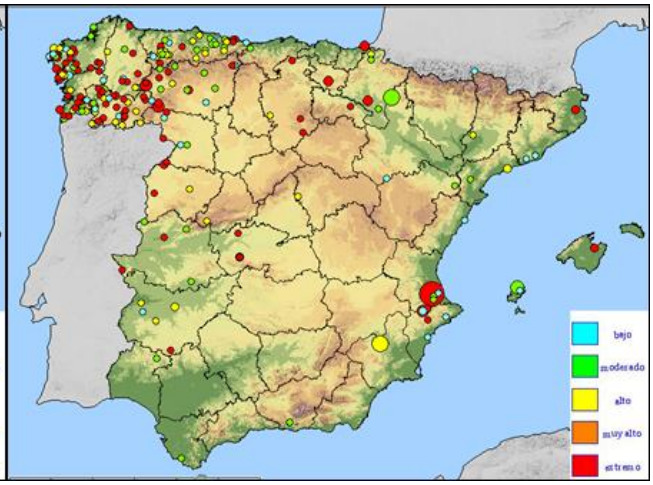

Figure 19. Fire risk level during 2010 new calibration

Later, fire data records were validated by separating two different periods; from May to October, and from November to April. In the next figures we can see the different calibrations for the two different periods as well as the fire risk level associated to each fire.

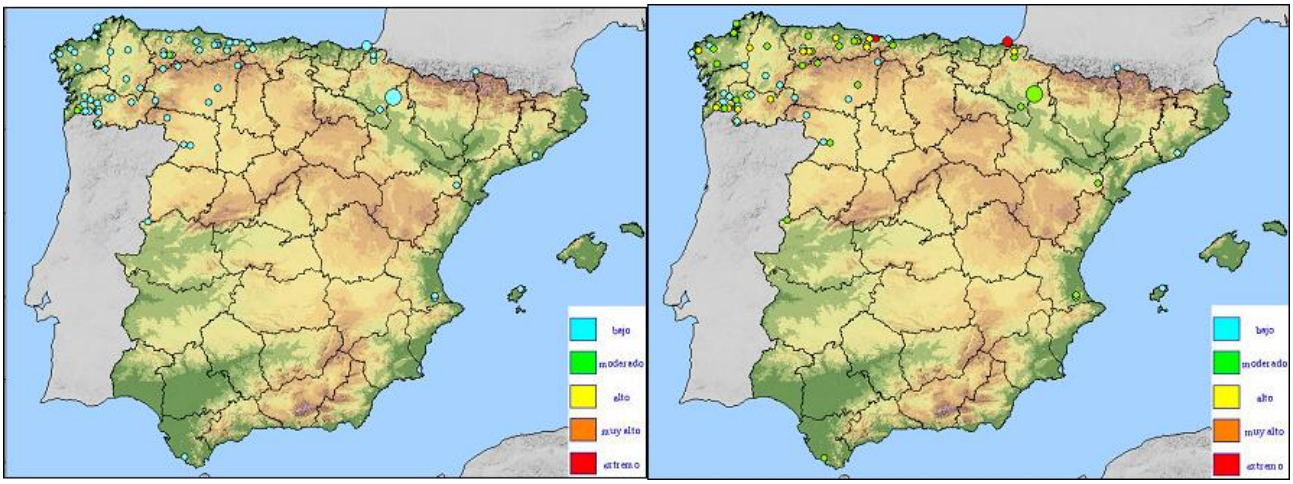

Figure 20. Fire risk level during November-April 2010 period with old (left) and new (right) calibration

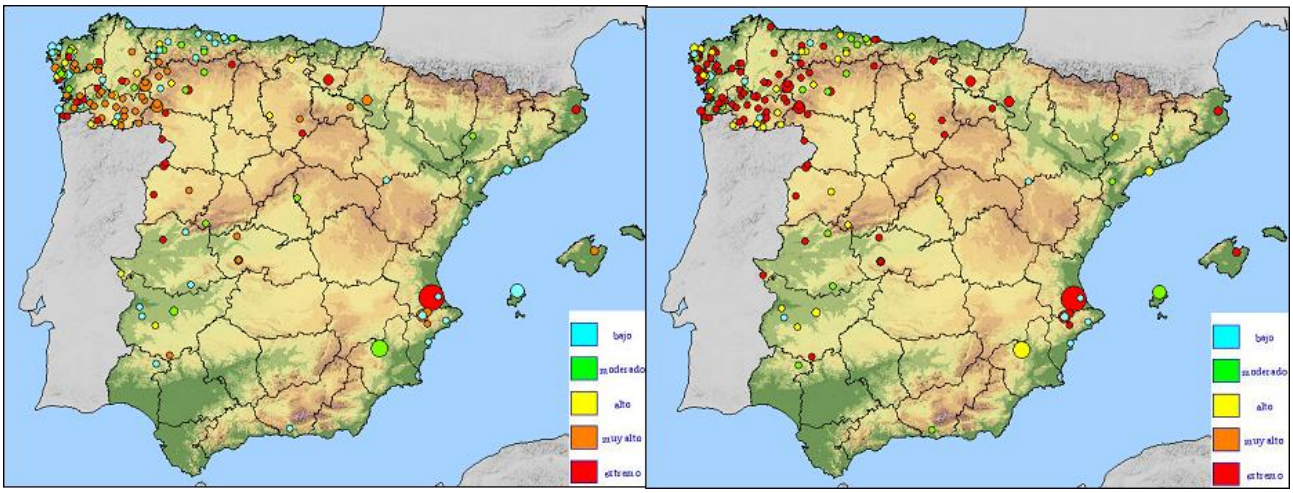

Figure 21. Fire risk level during May-October2010 period with old (left) and new (right) calibration.

3.2. **Canary Islands.**

Same validation procedures have been used for the fire occurrences in the Canary Islands during 2010 year, by comparing the old and the new calibration. Results are presented in the next figures. We can observe similar results to the ones obtained in the Iberian Peninsula and Balearic Islands, where the risk level associated to each fire with the new calibration appears, in most of the fires, in a higher danger class.

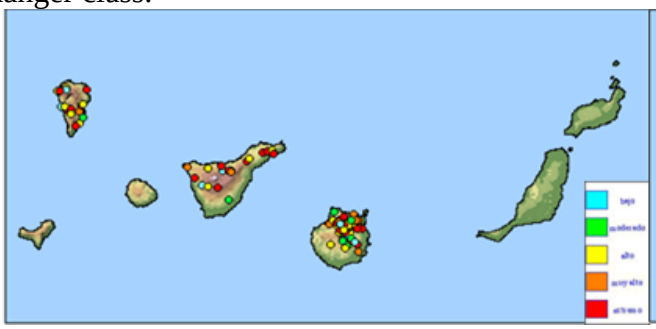

Figure 22. Fire risk level during 2010 old calibration

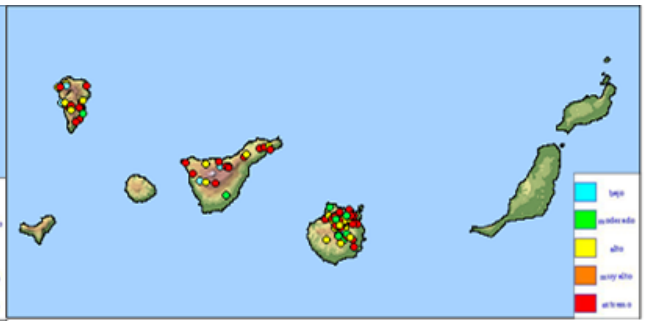

Figure 23. Fire risk level during 2010 new calibration

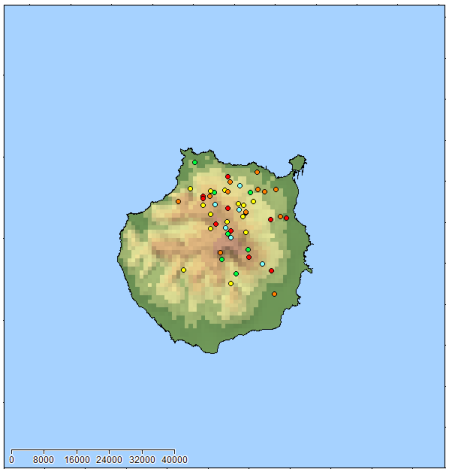

Figure 24. Fire risk level during 2010 old calibration

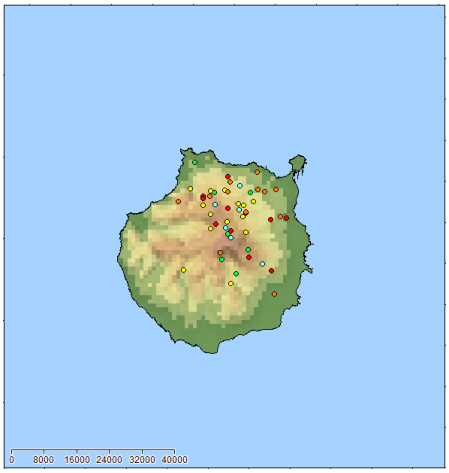

Figure 25. Fire risk level during 2010 new calibration.

4. **References.**

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