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Different approaches to model future burnt area in the Iberian Peninsula

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ABSTRACT

In this work we developed projections for future fire regimes in the Iberian Peninsula using outputs from Regional Climate Model (RCM) from the ENSEMBLES project. Wildfires are the cause of major ecological and economic impacts in this region, and the increasing evidence of climate change consequences in this region raises concerns on the future impacts of fires in the Iberian forests ecosystems. Our results confirm that the inter-annual variability of total burnt area is mainly controlled by meteorological conditions, in spite of the current efforts for fire control and suppression. We also show that this meteorology dominance over fire activity is not only true during the fire season itself, but also that certain specific meteorological backgrounds (such as prolonged droughts) may enhance the risk for severe wildfire episodes in some areas. Based on a previous classification of the Iberian Peninsula into four distinct pyro-regions, we developed statistical models which reproduce about two thirds of the inter-annual variability of the burnt area, using meteorological variables as predictors (calibrated with data from the ERA-Interim reanalysis). Specific models were developed for each sub-domain, testing their robustness for extrapolation under climate-change conditions. Using an ensemble of state-of-the-art RCM future climate scenarios, we present future BA projections considering two alternative techniques of statistical correction of model data often used in climate change impact studies: (1) unbiasing method; (2) delta change method. Our results clearly project large increases in mean burnt areas for all the considered pyro-regions, despite some fluctuations regarding each considered technique. By 2075, mean burnt areas could be about two to three times larger than in the present, taking into account current climate projections for the next century, and non-significant changes in other external factors, such as human activity, fire suppression or land use.

1. Introduction

Wildfires are not a recent hazard in the Iberian Peninsula; nevertheless, it is unquestionable that some of the most dramatic episodes have occurred since the turning of the century, particularly in western Iberia. The years of 2003 and 2005 correspond to landmark fire seasons in the fire history of Portugal, being responsible for the highest values of burnt area (hereafter, *BA*) since 1980 (Trigo et al., 2006; Pereira et al., 2011). Likewise, in the contiguous northwestern Spanish province of Galicia, the year of 2006 was characterized by a very high number of fires and large burned area (San-Miguel-Ayanz et al., 2013). It is well known the important human role on the shaping of fuel availability, which has a great impact in fire activity in Mediterranean ecosystems (de la Cueva et al., 2006; Costa et al., 2010; Pausas and Fernández-Muñoz, 2012). Some Iberian fire prone areas, such as the eastern coast of Spain (e.g. Valencia, Murcia, Catalonia) have witnessed a significant decrease of summer wildfire since the mid-90s, partly attributable to significant improvements in fire prevention and suppression schemes (Turco et al., 2013), taken after some of the worst fire occurrences in the region.

Nonetheless, apart from the anthropogenic influence and in spite of the fire suppression efforts in the Euro-Mediterranean areas, meteorological drivers play a key role in modulating the

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inter-annual variability of *BA* (Bedia et al., 2014), which is strongly controlled by summer meteorological conditions (Pereira et al., 2005; Trigo et al., 2006, 2013), specially during drought episodes (Pausas and Fernández-Muñoz, 2012; Gouveia et al., 2012), and to a lesser extent by previous precipitation, as antecedent conditions affect primary productivity (and hence fuel availability, Koutsias et al., 2013). In this regard, the recent work by Trigo et al. (2013) shows that this variability can be fairly well reproduced by statistical models based solely on meteorological variables. Despite significant and costly efforts in prevention and suppression made in recent years by national authorities, the recent rise in the frequency of extreme hot events (Ramos et al., 2011) and drought episodes in the Iberian area (García-Herrera et al., 2007; Sousa et al., 2011), has made its toll in scarring Iberian forests, as for instance, during episodes such as the mega-heatwave that affected western Europe in 2003 (Trigo et al., 2006; García-Herrera et al., 2010), most often related with the occurrence of large atmospheric blocking episodes (Trigo et al., 2005; Barriopedro et al., 2011). Such episodes lead to extremely dry atmospheric conditions that favor fire ignitions over a vegetation under hydric/hydrological stress and very low fuel moisture content.

The strong meteorological forcing over fire regimes raises serious concerns on the future of the Mediterranean basin forests, as most Global and Regional Climate Models (hereafter GCMs and RCMs) project an important warming in these areas (Brands et al., 2011, Ramos et al., 2011; Frias et al., 2012) leading to an increased fire danger potential (Bedia et al., 2013, 2014). Significant changes in precipitation regimes should also be expected, mainly in monthly mean precipitation and intra-annual variability, characterized by less precipitation outside the winter season, as well as a tendency toward more extreme events (Giorgi and Lionello, 2008; Argüeso et al., 2012). To address this issue, several authors have attempted to explicitly model future *BA* series based on different climate change scenarios (Carvalho et al., 2007; Pereira et al., 2013; Amatulli et al., 2013). Regardless of the method used and the inherent model uncertainties, all approaches consistently point to a much higher future *BA*.

It is widely recognized that RCM outputs cannot be directly applied in impact studies due to the biases inherited from the driving GCM (see e.g. Turco et al., 2013b), as well as those introduced by the regional climate model (RCM) as a result of different model errors and parameterizations (c.f., Christensen et al., 2008; Herrera et al., 2010). Thus, a validation/calibration process is needed before using this data in impact applications. This process requires the availability of historical data (or high-resolution reanalysis) to calibrate the model outputs in a particular region of interest. Besides, climate models present some difficulties in realistically representing intrinsic variability, a fact which may hamper future projections, especially for those variables in which daily scale processes are dominant. Different bias correction methods have been proposed and tested in the literature to adjust model biases and/or daily variability using observations, being the unbiasing and delta methods (Déqué, 2007) the most simple and popular ones. On the one hand, the unbiasing method (hereafter BC) operates by just modifying the mean magnitude of the future simulation by subtracting the difference of the control simulation and the corresponding control observations (generally on a monthly basis), thus not affecting the distributional properties of the simulated series. On the other hand, the delta change method (henceforth DCM) uses the control (daily) observations of the target variables as the future daily baseline, adapting their mean state and variance according to the projected (monthly) model changes, thus preserving the daily variability associated to the observed meteorological variables. This technique has been previously applied in the context of wildfire research (Flannigan et al., 2013) although comparative studies of both approaches in the framework of wildfire research are lacking to date. In this study, we investigate both types of model correction techniques for the estimation of future *BA* in the Iberian Peninsula.

The aim of this study is the generation of plausible future BA scenarios for the Iberian Peninsula in order to ascertain the potential impacts of climate change on wildfires. To this aim, the following steps are addressed:

(1) We analyze the relationships between inter-annual variability of observed *BA* and meteorological conditions, in particular the meteorological patterns associated with intense wildfire seasons;
(2) We develop statistical regression models capable to reproduce the inter-annual variability of *BA* series during the 1981–2005 control period, testing them with control simulation data from a set of state-of-the-art RCMs from the EU-funded project ENSEMBLES (van der Linden and Mitchell, 2009).
(3) We assess the uncertainty of the future projections derived from the bias correction technique by comparing the projected BA results after using either BC or DCM methods.

The manuscript is structured as follows:

The datasets and methodologies used are presented in Section 2 while an outlook at the control period fire climatology of Iberia and of each sub-domain is performed in Section 3. The links with meteorology, the development of the statistical model using observed data, the performance of RCMs simulations for the control period and the projected future scenarios are presented in Section 4. Finally, the discussion of the obtained results and used methods are found in Section 5.

2. Data and methods

2.1. Fire data

Portuguese fire data was obtained from the *Autoridade Florestal Nacional* (Pereira et al., 2011), while Spanish data was obtained from the *Dirección General de Biodiversidad* (Mérida et al., 2007). Building on both databases, we used the recent joint Iberian wildfire database (Trigo et al., 2013), encompassing their common period 1981–2005. Monthly *BA* time series are spatially disaggregated by (66) Continental administrative regions (hereafter AR), that correspond to (18) *Distritos* in Portugal, and (48) *Provincias* in Spain - (excluding the Atlantic archipelagos). We also computed the monthly Normalized Burnt Area (*NBA*) for each AR, defined as the quotient between the amount of *BA* in each AR and the corresponding area of the AR (Fig. 1).

Despite the important inter-annual variability, the northwestern sector of Iberia presents the highest rates of *NBA* in most years. Years 1981, 1985, 1989, 1995 and specially 2005 stand out as particularly severe in this sector, with annual *NBA* above 25‰ for a large number of AR. On the other hand, the years of 1991, 1995, 2003 and 2004 were particularly harsh in southwestern regions of the Peninsula. The Mediterranean area is also prone to some dramatic wildfire summers, namely before 1995. In contrast with other regions where summer fires explain most of the annual NBA, a well defined late winter or early spring fire season is found in the northernmost areas of Iberia (with similar magnitude compared to summer months), as shown in Fig. 2. In fact, this earlier peak is also found in northwest Iberia, but in this case, much smaller in magnitude when compared to the mean summer NBA. These different fire regimes have also been addressed in a preceding work (Trigo et al., 2013), where a cluster analysis allowed the identification of four spatially homogeneous pyro-regions (Fig. 2): northwest (NW_CLU), southwest (SW_CLU), north (N_CLU) and east (E_CLU).