Complex interactions of extreme events in Southern Europe and Brazil

a compound event perspective

Ana Russo, R. Libonati, J.L. Geirinhas, A.M. Ramos, P.S. Silva, P.M. Sousa, C.C. DaCamara, D.G. Miralles, R.M. Trigo

01 MOTIVATION

EXTREME EVENTS UNDER CLIMATE CHANGE CONDITIONS

- Record-breaking natural hazards occur regularly throughout the world, leading to a variety of impacts
- Since 1970 there were more than 11000 reported disasters (2 million deaths and US$ 3.64 trillion in losses)
- Droughts and heatwaves are both included in the top 4 disasters in terms of human losses, with uneven impacts throughout the world and a high likelihood that anthropogenic climate forcing will increase economic inequality between countries

As global warming increases, the likelihood of further large-droughts and mega-heatwaves also rises

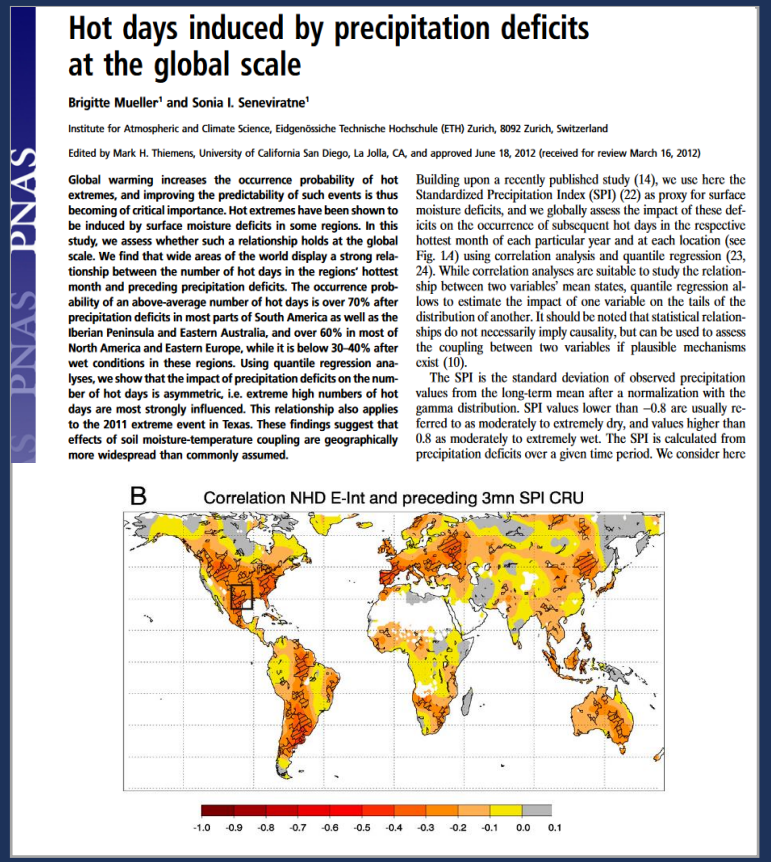
Conversations are like cherries; we never pick just one!

What about natural hazards?

01 MOTIVATION

EXTREME EVENTS UNDER CLIMATE CHANGE CONDITIONS

Strong evidence that droughts and heatwaves are at times synergetic – COMPOUND EVENTS



PNAS

Hot days induced by precipitation deficits at the global scale

Brigitte Mueller[1] and Sonia I. Seneviratne[1]

Institute for Atmospheric and Climate Science, Eidgenössische Technische Hochschule (ETH) Zurich, 8092 Zurich, Switzerland

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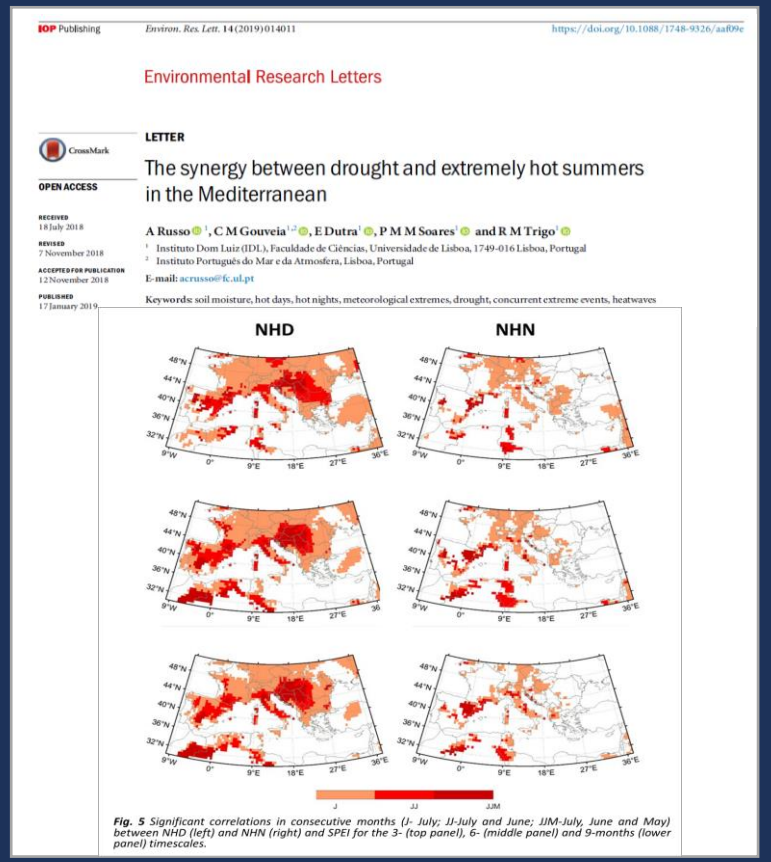
Global warming increases the occurrence probability of hot extremes, and improving the predictability of such events is thus becoming of critical importance. Hot extremes have been shown to be induced by surface moisture deficits in some regions. In this study, we assess whether such a relationship holds at the global scale. We find that wide areas of the world display a strong relationship between the number of hot days in the regions' hottest month and preceding precipitation deficits. The occurrence probability of an above-average number of hot days is over 70% after precipitation deficits in most parts of South America as well as the Iberian Peninsula and Eastern Australia, and over 60% in most of North America and Eastern Europe, while it is below 30–40% after wet conditions in these regions. Using quantile regression analyses, we show that the impact of precipitation deficits on the number of hot days is asymmetric, i.e. extreme high numbers of hot days are most strongly influenced. This relationship also applies to the 2011 extreme event in Texas. These findings suggest that effects of soil moisture-temperature coupling are geographically more widespread than commonly assumed.

Building upon a recently published study (14), we use here the Standardized Precipitation Index (SPI) (22) as proxy for surface moisture deficits, and we globally assess the impact of these deficits on the occurrence of subsequent hot days in the respective hottest month of each particular year and at each location (see Fig. 1*A*) using correlation analysis and quantile regression (23, 24). While correlation analyses are suitable to study the relationship between two variables' mean states, quantile regression allows to estimate the impact of one variable on the tails of the distribution of another. It should be noted that statistical relationships do not necessarily imply causality, but can be used to assess the coupling between two variables if plausible mechanisms exist (10).

The SPI is the standard deviation of observed precipitation values from the long-term mean after a normalization with the gamma distribution. SPI values lower than −0.8 are usually referred to as moderately to extremely dry, and values higher than 0.8 as moderately to extremely wet. The SPI is calculated from precipitation deficits over a given time period. We consider here

B Correlation NHD E-Int and preceding 3mn SPI CRU

-1.0 -0.9 -0.8 -0.7 -0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0.0 0.1



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Environmental Research Letters

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LETTER

The synergy between drought and extremely hot summers in the Mediterranean

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A Russo [1], C M Gouveia [1,2], E Dutra [1], P M M Soares [1] and R M Trigo [1]

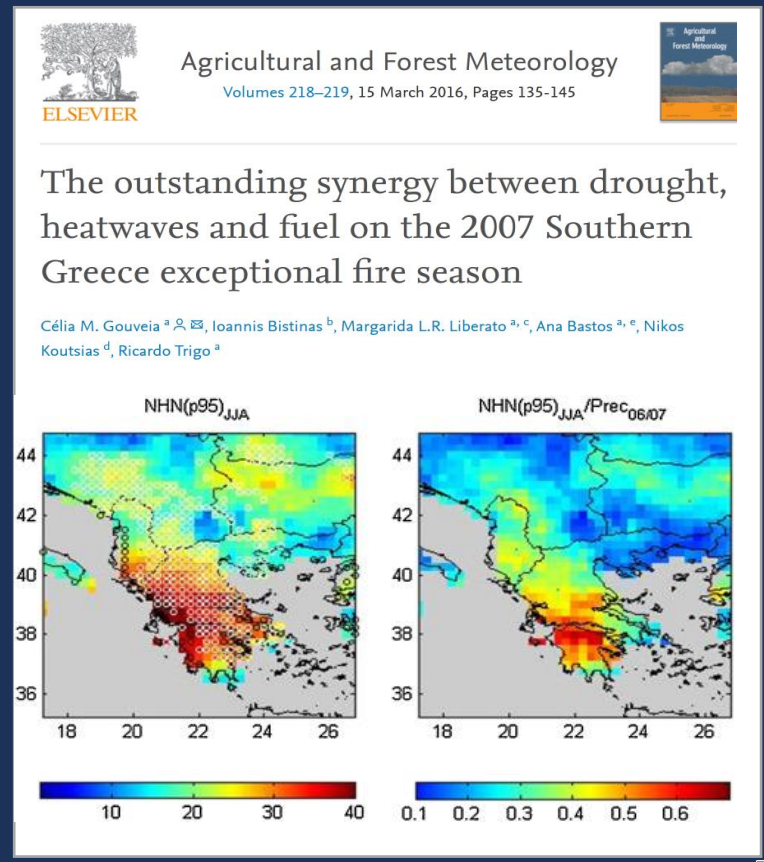
[1] Instituto Dom Luiz (IDL), Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal

[2] Instituto Português do Mar e da Atmosfera, Lisboa, Portugal

E-mail: acrusso@fc.ul.pt

Keywords: soil moisture, hot days, hot nights, meteorological extremes, drought, concurrent extreme events, heatwaves

Fig. 5 Significant correlations in consecutive months (J- July; JJ-July and June; JJM-July, June and May) between NHD (left) and NHN (right) and SPEI for the 3- (top panel), 6- (middle panel) and 9-months (lower panel) timescales.



ELSEVIER

Agricultural and Forest Meteorology

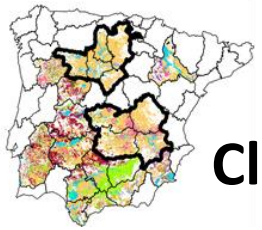
Volumes 218–219, 15 March 2016, Pages 135-145

The outstanding synergy between drought, heatwaves and fuel on the 2007 Southern Greece exceptional fire season

Célia M. Gouveia [a], Ioannis Bistinas [b], Margarida L.R. Liberato [a, c], Ana Bastos [a, e], Nikos Koutsias [d], Ricardo Trigo [a]

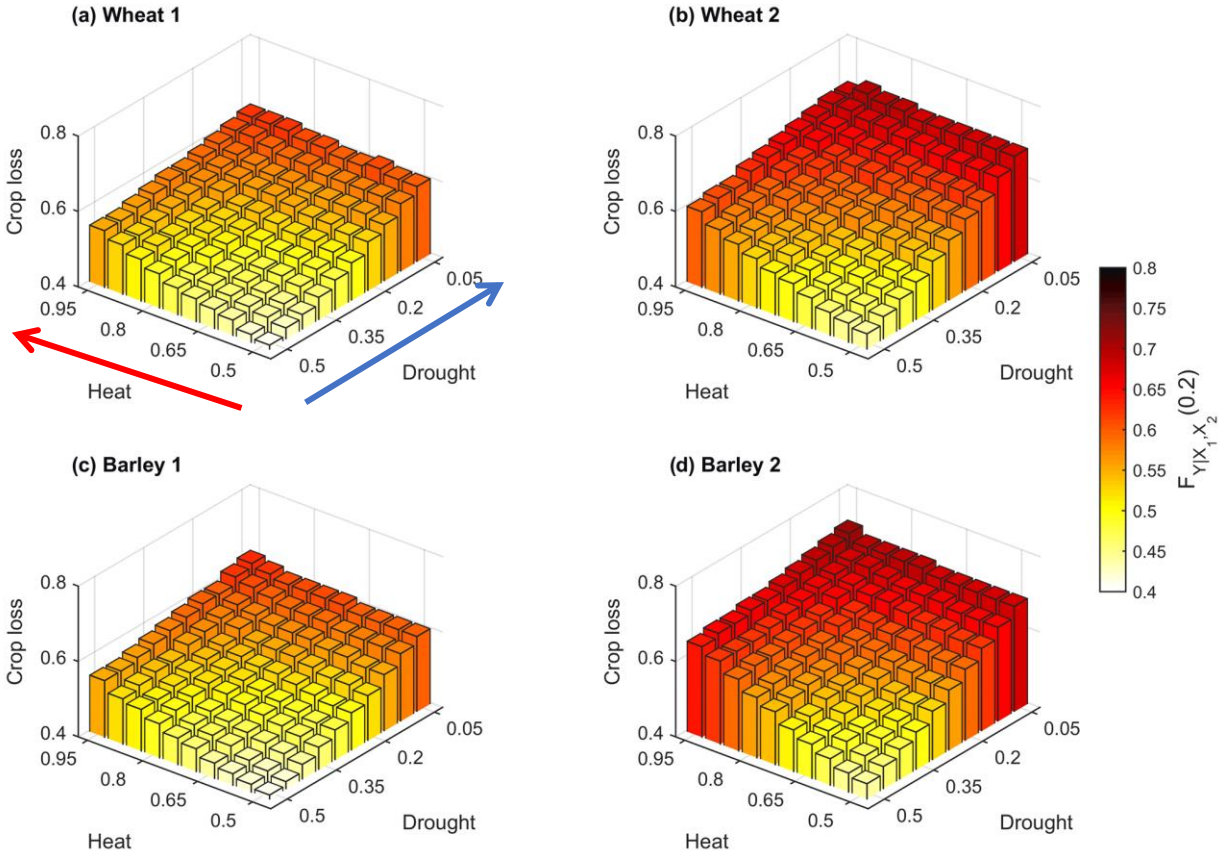
Wheat and barley t/ha

Threshold for crop failure
20th percentile



Cluster 1

Cluster 2



IBERIA | 02

CROP LOSSES

ELSEVIER

Agricultural Water Management
Volume 223, 20 August 2019, 105689

Copula-based agricultural drought risk of rainfed cropping systems

Andreia F.S. Ribeiro [a], Ana Russo [a], Célia M. Gouveia [a, b], Patrícia Páscoa [a]

Risk of crop failure due to compound dry and hot extremes estimated with nested copulas

Andreia Filipa Silva Ribeiro [1,2], Ana Russo [2], Célia Marina Gouveia [2,3], Patrícia Páscoa [2,3,4], and Jakob Zscheischler [1,5]

The probability of crop-loss increases with the severity of the compound hot and dry conditions

Drought plays the dominant role in crop-loss due to the compound event

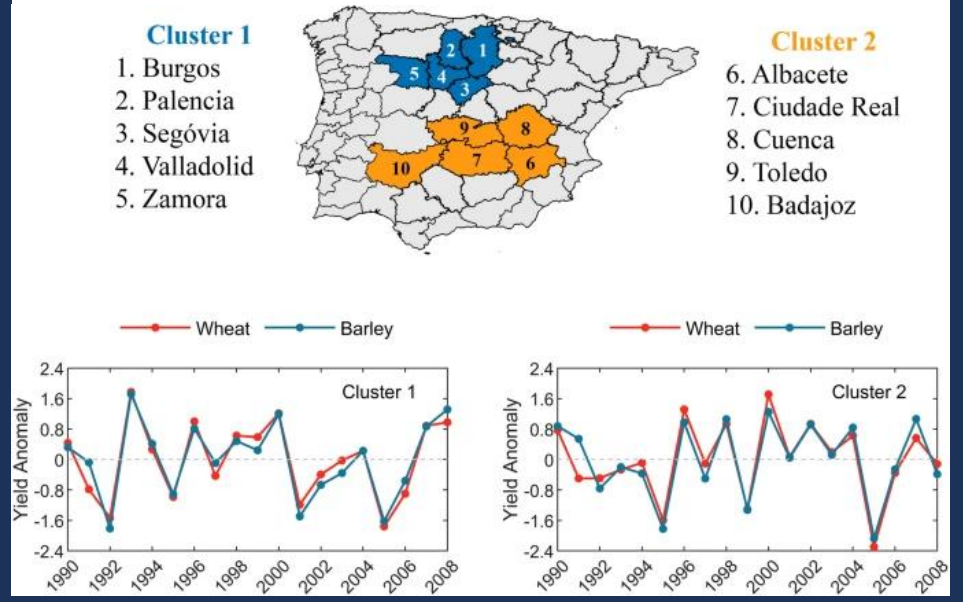
IBERIA | 02

CROP LOSSES

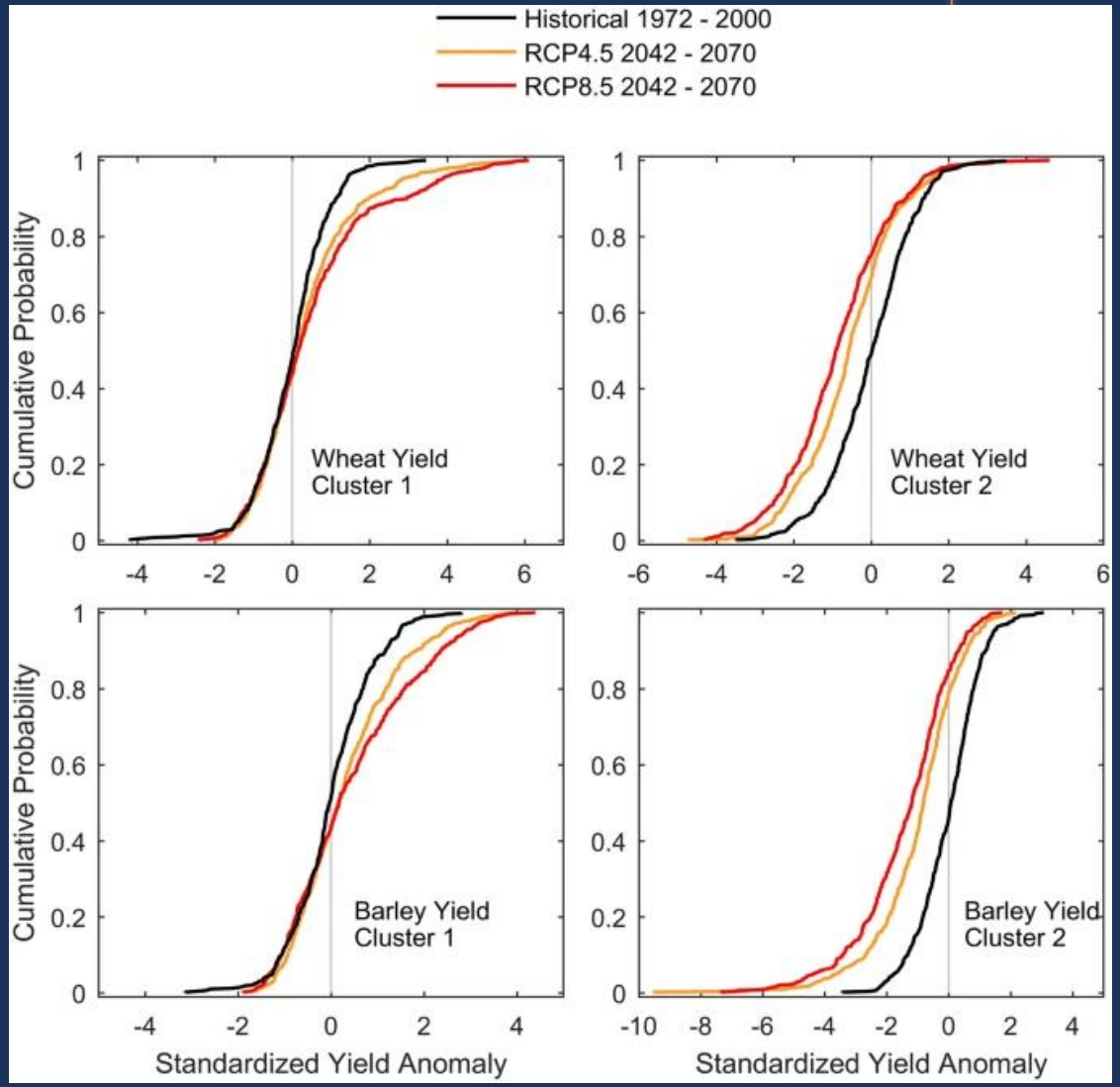
The impact of climate change in wheat and barley yields in the Iberian Peninsula

Virgílio A. Bento, Andreia F. S. Ribeiro, Ana Russo, Célia M. Gouveia, Rita M. Cardoso & Pedro M. M. Soares

Scientific Reports **11**, Article number: 15484 (2021) | Cite this article



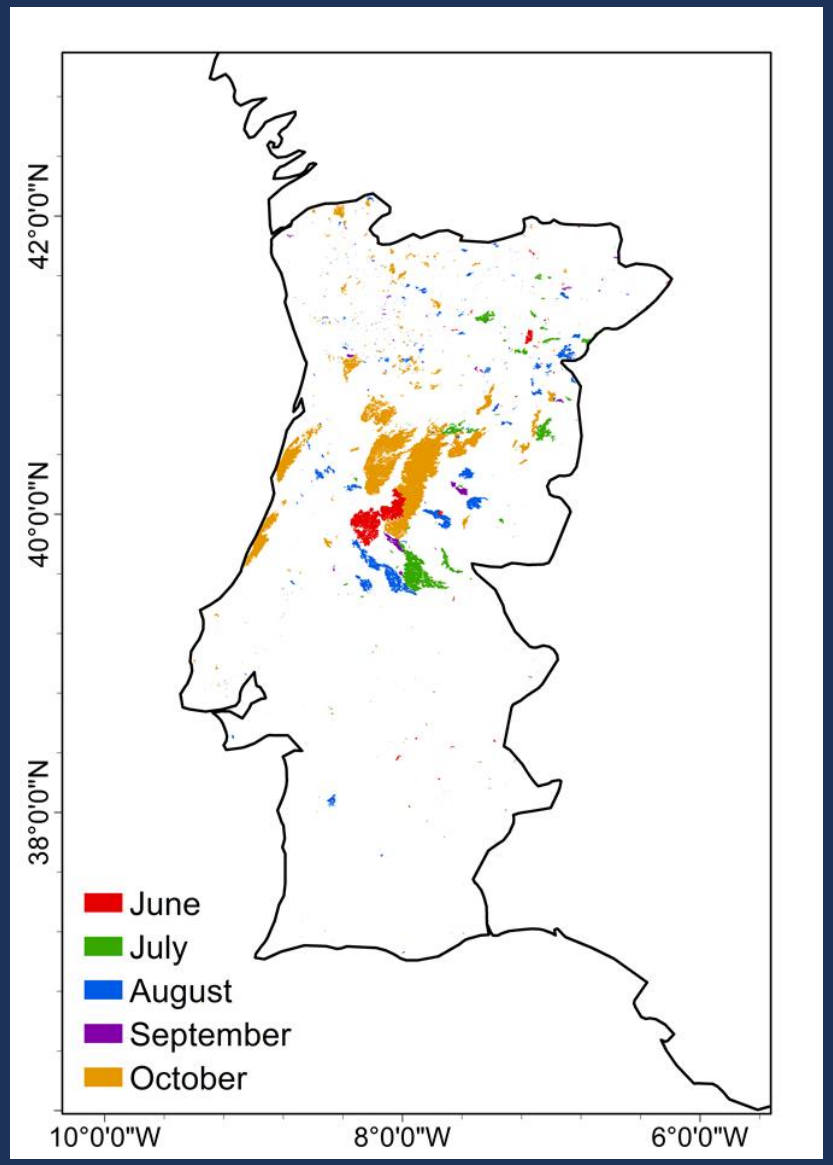
- **Cluster 1:** positive future results (low losses and high productivity)
- **Cluster 2:** negative future results (higher losses and lower productivity)



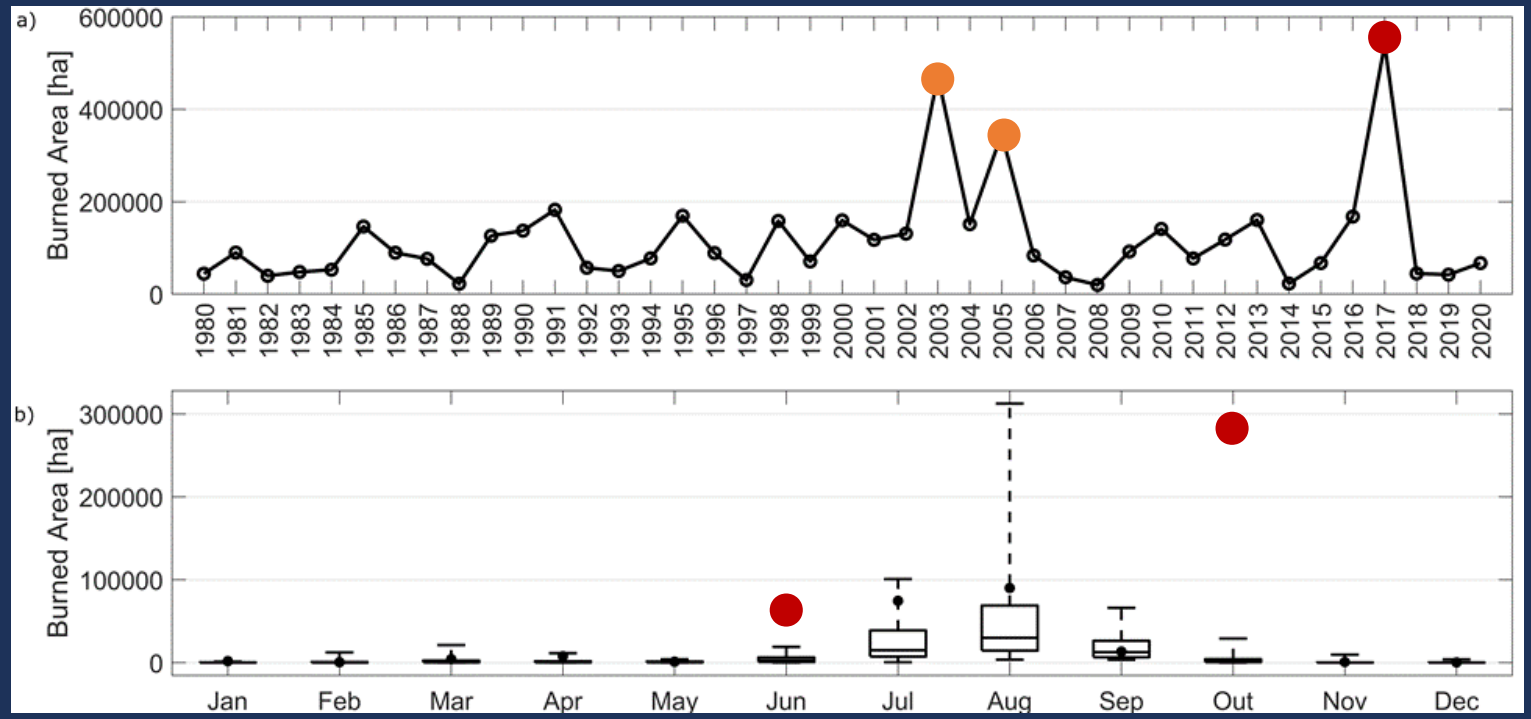
IBERIA

THE DESTRUCTIVE FIRES OF OCTOBER 2017 IN PORTUGAL

02



2017 monthly burned areas

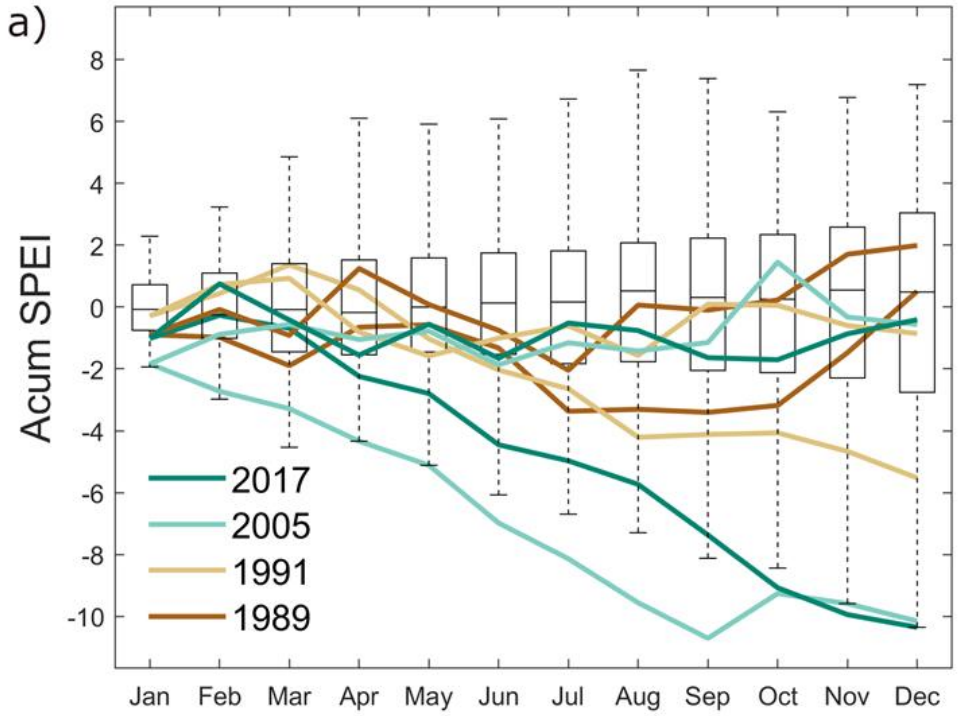


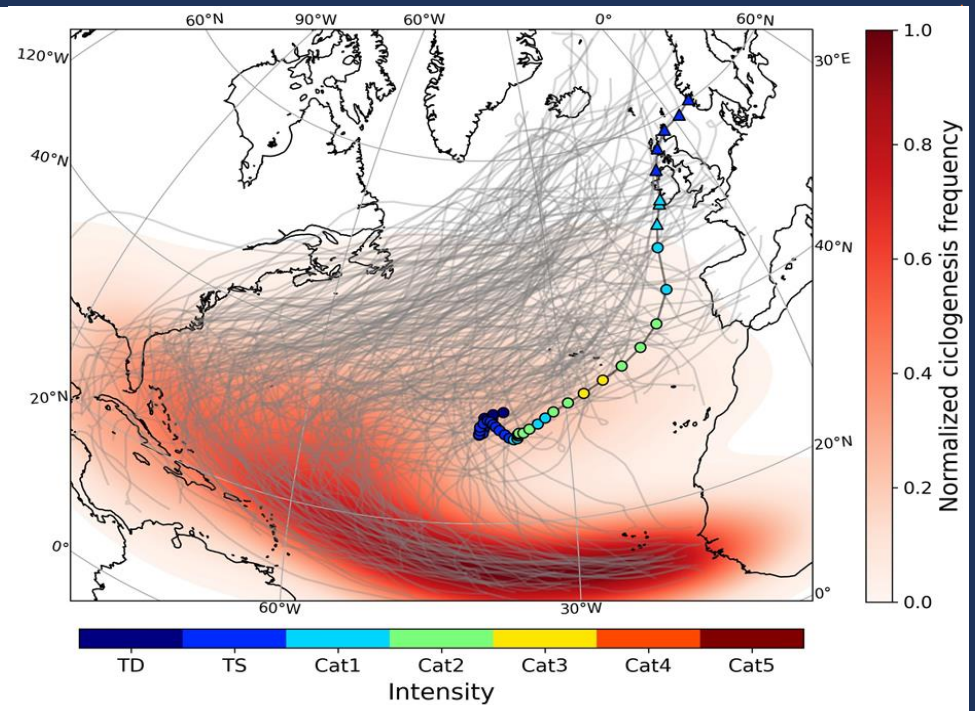
Annual and monthly accumulated burned areas

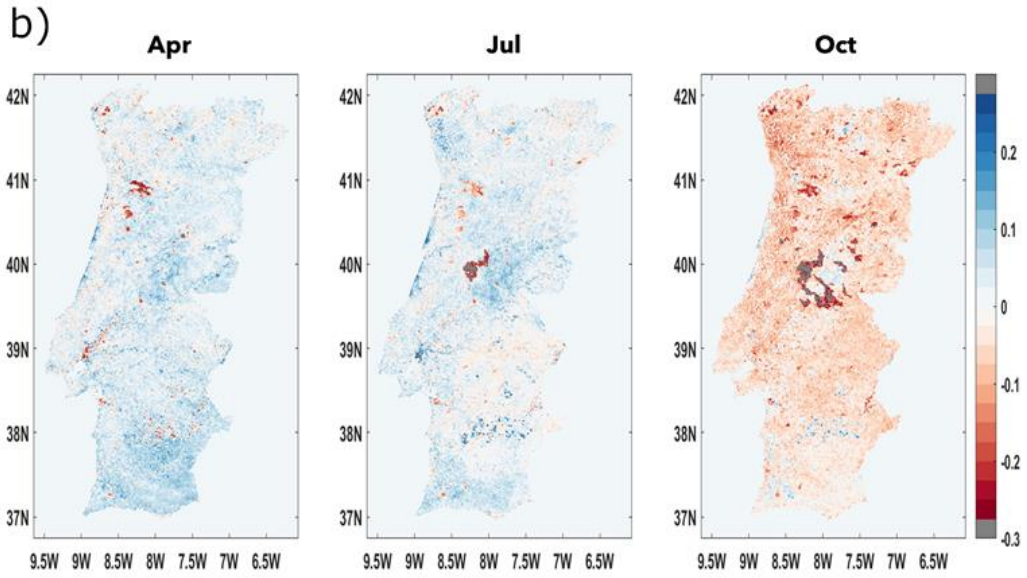
- The wildfires caused 55 deaths (51 PT, 4 SP), and dozens injured
- More than half of the 2017 burn area occurred in these two days

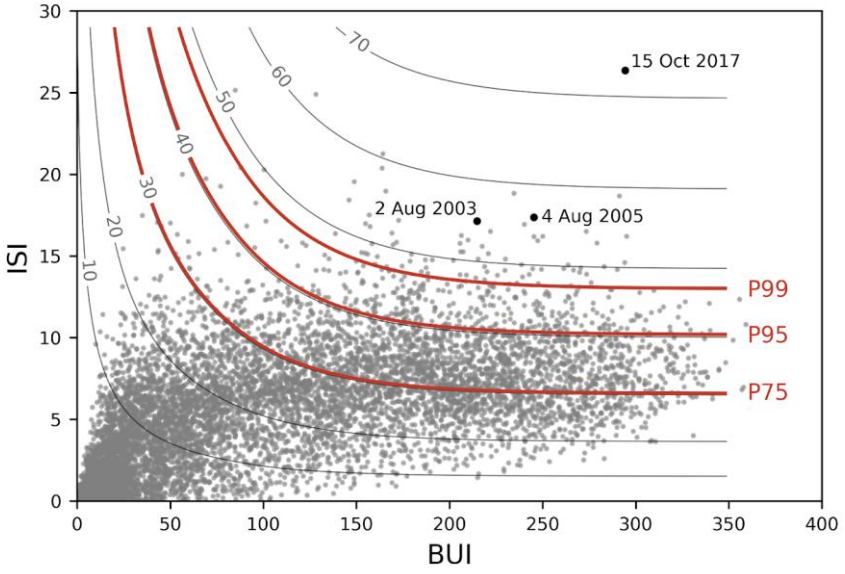
02

NDVI anomalies









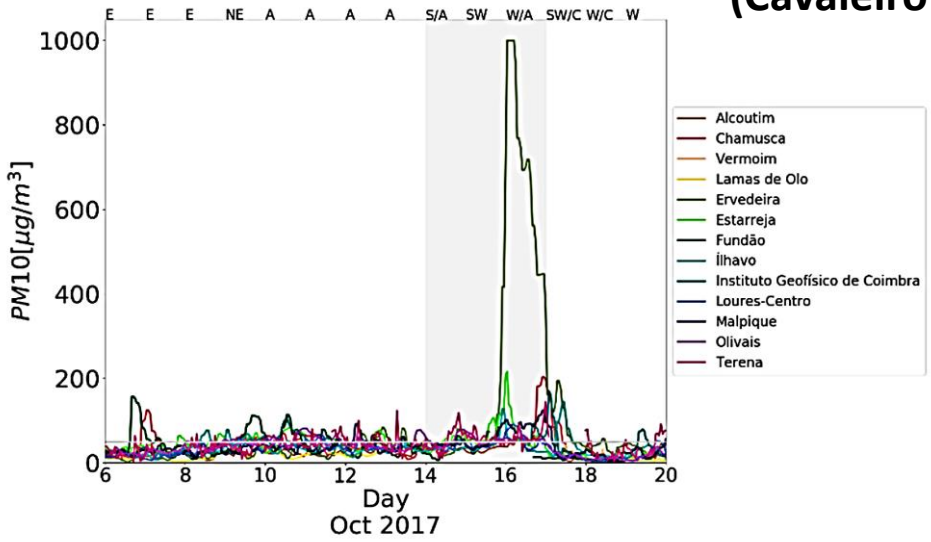
FWI

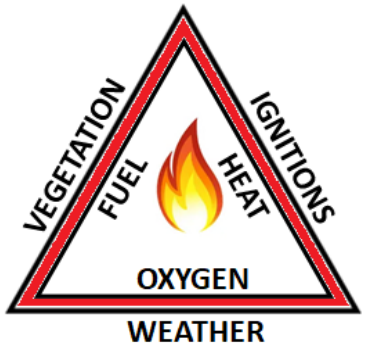
IBERIA

THE DESTRUCTIVE FIRES OF OCTOBER 2017 IN PORTUGAL

02

(Cavaleiro et al., 2021)





Long-term Drought → Vegetation stress

Hurricane Ophelia

Fire Ignitions

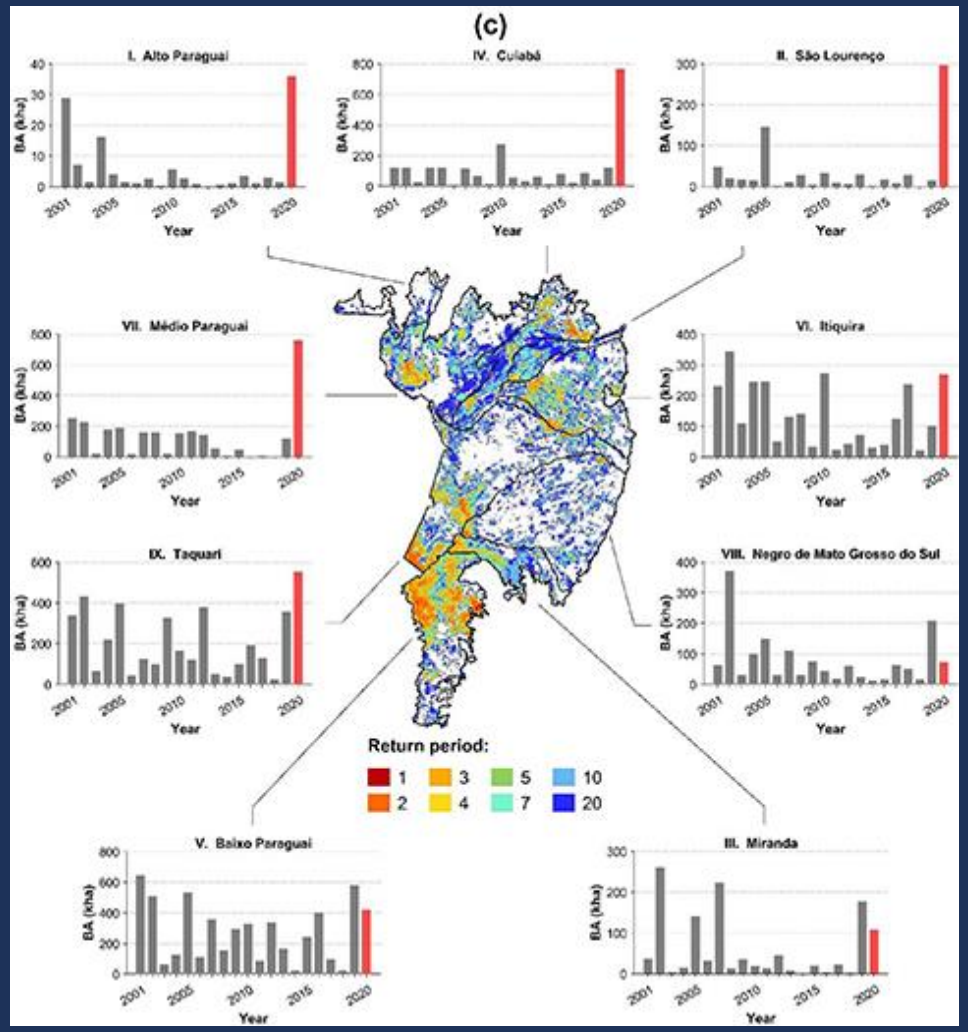
→ Wildfires → Socio-economic and ecological impacts

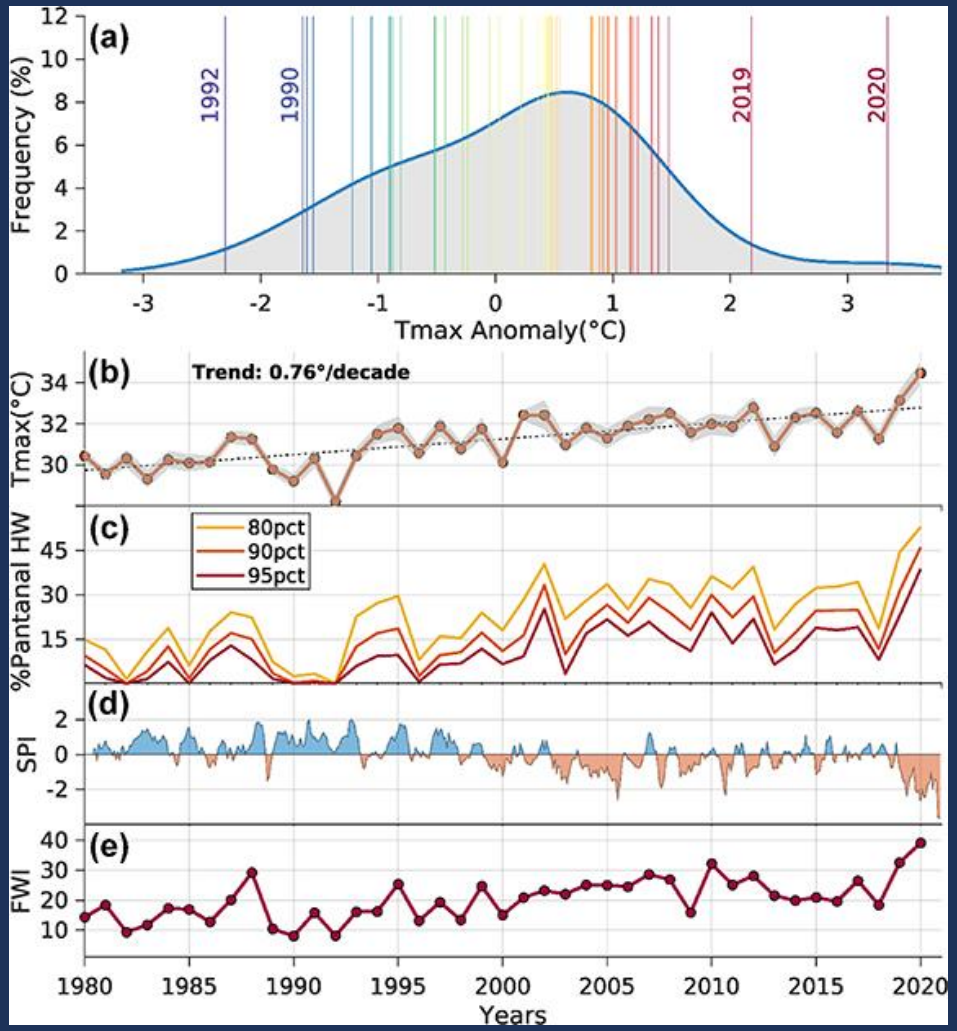
- **Human Losses**
- **Burned Infrastructures**
- **Poor Air Quality**

03

SOUTH AMERICA

2020 PANTANAL FIRE SEASON



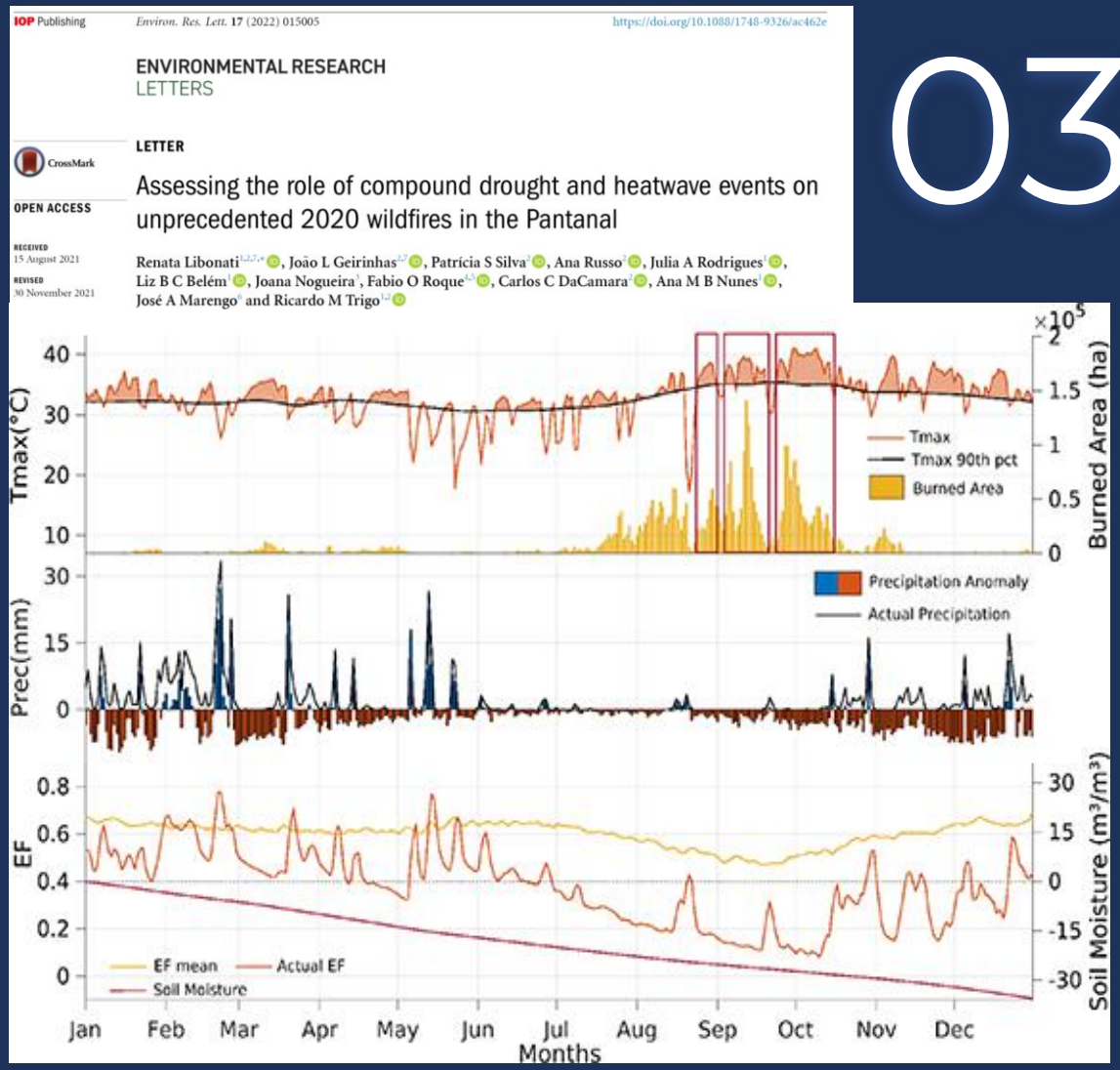


The BA recorded over the entire Pantanal during three massive HPs accounted for 55% of the total 2020 BA.

03

SOUTH AMERICA

2020 PANTANAL FIRE SEASON



1. Long-term precipitation deficits and large evaporation rates were essential to dry out the soil and vegetation and to reduce the flood pulse, providing unusual amounts of fuel to fires

2. Soil desiccation played a key role in boosting the concurrence of extremely hot conditions through the establishment of a water-limited regime and an increase in the sensible heat flux between the surface and the atmosphere, increasing flammability thresholds

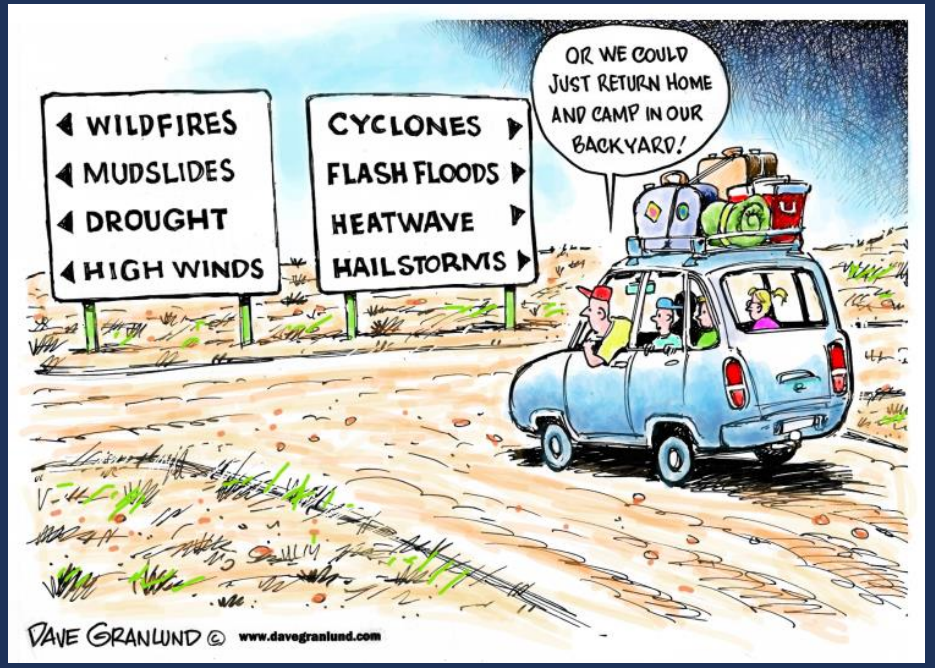
Concurring warm and dry conditions controlled the partitioning of water and energy fluxes at the surface

FINAL REMARKS

TAKE HOME MESSAGES

04

- **Extreme impacts don't require extreme weather**
  "The whole is greater than the parts"
- **The analysis of compound events has** particular **advantages**
- **Extreme events have impacts on agriculture, fires and vegetation**
- **Compounded events have higher impacts than isolated events, as seen on these examples for the Iberian Peninsula and South America**



THANK YOU!

Do you have any questions?

acrusso@fc.ul.pt

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