Assessing the predictability of fire occurrence and area burned across phytoclimatic regions in Spain

Supplementary Material

J. Bedia, S. Herrera, J.M. Gutiérrez

1 Description of the Fire Weather Index System

The Canadian Forest Fire Weather Index (FWI System) constitutes a building block of the Canadian Forest Fire Danger Rating System (CFFDRS) established in Canada since the early 70's (van Wagner, 1987; Stocks et al., 1989) and subsequently adopted in other regions of the world, such as the Mediterranean (Viegas et al., 1999; Dimitrakopoulos et al., 2011), Indonesia and Malaysia (deGroot et al., 2006) or New Zealand (Briggs et al., 2005), among others.

The Fire Weather Index (FWI) System consists of six components rating the effects of fuel moisture content and wind on a daily basis, based on various factors related to potential fire behaviour (Fig. 1). The first three components, referred to as the Fine Fuel Moisture Code (FFMC), the Duff Moisture Code (DMC) and the Drought Code (DC), rate the average moisture content of different soil layers, respectively fine surface litter, decomposing litter, and organic layers. Wind effects are then added to FFMC to form the Initial Spread Index (ISI), which is an indicator of the rate of fire spread. The remaining two fuel moisture codes (DMC and DC) are combined to produce the Build Up Index (BUI), which rates the total amount of fuel available for combustion. BUI is finally combined with ISI to produce the Fire Weather Index (FWI), a dimensionless index rating the potential fire line intensity given the meteorological conditions in a reference fuel type (mature pine stands) and level terrain. The Daily Severity Rating (DSR, van Wagner, 1970) is calculated as an exponential function of FWI, used to better reflect the expected efforts required for fire suppression. Moreover, DSR was specifically designed to be averaged either in time (e.g. seasonally, leading to the seasonal severity rating, SSR) or in space in order to characterize the average fire danger conditions over certain areas/regions. The FWI System uses as input four meteorological variables: daily accumulated precipitation and instantaneous wind speed, relative humidity and temperature. According to the standard data recording protocol, these variables should be measured at noon local standard time (Lawson and Armitage, 2008).

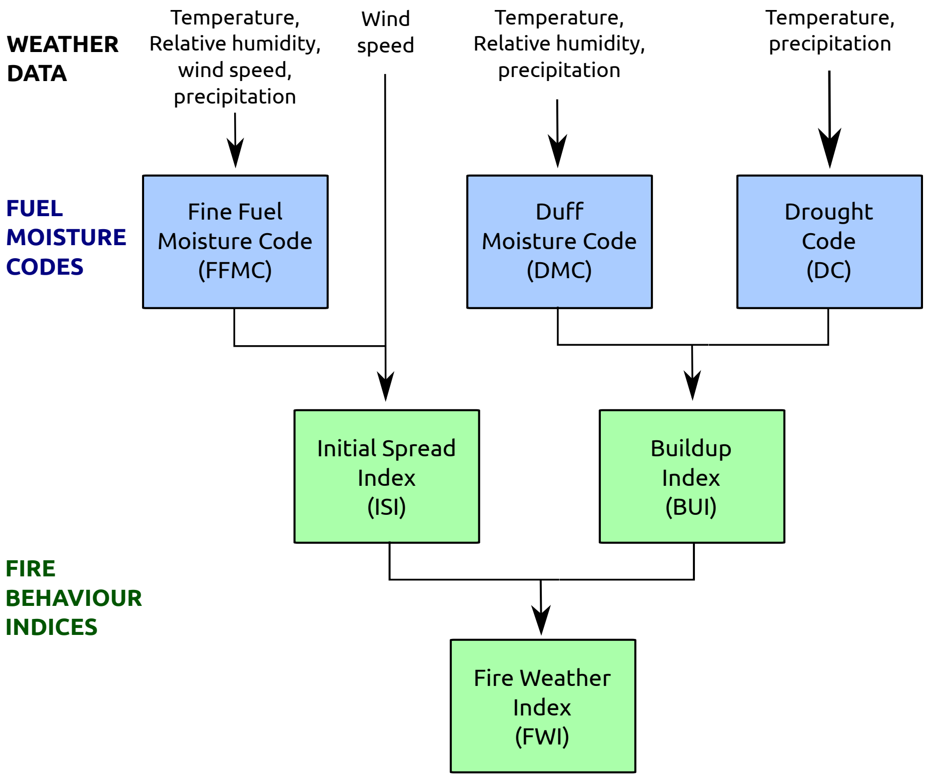

Figure 1: Block diagram of the CFFWIS (Adapted from van Wagner, 1987)

2 Graphic representation of the experimental design

In the following figures, a graphical display of the data analysis approach is presented. Fig. 2 represents the data of phytoclimatic zone 4, characterized by an annual unimodal fire distribution, on which fire danger days are concentrated in the aestival months. On the other hand, Fig. 3 characterises the data structure of phytoclimatic zone 13-14-15, which has a bimodal fire distribution, with two distinct peaks of fire activity concentrated in late-winter/early-spring and summer (See Fig. 2 of the manuscript). Note that in both cases, the predicted probabilities correspond to models considering climate-only variables.

In both figures (2 and 3) the panels on the left **(a)** represent the data matrix of the observed fires at the grid-box scale. Rows represent from bottom to top the time series of the analysis period (1990–2008, 6940 days). Columns correspond to the 25km grid boxes belonging to the phytoclimatic type. Fire events (those above the threshold of 0.1ha of burnt area) are denoted by the blue lines. The bar plot on the right hand side of the matrix depicts the daily fire counts, and the bar plot on the top the total fire counts per pixel for the whole analysis period. Panel **(b)** represents the modelled probabilities of fire occurrence. The central matrix corresponds to the predicted probabilities of fire occurrence for each day and for each grid box. The graph on the right hand side corresponds to the mean daily probabilities (grey line), and the two types of probability thresholds considered for case classification: the global probability threshold (blue line) and the monthly probability threshold (red line), which can take 12 different values, one for each month of the year. The resulting binary classification using the monthly probability threshold leads to the daily predicted fire counts presented in the left hand side bar plot. The bar plot on the top depicts the mean predicted probabilities for each grid box. The fire occurrence at the phytoclimatic zone level (areal approach) is represented in panel **(c)**. In this case, fire occurrence takes place when a fire occurs in at least one of the pixels belonging to that zone (note that this matrix has the same number of rows -days- than (a) and (b) but one single column, as all pixels integrating the area have been aggregated). Finally, panel **(d)** represents the predicted probabilities by the areal modelling approach. The time series of the daily predicted probabilities with the two probability thresholds are presented in the right hand side plot. The column on the left represents the resulting binary fire occurrence prediction (grey=occurrence, white=absence) using the monthly probability threshold.

As a result, In Fig. 2a most fire occurrences are grouped around contiguous horizontal lines in the matrix, corresponding to the summer dates. On the contrary, in Fig. 3 fire data area also aggregated but more frequently, corresponding to late winter/early spring and then again in summer dates. As a result, vertical "band" effects in panels a/b can be regarded as inhomogeneities at the gridbox scale in the fire/climate characteristics of the phytoclimatic zone (for instance pixels at higher altitudes where fire becomes a rare event ...), whereas horizontal inhomogeneities correspond to the natural variability of climate (e.g. specially warm/dry periods ...).

3 Fire Occurrence Models

Table 1: ROC skill area (RSA) attained by the fire occurrence models for each phytoclimatic zone (areal approach) using the MARS algorithm (Results presented in the paper correspond to GLM). The quantilic range (97.5–2.5%) after 100 randomly selected fire absences is indicated in parenthesis. Results are presented for the different burned area thresholds used for fire occurrence definition, and for the climatic-only models.

Phyt. zone	**0.1ha**	**1ha**	**10ha**	**100ha**
2-3	0.69(0.01)	0.69(0.02)	0.74(0.04)	0.78(0.09)
4	0.75(0.01)	0.77(0.01)	0.79(0.02)	0.81(0.06)
5	0.79(0.01)	0.81(0.01)	0.84(0.03)	0.84(0.07)
6	0.75(0.01)	0.76(0.01)	0.80(0.02)	0.83(0.03)
7-8	0.73(0.01)	0.75(0.01)	0.79(0.04)	0.78(0.09)
9	0.68(0.01)	0.70(0.01)	0.76(0.02)	0.81(0.05)
10-11-12	0.68(0.01)	0.68(0.01)	0.69(0.02)	0.75(0.03)
13-14-15	0.64(0.01)	0.61(0.01)	0.62(0.01)	0.67(0.04)

Table 2: Total number of daily fire events (1990-2008) considering the different area thresholds for fire occurrence definition.

	AREAL				**GRIDBOX**			
	0.1ha	**1ha**	**10ha**	**100ha**	**0.1ha**	**1ha**	**10ha**	**100ha**
2-3	3225	2136	570	115	6135	3202	659	122
4	3890	2842	995	241	11145	6428	1424	281
5	2862	2231	927	177	7483	4918	1374	204
6	4536	3872	1781	423	22152	13779	3380	551
7-8	3325	2348	782	168	7062	4151	1014	180
9	4652	3749	1650	422	19458	11286	2737	507
10-11-12	4675	3942	2039	539	26724	16387	4596	760
13-14-15	5520	4868	2586	583	70517	41177	9789	1074

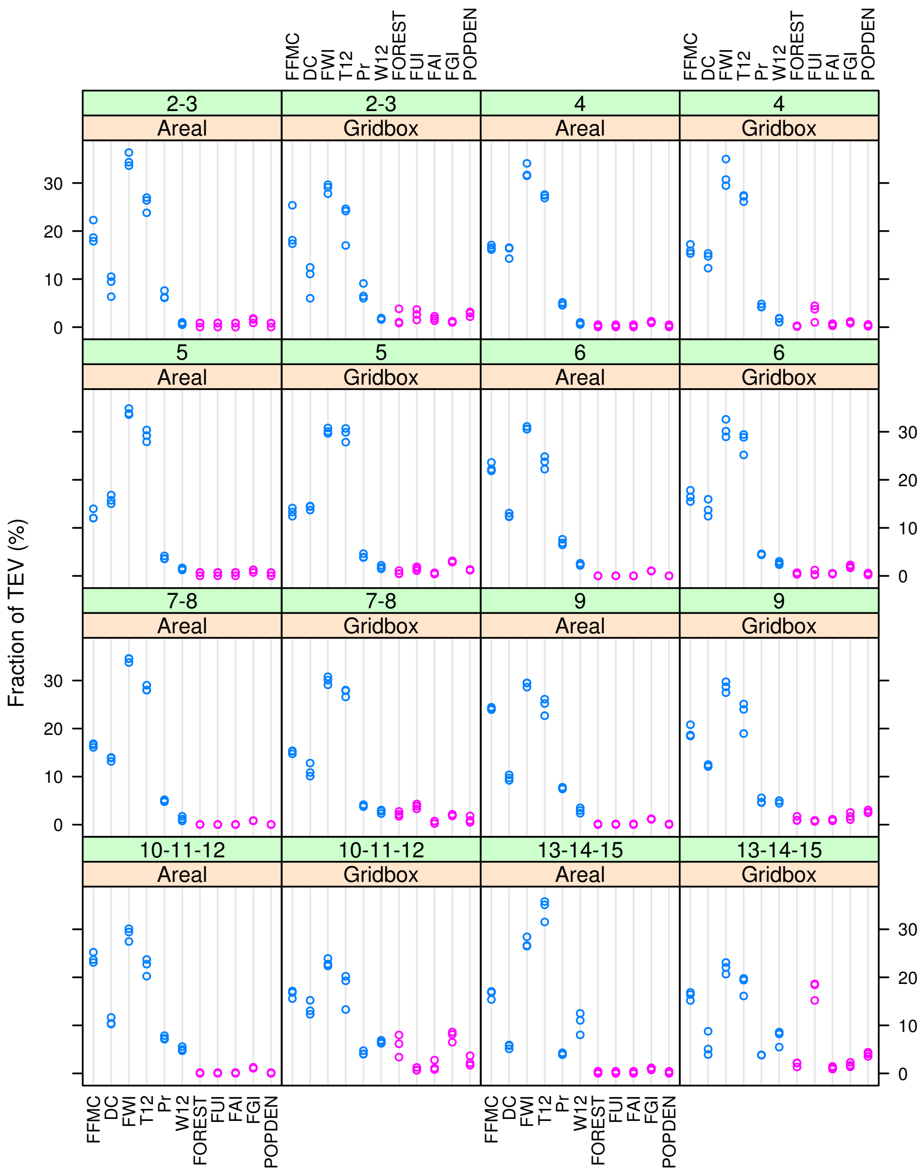

Figure 4: Variable importance (% of Total Explained Variance) in the fire occurrence models for each phytoclimatic zone and considering both the grid-box and areal models and the inclusion of socio-economic/LULC as co-variables (pink color). The results presented correspond to the 3-fold-cross validation, each fold corresponding to a different period of the socio-economic LULC statistics, considering the minimum area threshold of 0.1 ha to define fire occurrence.

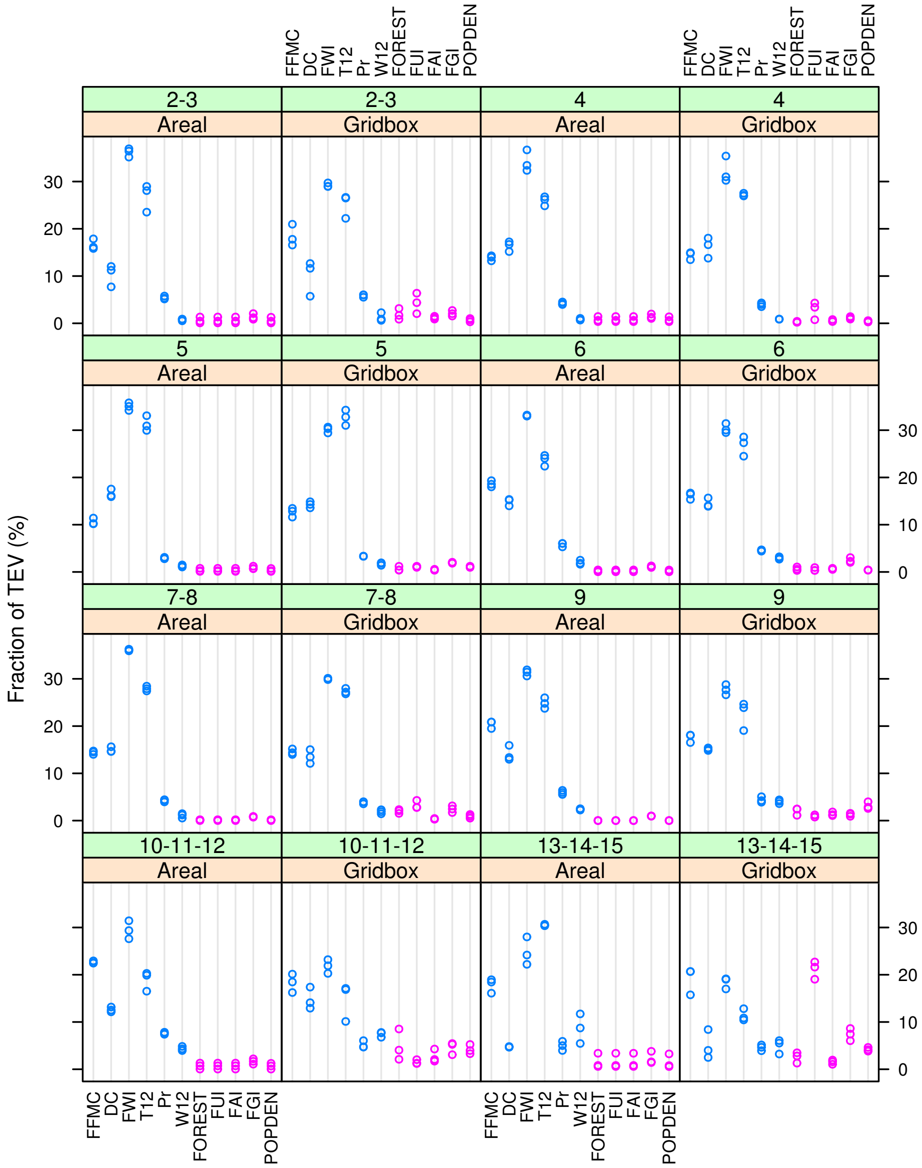

Figure 5: Same as Fig. 4, but using the minimum area threshold of 1 ha.

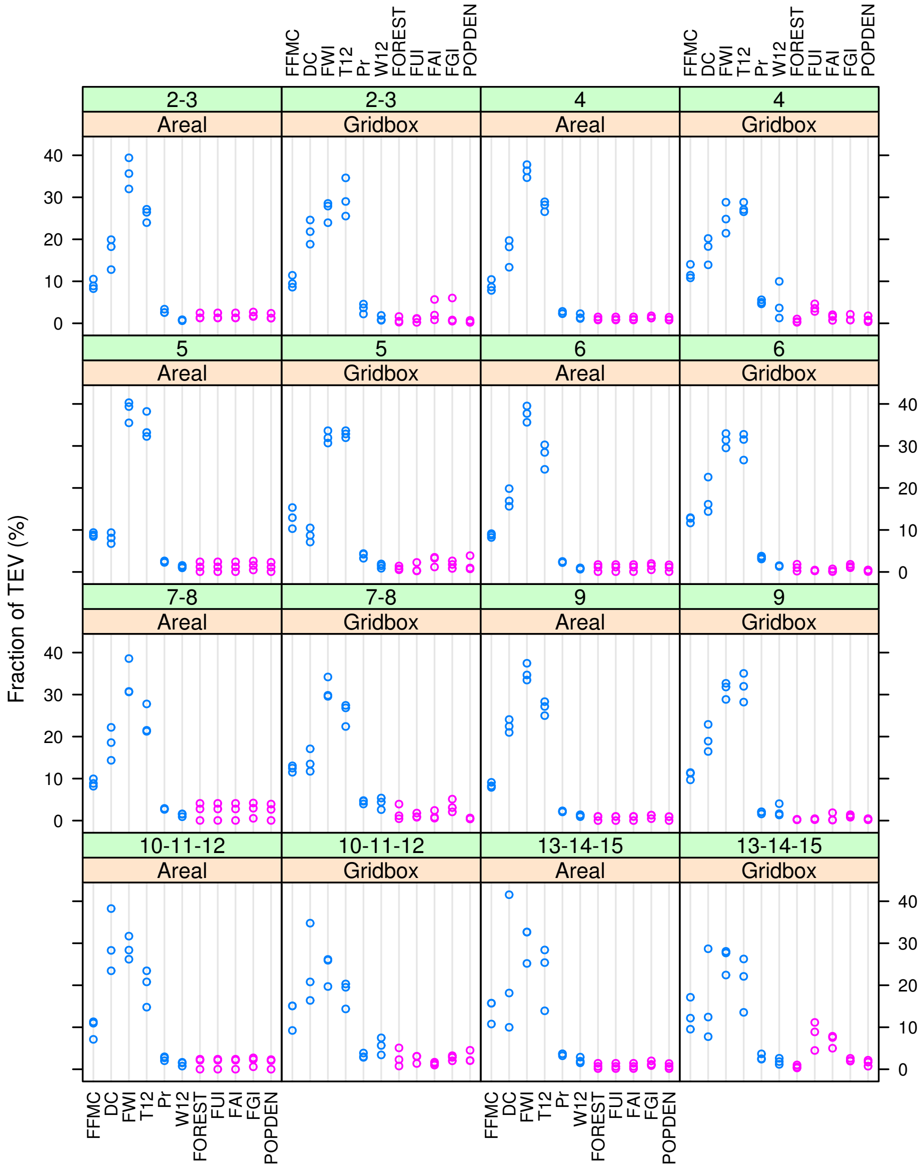

Figure 6: Same as Fig. 4, but using the minimum area threshold of 100 ha.

References

Briggs, C., Price, R., and Pearce, G.: Spatial prediction of wilfire hazard across New Zealand, Landcare Research Contract Report LC0506/014, New Zealand Fire Service, Chrischurch, New Zealand, URL `http://www.fire.org.nz/Research/Publishsed-Reports/Pages/Impact-of-Climate-Change-on-Long-term-Fire-Danger.aspx`, 2005.

deGroot, W., Field, R., Brady, A., Roswintiarti, O., and Mohamad, M.: Development of the Indonesian and Malaysian Fire Danger Rating Systems, Mitig. Adapt. Strat. Glob. Change, 12, 165–180, 2006.

Dimitrakopoulos, A., Bemmerzouk, A., and Mitsopoulos, I.: Evaluation of the Canadian fire weather index system in an eastern Mediterranean environment, Meteorol. Appl., 18, 83–93, 2011.

Lawson, B. and Armitage, O.: Weather guide for the Canadian Forest Fire Danger Rating System, Tech. rep., Nat. Resour. Can., Can. For. Serv., Edmonton, Canada, 2008.

Stocks, B., Lawson, B., Alexander, M., Van Wagner, C., McAlpine, R., Lynham, T., and Dube, D.: The Canadian Forest Fire Danger Rating System - An Overview, For. Chron., 65, 450–457, 1989.

van Wagner, C. E.: Conversion of William's Severity Rating for use with the Fire Weather Index, Information Report PS–X–21, Canadian Forestry Service, Ontario, Canada, 1970.

van Wagner, C. E.: Development and structure of the Canadian Forest Fire Weather Index, Forestry Tech. Rep. 35, Canadian Forestry Service, Ottawa, Canada, 1987.

Viegas, D., Bovio, G., Ferreira, A., Nosenzo, A., and Sol, B.: Comparative study of various methods of fire danger evaluation in southern Europe, Int. J. Wildland Fire, 9, 235–246, 1999.

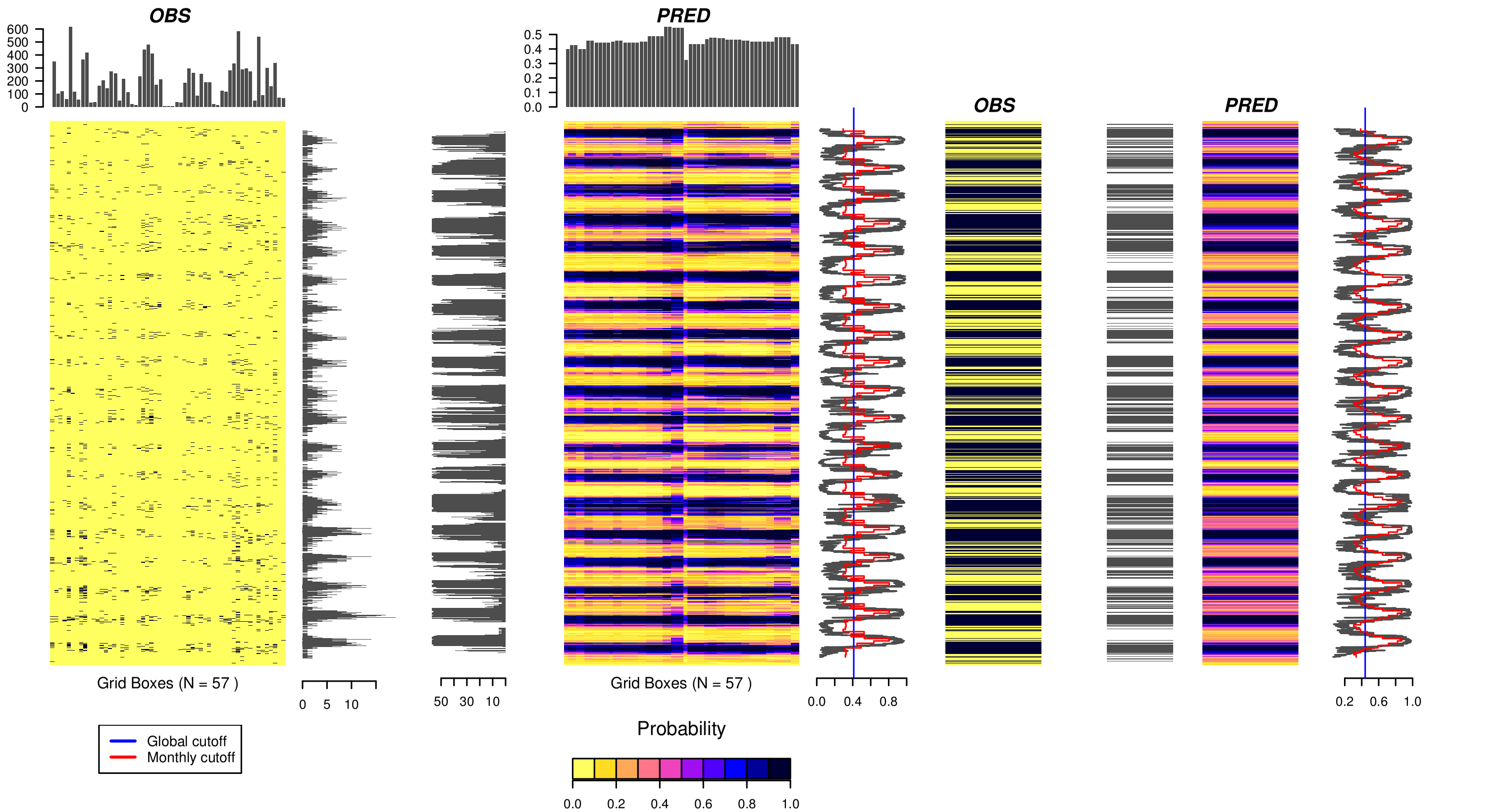

Figure 2: Observed and predicted data representation of fire occurrence considering both the grid-box (a-b) and areal (c-d) approaches. The example corresponds to the phytoclimatic zone 4, characterised by an unimodal annual fire regime. See text for more details.

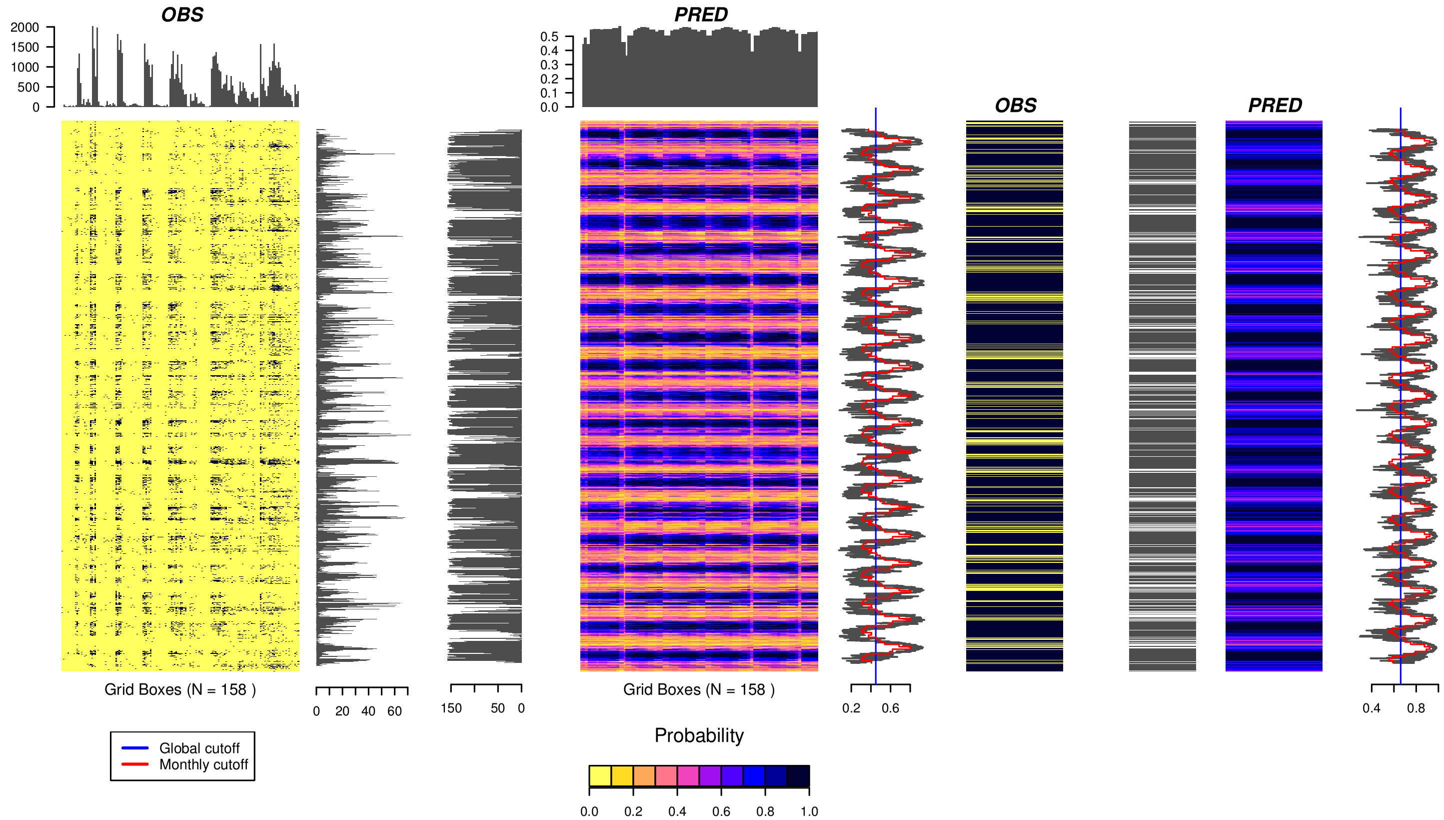

Figure 3: Same as Fig. 2 but for phytoclimatic zone 13-14-15.