Barcelona Supercomputing Center
Centro Nacional de Supercomputación

EXCELENCIA SEVERO OCHOA

Current and future drought impacts on forest fire risk

Marco Turco - Postdoctoral researcher

25.04.2019

MISTRALS workshop on droughts

Questions

Higher temperatures and drier conditions cause larger fires in Mediterranean Europe.

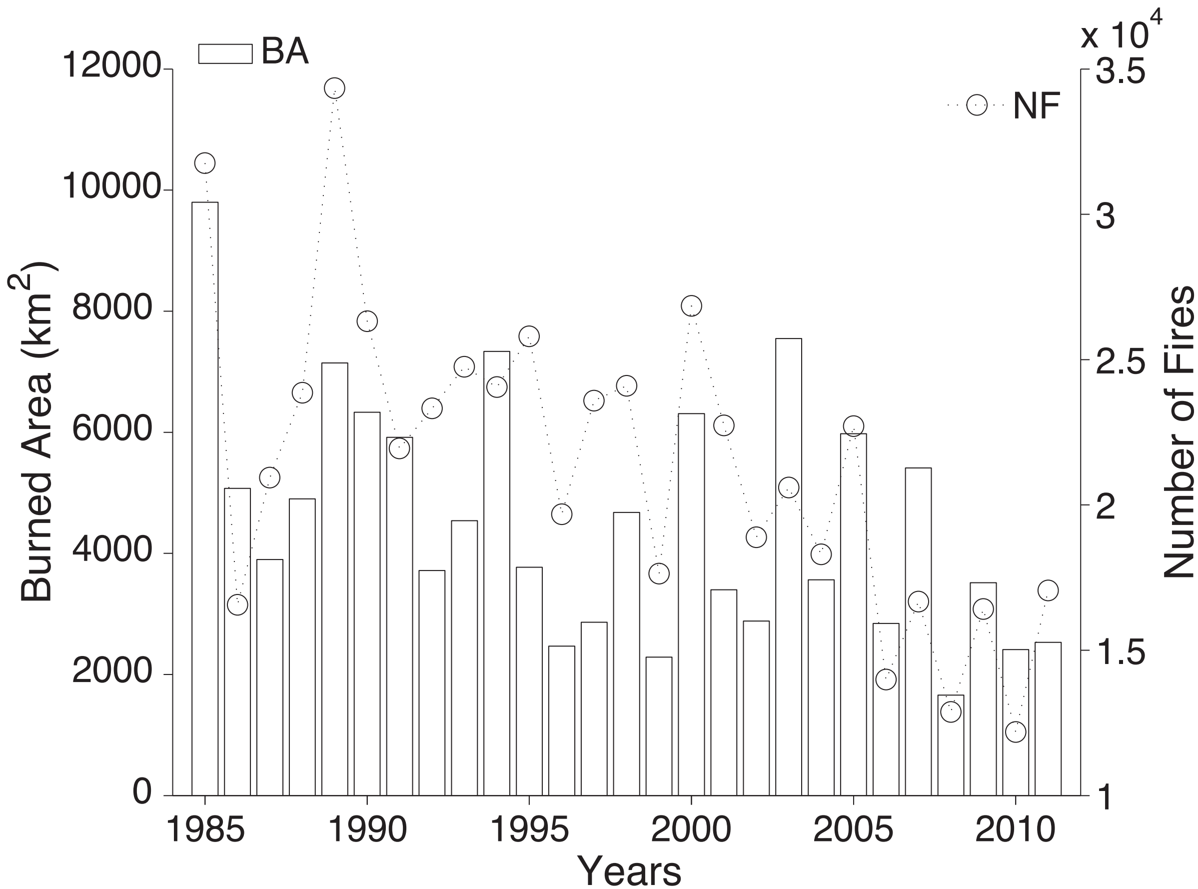
It is so simple?

The short answer is **YES**.

But in order to arrive and give strength to this conclusion we have previously analyzed several important issues.

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Are fires increasing?



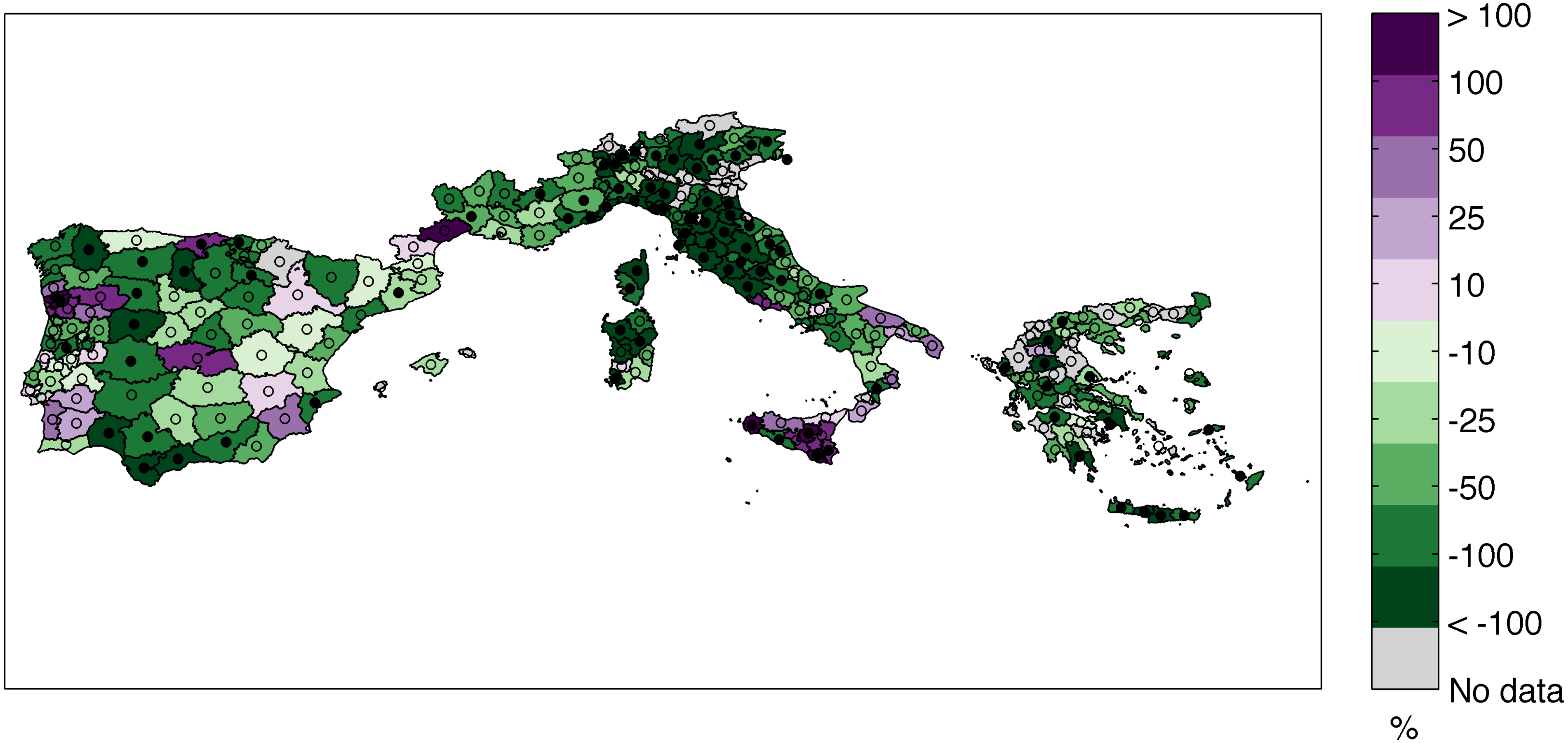
BA decreased by about 3020 km2 over the 27-year-long study period (i.e. about **-66%** of the mean historical value).

Similar overall results were found for the annual number of fires (NF), which globally decreased by about 12600 in the study period (about **-59%**).

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco M. et al. Decreasing Fires in Mediterranean Europe. Plos One 2016

Annual Burned Area trends for the period 1985-2011

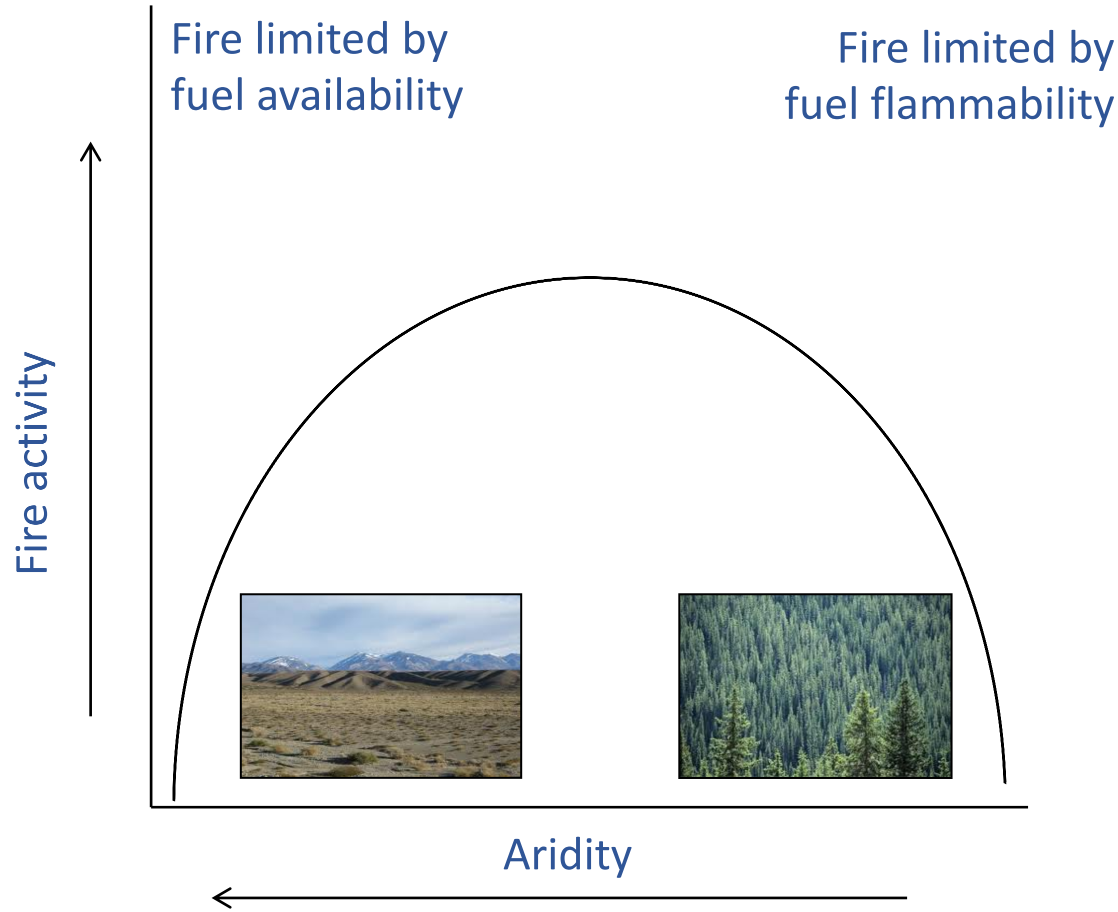


Significant trends ($p < 0.05$) are indicated by the filled black circles. Trends are shown as the percentages of the total trend for the available period (e.g., ha per 27 years) divided by the historical mean calculated over the same period (e.g. 1985-2011) .

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco M. et al. Decreasing Fires in Mediterranean Europe. Plos One 2016

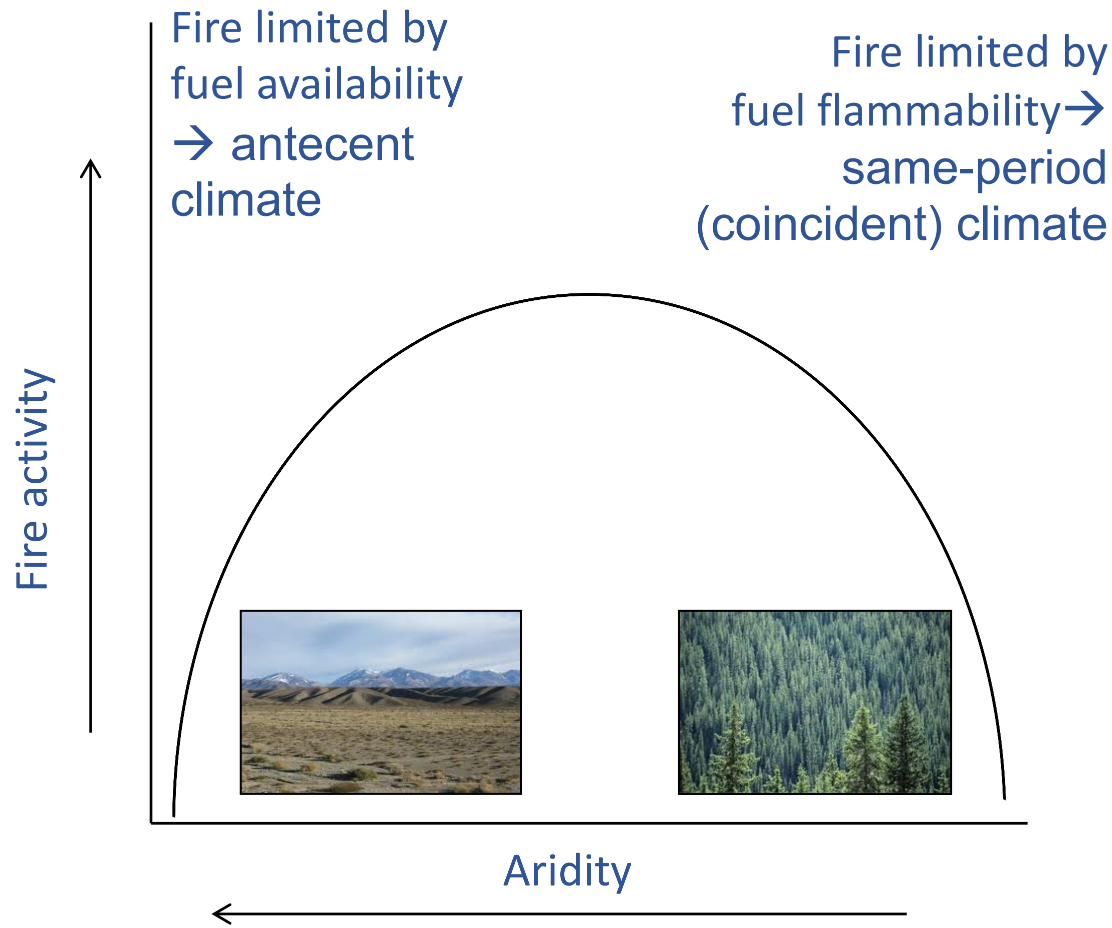
Which is the link between climate and fires?



Adapted from Pausas J.G. & Bradstock R.A. 2007. Fire persistence traits of plants along a productivity and disturbance gradient in Mediterranean shrublands of SE Australia. Global Ecology & Biogeography 16: 330-340.

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

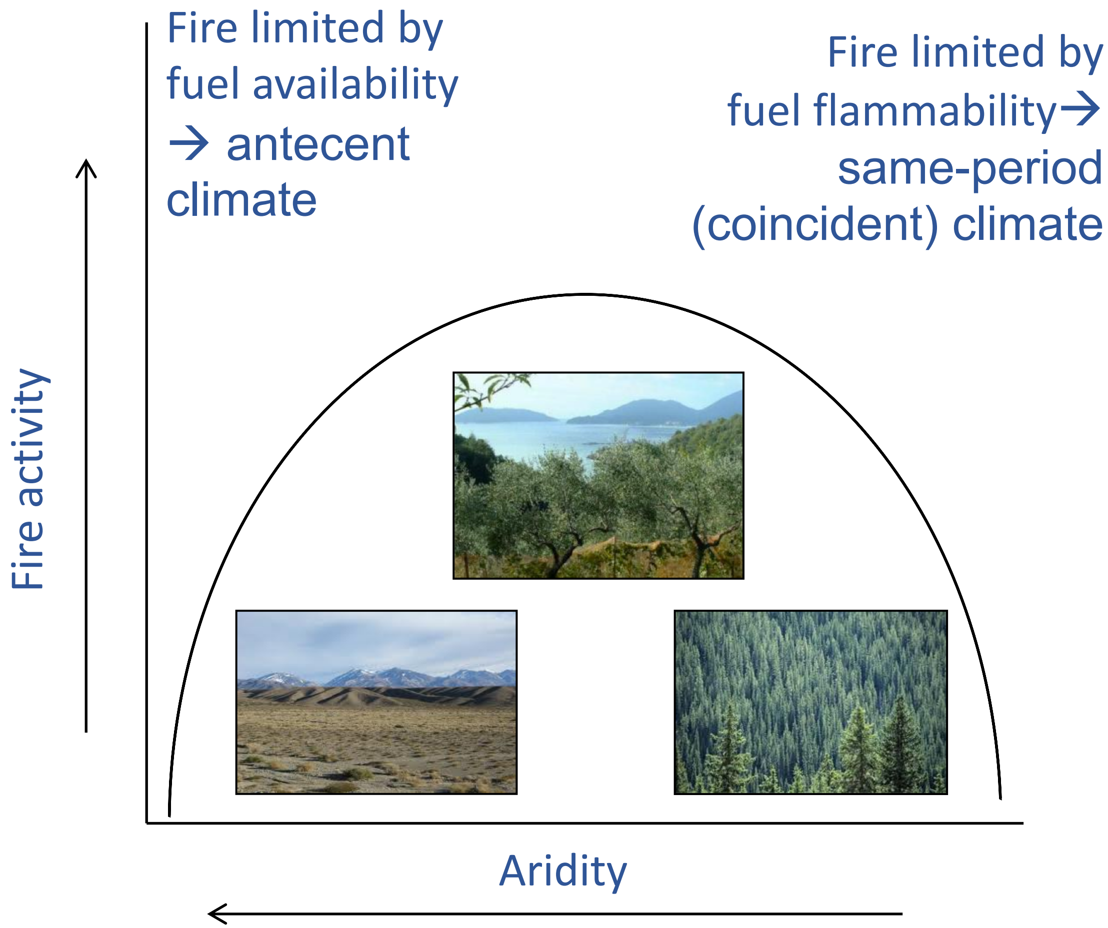
Which is the link between climate and fires?



Adapted from Pausas J.G. & Bradstock R.A. 2007. Fire persistence traits of plants along a productivity and disturbance gradient in Mediterranean shrublands of SE Australia. Global Ecology & Biogeography 16: 330-340.

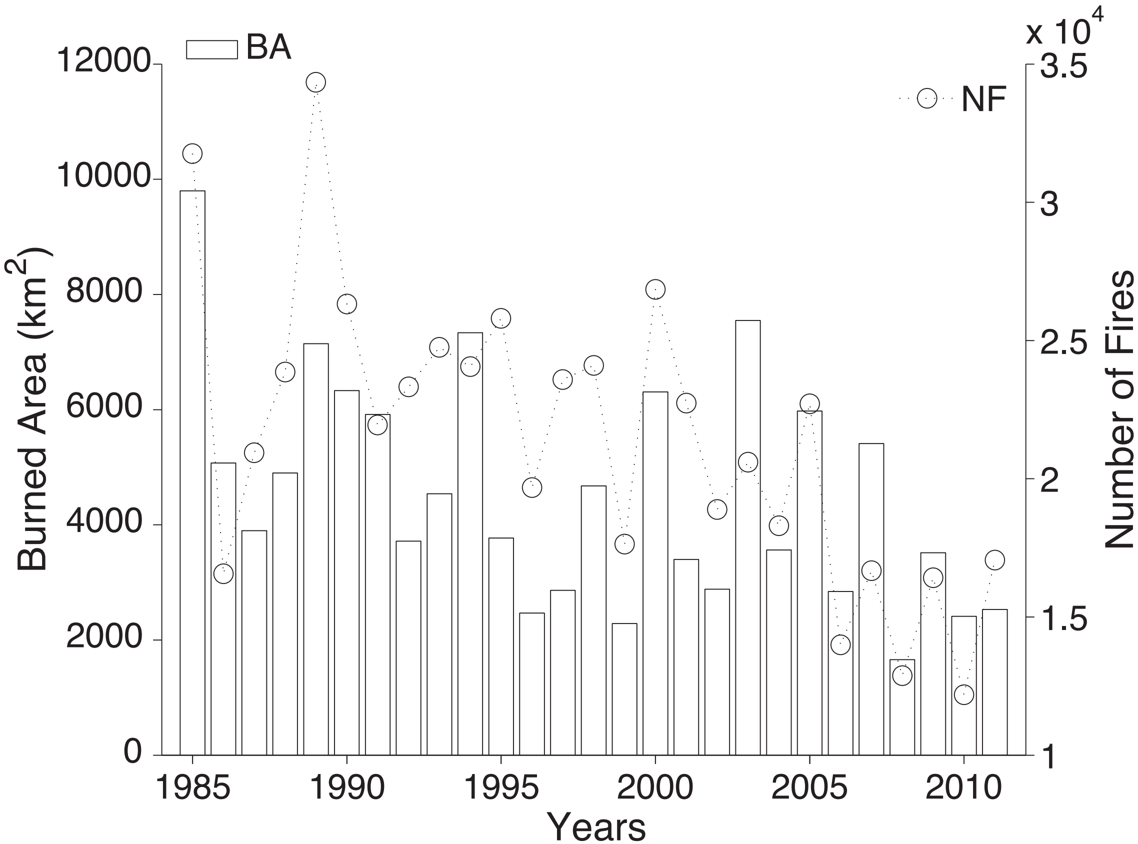
Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Which is the link between climate and fires?



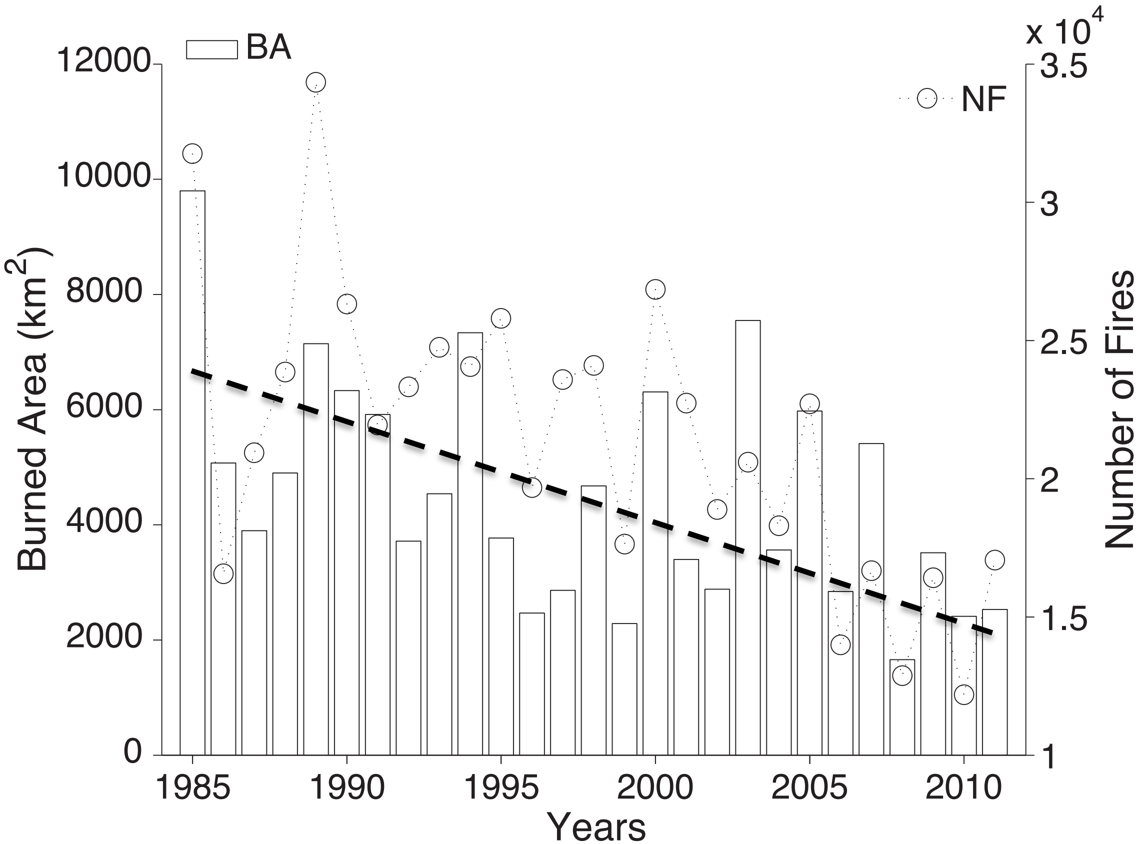
Adapted from Pausas J.G. & Bradstock R.A. 2007. Fire persistence traits of plants along a productivity and disturbance gradient in Mediterranean shrublands of SE Australia. Global Ecology & Biogeography 16: 330-340.

Which is the link between climate and fires?



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Which is the link between climate and fires?



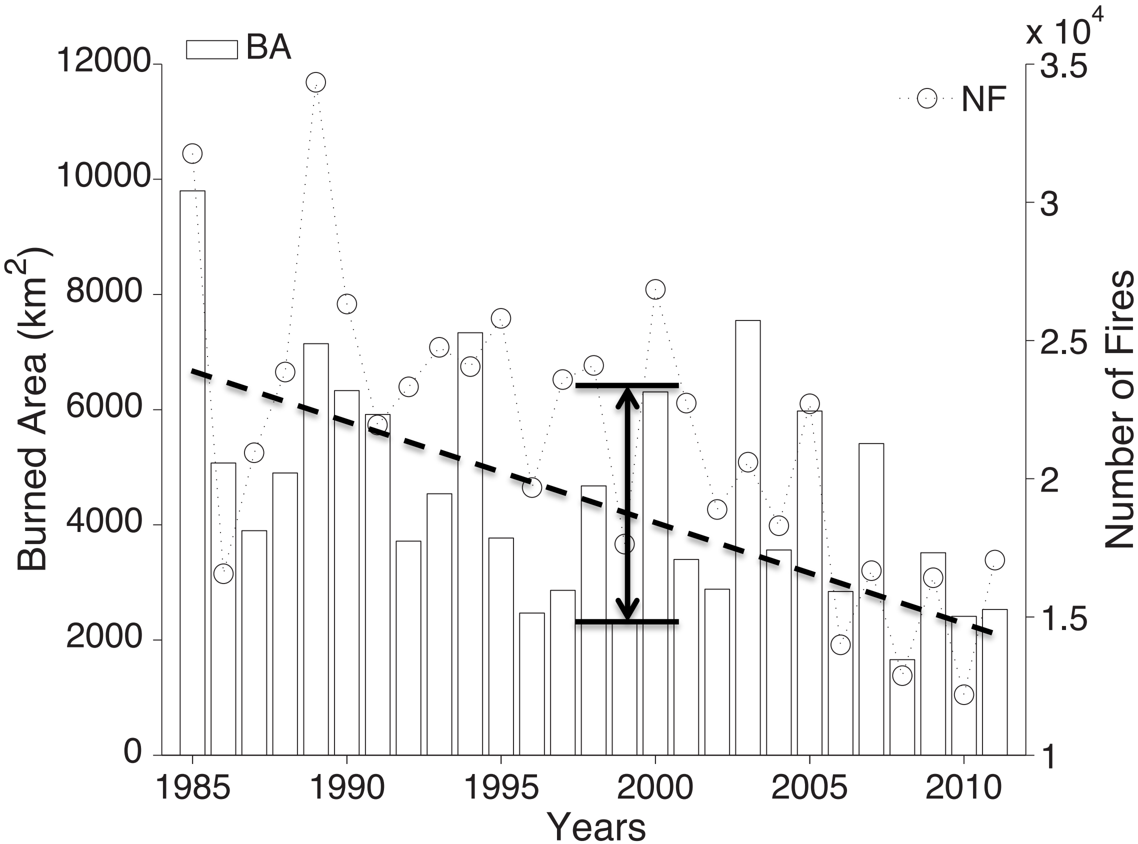
Two main working hypotheses :

1. Anthropogenic effects and climate trends
are "slowly changing factors".
They drive variations
on the scales of decades

Turco M., Llasat M. C., von Hardenberg J., Provenzale A. Impact of climate variability on summer fires in a Mediterranean environment (northeastern Iberian Peninsula). Climatic Change, 2013

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Which is the link between climate and fires?



Two main working hypotheses :

1. **Anthropogenic effects** and **climate trends** are "**slowly changing factors**". They drive variations on the scales of decades

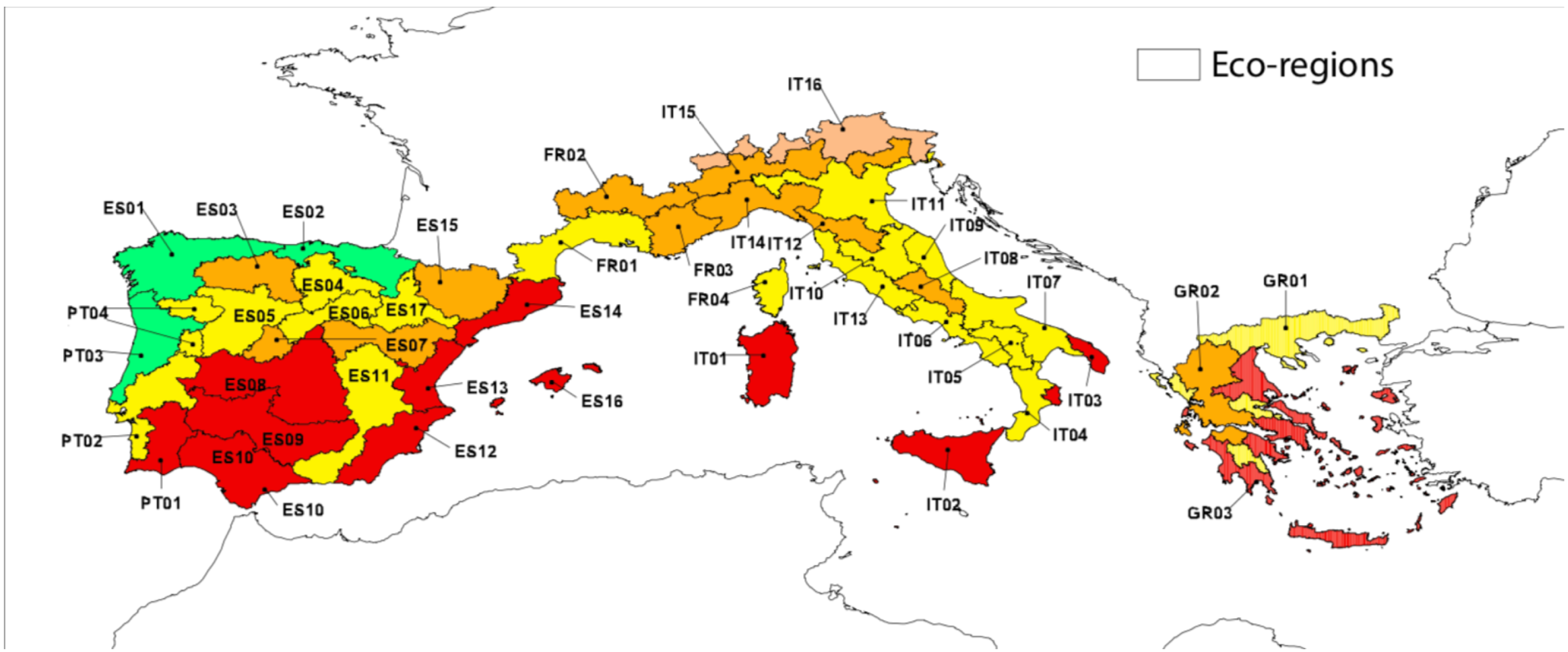
2. Although most fires are ignited by people, the **year-to-year changes** in the ease of ignition and in the burned areas, are mainly related to the **interannual climate variability**

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco M., Llasat M. C., von Hardenberg J., Provenzale A. Impact of climate variability on summer fires in a Mediterranean environment (northeastern Iberian Peninsula). Climatic Change, 2013

Data-driven climate-fire model

We aim to model BA(*i*,*t*): the Burned Area in the ith eco-region and summer *t* (total BA June-September)



Turco, M. et al. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7, 81 (2017)
Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

BSC Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Data-driven climate-fire model

$$\log[BA(i,t)] = \beta_1(i) + \beta_2(i)\, SPEI_{sc,m}(i,t) + \beta_3(i)\, T(t) + \varepsilon(i,t)$$

$\beta 1$ is the intercept

$\beta 2$ represents the sensitivity of BA in each region to the SPEI

$\beta 3$ is the coefficient of the time term T (in years) that characterizes the temporal trends of BA, thus taking into account the possible influence of slowly changing factors over the study period

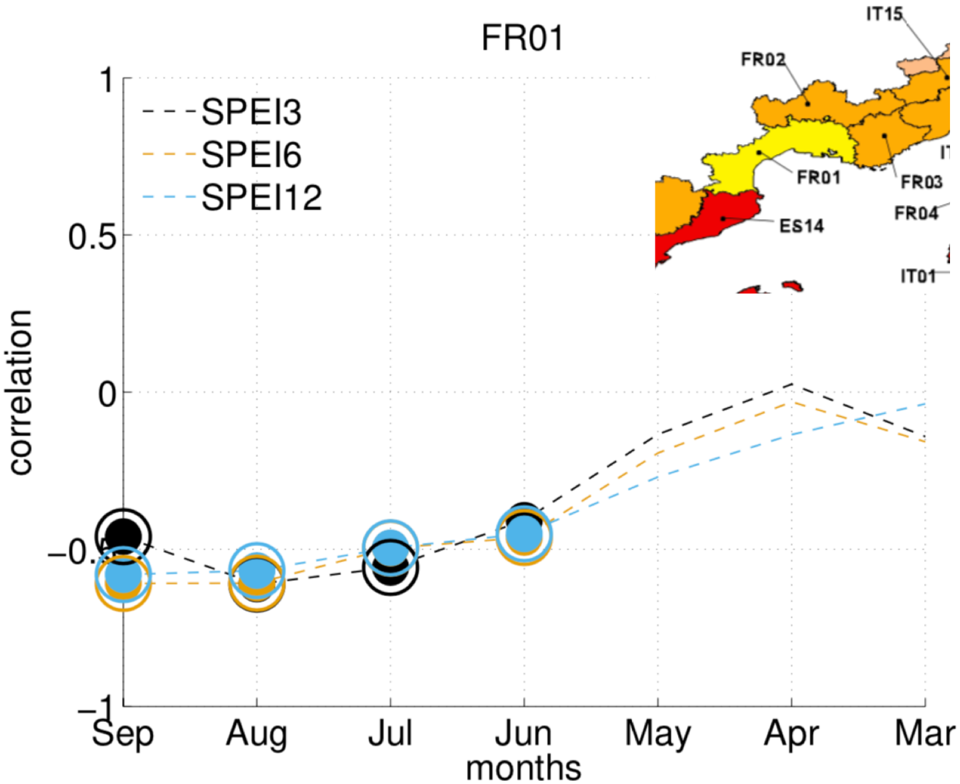
ε is a stochastic noise term

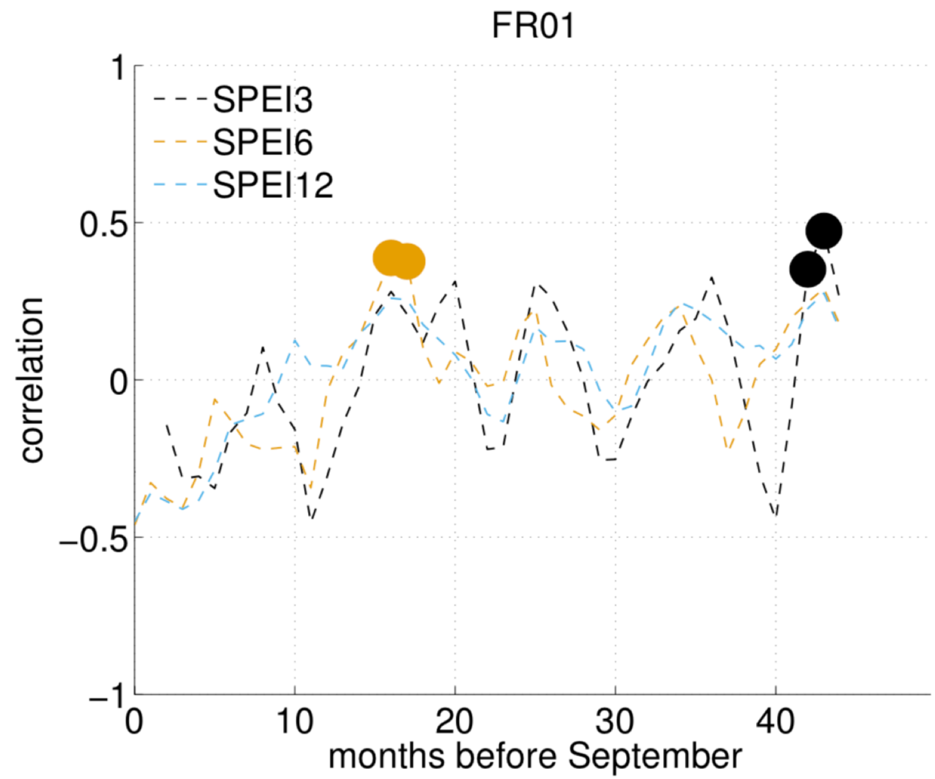
$SPEI_{sc,m}$: m is the month for which the SPEI is computed (which we allow to vary from previous spring to coincident summer months) and sc is the time scale (number of months) used to compute the SPEI (we consider periods of 3, 6, and 12 months)

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7, 81 (2017).

Coincident vs antecedent climate

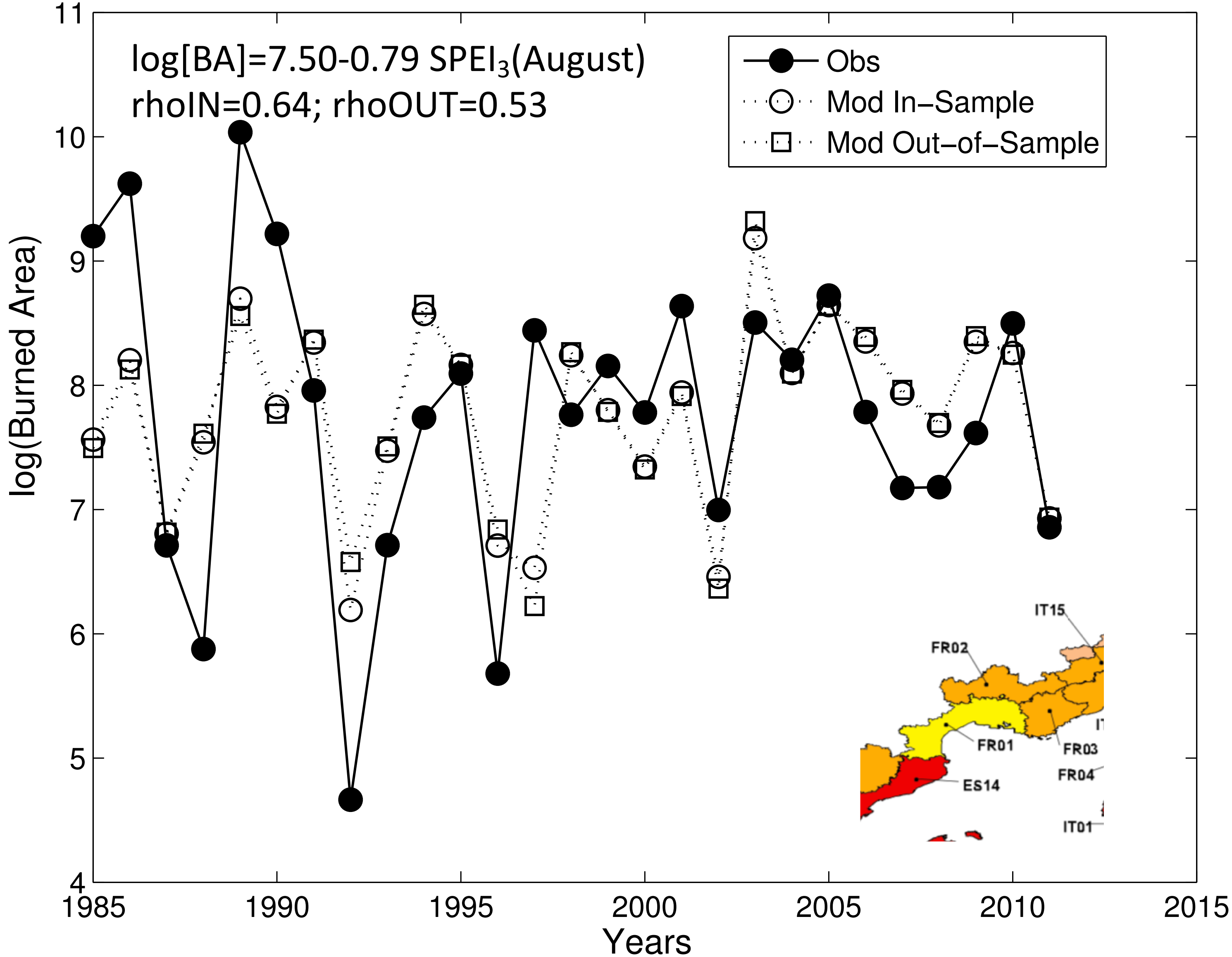




- p-value<0.05
- p-value<0.05 & collectively significant with a False Discovery Rate test (Ventura et al. 2004)

Turco, M. et al. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7, 81 (2017).
Ventura, V., Paciorek, C. J. & Risbey, J. S. Controlling the proportion of falsely rejected hypotheses when conducting multiple tests with climatological data. Journal of Climate 17, 4343–4356 (2004).

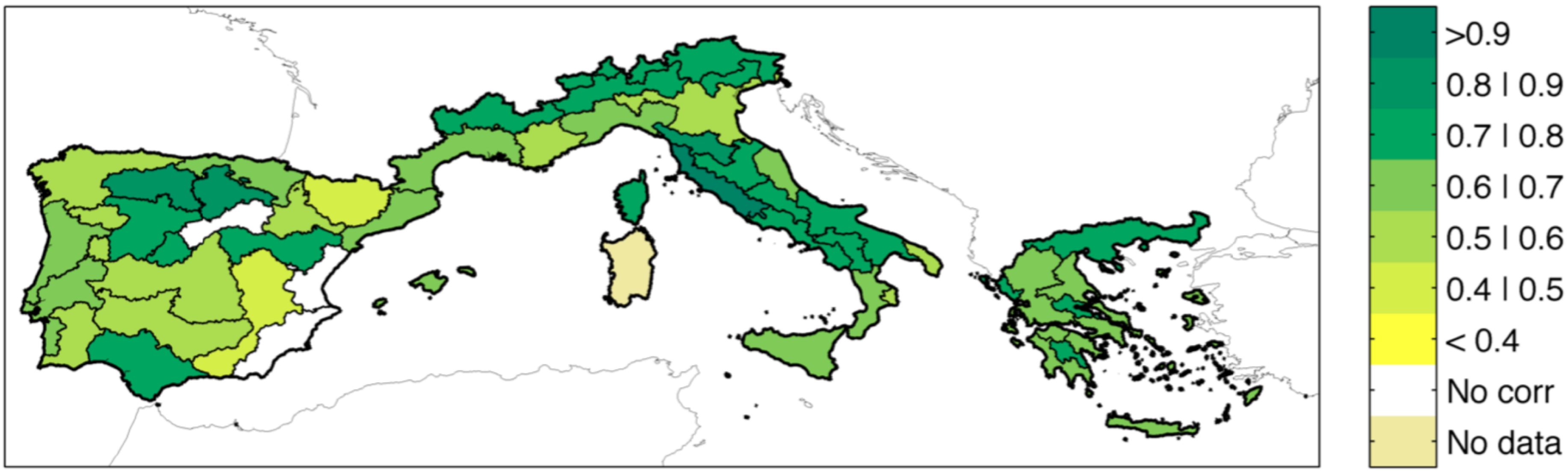
Barcelona Supercomputing Center
Centro Nacional de Supercomputación



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. On the key role of droughts in the dynamics of summer fires in Mediterranean Europe. Sci. Rep. 7, 81 (2017).

Correlation between modelled and observed log(BA) for each eco-region



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

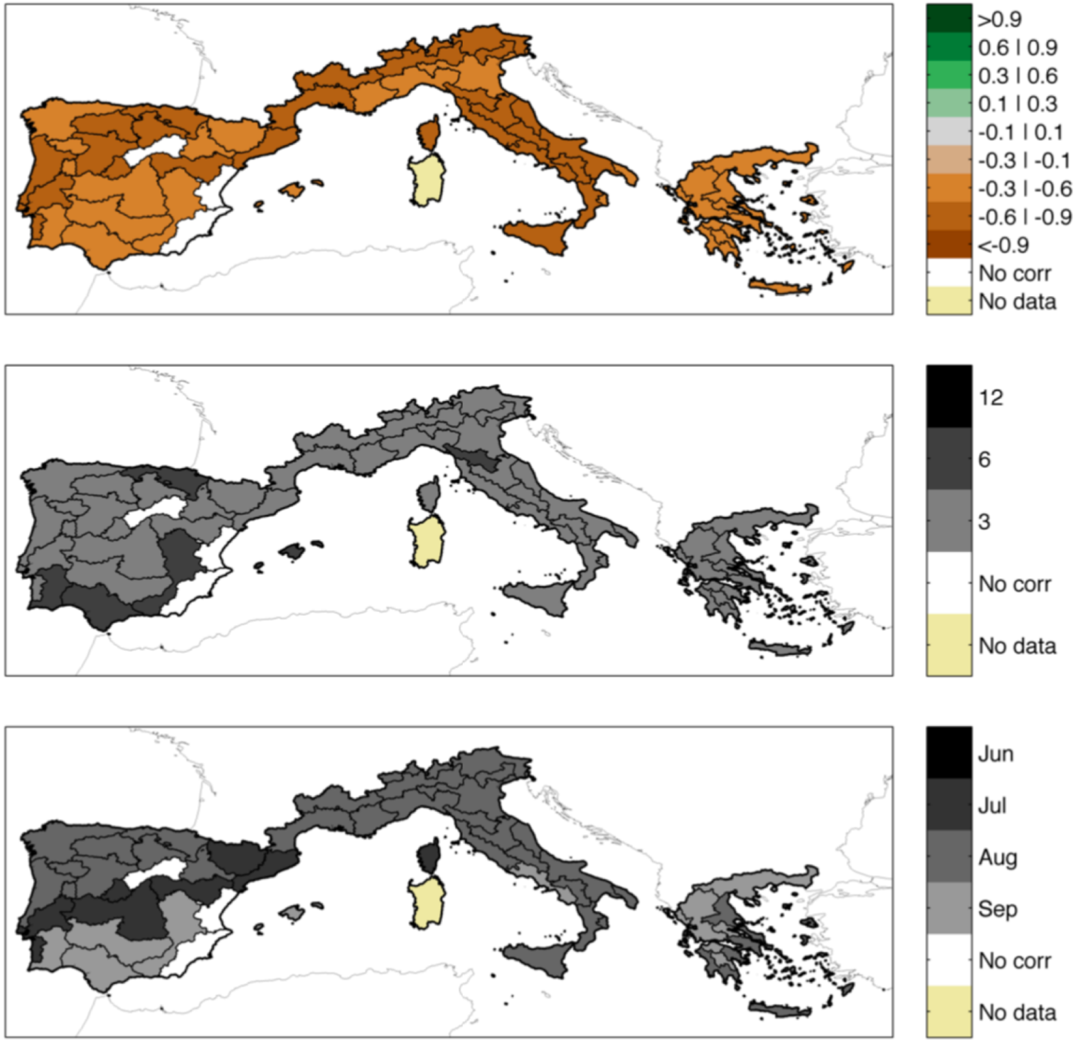
Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Current drought impacts on forest fire risk

Correlation between detrended[log(BA)] and detrended($SPEI_{sc,m}$)

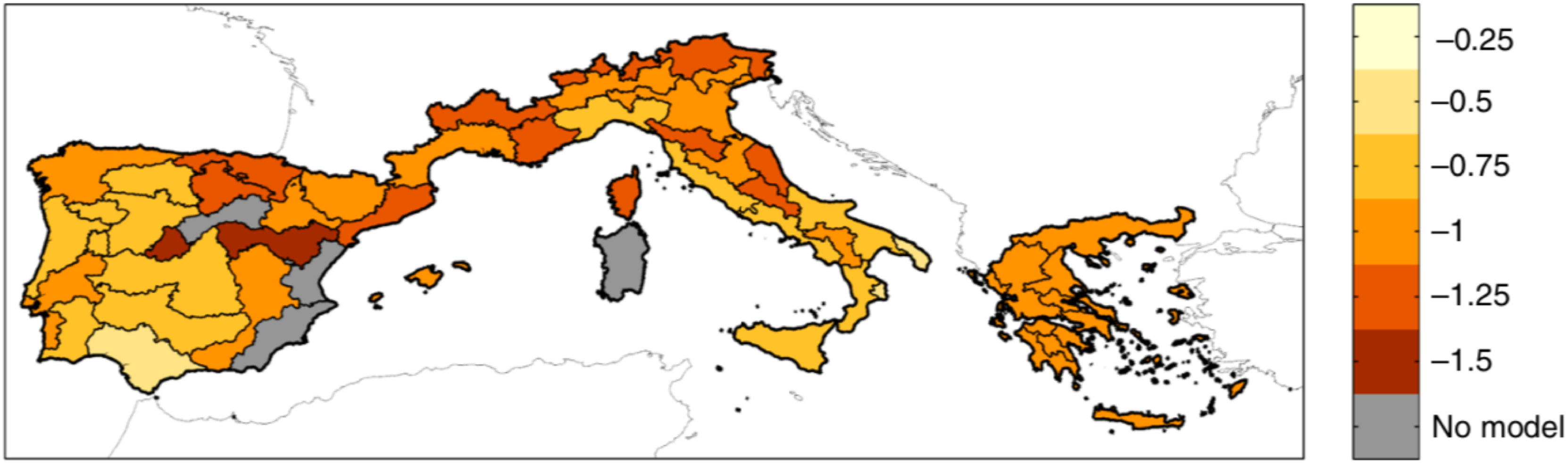
sc: time scale of the SPEI index (3, 6 or 12 months)

m: final month of accumulation of the SPEI



Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Current drought impacts on forest fire risk



Sensitivity of burned area to SPEI variations.

This sensitivity is represented by the coefficients β2 of Eq.:

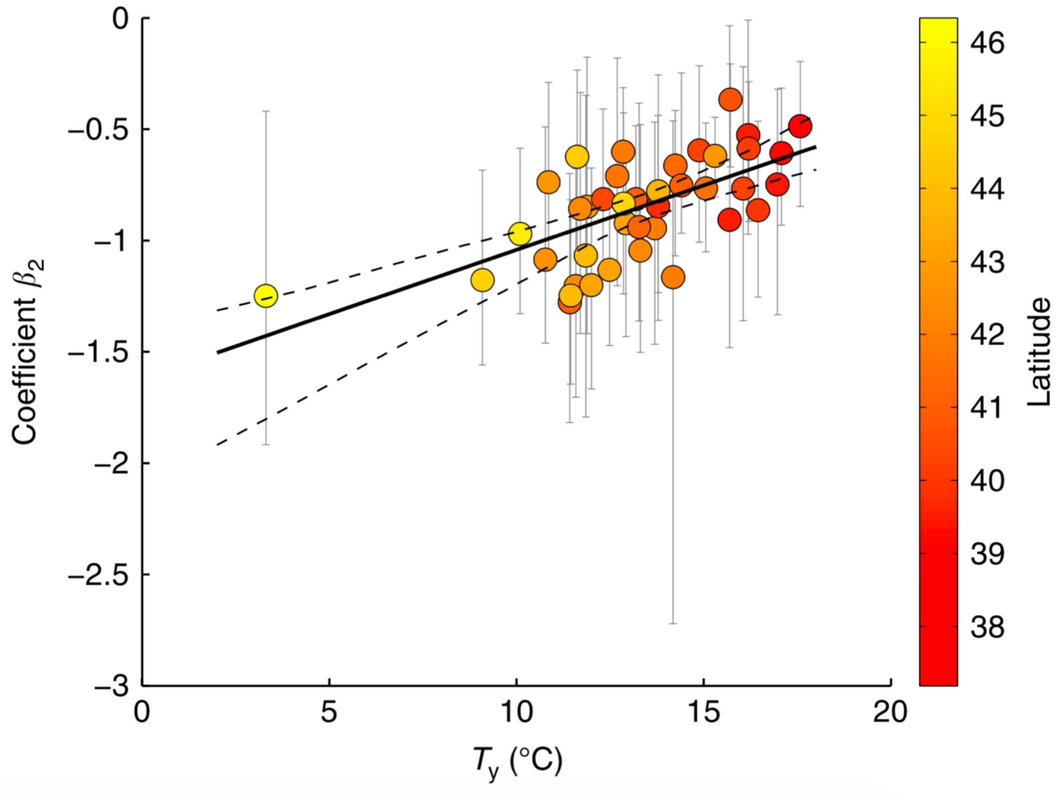
$\log[BA(i,t)] = \beta_1(i) + \beta_2(i)\, SPEI_{sc,m}(i,t) + \beta_3(i)\, T(t) + \varepsilon(i,t)$

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Current drought impacts on forest fire risk

$\beta_2(i) = -1.62 + 0.057\ T_y(i)$
rho = 0.64



Relationship between the long-term average of annual temperature (T_y) versus the sensitivity of burned area to SPEI (β_2) for the different eco- regions.

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

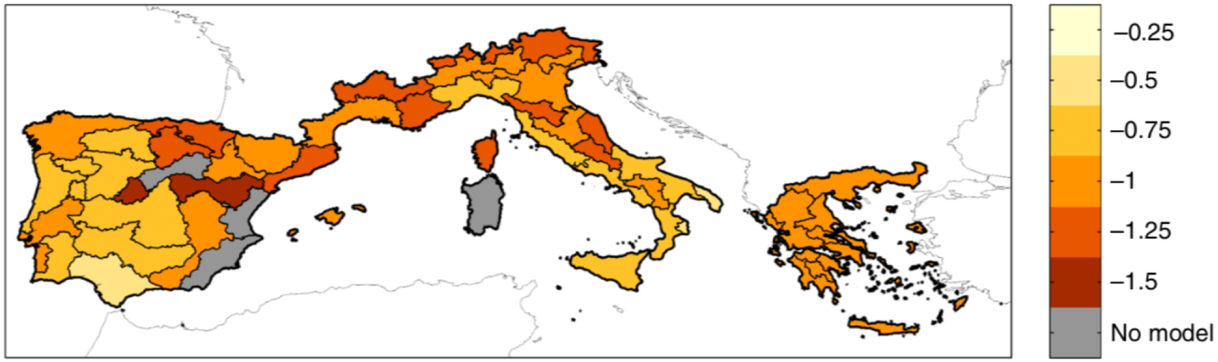
Space for time: non-stationary model

Stationary model:

$$\log[BA(i,t)]_{climate} = \beta_1(i) + \beta_2(i)\, SPEI_{sc,m}(i,t) + \varepsilon(i,t)$$

Non-stationary model:

$$\log[BA(i,t)]_{climate} = \beta_1(i) + [-1.62 + 0.057\, T_y(i)]\, SPEI_{sc,m}(i,t) + \beta_3(i)\, T(t) + \varepsilon(i,t)$$



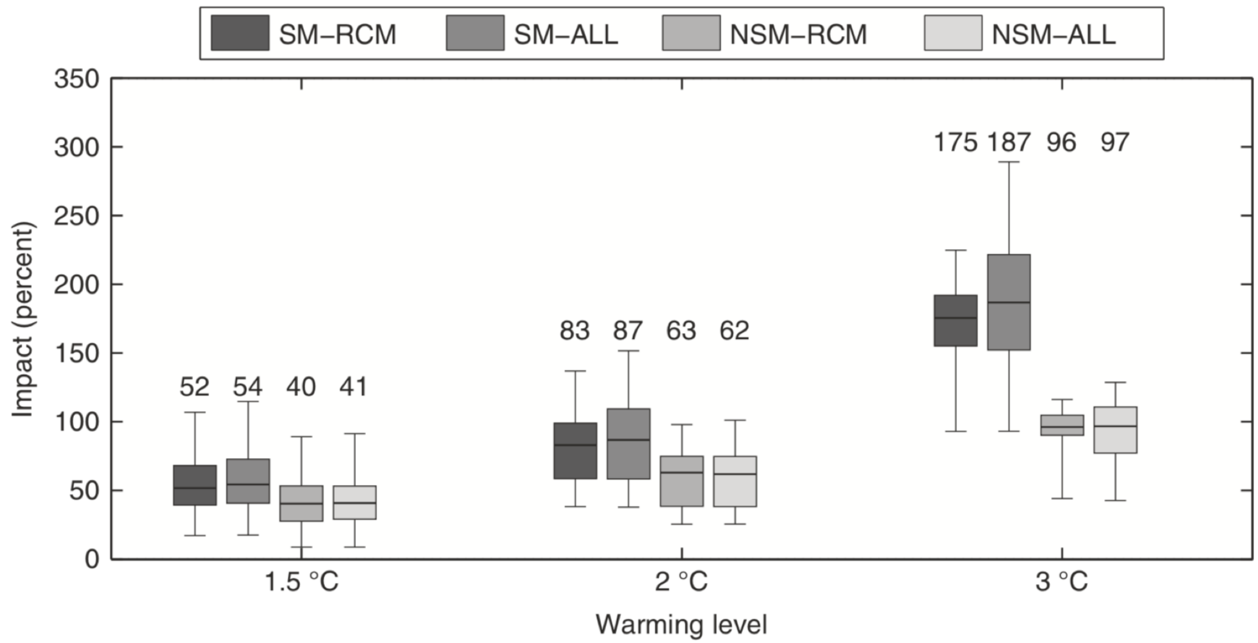
Butler, E. E. & Huybers, P. Adaptation of US maize to temperature variations. Nat. Clim. Chang. 3, 68–72 (2013).

Carleton, T. A. & Hsiang, S. M. Social and economic impacts of climate. Science 353, aad9837 (2016).

Moore, F. C. & Lobell, D. B. Adaptation potential of European agriculture in response to climate change. Nat. Clim. Chang. 4, 610–614 (2014).

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Future drought impacts on forest fire risk

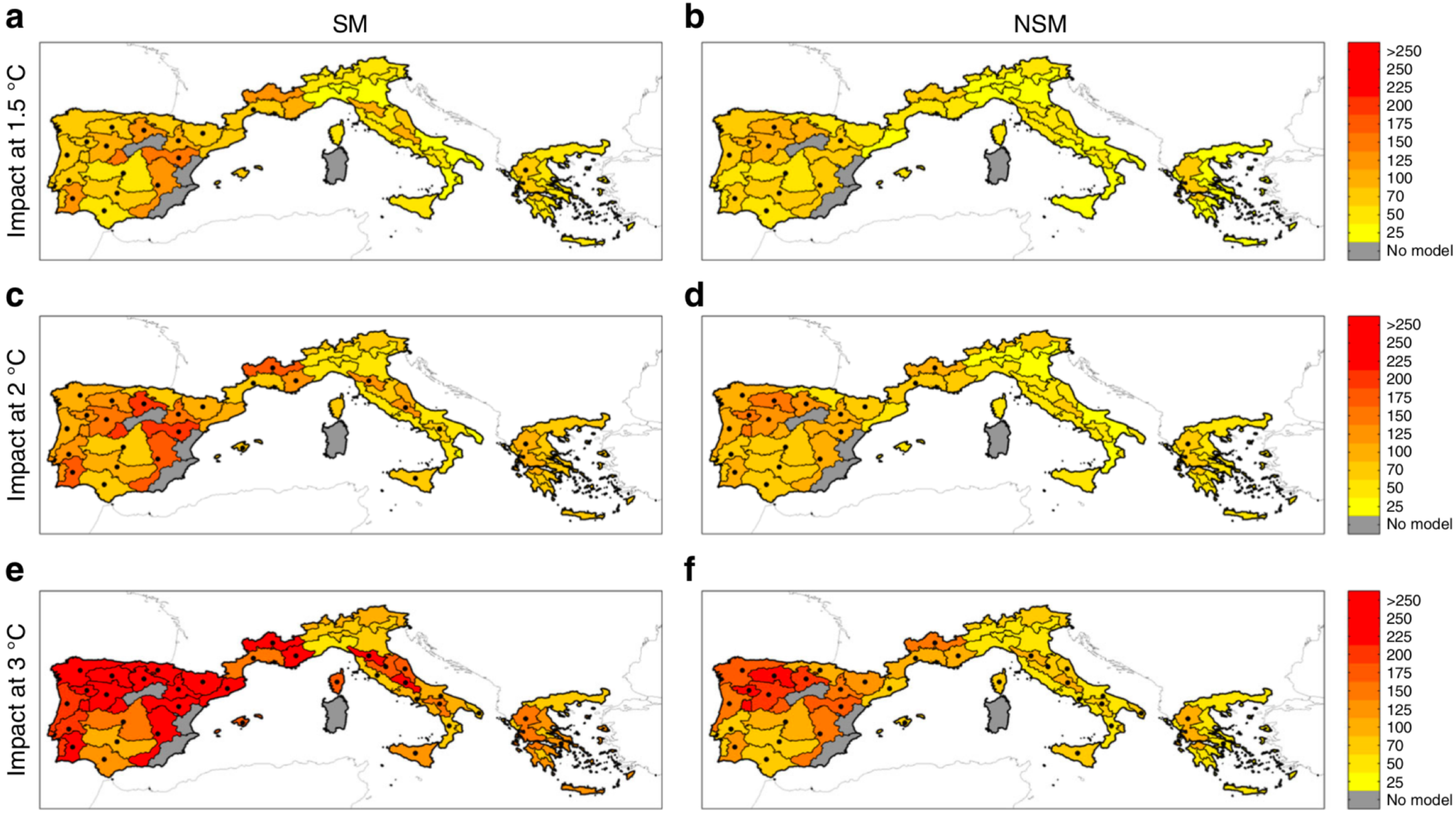


SM: stationary model
NSM: non-stationary model
RCM: uncertainty from the ensemble of RCM projections (2 ensembles of 9 EURO-CORDEX RCMS)
ALL: accounting for both RCM and regression model uncertainties (1000 bootstrap replications × the ensemble of RCMs)

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Future drought impacts on forest fire risk

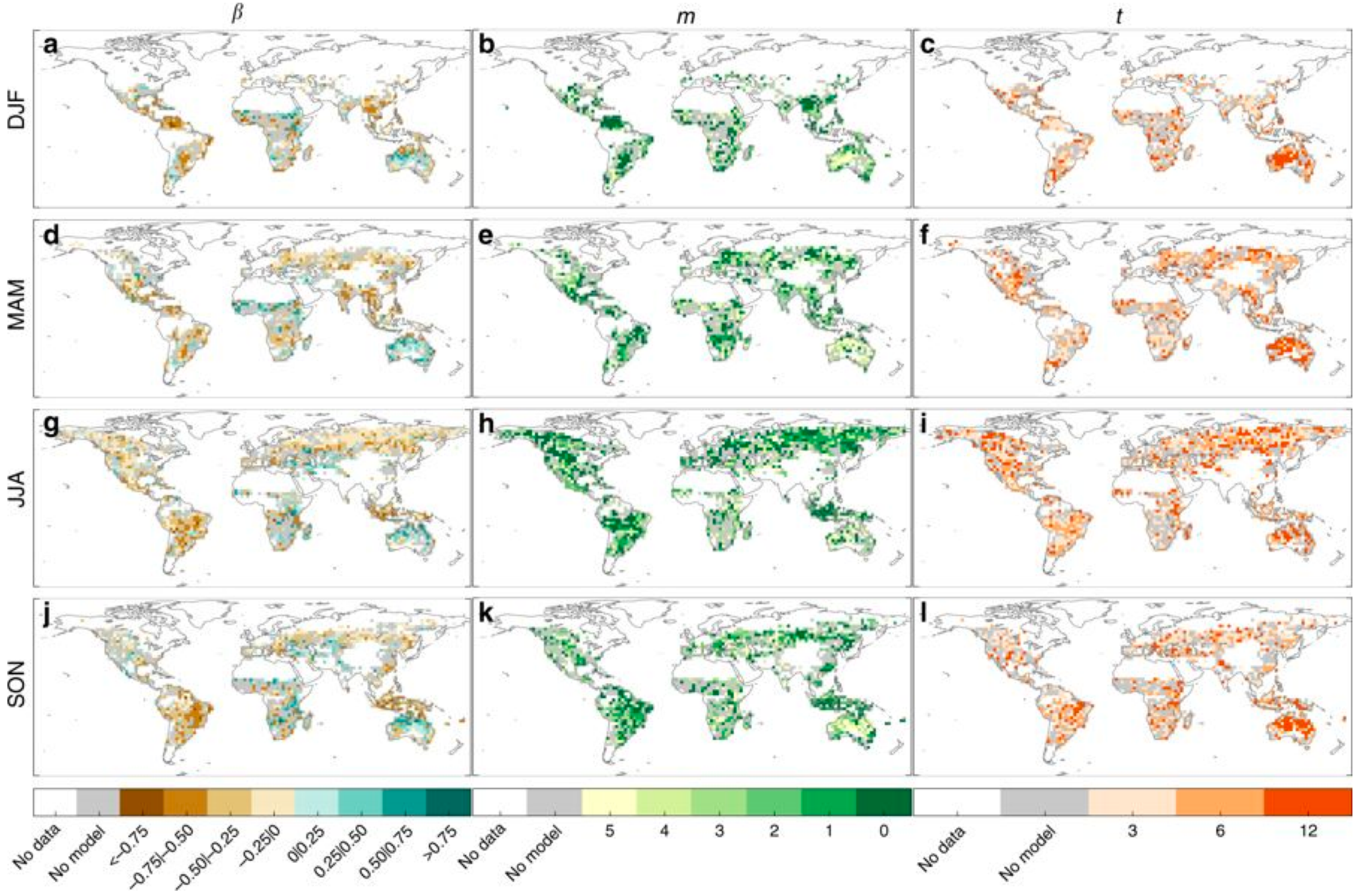


Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

At global scale?

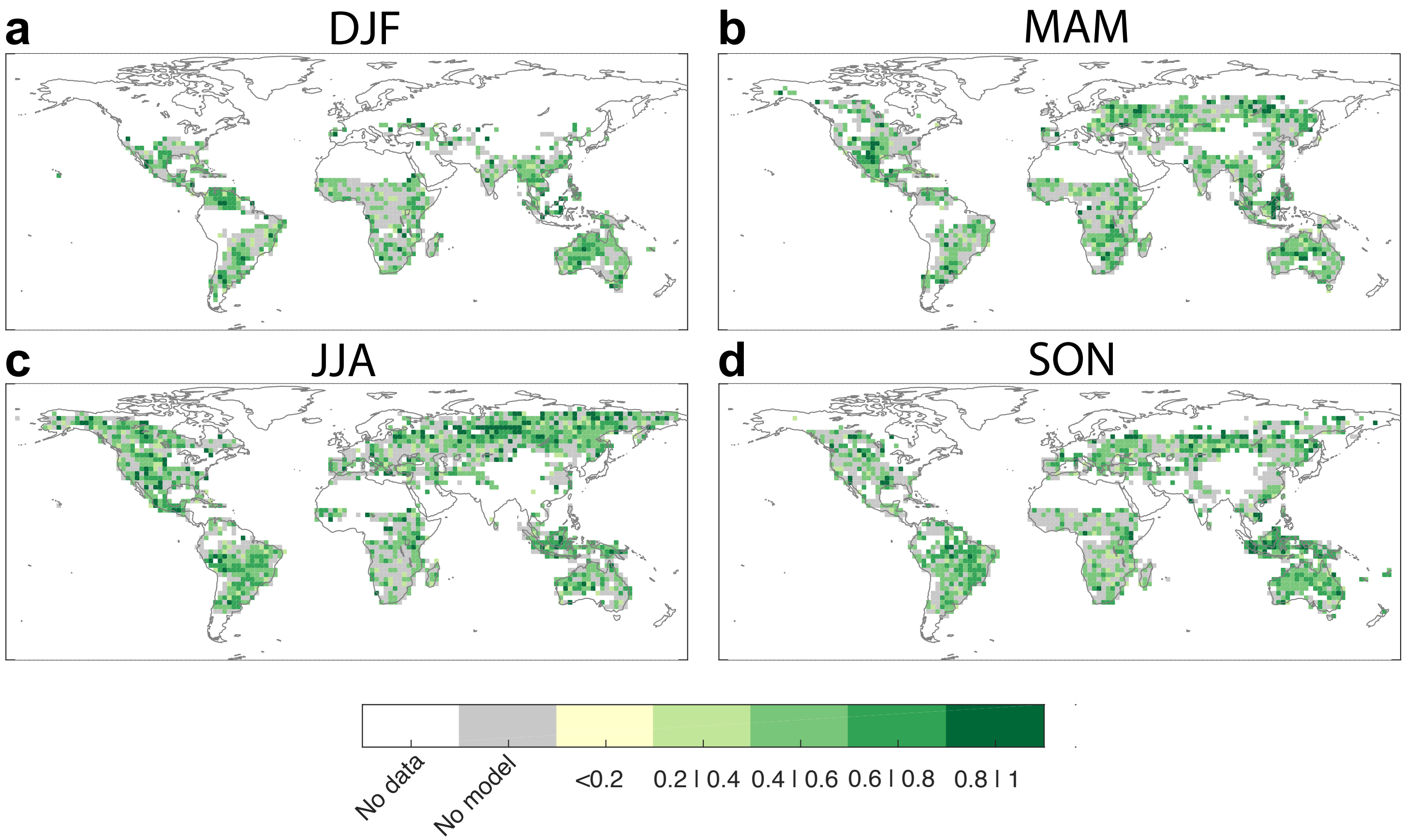
SPEI$_{m,t}$- BA global links



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Skilful forecasting of global fire activity using seasonal climate predictions. Nat. Commun. 9, 2718 (2018).

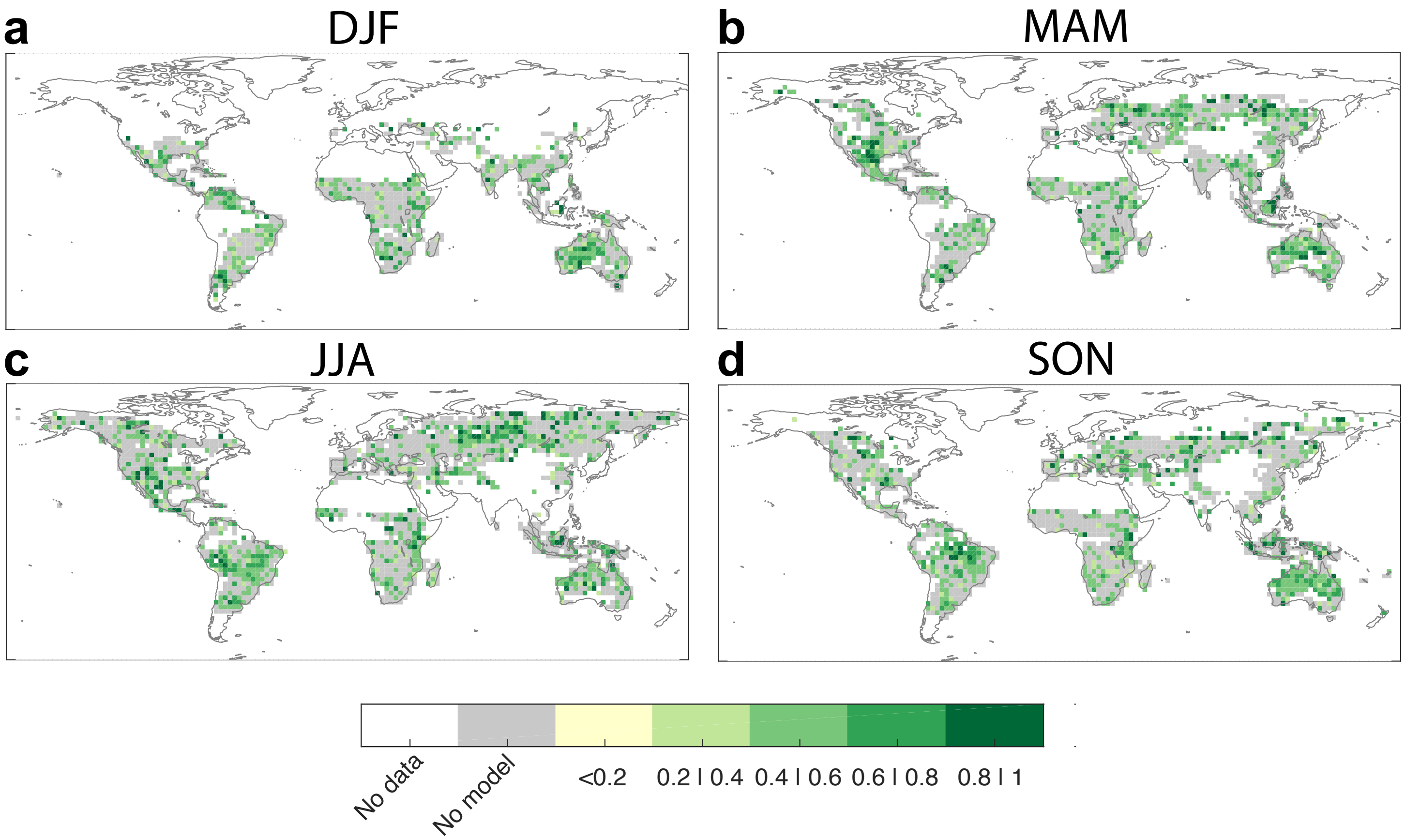
SPEI-BA model reconstructions: correlation



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Skilful forecasting of global fire activity using seasonal climate predictions. Nat. Commun. 9, 2718 (2018).

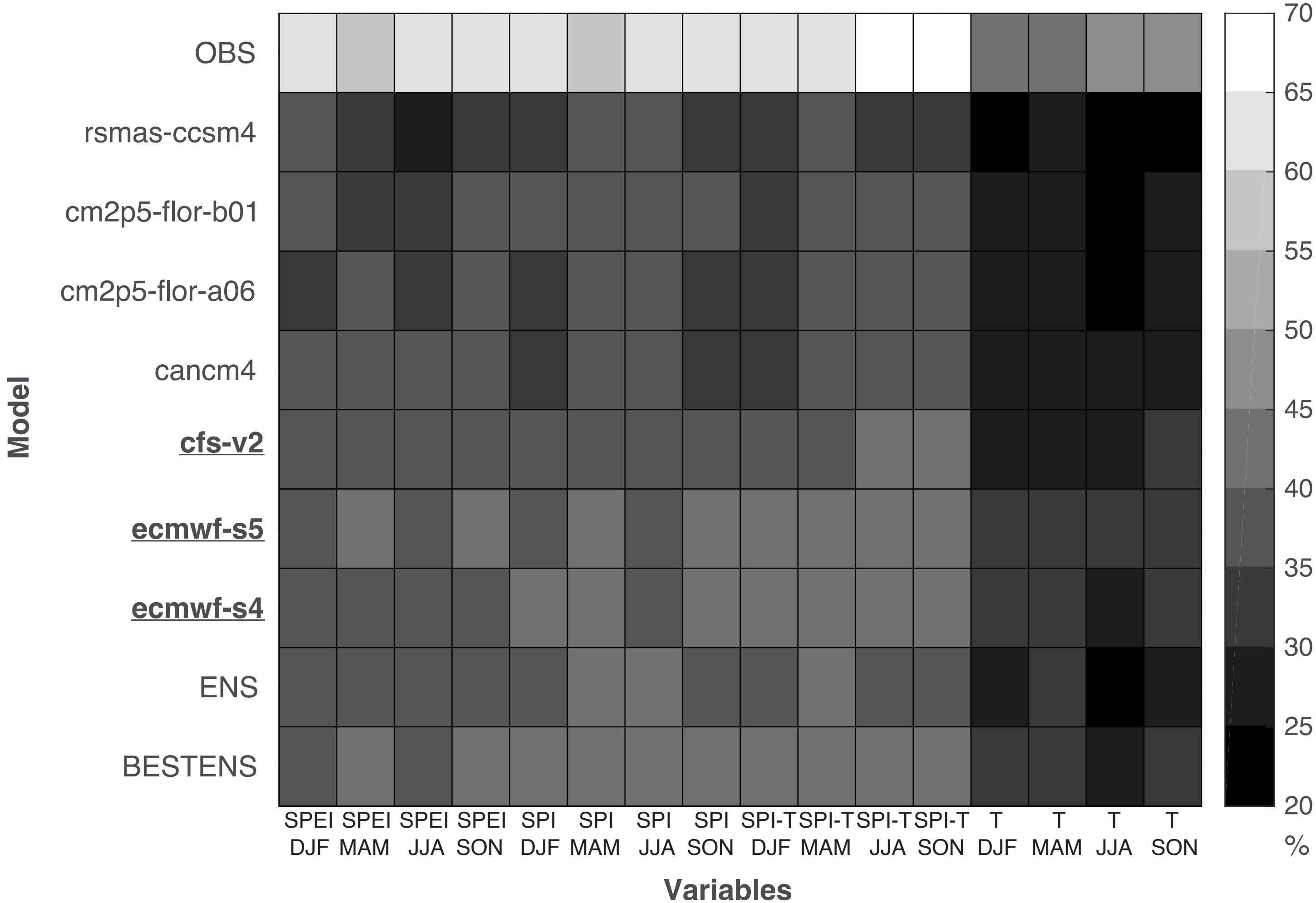
SPEI-BA model predictions: correlation



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Skilful forecasting of global fire activity using seasonal climate predictions. Nat. Commun. 9, 2718 (2018).

SPEI-BA model predictions skill



% of global burnable area with skilful burned area predictions

Turco, M. et al. Skilful forecasting of global fire activity using seasonal climate predictions. Nat. Commun. 9, 2718 (2018).

Limitations

- Fire data availability and quality → few studies analysed the temporal relationship between climate and fires at global scale
- Presumably, the complex relationships between climate, vegetation and fires hamper the applicability of fire impact models to conditions that are very different from the current ones
- In the future, it is expected that a warmer and drier climate can affect wildfire activity not only by leading to more favorable conditions for burning, but also modifying the structure of the fuel (availability and continuity) to be burned
- Coming down from the ivory tower: make weather/climate information action oriented --> the co-production of customized climate services allows fire-risk outlooks to be translated into usable information for fire management (see our latest study: Turco et al. Seasonal prediction of climate-driven fire risk for decision-making and operational applications in a Mediterranean region. Science of The Total Environment, available online 23 April 2019)

Conclusions

- Fires are not increasing in Mediterranean Europe --> the negative trends can be explained, at least in part, by an increased effort in fire management and prevention

- There is a strong evidence that the same-summer-drought is related to fires

- Overall, we found that the projected increase in drought conditions leads to larger burned area values and that limiting global warming to 1.5°C can strongly reduce the increase of burned area

- These results, in combination with the increase in societal exposure to large wildfires in recent years, call for a rethinking of current management strategies

- Substantial BA predictability exists based on antecedent and forecasted climate conditions that can be exploited for fire risk management months ahead

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

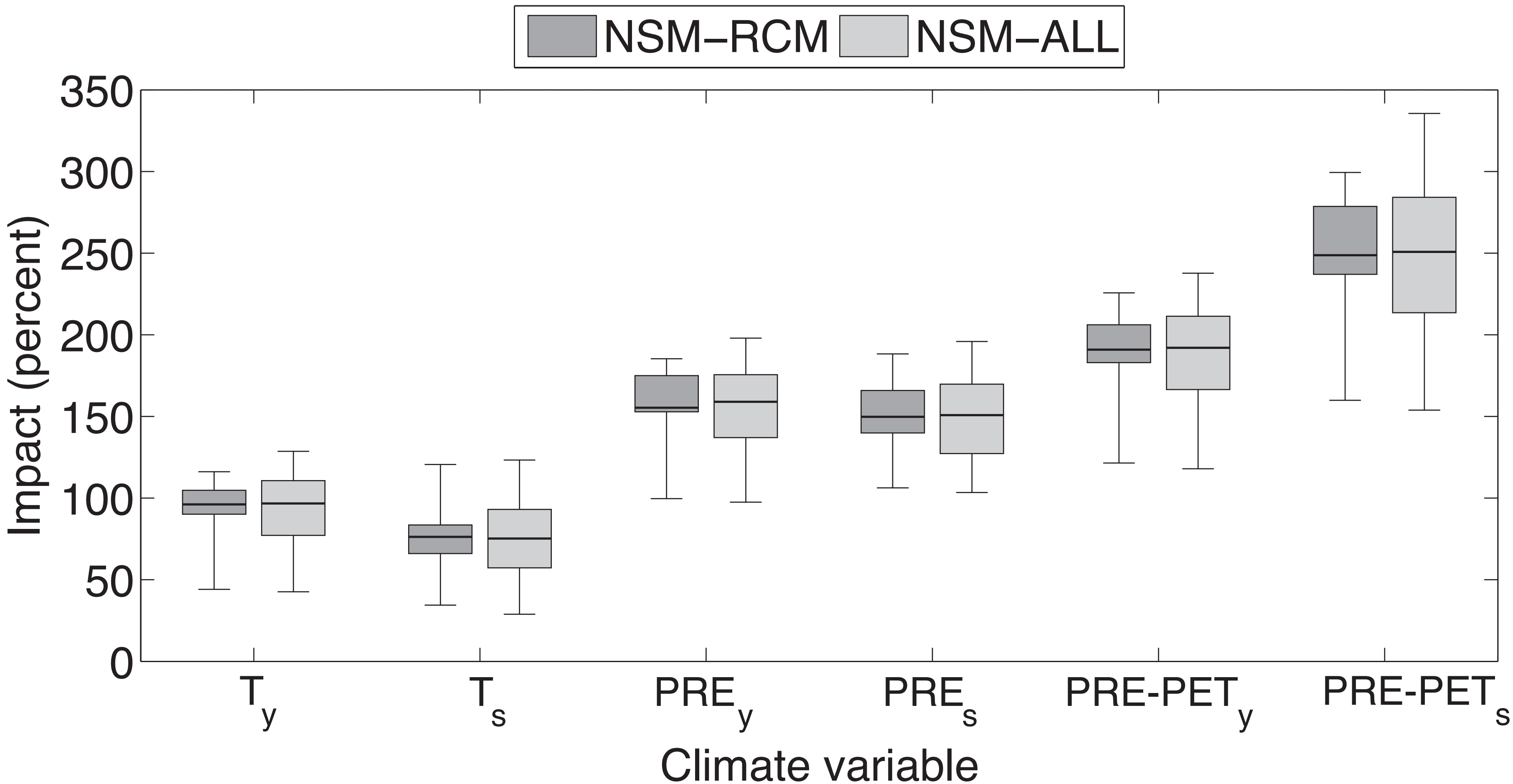
EXCELENCIA SEVERO OCHOA

Thank you

marco.turco@bsc.es

Extra slides

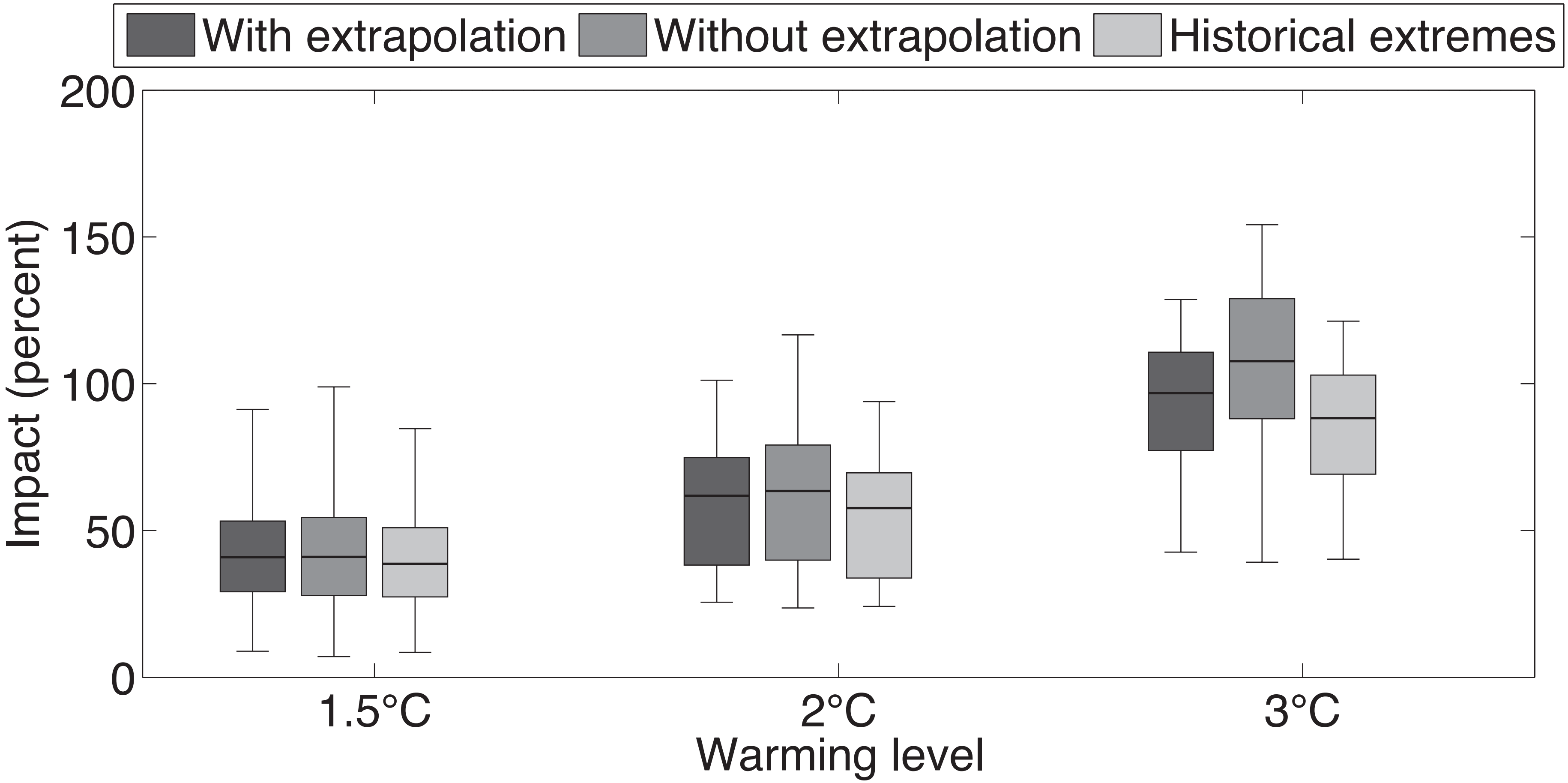
Future drought impacts on forest fire risk



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

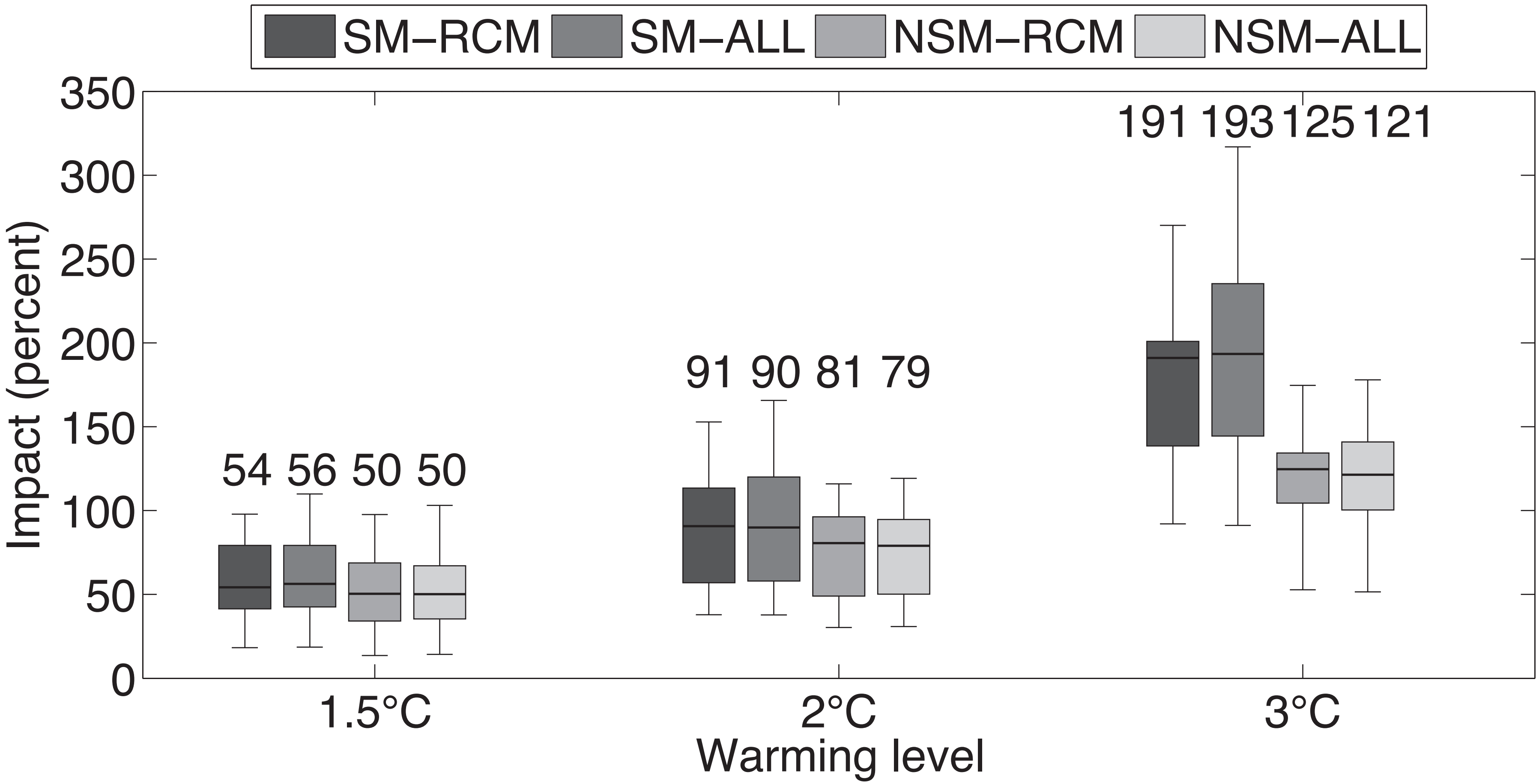
Future drought impacts on forest fire risk



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Future drought impacts on forest fire risk



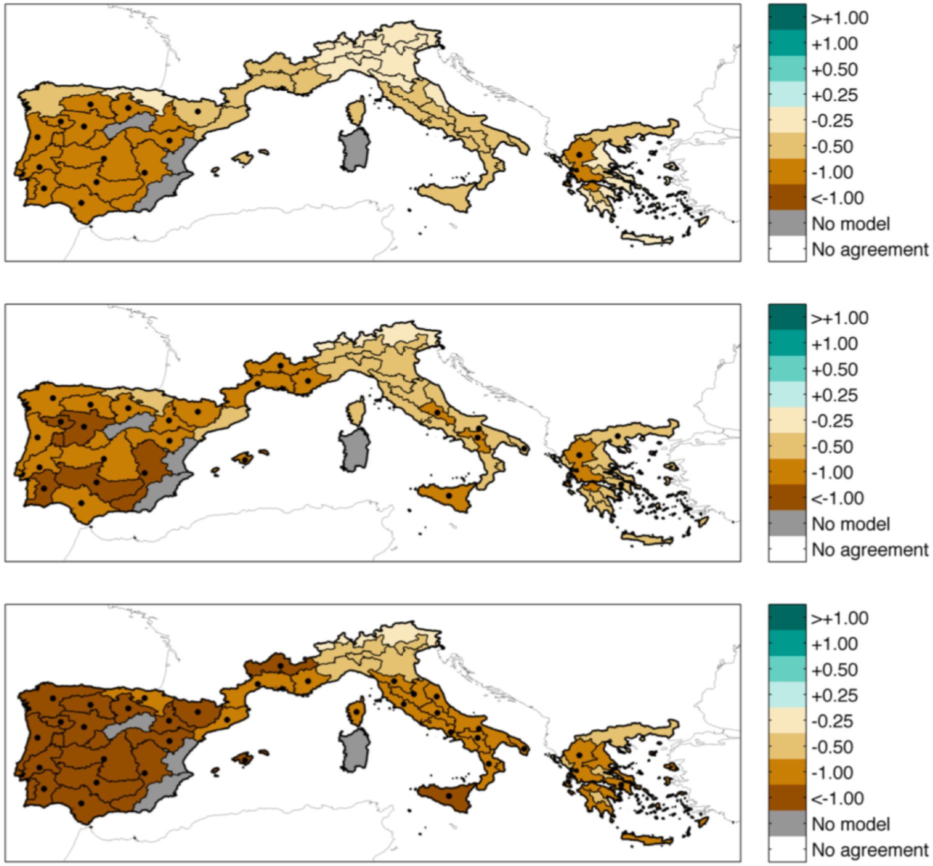
Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Ensemble mean SPEI changes

1.5ºC

2ºC

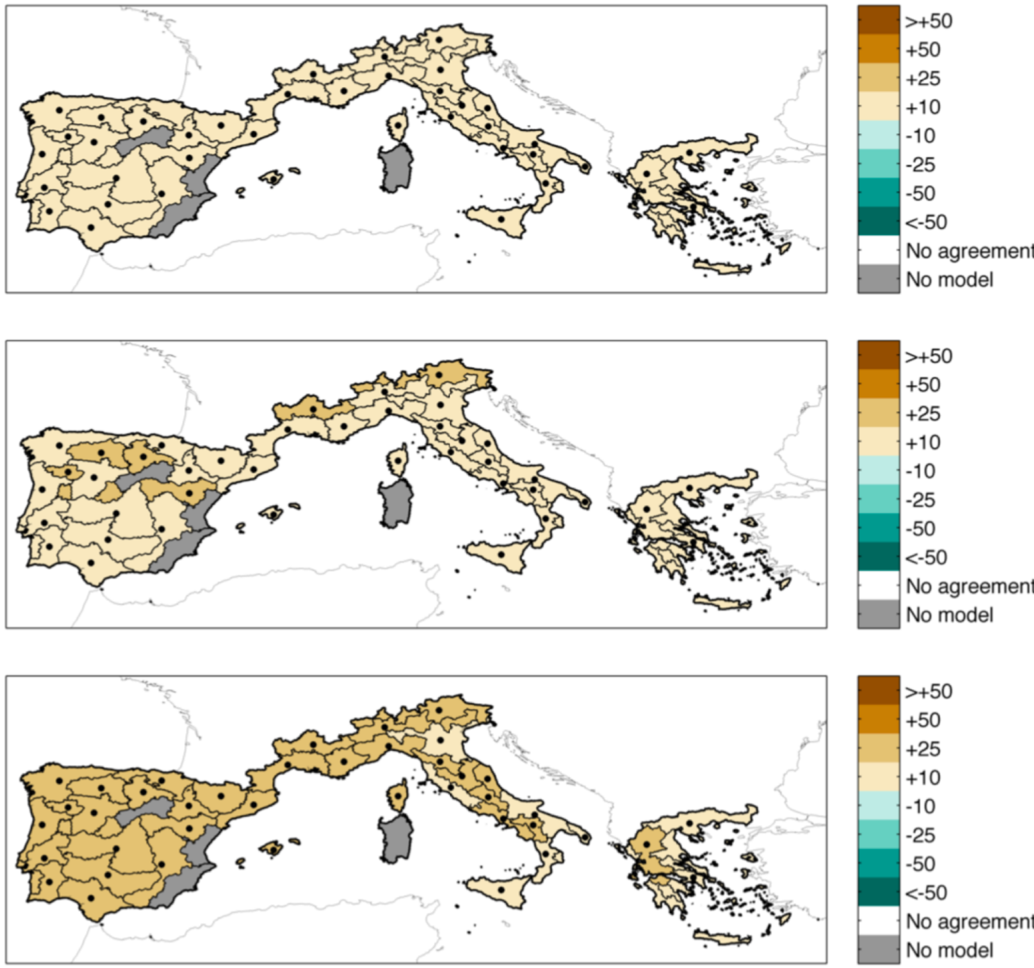
3ºC



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

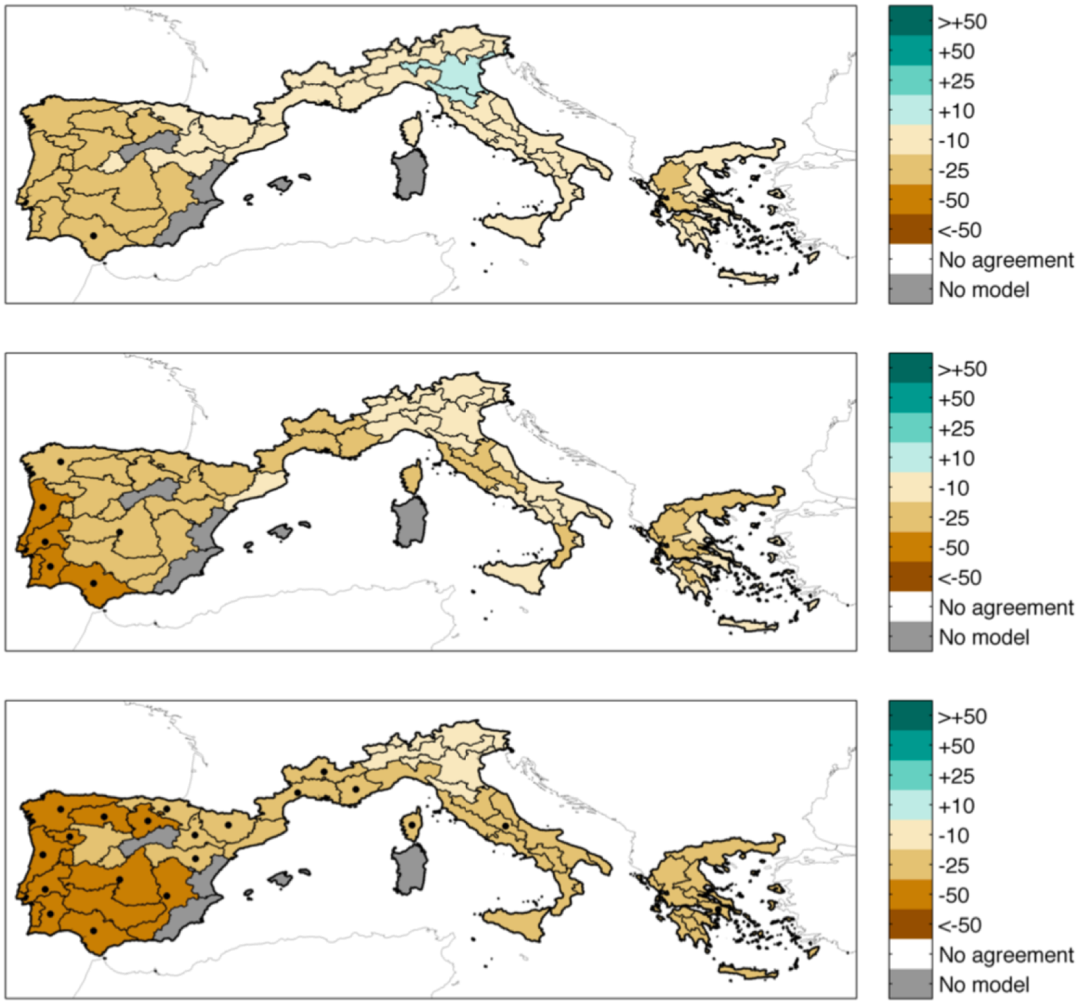
PET changes



Barcelona
Supercomputing
Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

PRE changes



Barcelona Supercomputing Center
Centro Nacional de Supercomputación

Turco, M. et al. Exacerbated fires in Mediterranean Europe due to anthropogenic warming projected with non-stationary climate-fire models. Nat Commun, 9(1), 3821 (2018a)

Attribution model

$$Y = a\, CC + b\, AC + c\, T + \varepsilon$$

where $Y = log(BA)$ or $log(NF)$

CC = Coincident Climate

AC = Antecedent Climate;

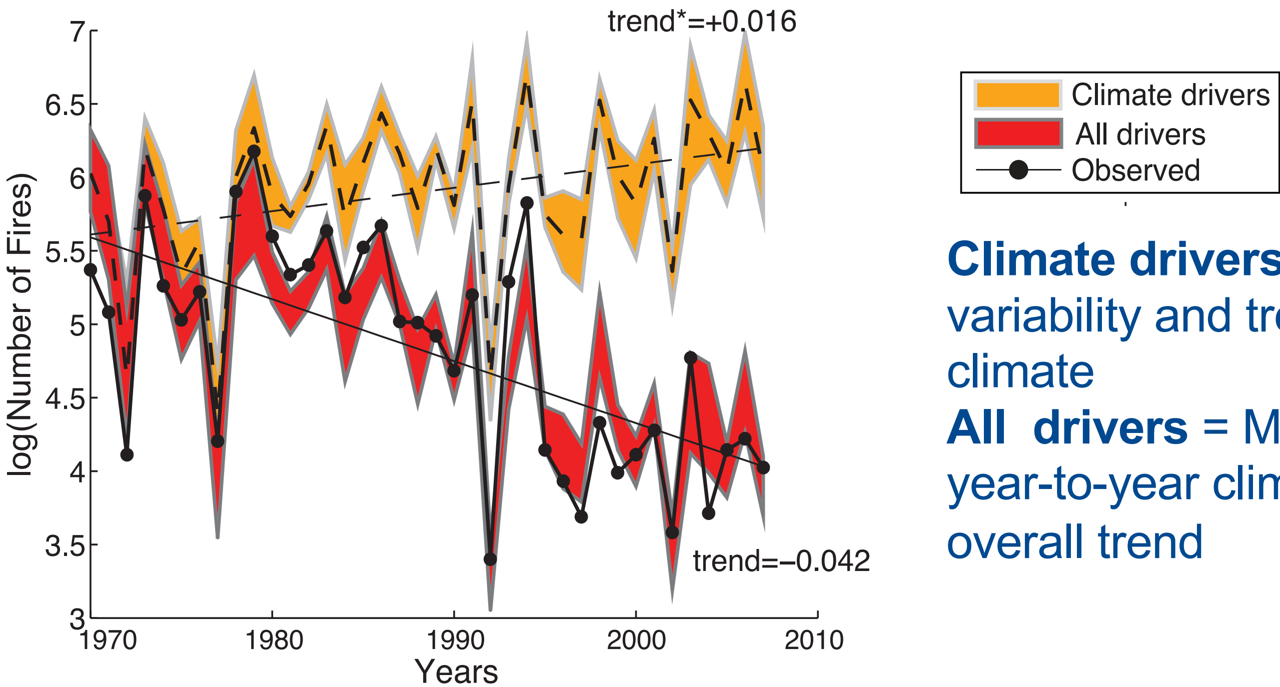
T* = Time*;

c* is the trend slope, *f(human activity, climate, etc.)

More details at:

Turco, M., Llasat, M. C., Hardenberg, J. and Provenzale, A. Climate change impacts on wildfires in a Mediterranean environment. Clim. Change 125 (3-4), 369-380 (2014)

Fire response to recent climate trends in Catalonia



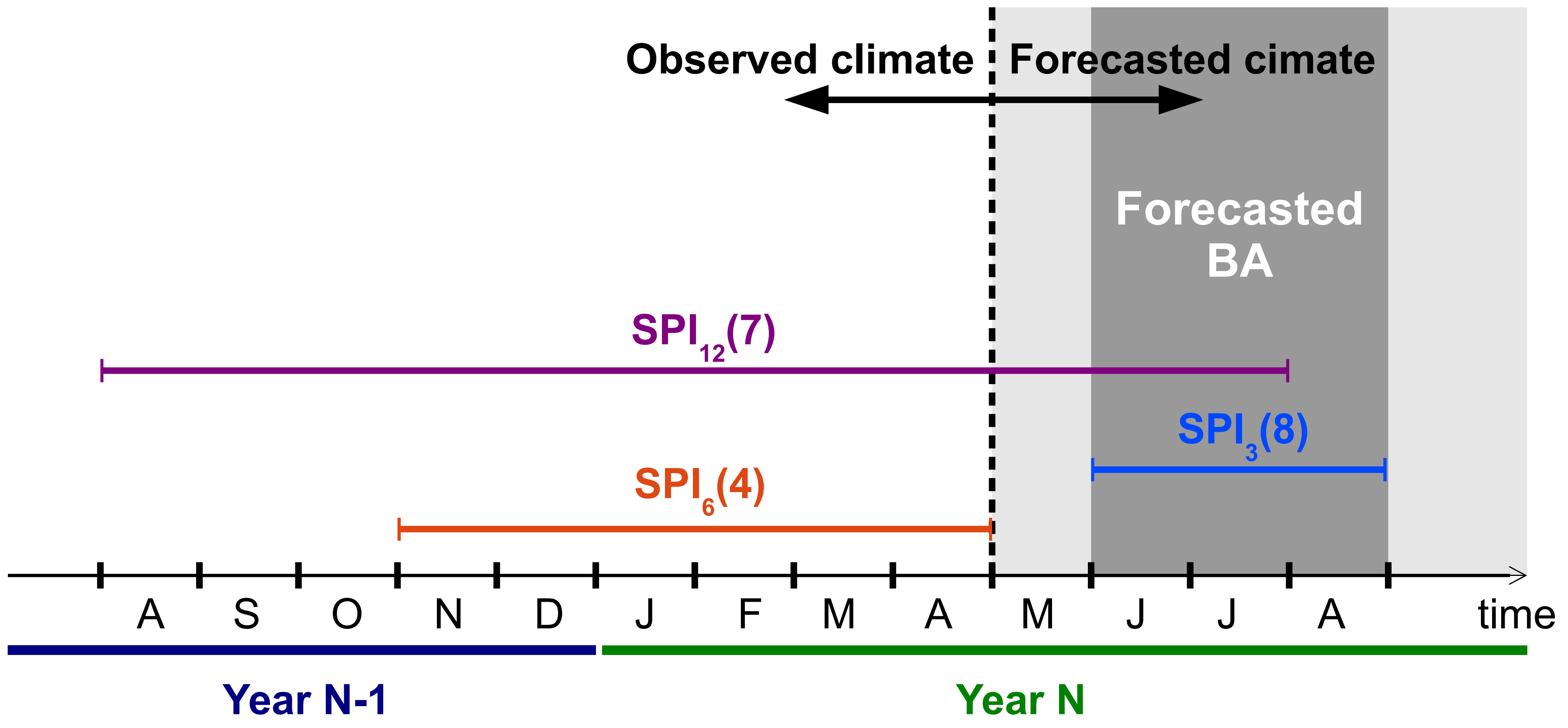
Climate drivers = both interannual variability and trend are driven by climate

All drivers = MLR considers the year-to-year climate variation + overall trend

While the actual trend is negative, climate forcing alone would have led to a positive trend in the total number of fires series.

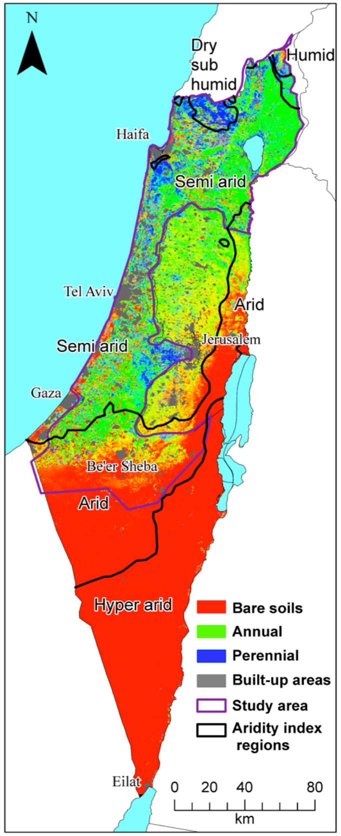
Turco M., Llasat M. C., von Hardenberg J., Provenzale A. Climate change impacts on wildfires in a Mediterranean environment. Climatic Change, 2014

SPEI-BA global links



Turco, M. et al. Skilful forecasting of global fire activity using seasonal climate predictions. Nat. Commun. 9, 2718 (2018).

Drier conditions lead to more fires? It depends on where and when



Correlations: drought against NF

	MAM	JJA	SON
$SPEI_3$ vs. NF	-0.61**		-0.51**
$SPEI_6$ vs. NF	-0.39*		-0.53**
$SPEI_{12}$ vs. NF	-0.31		-0.07

* $p < 0.05$, ** $p < 0.01$

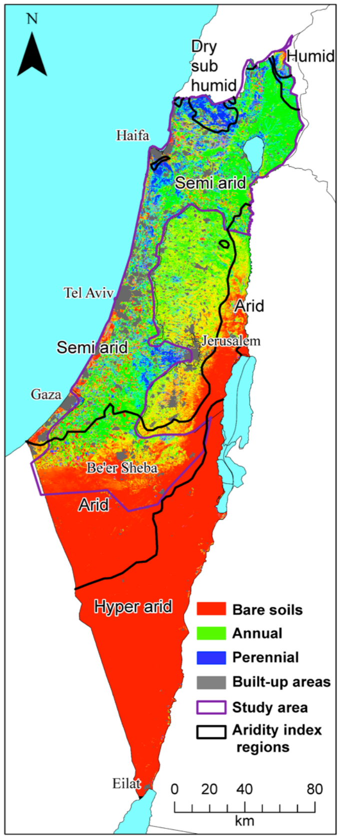
Negative SPEI values → dry conditions

- thus negative correlations in MAM and SON → dry conditions lead to more fires

SPEI: Standard Precipitation and Evaporation index (Vicente-Serrano et al. 2010)

Vicente-Serrano, S. M., Beguería, S., López-Moreno, J. I. A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. Journal of Climate, 2010
Turco, M., Levin, N., Tessler, N., Hadas, S. Recent changes and relations among drought, vegetation and wildfires in the Eastern Mediterranean: the case of Israel. Global Planetary Change, 2016

Drier conditions lead to more fires?
It depends on where and when



Correlations: drought against NF

	MAM	JJA	SON
$SPEI_3$ vs. NF	-0.61**	-0.2	-0.51**
$SPEI_6$ vs. NF	-0.39*	+0.14	-0.53**
$SPEI_{12}$ vs. NF	-0.31	+0.44*	-0.07

* $p < 0.05$, ** $p < 0.01$

Negative SPEI values → dry conditions

- thus negative correlations in MAM and SON → dry conditions lead to more fires
- positive correlations in JJA indicate that above normal wet conditions are related to above normal NF in summer

Vicente-Serrano, S. M., Beguería, S., López-Moreno, J. I. A multiscalar drought index sensitive to global warming: The standardized precipitation evapotranspiration index. Journal of Climate, 2010
Turco, M., Levin, N., Tessler, N., Hadas, S. Recent changes and relations among drought, vegetation and wildfires in the Eastern Mediterranean: the case of Israel. Global Planetary Change, 2016

Drought variables identification

1. **Domain**: Mediterranean Europe, at NUTS2 level (i.e. regions); Fire season: from **June to September**

2. Since BA follows approximate log-normal distributions we normalize this variable by applying a **log transformation** (i.e. Y = ln(BA))

3. We remove the influence of slow-changing factors by performing a **detrending** of the data (both ln(BA) and drought indicators)

4. We calculate the **cross-correlation** (and partial correlations) among detrended ln(BA) and drought indicators for different time and accumulation period

5. We consider only correlation maps with **field significance** at least greater than 95% (see Turco and Llasat 2011 for details on the field significance test)

Conclusions

- this increase is much higher for 2 °C (with values between 62 to 87% depending on the model specifications) and 3 °C of global warming (with values between 96 to 187%) compared to the 1.5 °C target
- the results indicate that NSM (non-stationary) models generally led to lower impacts, especially for larger temperature variations. For the +3 °C 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 approac
- we note that the overall uncertainty is dominated by the RCM spread rather than by the uncertainties related to the climate-fire model