# Climate change impacts on summer fires in Mediterranean Europe


**Marco Turco[1], Joaquín Bedia[2,3], Sonia Jerez[4], Maria Carmen Llasat[1], Juan Pedro Montávez[4], Antonello Provenzale[5] and Juan José Rosa Cánovas[4]**

[1]Department of Applied Physics, University of Barcelona, 08028 Barcelona, Spain; [2]Predictia Intelligent Data Solutions, 39005 Santander, Spain; [3]Santander Meteorology Group. Department of Applied Mathematics and Computing Science, University of Cantabria, 39005, Santander, Spain; [4]Regional Atmospheric Modeling Group, University of Murcia, 30100 Murcia, Spain; [5]Institute of Geosciences and Earth Resources (IGG), National Research Council (CNR), 56124 Pisa, Italy.


## Abstract


The observed trend towards warmer and drier conditions in southern Europe is projected to continue in the next decades, possibly leading to increased risk of large fires. However, an assessment of climate change impacts on fires at (and above) the 1.5ºC Paris target is still missing. **Here, we estimate future summer burned area in Mediterranean Europe under 1.5, 2 and 3ºC global warming scenarios, accounting for possible modifications of climate-fire relationships under changed climatic conditions owing to productivity alterations**. We found that such modifications could be beneficial, roughly halving the fire-intensifying signals. In any case, the burned area is robustly projected to increase. **The higher the warming level is, the larger is the increase of burned area, ranging from ~40% to ~100% across the scenarios. Our results indicate that significant benefits would be obtained if warming were limited to well below 2ºC.** More details: Turco et al. (2018a).


## Modelling approach

First, we consider the **stationary SPEI-BA model** (hereinafter SM):

$$\log[BA(i, t)] = \beta 1(i) + \beta 2(i) \cdot SPEI(i, t) \qquad (1)$$

where BA is the Burned Area in the *i*th eco-region and summer *t*; $\beta 1$ is the intercept; $\beta 2$ represents the sensitivity of BA in each region to dry conditions as summarized by the SPEI. For more details see Turco et al. (2017, 2018a,b).

The response of BA to SPEI variations (i.e. the parameter $\beta 2$, that is the fingerprint of climate on BA), is negative (that is, warmer and drier summers lead to larger fires) and we observe that the generally higher absolute values of the parameter $\beta 2$ (i.e., a higher BA sensitivity to SPEI variation) are in the northern region. The statistical analysis that follows provides a confirmation (Fig. 1).

The relationship between the long-term average of annual temperature (*Ty*) versus the sensitivity of BA to SPEI ($\beta 2$) for the different eco-regions suggests that in (northern) colder, wetter and more productive regions (where *Ty* shows lower values), drought plays a more prominent role for BA than in (southern) drier regions (where *Ty* shows larger values; Fig. 1). We interpret this spatial variation as a surrogate for potential non-stationarity in the BA-SPEI links. That is, the value of $\beta 2$ in southern regions may serve as an analogue for the BA-SPEI relation in the northern regions that will experience an increase in temperature.

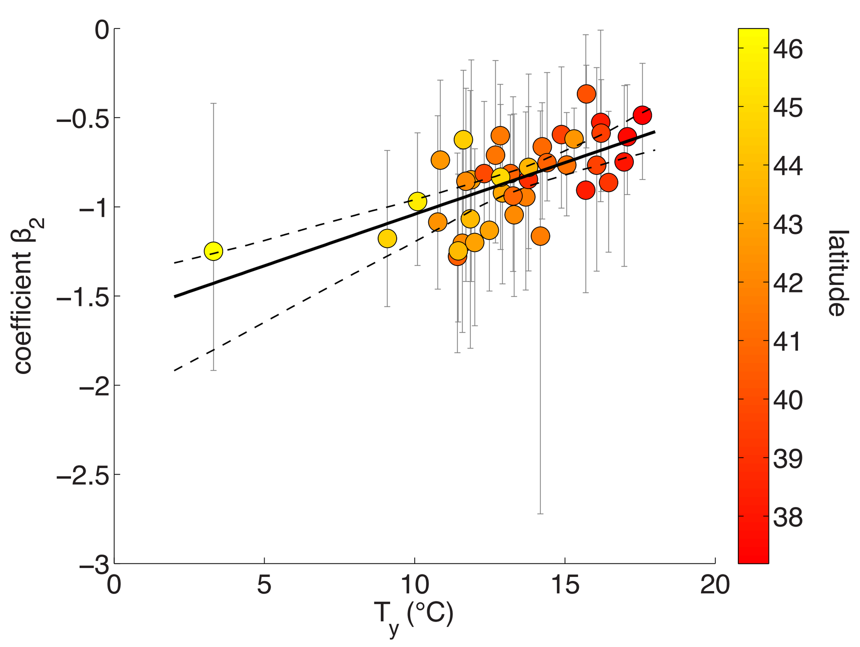


**Fig. 1.** Relationship between the long-term average of annual temperature (Ty) versus the sensitivity of burned area to SPEI ($\beta 2$) for the different eco-regions. The colours of the points indicate the latitude of the centroid of the sub-region. Grey bars enclose 95% confidence intervals of the individual $\beta 2$ values. The black line indicates the best linear fit, while dashed lines indicate the 95% confidence interval of a linear regression

Thus, to take into account the potential changes in the SPEI-BA links, we redefine $\beta 2$ in Eq. 1 to follow the *Ty*-$\beta 2$ relationship, in what we call the **non-stationary model** (hereinafter, NSM):

$$\log[BA(i, t)] = \beta 1(i) + (\gamma 1 + \gamma 2 \cdot Ty(i)) \cdot SPEI(i, t) \qquad (2)$$

At this point, we drive the models in Eqs. 1 and 2 with Regional Climate Model (RCM) EURO-CORDEX projections, selecting the temporal windows where the global mean temperature increase is 1.5, 2 or 3ºC.

## Results

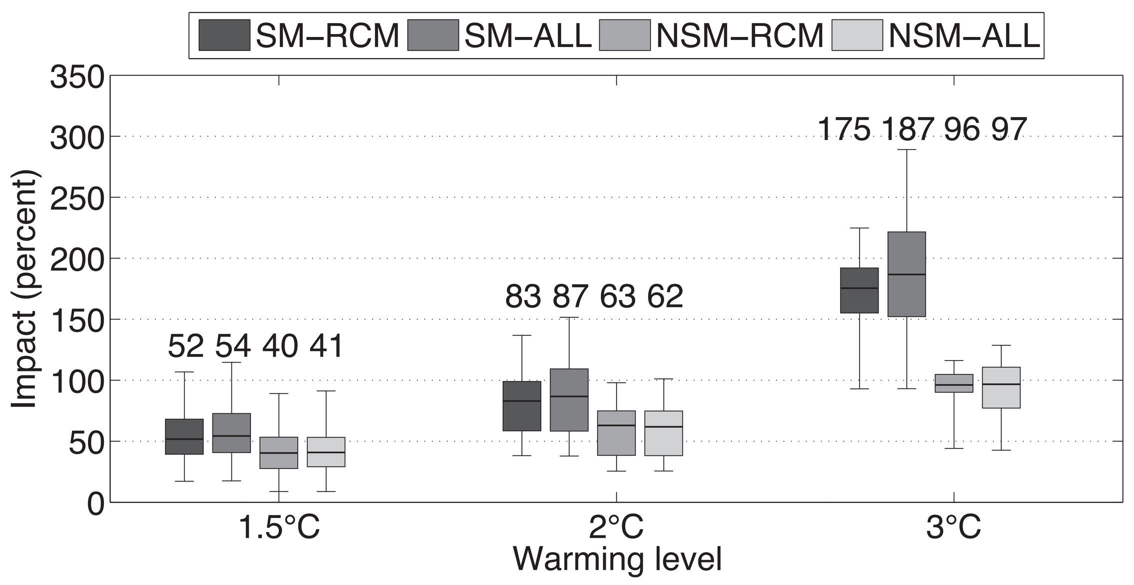


**Fig. 2.** Burned area changes in Mediterranean Europe (in %) for each warming level considering the stationary model SM (i.e., using Eq. 1) and the non-stationary model NSM (i.e., using Eq. 2). Boxplots show the uncertainty from (i) the ensemble of RCM projections (SM- or NSM-RCM) and (ii) accounting for both RCM and regression model uncertainties (1000 bootstrap replications x the ensemble of RCMs; SM- or NSM-ALL). The median is shown as a solid line, the box indicates the 25-75 percentile range, while the whiskers show the 2.5-97.5 percentile range. The numbers above the boxes indicate the median values

The spatially averaged **Burned Area changes for different warming levels** and for different model specifications are displayed in Fig. 2. Four main conclusions can be drawn from this analysis:

**1. a robust increase in BA is projected over Mediterranean Europe**

**2. this increase is much higher for 2ºC** (with values between 62% to 87% depending on the model specifications) **and 3ºC of global warming** (with values between 96% to 187%) **compared to the 1.5ºC target** (with values between 40% to 54%)

**3.** the results indicate that **non-stationary models generally led to lower impacts**, especially for larger temperature variations. For the +3ºC case, BA shows increases of 175% to 187% (depending on considering only the RCMs or the model+RCMs spread) with SM and of +96% to +97% with the NSM approach

**4. the overall uncertainty is dominated by the RCM spread rather than by the uncertainties related to the climate-fire model**. Indeed, there are only minor differences between the (N)SM-RCM boxes (RCM model uncertainty, as given by the multimodel spread) and between the (N)SM-ALL boxes (RCM+model parameter estimation uncertainty, estimated by the spread of 1000 bootstrap model replications for each RCM)

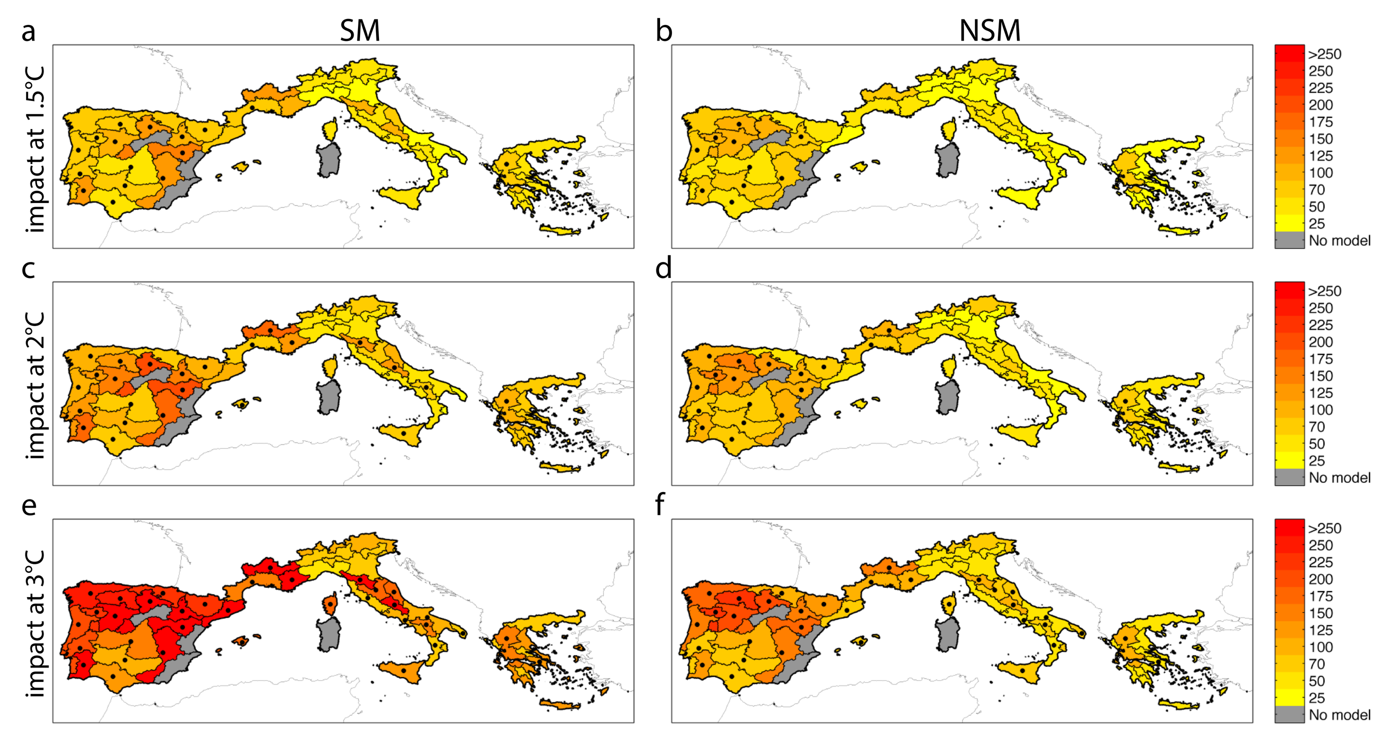


**Fig. 3.** Ensemble mean burned area changes (%) for (a) the +1.5ºC case with the stationary model SM (i.e., using Eq. 1), (b) the +1.5ºC case with non-stationary model NSM (i.e., using Eq. 2), (c) the +2ºC case with SM, (d) the +2ºC case with NSM, (e) the +3ºC case with SM, and (f) the +3ºC case with NSM. Dots indicate areas where at least 50% of the simulations (1000 bootstrap replications x the ensemble of RCMs) show a statistically significant change and more than 66% agree on the direction of the change. Coloured areas (without dots) indicate that changes are small compared to natural variations, and white regions (if any) indicate that no agreement between the simulations is found

At the 1.5ºC warming target, all regions exhibit a moderate increase in BA, with significant changes mostly in the Iberian Peninsula (Fig. 3, panels a and b). Larger increases in BA are foreseen for the +2ºC case (Fig. 3, panels c and d) with a larger number of eco-regions displaying significant changes. For the +3ºC case (Fig. 3, panels e and f), the BA shows even larger positive changes that are significant in the majority of eco-regions. **The obtained BA increases are consistent with the SPEI projected changes, depicting an overall intensification of drought conditions across regions that increases progressively with the level of global warming.**

## Conclusions

We illustrate that plausible levels of modification of the SPEI-BA links could reduce the impacts of climate change on BA. That is, if we consider only direct climate-fire linkages through the stationary model, the BA projections are higher (especially considering the 3ºC scenario) than if we consider also the potential indirect effects of climate-driven changes in fuel productivity. **Non-stationary models reduce the sensitivity of fire activity to dry periods by taking into account potential changes in productivity as a result of warming**.

**In any case, at or above 1.5ºC of warming, Mediterranean BA is projected to increase, and at higher warming levels this increase becomes even larger**. These results, in combination with the increase in societal exposure to large wildfires in recent years, call for a rethinking of current management strategies. **Climate change effects could overcome fire prevention efforts, implying that more fire management efforts must be planned in the near future**. The negative measured trend of BA in Mediterranean Europe in the past few decades can be explained by an increased effort in fire management and prevention (Turco et al. 2016). However, keeping fire management actions at the current level might not be sufficient to balance a future increase in droughts. In this sense, the ability to model the link between climate and fire is crucial to identifying **key actions in adaptation strategies**. In particular, **seasonal climate forecasts** may enable a more effective and dynamic adaptation to climate variability and change, offering an under-exploited opportunity to reduce the fire impact of adverse climate conditions (Turco et al. 2018b).

In summary, our results support the statement of the **Paris Agreement** that reports that **limiting the temperature increase to 1.5ºC would "significantly reduce the risks and impacts of climate change"**.

## References


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Corresponding author: turco.mrc@gmail.com