Summer Fire Predictability in a Mediterranean Environment

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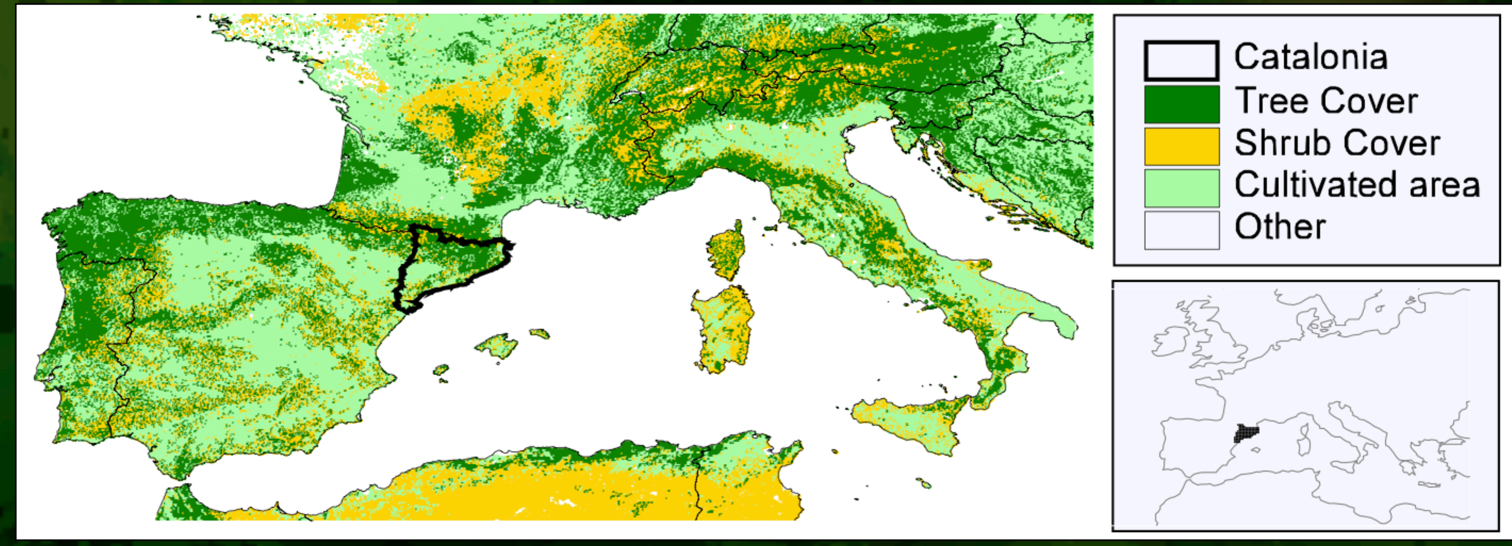
Abstract

Each year approximately 5x10^5 hectares burn in Europe. Most of these are Mediterranean summer fires that lead to damage to the natural environment, loss of lives and important economic losses every year. In this contribution we explore the seasonal predictability of summer wildfires in a Mediterranean region (NE Spain), developing a multiple linear regression model with antecedent and current-summer drought indices (SPI and SPEI). We test three forecast systems based on: ***seasonal ECMWF System-4 forecasts***, ***persistence*** and ***climatology***. These approaches are evaluated through a leave-one-out cross-validation over the period 1983-2012. The results suggest that long-term forecasts of above-normal burned area are feasible in NE Spain, an outcome that could be potentially applied to other Mediterranean-type regions.



Region

This study is focused on Catalonia (Fig. 1). Approximately 60% of its area (3.2x10^4 km^2) is covered by shrubland and forest. High intensity, stand-replacing fires are common in this area.

Fig 1. Domain of study and dominant land cover from the Global Land Cover dataset GLC2000 (Bartholomé & Belward, 2005).

Data

Observations

We used the publicly available daily precipitation and temperature high-resolution (0.25° x 0.25°) gridded dataset EOBS (v9.0, Haylock et al. 2008) over the period 1950-2012.

Fire

The employed forest fire data for the period 1983-2012 are obtained from the Forest Fire Prevention Service of the "Generalitat de Catalunya" (SPIF). We analyzed the burned of the summer months from June to September (BA, hereinafter).

Modeled

The seasonal forecast data is given by the ECMWF System-4 (Molteni et al. 2011), a fully-coupled general circulation model that provides operational multi-variable seasonal predictions at 0.75º horizontal resolution. We consider the 30-year re-forecast (1981-2010) with a 15-member ensemble and 7-month lead-time for predictions.

Methodology

We considered two standard drought indices: the Standardized Precipitation Index (SPI; Mc Kee et al. 1993) and the Standard Precipitation and Evaporation index (SPEI; Vicente-Serrano et al. 2010). The SPEI is mathematically similar to SPI, but includes the effects of temperature. In order to compute SPI (and SPEI) from forecast precipitation (and temperature), we merged the seasonal forecasts of precipitation (and temperature) with the antecedent series of historical records from EOBS, following the methodology from Dutra et al. (2013). Our approach builds on these studies by exploring the predictive relationship between drought indicators and fires through a statistical model. This method links drought indices to BA through a multiple linear regression model (MLR hereafter) based on the following hypothesis: ***antecedent droughts influence fuel structure, while current-year drought promotes favourable conditions for ignition and combustion*** (Turco et al. 2013). Essentially, the model relates year-to-year changes in BA with current and antecedent droughts,

$$\log(BA) = a \cdot DIC(\tau_a) + b \cdot DIA(\tau_b) + \varepsilon,$$

Eq.1. *DIC* refers to the Drought Index Current (SPI or SPEI) condition and *DIA* to the Drought Index Antecedent situation; *a* and *b* are coefficients that represent the sensitivities of BA to *DIC* and *DIA*, respectively; finally, τ_a and τ_b are the months to which the indexes *DIC* and *DIA* refer, respectively.

To avoid artificial skill, the data are linearly detrended in each step of the cross-validation. To estimate the uncertainty of this kind of predictions, we followed the methodology proposed by Calmanti et al. (2007). Basically, this consists in calculating the variance, V, of the residuals in the calibration period; then generating 1000 random residual time series with the same variance, V, and finally adding the stochastic residuals to the predicted values to generate an ensemble of 1000 predictions. The verification results are obtained through a leave-one-out cross-validation in which we iteratively test one year using the remaining observations as training data.

Results

We tested several MLR combinations with SPI/SPEI for 3, 6, 9 and 12 accumulation months and the best results show up with SPI/SPEI 6-month accumulation for τa and τb of 1 and 27 months, respectively. We focus on the SPEI drought index because it performs slightly better.

$$BA = -1.05 \cdot SPEI6(1) + 0.61 \cdot SPEI6(27) + \varepsilon$$

Eq.2. SPEI statistical model for BA.

From an operational point of view, we also assess whether this model can be used to separate positive and negative anomalies. We thus evaluate whether the MLR model can predict the occurrence of events, defining as events those cases with above-normal fire activity. We consider probabilistic forecast values ranging between 0% and 100% obtained as the percentage of the 1000 different out-of-sample predictions above their mean values.

Left column of figure 2 shows the observed BA evolution together with the application of the MLR (eq. 2) according to the three forecast approaches described. The right column shows the ROC diagrams for these forecast systems. At first glance, the seasonal S4 forecast does not add any noticeable improvement with respect to the climatology forecast. However, both predictions show some amount of skill, with correlations of 0.36 (pValue=0.06) and 0.37 (pValue=0.04) and RA of 0.58 and of 0.59. We argue that this source of predictability is entirely attributable to antecedent drought variables. The persistence forecast shows the best results considering the drought condition in May, with a correlation of 0.49 (pValue<0.01) and RA of 0.72.

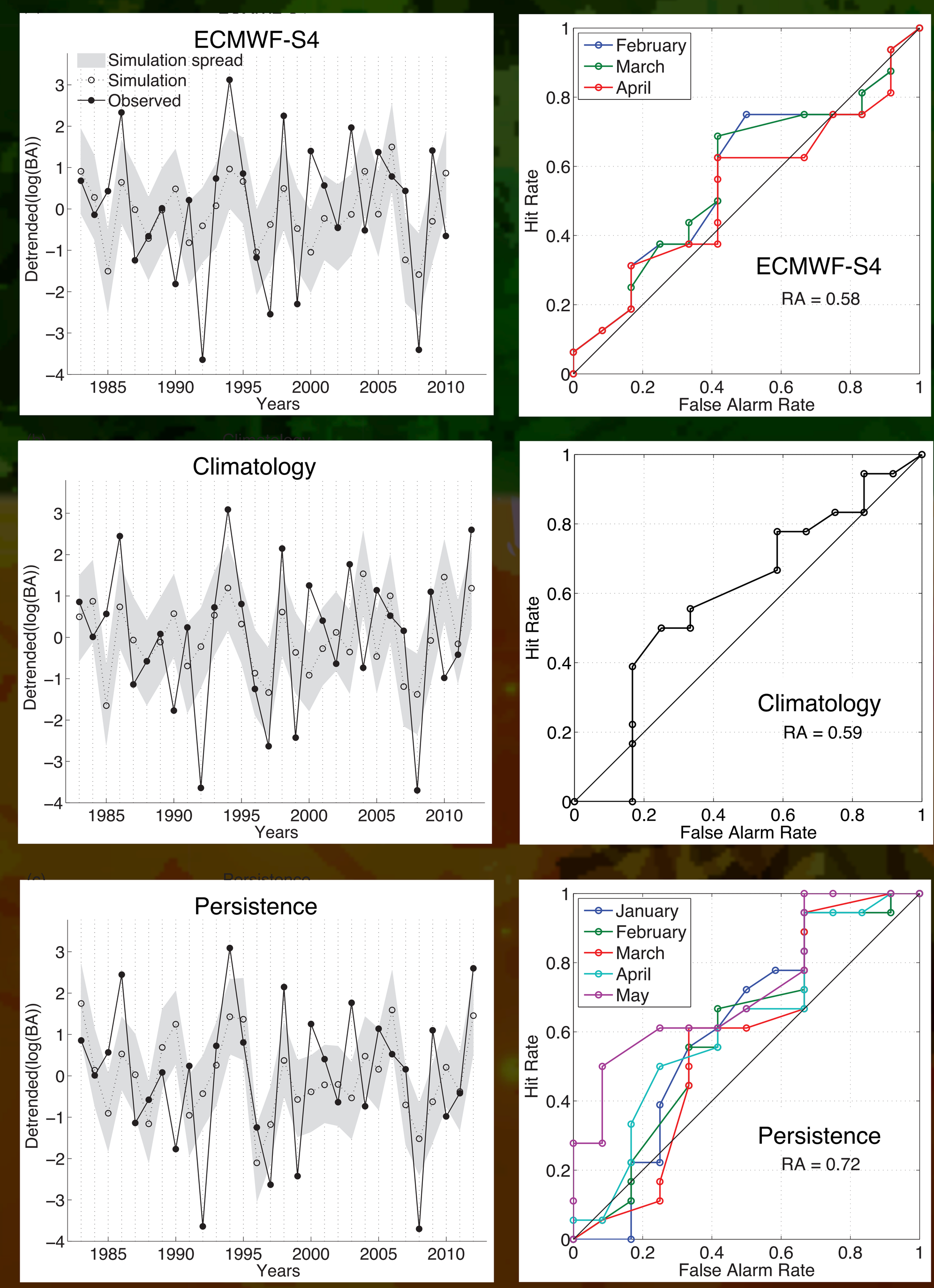


Fig 2. MLR model (eq. 2) and ROC diagrams for above normal BA considering the three forecast approaches: ECMWF-S4, Climatology and Persistence.

Conclusions

- Current skill of the ECMWF System-4 forecasts it is not enough to surpass 'climatology' and 'persistence' controls.
- The use of drought 'persistence' in eq. 1 leads to more satisfactory results, increasing predictability beyond 'climatology'.
- This approach could also be applied to other geographical areas with similar characteristics to Catalonia's, such as several Mediterranean regions covered by the so-called "Mediterranean scrub".
- The empirical drought-fire model proposed does not require large computational costs and can provide a first-guess estimate of the expected fire conditions for the summer season.

Acknowledgements

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