# HOT AND DRY METEOROLOGICAL EXTREMES IN THE MEDITERRANEAN

A. **Russo**[1], A. Ribeiro[1], C.M. Gouveia[1,2] , E. Dutra[1], P.M.M. Soares[1], R.M. Trigo[1], C. Pires[1] , Jakob Zscheischler [3]

[1]Instituto Dom Luiz, Universidade de Lisboa, Portugal

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

[3]U. Bern, Switzerland

acrusso@fc.ul.pt

# MOTIVATION

Weather and climate extreme events:

- **More frequent, severe and longer**
- **High social and economic impacts**

Spinoni et al., 2015

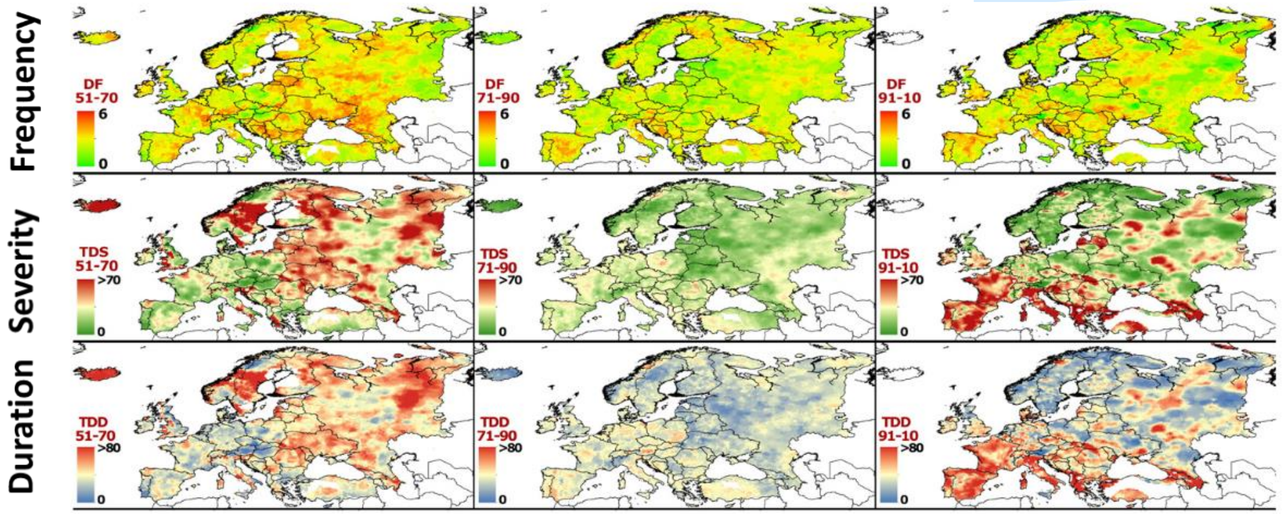
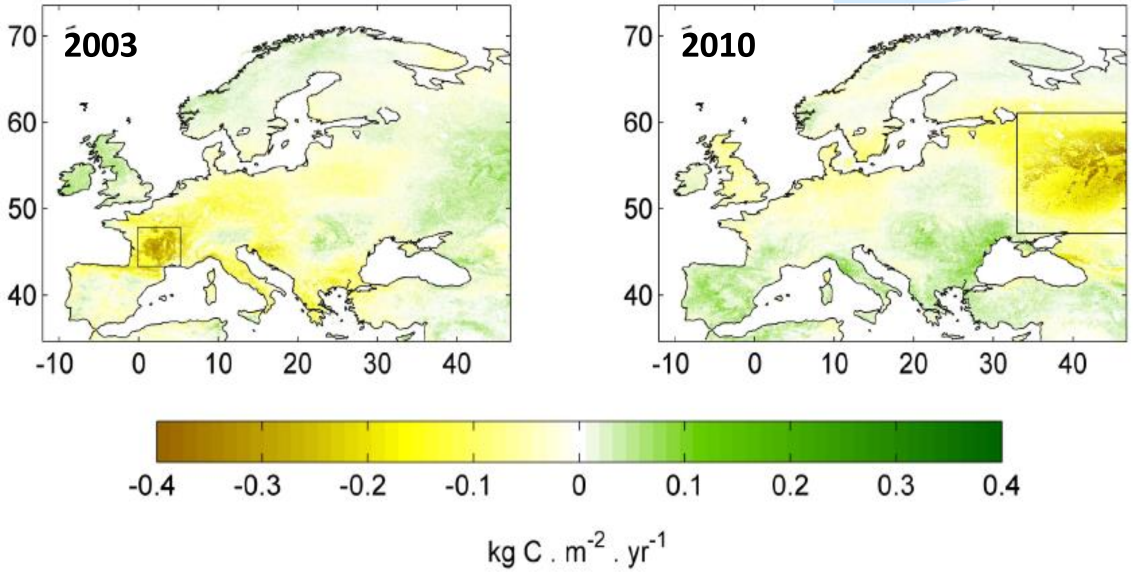
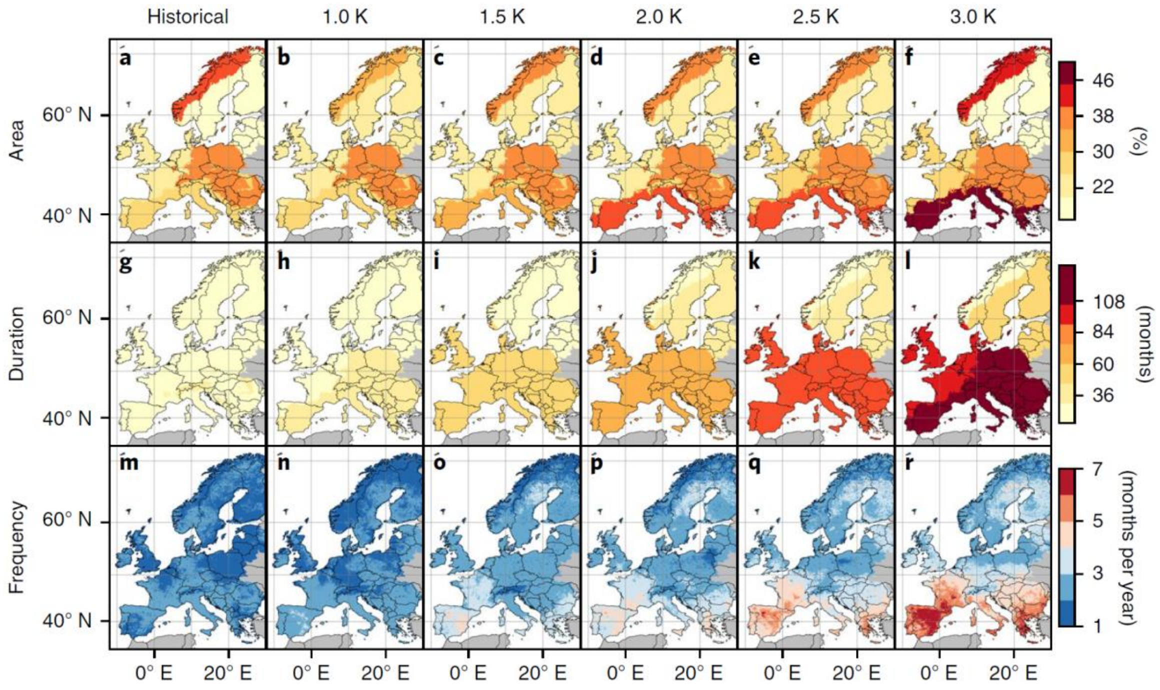



Fig. 1. Drought frequency (DF; events/decade), severity (TDS; score/decade), and duration (TDD; months/decade) maps for 1951–1970 (left), 1971–1990 (mid), and 1991–2010 (right).

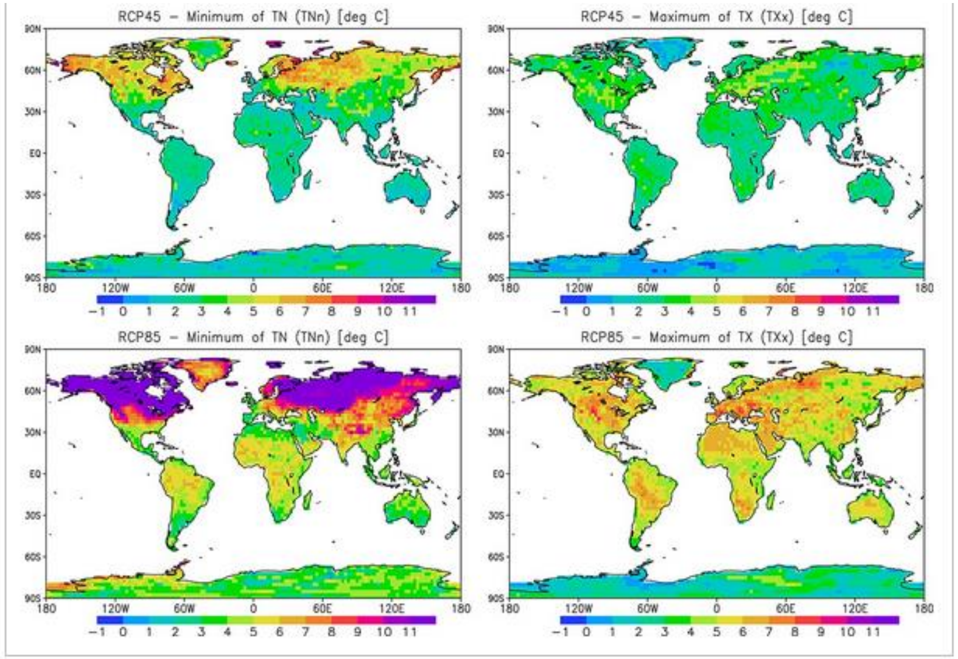
Bastos et al., 2014



# MOTIVATION




**Samaniego et al., 2018**. Anthropogenic warming exacerbates European soil moisture droughts. **Nature Clim. Change**.




**Sillmann et al., 2013.** Climate extremes indices in the CMIP5 multimodel ensemble: Part 2. Future climate projections. **JGR-Atmospheres.**

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

# MOTIVATION

**Miralles et al., 2019.** Land–atmospheric feedbacks during droughts and heatwaves: state of the science and current challenges. Ann N Y Acad Sci.

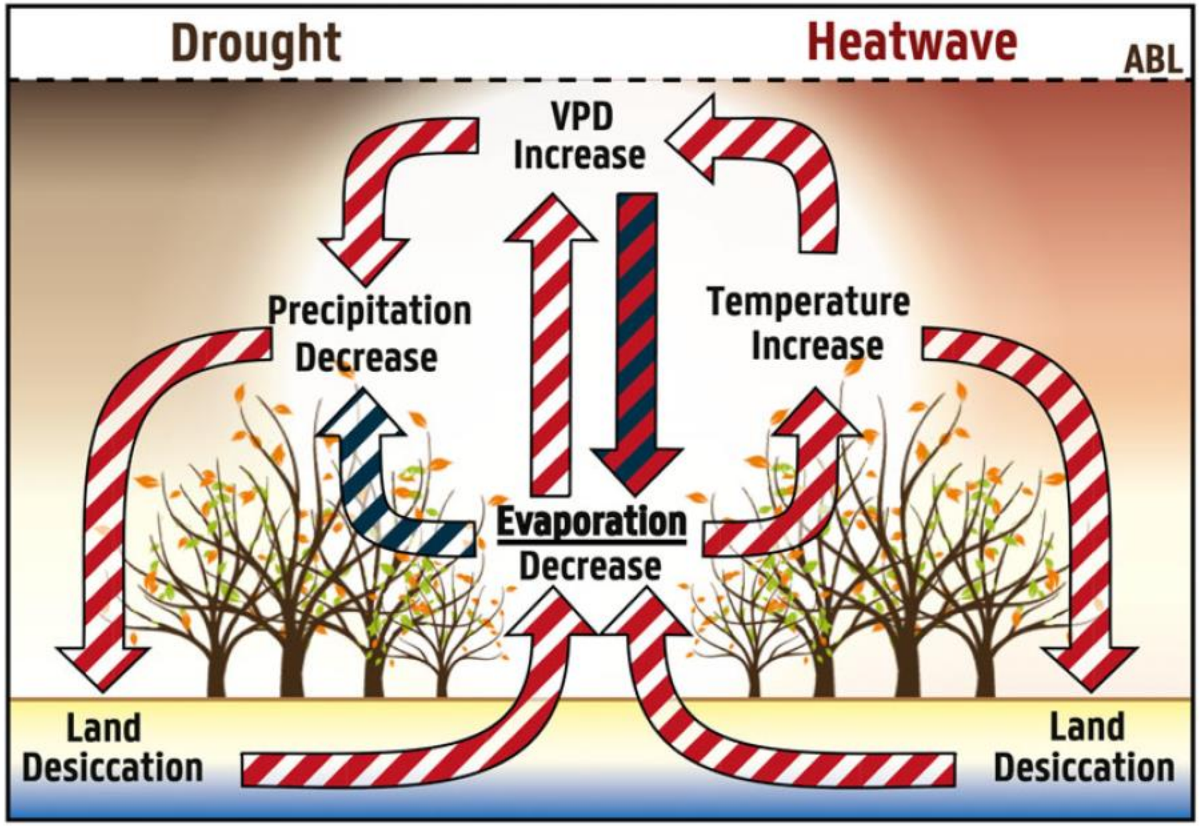



**Figure 1.** Land feedbacks as local intensifiers of hydro-meteorological extremes.

Events of combined water scarcity and extreme heat

- Australia (2005–2007)
- Northeastern China (2009)
- Europe (2003, 2010,and 2017)
- Greece (2007)
- United States (2013–2015)

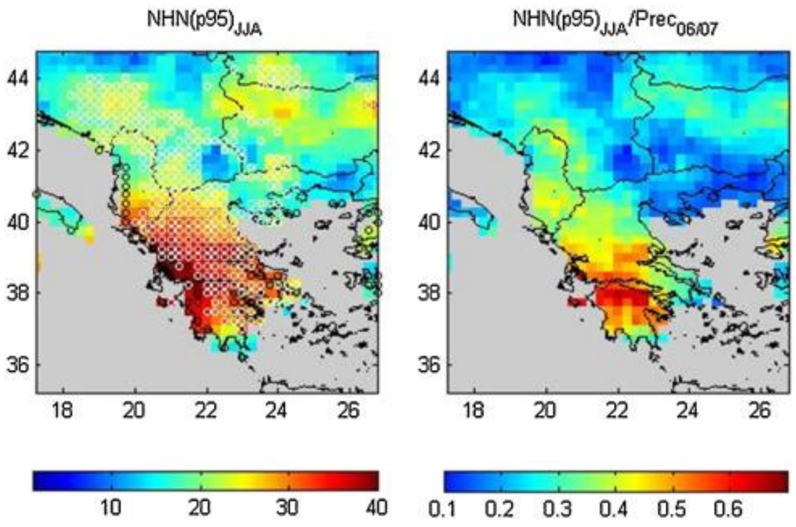
# IMPACTS

- Soil moisture - temperature feedbacks **impacts on fires, agriculture and health**

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]




https://doi.org/10.5194/bg-2020-116
Preprint. Discussion started: 1 April 2020

Biogeosciences Discussions
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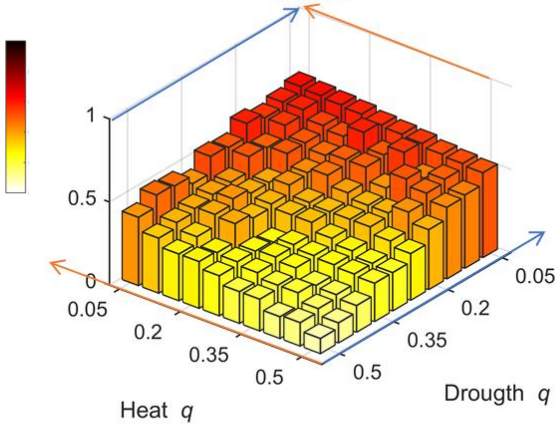
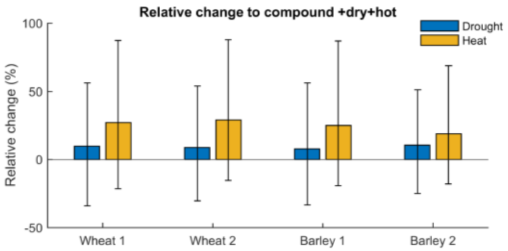
EGU

## 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]

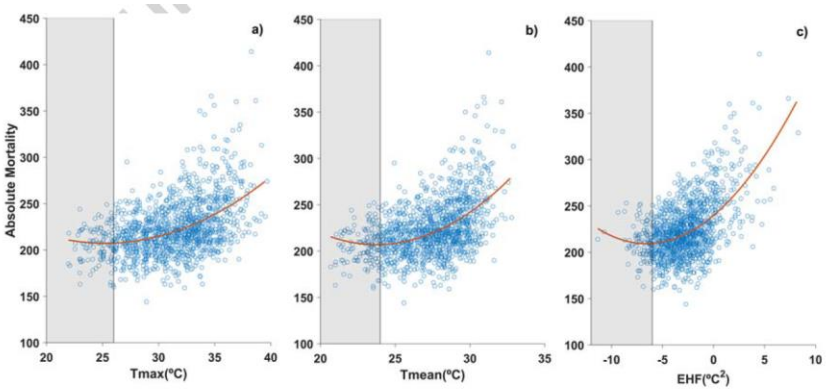



International Journal of Biometeorology
https://doi.org/10.1007/s00484-020-01908-x
ORIGINAL PAPER

## Heat-related mortality at the beginning of the twenty-first century in Rio de Janeiro, Brazil

João L. Geirinhas [1,2] · Ana Russo [1,2] · Renata Libonati [1,2,3,4] · Ricardo M. Trigo [1,2,3] · Lucas C. O. Castro [2,3] · Leonardo F. Peres [2,3] · Mônica de Avelar F. M. Magalhães [2,5] · Baltazar Nunes [2,6,7]

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# Storyline

João

| Goal 1 | Goal 2 | Goal 3 | Goal 4 | Goal 5 | Goal 6 |
|---|---|---|---|---|---|
| Individual Hazards | Drought-related hot summers | Conditional probabilities of crop-loss | Risk due to compound hot and dry extremes | Drought conditions under climate change | Impacts on health and mortality |

Andreia

# A compound vs individual event perspective

"Understanding compound events requires an analysis of the complex causal chains that can lead to extreme impacts"
*Zscheischler et al. 2018, Nature Climate Change*

**Goals**

1. Analyse drought and hot events on a compound event perspective

2. Describe the dependence structures between the dry and hot conditions

# METHOD

- **Proxy for surface moisture deficits: Standardized Precipitation Evapotranspiration Index** (SPEI) allow for inter-seasonal comparison through the computation of drought's duration, magnitude and intensity

- **Hot extreme identification:** percentile-based (are more comparable across different climatic regions)
  - **NHD** (number of hot days/month): number of days with a maximum temperature exceeding the 90th percentile (TX90p)

## Correlation analysis

- **Pearson correlation coefficient between NHD and the preceding months' SPEI**
- **Identification of hotspots of predictability of extreme hotness preceded by dryness**

## Copulas

- **Estimation of joint probability distributions between NHD and the preceding months' SPEI**
- **Generation of larger samples preserving the dependence structures**

# DATA

## DROUGHT

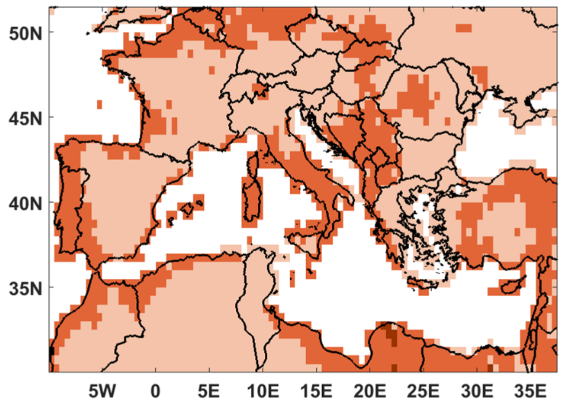
***SPEI***

- **CRU TS4.01 monthly data (0.5° x 0.5 °)**
- **1980-2014**
- **1950-2014**
- **Different time scales (3,6,9)**
- **Evapotranspiration (Penman-Monteith)**
- **Month preceding the hottest months of each year**

## HOT EXTREMES

- **ECAD-EOBS daily data** (0.5° x 0.5 °) (**Version 14**)
- **1980-2014**
- **1950-2014**
- Monthly **NHD**

- The hottest month was determined for each year




✓ The **most frequent hottest** months are either **July** or **August**

*Russo et al. (2018)*

**CORRELATION AND JOINT PROBABILITY ANALYSIS** between the hottest months NHD and the preceding months' SPEI

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# CORRELATIONS' RESULTS

## 1980-2014

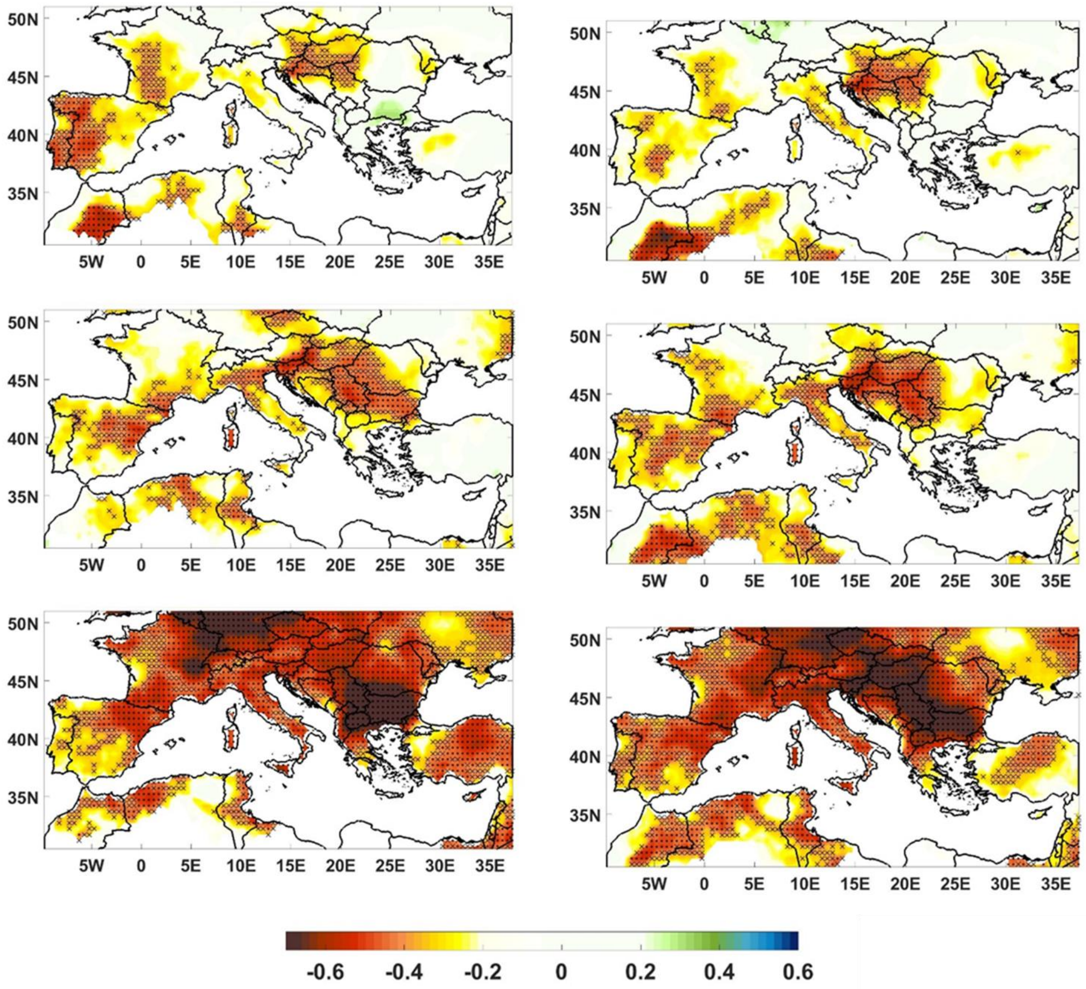
3-MONTHS | 6-MONTHS

NHD | NHD

May

June

July




X (•) Statistically significant at 95% (99%)

Positive correlations are usually located in northern France, Germany, Albania, Romania, Bulgaria or Ukraine, and mostly not statistically significant

Negative significant correlations are mostly located in the **Iberian Peninsula (IP), Balkans (BKS) and on northern Africa**

# MAXIMUM CORRELATIONS

## *NHD vs. SPEI*

| | Index | May | | |
|---|---|---|---|---|
| | | Corr | IP | BKS |
| NHD | SPEI_3 | -0.60 | -0.55 | -0.51 |
| | SPEI_6 | -0.70 | -0.49 | -0.56 |
| | SPEI_9 | -0.66 | -0.46 | -0.52 |

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**MAY**: SPEI at 3-months' time scale

**JUNE**: SPEI at 3 and 6-months' time scale

**JULY**: SPEI at 6-months' time scale

Reflecting that the winter and spring water balance (precipitation-evaporation) have a major importance on the occurrence of NHD in the summer

# HOT SPOTS

3-Months

6-Months

9-Months

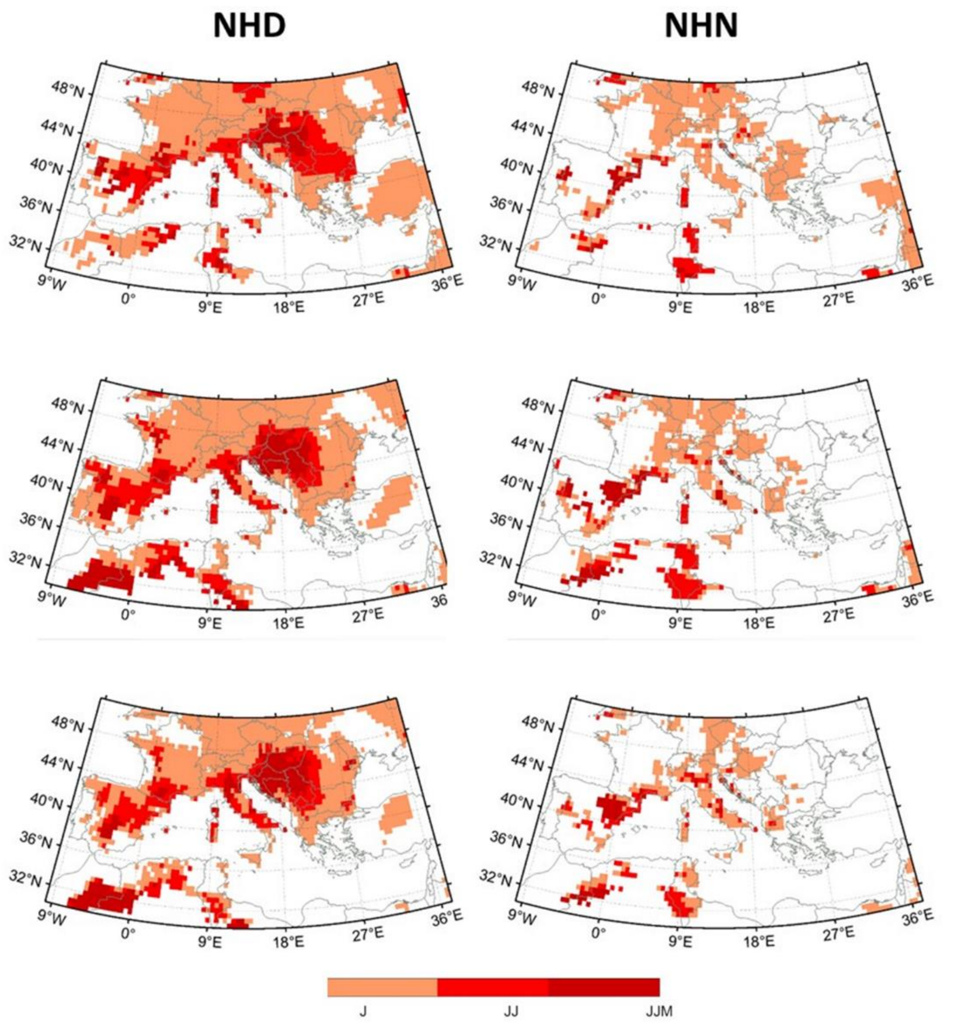
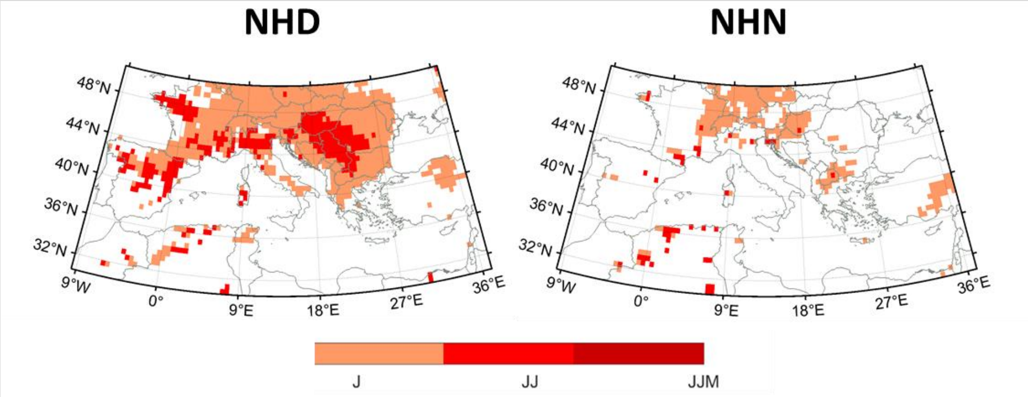



***Fig. 5*** *Significant correlations in consecutive months (J- July; JJ-July and June; JJM-July, June and May) between NHD (left) and NHN (right) and SPEI for the 3- (top panel), 6- (middle panel) and 9-months (lower panel) timescales.*

There is a spatial consistency on certain areas where consecutive months' present significant correlation values

The <u>Iberian Peninsula</u>, <u>northern Italy</u>, <u>northern Africa</u> and the <u>Balkans</u> are the main hotspots of predictability of extreme hot temperatures in the summer preceded by the occurrence of drought events in the spring or early summer



# MAIN CONCLUSIONS

- **Most regions exhibit significantly negative correlations**, i.e. high **NHD** or **NHN** following r… …d **NHN** early warning
- Correlatio…
- **Soil moistu…**

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LETTER

## The synergy between drought and extremely hot summers in the Mediterranean

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

Supplementary material for this article is available online

# JOINT PROBABILITY ANALYSIS

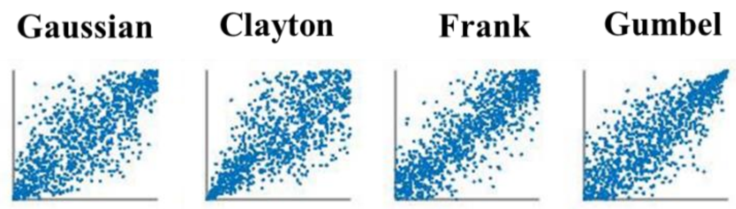
## 1950-2014

IP

| | | AIC | | | |
|---|---|---|---|---|---|
| | | Gaussian | Clayton | Frank | Gumbel |
| -SPEI_3 | May | -3.37 | -0.43 | -2.33 | -3.81 |
| | June | -16.4 | -11.0 | 14.8 | -17.2 |
| | July | **-33.2** | -26.3 | -30.9 | -31.6 |
| -SPEI_6 | May | **-3.00** | -0.46 | -1.54 | -2.54 |
| | June | -12.4 | -5.87 | -10.2 | -12.6 |
| | July | **-28.5** | -19.2 | -24.0 | -26.8 |
| -SPEI_9 | May | **-4.09** | -2.76 | -3.09 | -3.58 |
| | June | **-12.23** | -6.98 | -10.7 | -11.8 |
| | July | **-24.8** | -16.7 | -21.5 | -22.3 |

Copula models support correlation analysis and are able to capture **tail dependence**

**Step 1:** Fit the copula functions and select the more adequate copula function based on the values of the Akaike's Information Criteria (AIC)




- **MAY: SPEI at 3-months' time**
- **JUNE: SPEI at 3-months' and 6-months' time scale**

→ Suggest higher probabilities of joint high extremes

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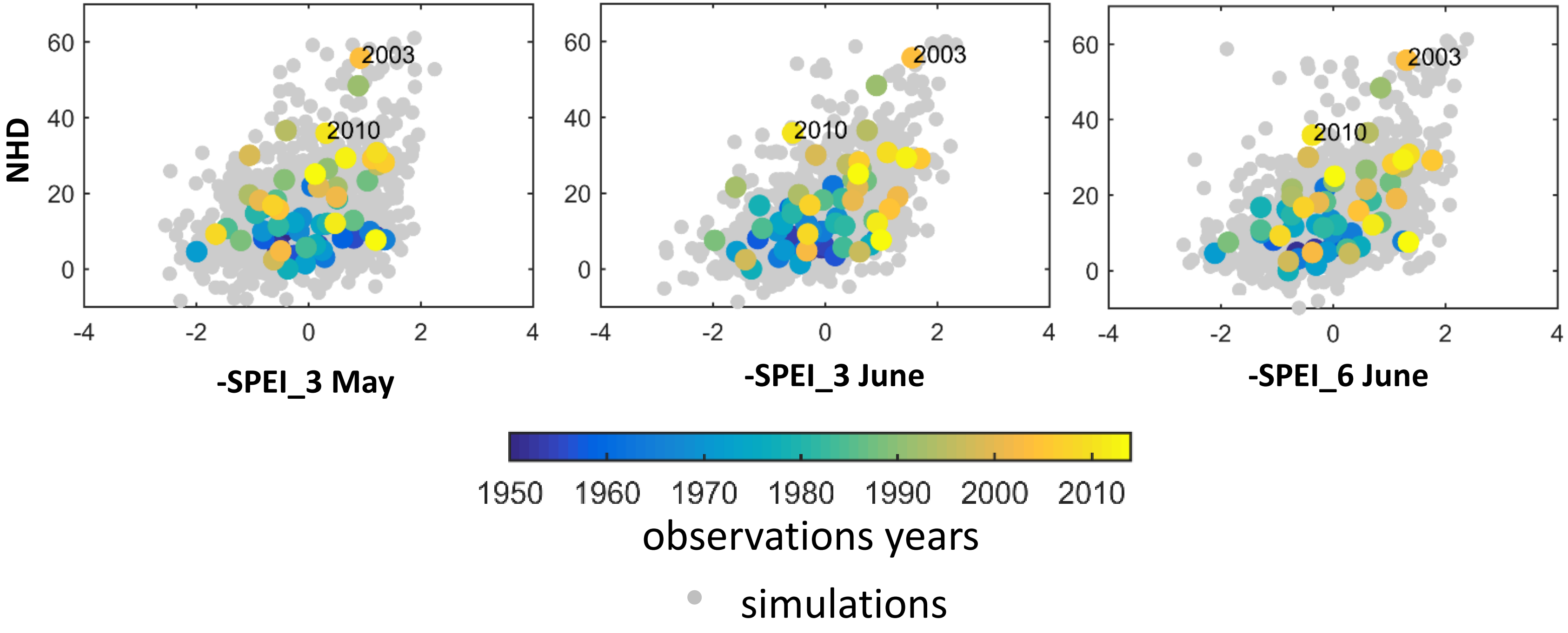
# JOINT PROBABILITY ANALYSIS

## 1950-2014

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**Step 2:** Generation of larger samples preserving the dependence structures

- Dependence in the upper tail between the ocurrence of hot days and previous dryness

- Mega heat waves in 2003 and 2010 captured by the simulations

Based on copula models, the smallest time-scales corroborate correlation results and point to higher probabilities of **joint high extremes**

Cluster and Principal Component Analysis (PCA) identified 6 different regions over the Iberian Peninsula (IP) where spatial averages of SPEI and NHD were computed (**Fig. 1 a**).

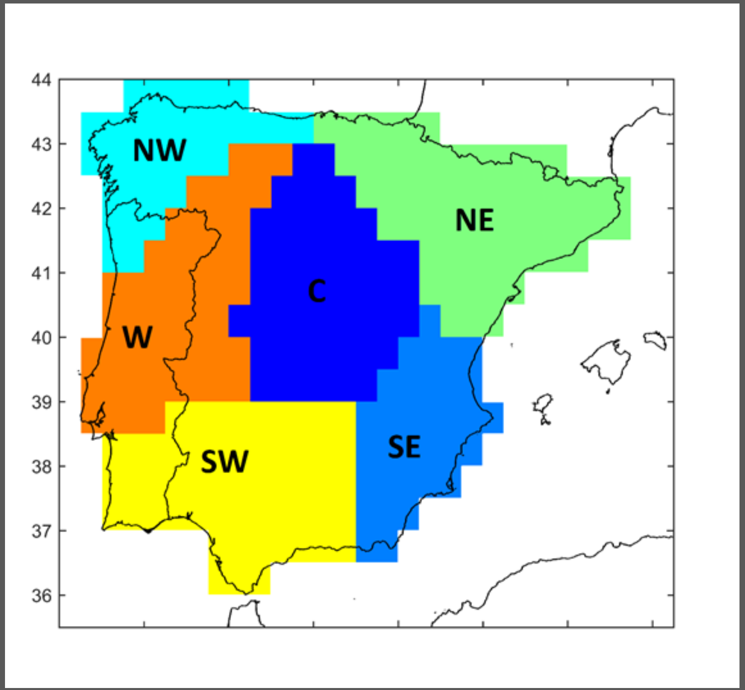
Assessment of the probability of summer hot days being preceded by drought events in spring and early summer, based on their joint probability distribution (copula theory) **[5,6,7]**.

Normal, t, Clayton, Frank, Gumbel and Joe copulas used, being the copula model selection performed based on the Bayesian information criterion (BIC).

Correlation for each pair SPEI and NHD over each region examined in terms of the Kendall's τ . The upper tail dependence $\boldsymbol{\lambda_U}$ is based on parametric estimator θ by $\boldsymbol{\lambda_U = 2 - 2^{\frac{1}{\theta}}}$ **[6]**

Copula-based samples of NHD under: i) drought (SPEI <= -0.84) and ii) normal/wet conditions (SPEI > -0.84) **[7]** used to obtain the conditional survival functions 1-$Fv_{sim,dry}$ and 1-$Fv_{sim,wet}$ (Fig. 2)

Extreme summers identified by conditional probability of exceeding the NHD 80th percentile for: i) 1-Fvsim,dry(0.8) (drought) and ii)1-Fvsim,wet(0.8) (wet/normal)



# Data and methods

- **SPEI (Standardized Precipitation Evapotranspiration  Index)**

CRU TS4.01 monthly data (0.5° x 0.5 °)

1950-2014

Different time scales (3,6,9)

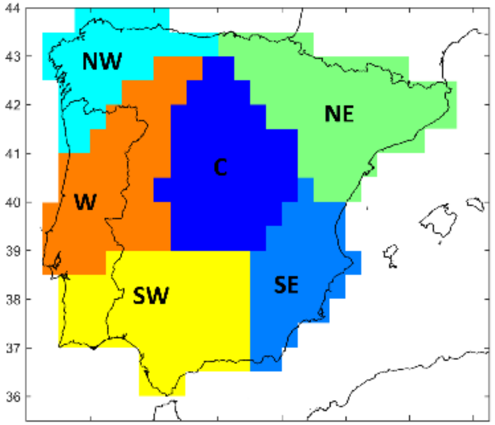
Evapotranspiration (Penman-Monteith)

- **NHD (number of hot days/month)** ECAD-EOBS daily data (0.5° x 0.5 °) (Version 14)

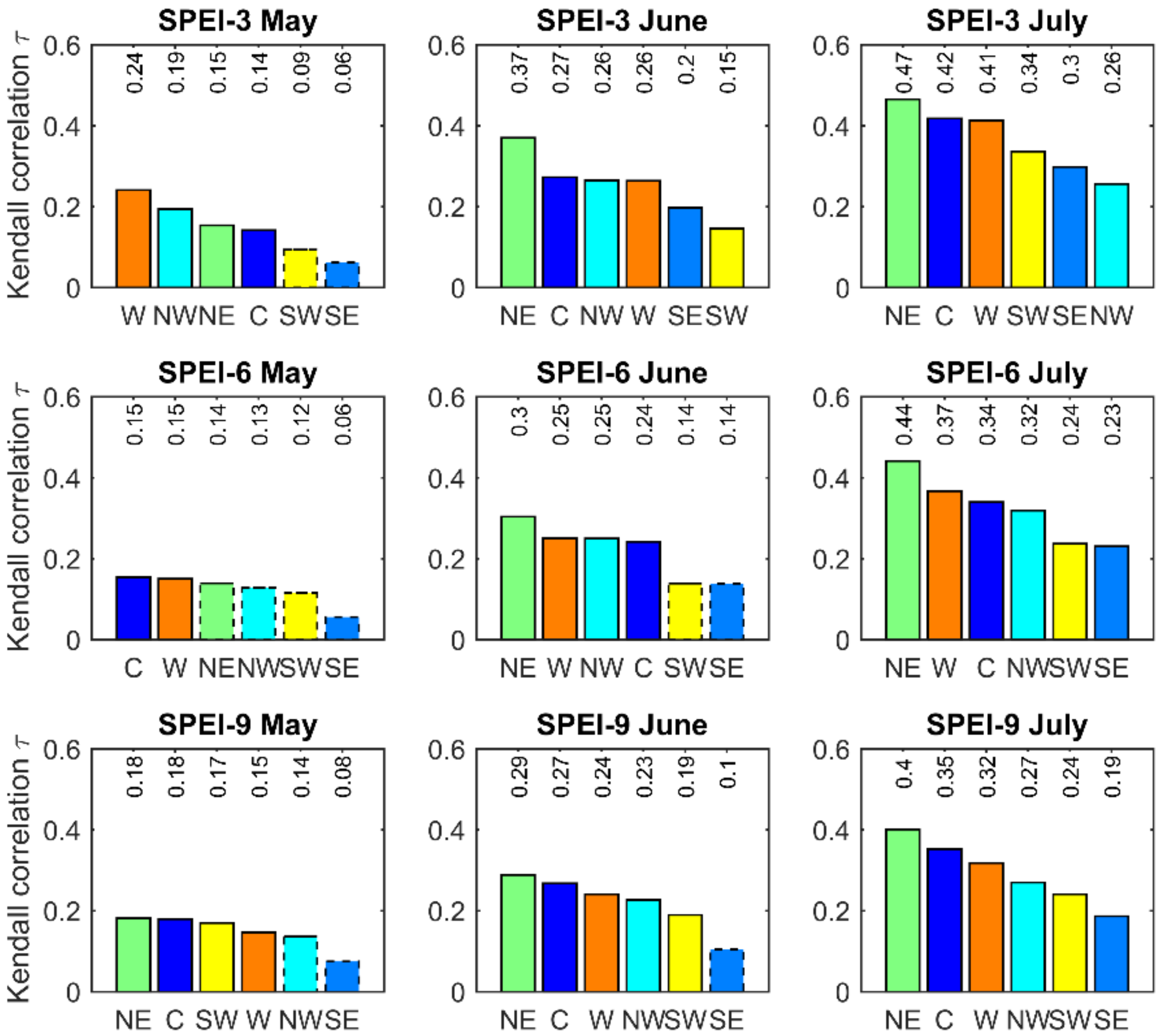
Main spatial-temporal drought modes based on SPEI over the IP applying a Principal Component Analysis (PCA) and cluster analysis

Correlation and joint probability analysis between the hottest months NHD and the preceding months' SPEI over each region

# Results




- Regionalization similarly to the ones obtained by Vicente-Serrano (2006) and Russo et al. (2015)




- **Kendall's $\tau$ increases from May to July**
- **NE exhibits a strong $\tau$ particularly in June and July**

**a) Wet/normal conditions preceding summer** **b) Dry conditions preceding summer**

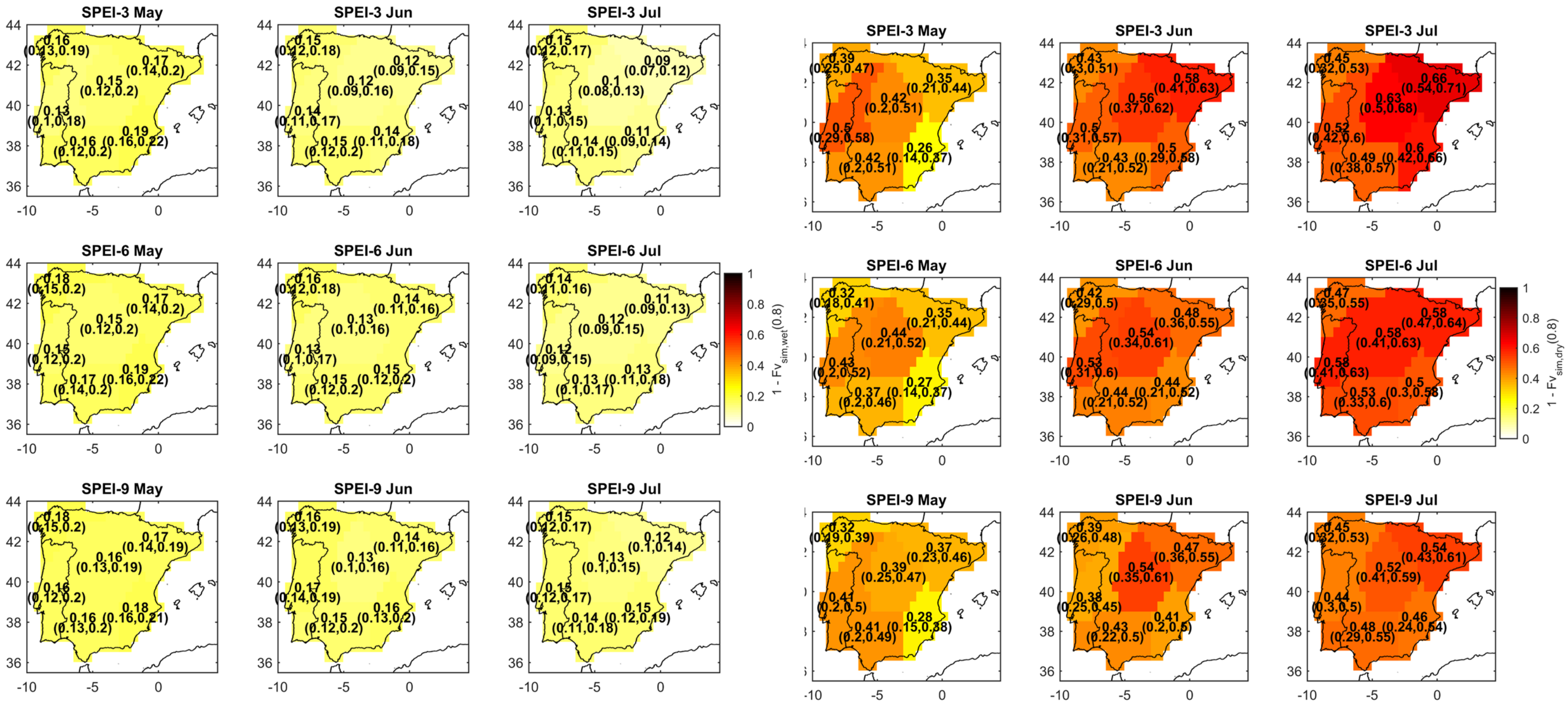



**Fig. 3** – a) Conditional probability of summer NHD exceeding the quantile 0.8 based on the copula samples over drought regions preceded by **wet/normal** conditions (1-$Fv_{sim,wet}$(0.8)) and b) **dry** conditions (1-$Fv_{sim,dry}$(0.8)).

- The deper … tail dependence…
- The transi … he probability of exceedin…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# Drought-related hot summers: A joint probability analysis in the Iberian Peninsula


Andreia F.S. Ribeiro [a], Ana Russo [a], Célia M. Gouveia [a, b], Carlos.A.L. Pires [a]


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IMPECAF WEATHER EXTREMES

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