

## WP5 - INDICES TIME EVOLUTION & RELATIONS WITH ATMOSPHERE



*European Research Area  
for Climate Services*

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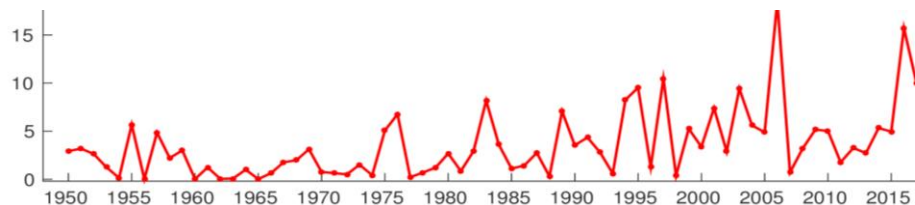
Philip Craig, Albert Osso\* (also Len Shaffrey, Emily Black, Ed Hawkins) at University of Reading

Contributions: UCantab/RMIB/ULisbon/CNR-IRPI/CNR-ISAFOM/EHI-Cantab/BSC-CNS...

\*now University of Graz

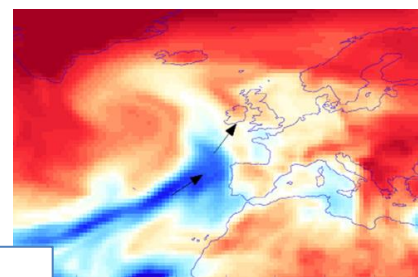
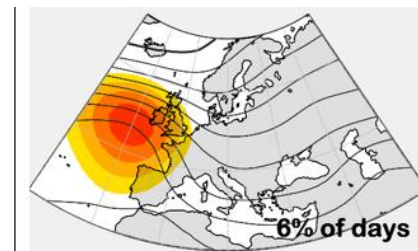
## WP5 - Indices Time Evolution & Relations with Atmosphere

Aim: quantify variability/change in indices and establish link to atmospheric circulation patterns



### Deliverables:

- Inventory and Catalogue of Indicators of circulation variability for comparison with the INDECIS-ISD
- Report on temporal evolution of the INDECIS-QCHDS and INDECIS-ISD, including the time-emergence of climate-change signals and relation with atmospheric patterns
- Report on the relation between INDECIS-QCHDS and INDECIS-ISD and atmospheric patterns



Compile teleconnection indices



Evaluate physical linkages between atmospheric variability, extremes & sectorial indices

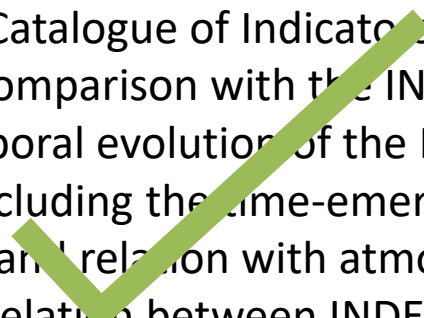
Analyse temporal evolution of INDECIS-QCHDS/ISDs



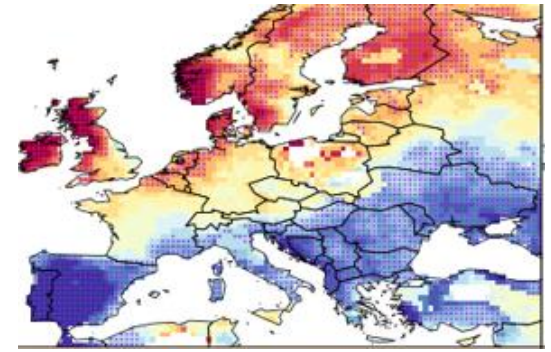
Investigate time-emergence of observed climate change signal

WP 2,3,4

WP 6,7



## WP5.2 - some key results: Time evolution of INDECIS metrics/emergence [UReading/UCantab/BSC-CNS/CNR-IRPI/RMIB]



- Increases in precipitation in N Europe (Scandinavia, UK, Ireland), decreases over Spain/Portugal
- Longest Wet Spell increases UK, Scandinavia and NE Europe, decreased Central Europe/Iberian Peninsula (Winter/Spring); increased fraction of heavy precipitation
- Development of piecewise linear quantile regression model to examine extreme precipitation: suggests change-point in temperature scaling over W Europe
- Precipitation trends in Italy: hydrology impacts from reduced September rainfall in Po catchment; Alpine skiing impact from shift in precipitation Dec to Feb
- Increased hot extremes; winter Longest Dry Period increase S Europe, decrease N
- Time of emergence of flood-related and drought-associated INDECIS products

<http://www.indecis.eu/wp5.php>

# 1. Information sources and methodology



NCAR  
UCAR

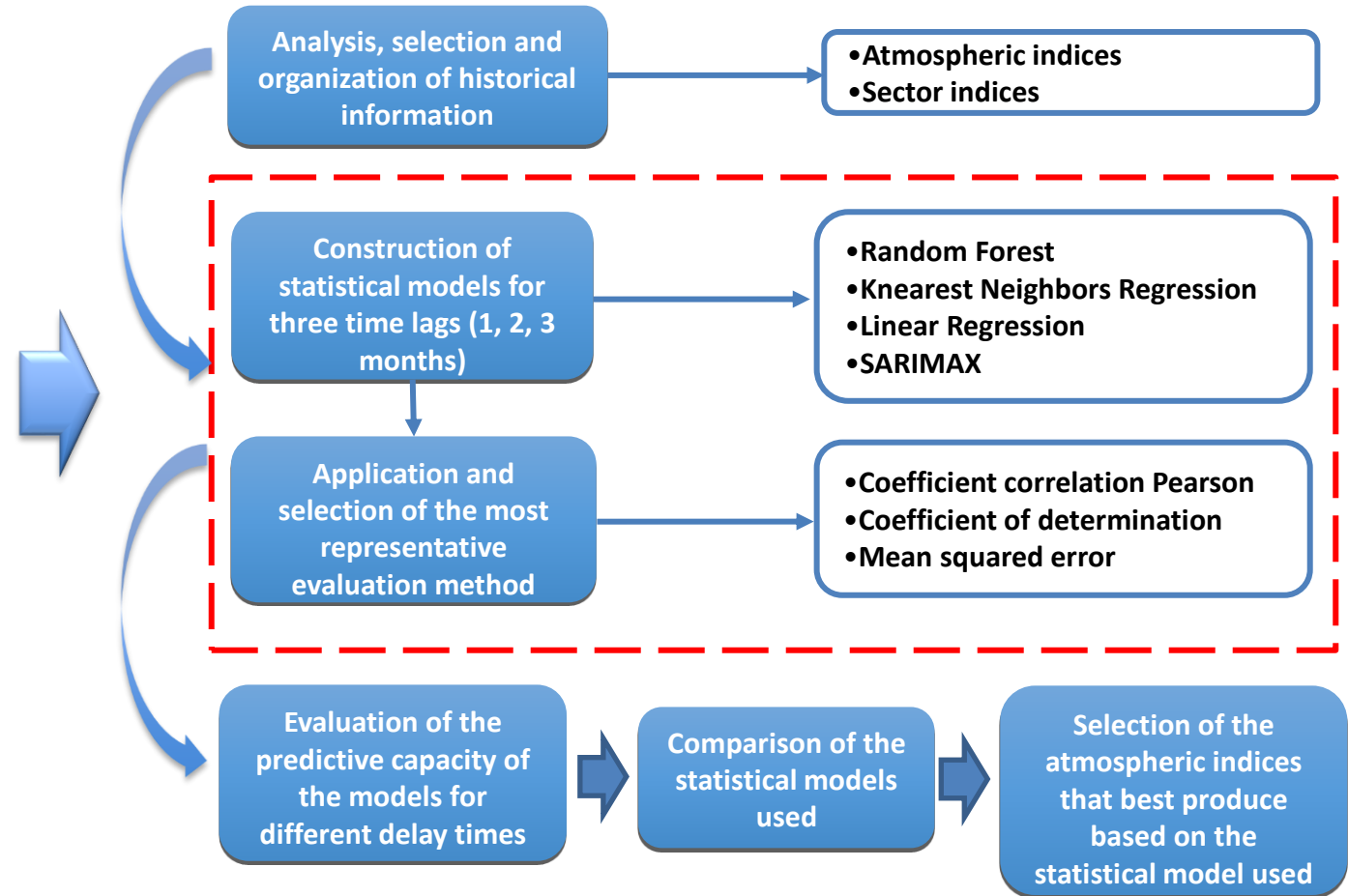
## Atmospheric indices

NORTHERN HEMISPHERE TELECONNECTION PATTERNS	
NAO	North Atlantic Oscillation
EA	East Atlantic Pattern
WP	West Pacific Pattern
EP/NP	East Pacific/North Pacific Pattern
PNA	Pacific/North American Pattern
EA/WR	East Atlantic/West Russia Pattern
SCA	Scandinavia Pattern
TNH	Tropical/Northern Hemisphere Pattern
POL	Polar/Eurasia Pattern
PT	Pacific Transition Pattern
NIÑO - ONI	El Niño 3.4 - Oceanic Niño Index

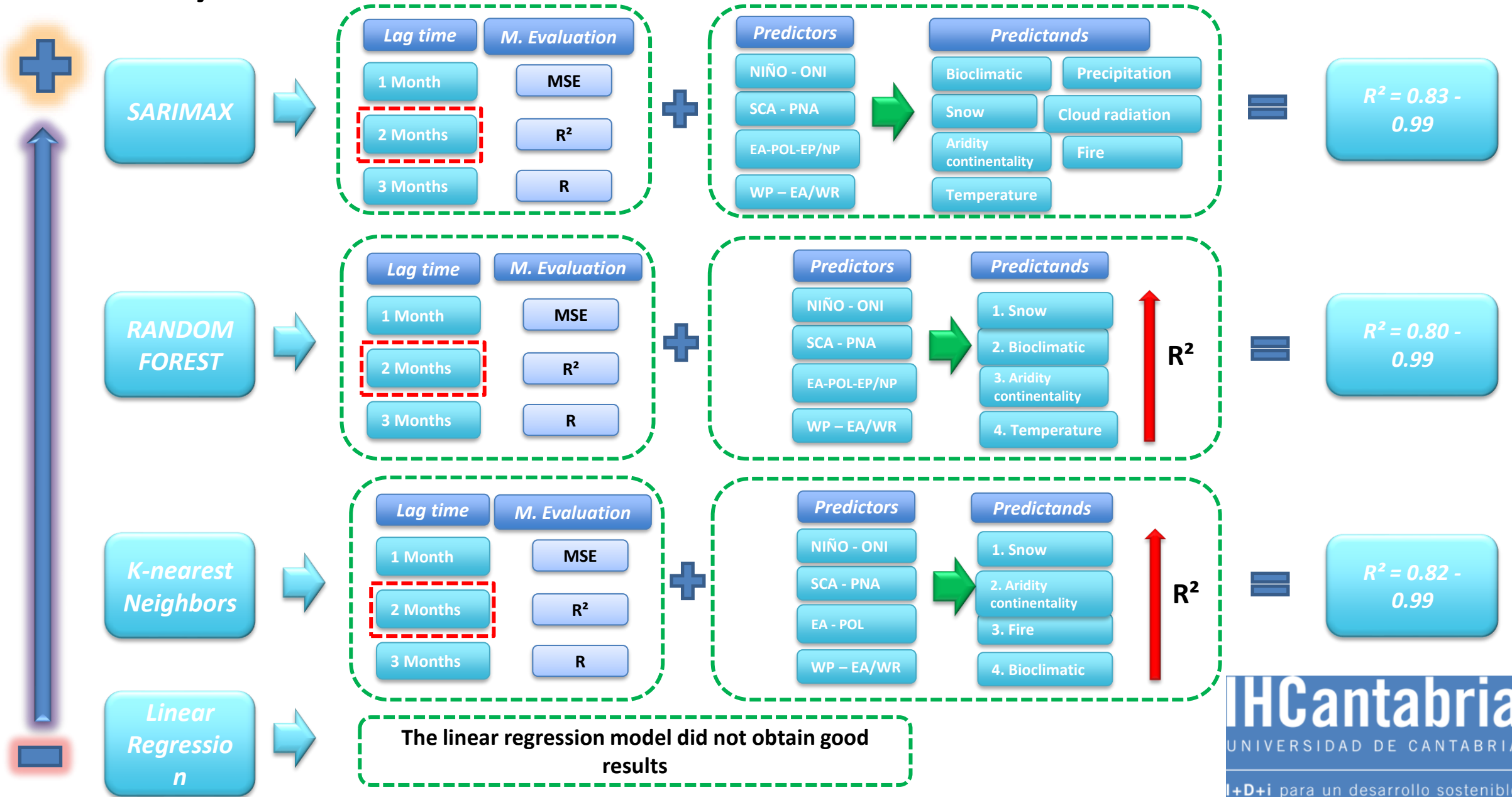
*Indecis*  
Sectorial Climate Services

## Sector indices

SECTORAL INDEX GROUPS	
	Precipitation
	Temperature
	Wind
	cloud_radiation
	Snow
	Bioclimatic
	Aridity continentality
	Drought
	Fire and Tourism



# 2. Analysis of results



### 3. Conclusions

- Statistical models **Random Forest, K-nearest Neighbors** and **Sarimax**
- **2-month lag times better** than lag time of 1 and 3 months.
- **Linear Regression model** did not show satisfactory results
- **Sarimax model:** best predictive capacity;
- **Random Forest model:** lower predictive quality
- **K-nearest Neighbors model**, slightly lower  $R^2$ , similar to the Random Forest model.
- **Linear Regression model:** did **not present satisfactory results.**
- all models built display small difference between determination coefficients ( $R^2$ ) calculated from the relationship of any sector index, with respect to each atmospheric index - variation percentage mainly less than 1%.

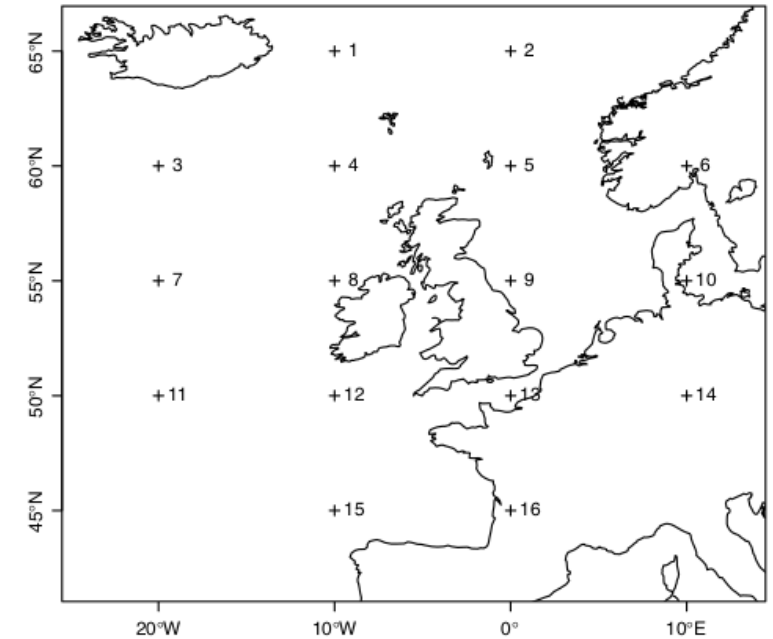
- Assess the potential improvement of CMIP6 over CMIP5 GCMs regarding the statistical analysis between circulation types in a process-based validation.
- Provide a quantitative ranking of models, to aid in the plausibility step of model selection over Europe for downscaling purposes.

### DATA

- 9 pairs of Earth System Models from CMIP5 and CMIP6 and 4 reanalysis products to work as pseudo-observations.
- Years: 1981-2010
- Variable: PSL (sea-level pressure)

### METHODS

- Lamb Weather Types (LWTs) [Lamb, 1972] → 26 circulation types
- Validation measures:
  1. Relative Bias
  2. Kullback-Leibler Divergence (KL)
  3. Two-Proportions Z-Test (Z-Test)
  4. Transition probability matrix score (TPMS)

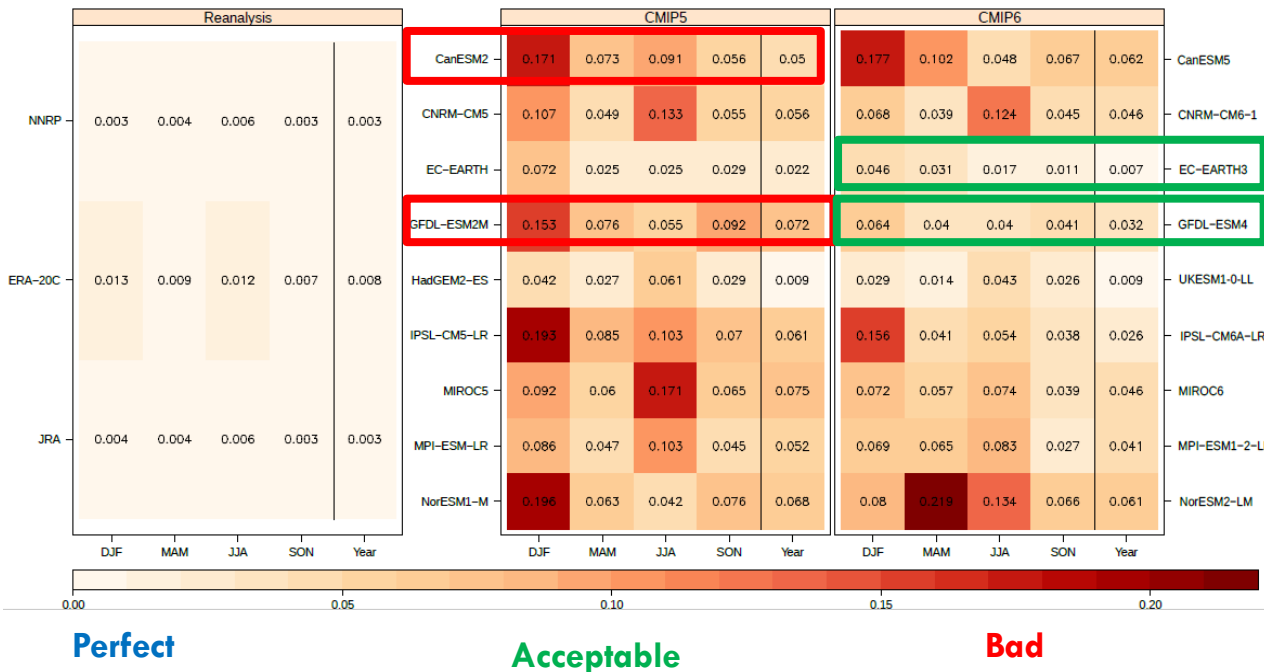


*Location of grid points around British Isles used in the calculation of the LWTs. (Source: Jones et al., 2013)*

**Distributional similarity of GCM vs. reanalysis Weather Types**  
Kullback- Leibler Divergence (KL):

$$KL(P||Q) = \sum_{x \in X} P(x) \log \frac{P(x)}{Q(x)}$$

P(x): GCM  
Q(x): Reanalysis

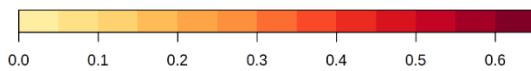


**CONCLUSIONS:**

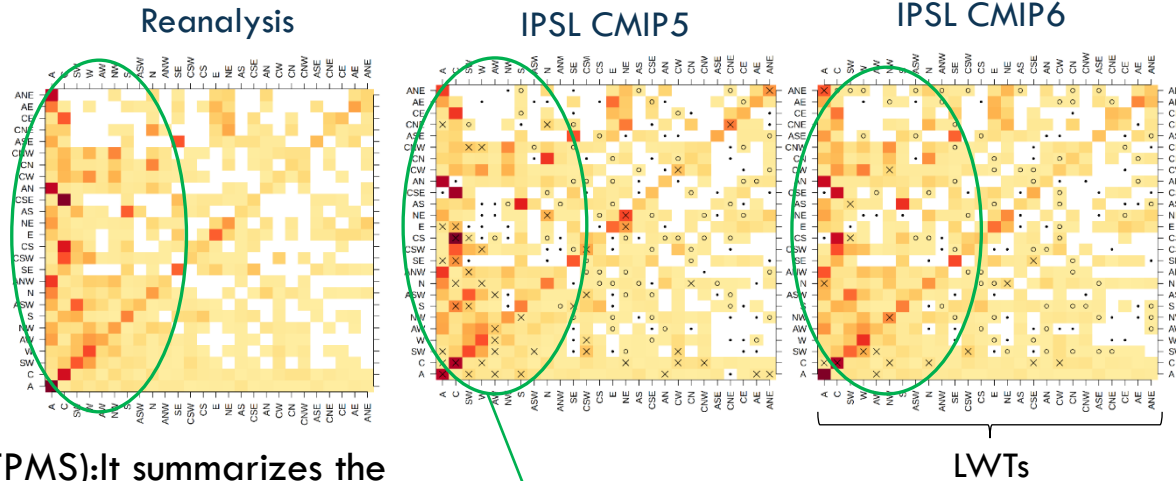
- ✓ CMIP6 models in general yield better weather type reproducibility than CMIP5
- ✓ Best CMIP5 models remain the best in CMIP6
- ✓ Improvement in atmospheric representation seems related with improvement in GCM resolution
- ✓ Reanalysis uncertainty is negligible. It does not affect the overall results



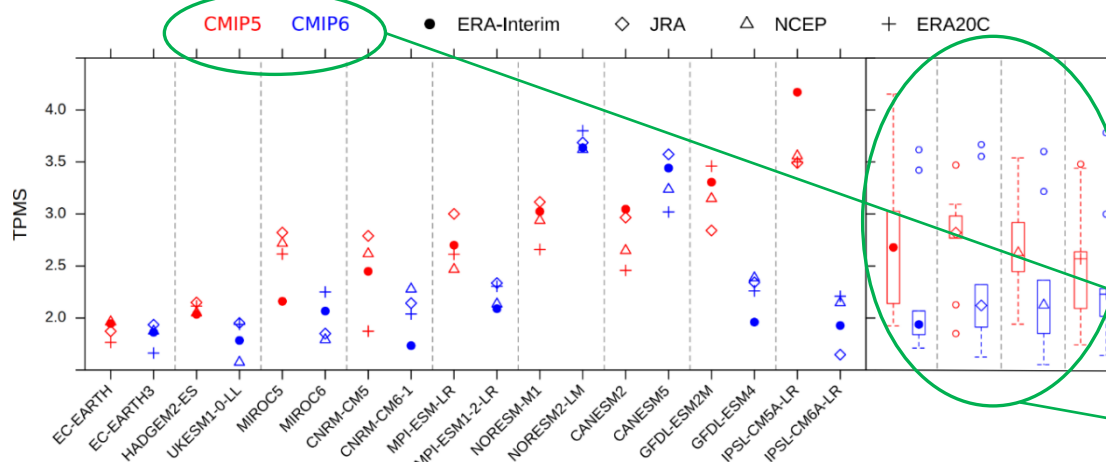
Day-to-day probability of transition from WT1 to WT2: Transition probability matrix (TPM): Example



$$A_{ij} = p(X_t = j | X_{t-1} = i)$$



Transition probability matrix score (TPMS): It summarizes the information from the Transition probability matrix of GCMs



Order regarding CMIP5 TPMS from best to worst

$$TPMS = \sum_{p \in A^*} |p_m - p_o| \quad \begin{matrix} p_m: \text{GCM} \\ p_o: \text{Reanalysis} \end{matrix}$$

**CONCLUSIONS:**

- ✓ The GCM TPM fingerprints generally represent the pattern of most likely transitions as represented by the reanalysis
- ✓ TPMS: CMIP6 is better than CMIP5
- ✓ Reanalysis uncertainty is negligible. It does not affect the overall results

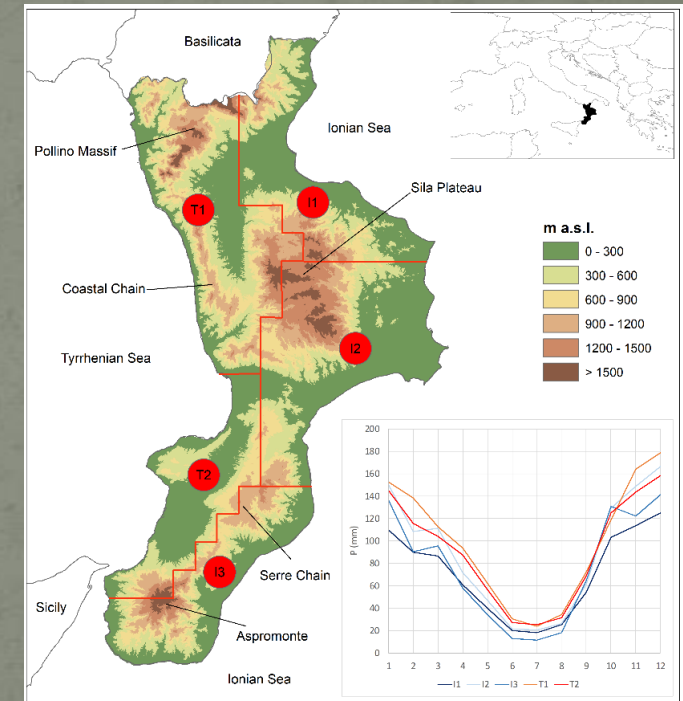
INDECIS data catalogue & new stations → WP5: finding relevant teleconnections for Europe/Mediterranean → teleconnection/variables correlation analysis → **regional correlation analysis**

- Motivation: does correlation of a regional database with teleconnection indices provide more insight than correlating individual station data to indices?
- Climate change implications: Is there a change in the correlation over time?

- Method: Pearson correlation, 95% significance
- Time frames: 1951-1980, 1981-2010, and 1951-2010

## Test area: CALABRIA

1951-2010 – 5 Rain Zones, 79 rain gauge stations



Teleconnection indices: NAO, ONI, MOI, WeMOI, EA, EA/WR, SCAND

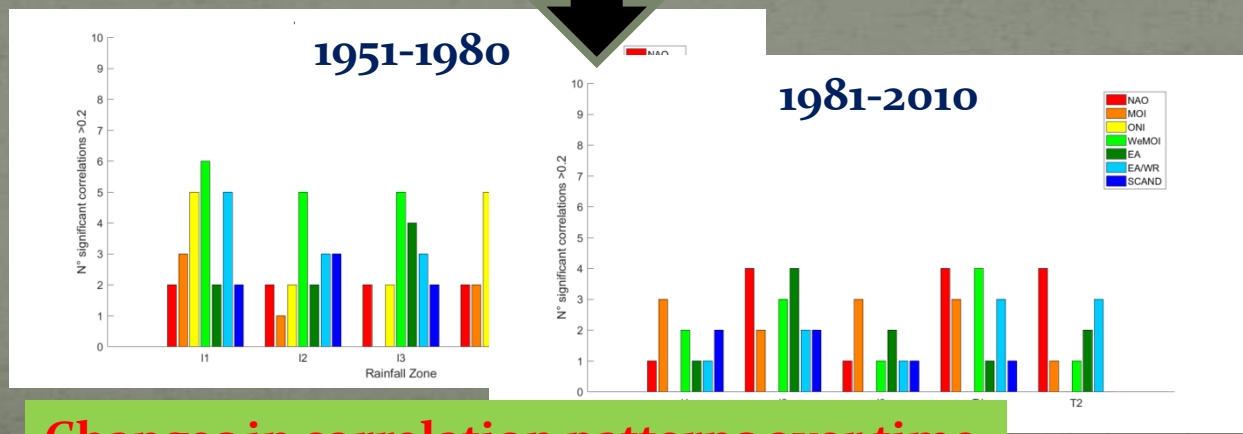
- Using individual stations, only a fraction of them will yield significant correlations
- A regional database will use **all valid data available**

Rainfall Zone	stations correlating significantly (1)
I1 (11 stations)	54%
I2 (13 stations)	31%
I3 (19 stations)	37%
T1 (20 stations)	50%
T2 (16 stations)	44%
<b>Calabria</b>	<b>43%</b>

- PERFORMED ANALYSES:
  - Seasonal indices vs seasonal precipitation
  - Seasonal indices vs monthly precipitation
  - Monthly indices vs monthly precipitation

(1) Averaged over all the correlations in the study

Caroletti, Coscarelli & Caloiero: “A sub-regional approach for the analysis of atmospheric teleconnection influence on precipitation in Calabria”, EGU2020-3078, EGU General Assembly 2020  
 Caroletti, Coscarelli & Caloiero: “A micro-climatic regional approach to the influence analysis of teleconnection patterns on precipitation in Calabria (Southern Italy)” - submitted to International Journal of Climatology



**Changes in correlation patterns over time**

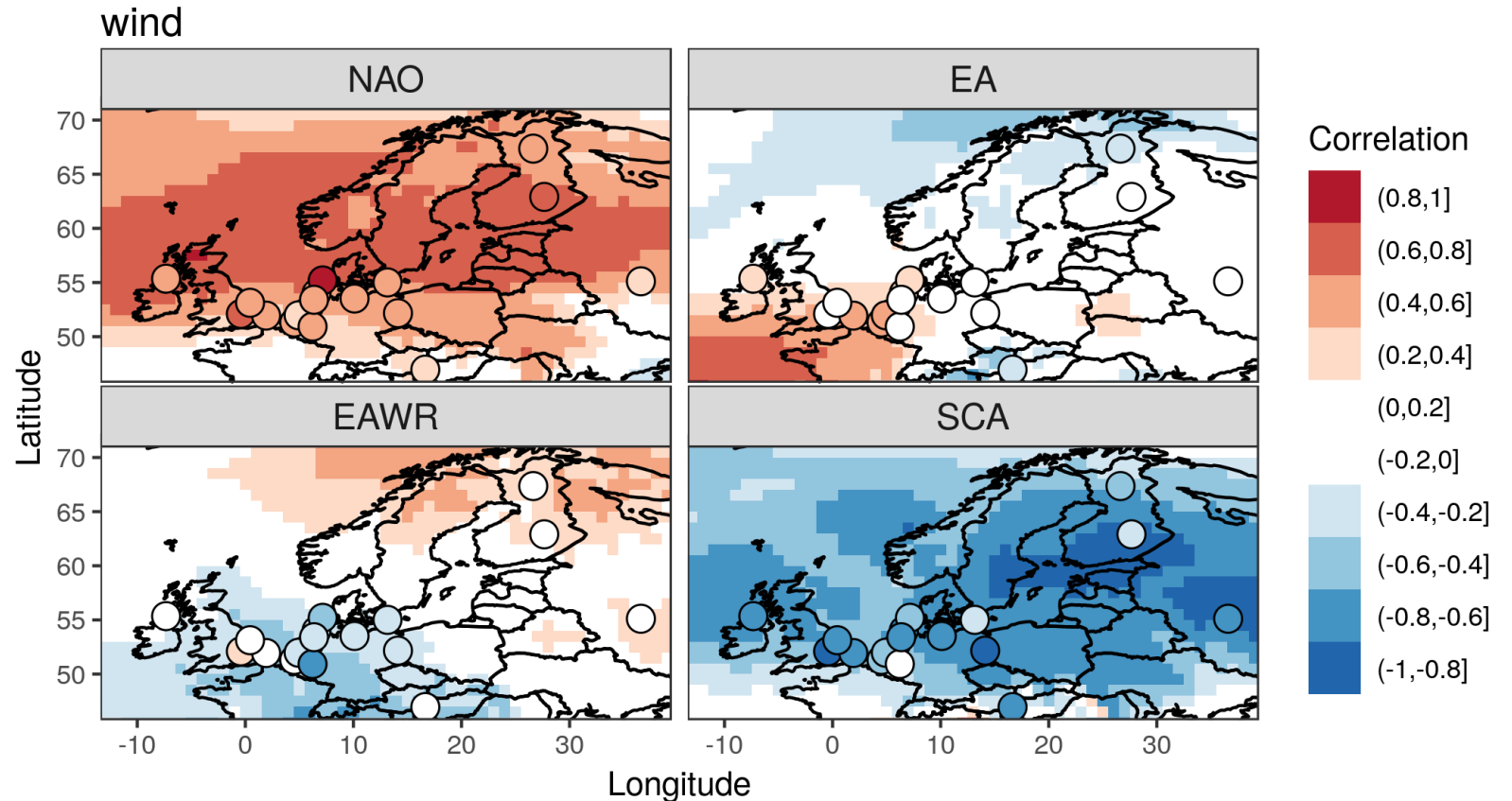
Caroletti, Coscarelli & Caloiero – CNR, Cosenza, Italy

# Indices relationship with the Euro-Atlantic circulation patterns

- Point observations: hub-height winds at tall towers
- Gridded observations (background): ERA5 100m winds
- Pearson correlation coefficient

## Key messages:

- Strongest correlations noted for NAO and SCA.
- Good agreement between tower and grid scale correlations

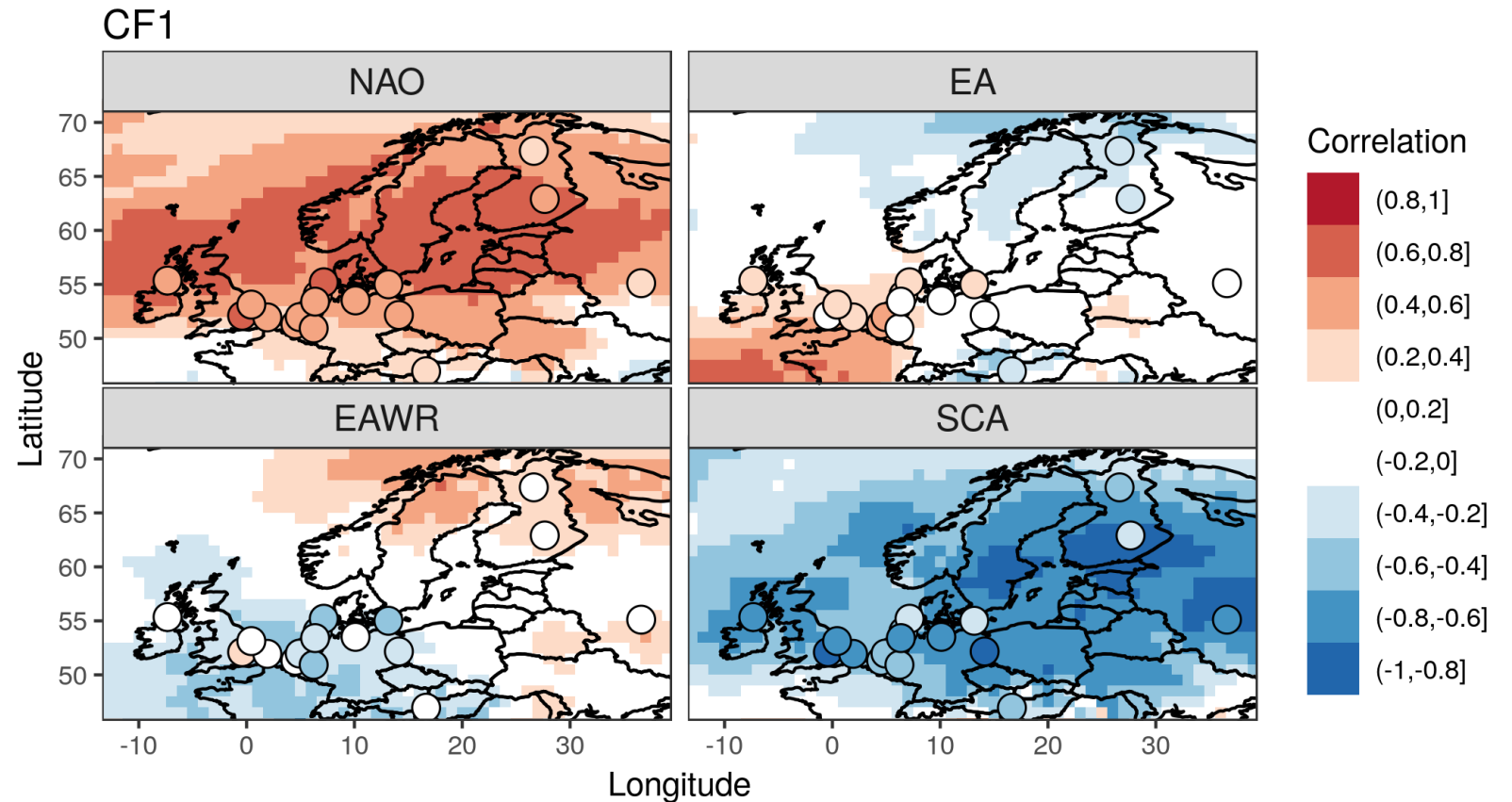


# Indices relationship with the Euro-Atlantic circulation patterns

- Point observations: CF at tall towers
- Gridded observations (background): CF derived from ERA5 100m winds
- Pearson correlation coefficient

## Key messages:

- Similar correlations to wind speed.
- Positive phases of NAO and EA/WR bring increased winds and higher CF to northern Europe

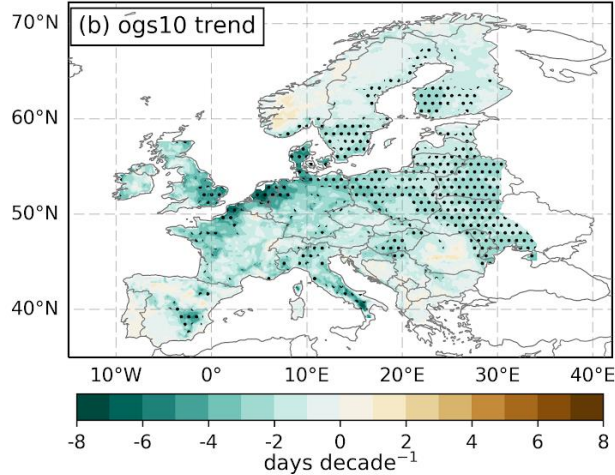


# Linking growing season metrics to atmospheric circulation patterns

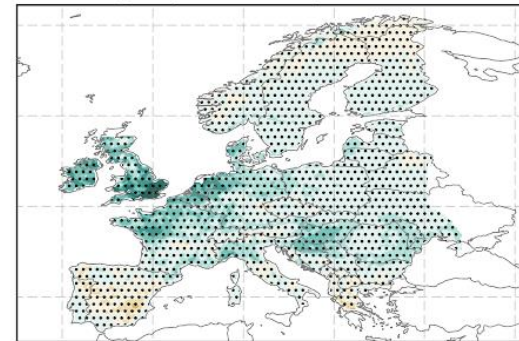
Focus on variables relevant to the agriculture sector:

- Growing season onset (ogs10)
- Total growing season precipitation (gsr)
- Mean growing season temperature (ta\_o)

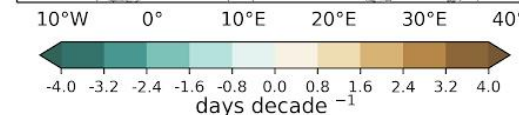
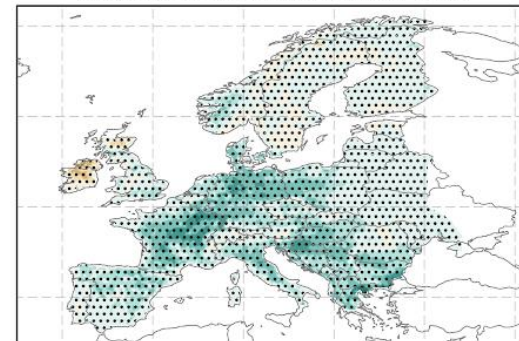
Use linear regression to remove signal of NAO, SCA, EA, EAWR from variable time series (Bhend & von Storch, 2008, *Clim. Dyn.*; Iles & Hegerl, 2017, *ERL*)



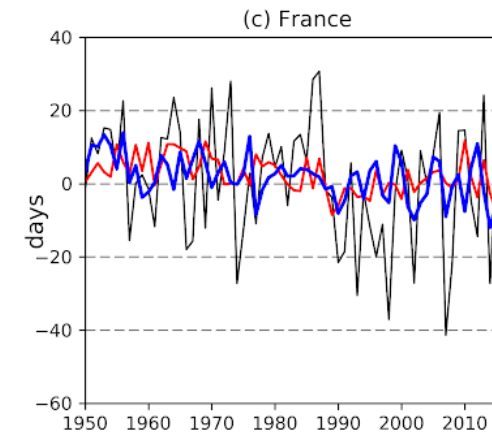
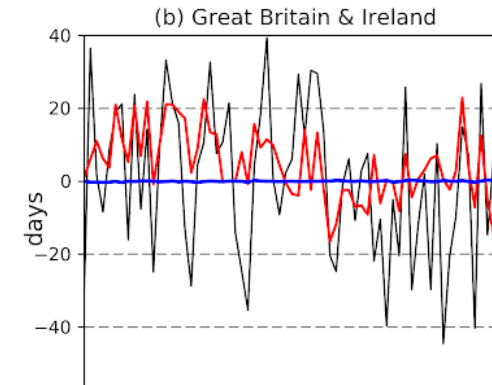
(b) ogs10 JFM NAO component of trend



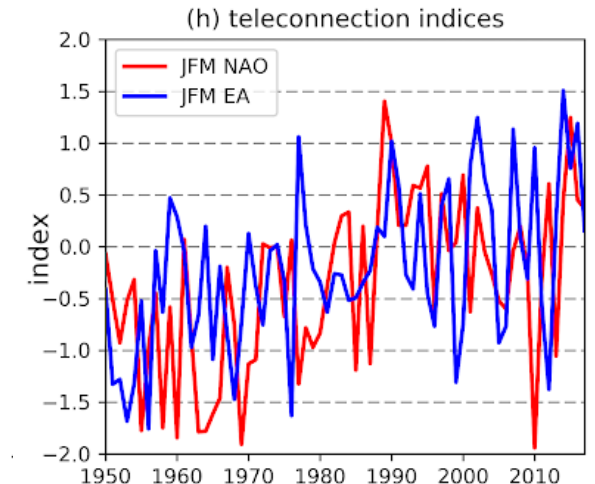
(e) ogs10 JFM EA component of trend



← early onset late onset →



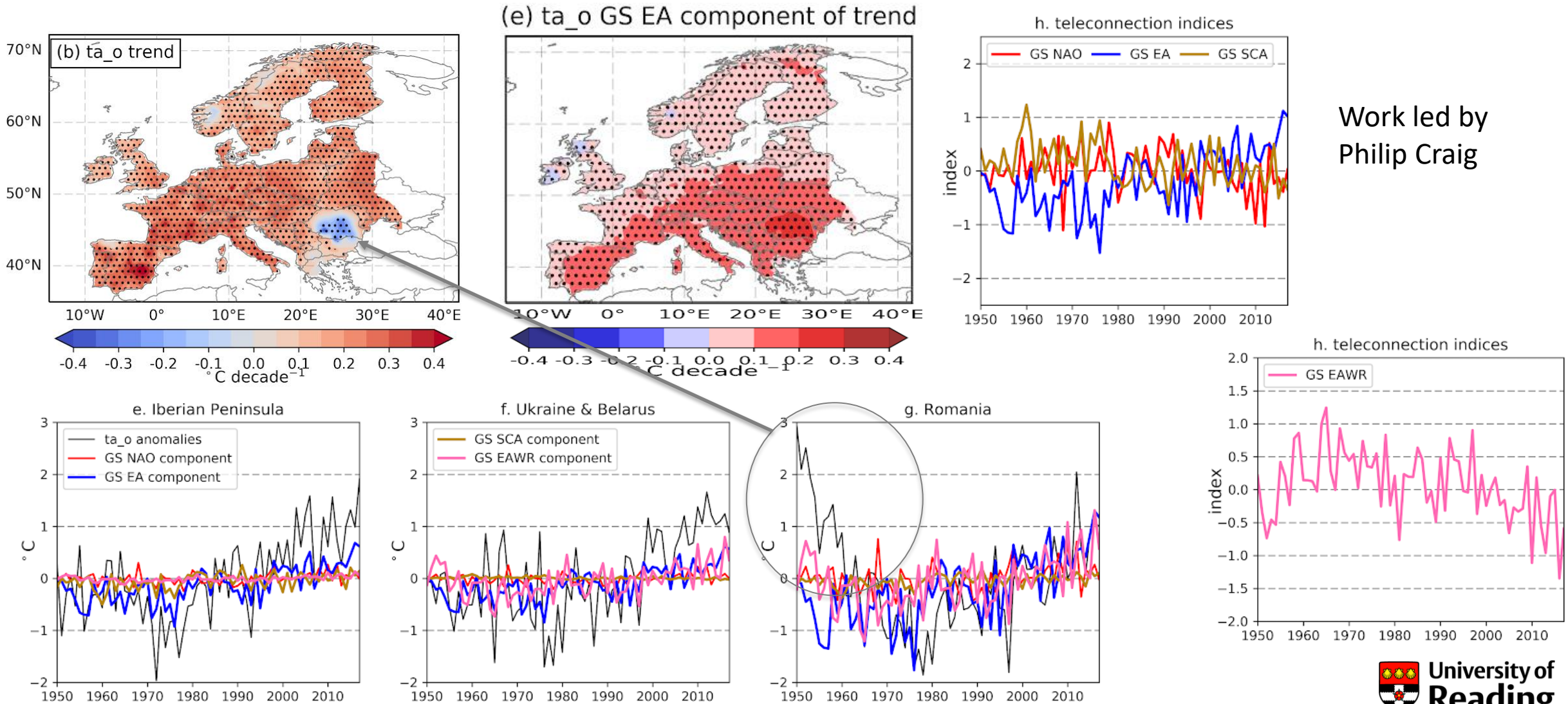
+ve trend in JFM NAO & EA



Early onset: NAO+ & EA+

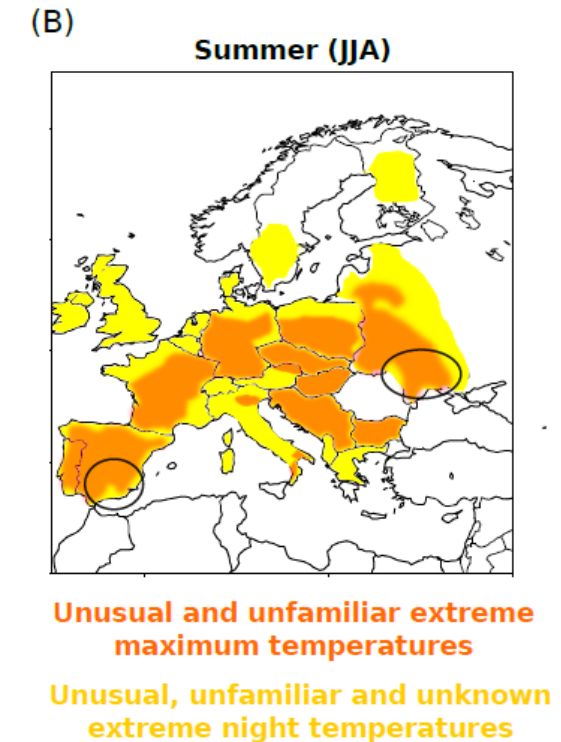
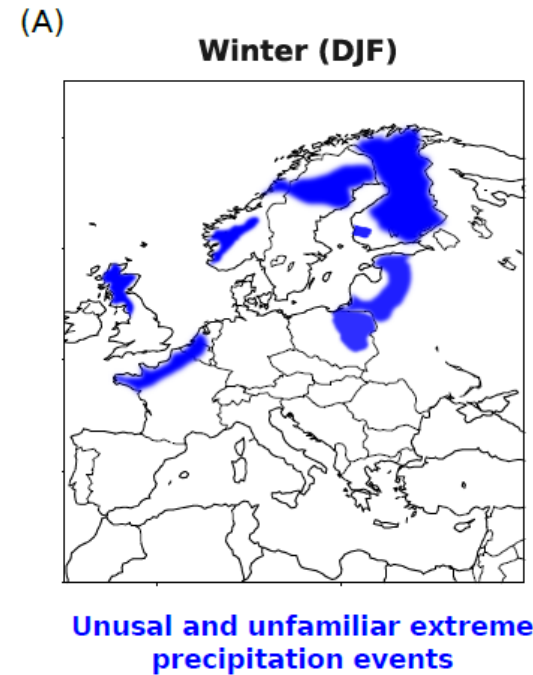
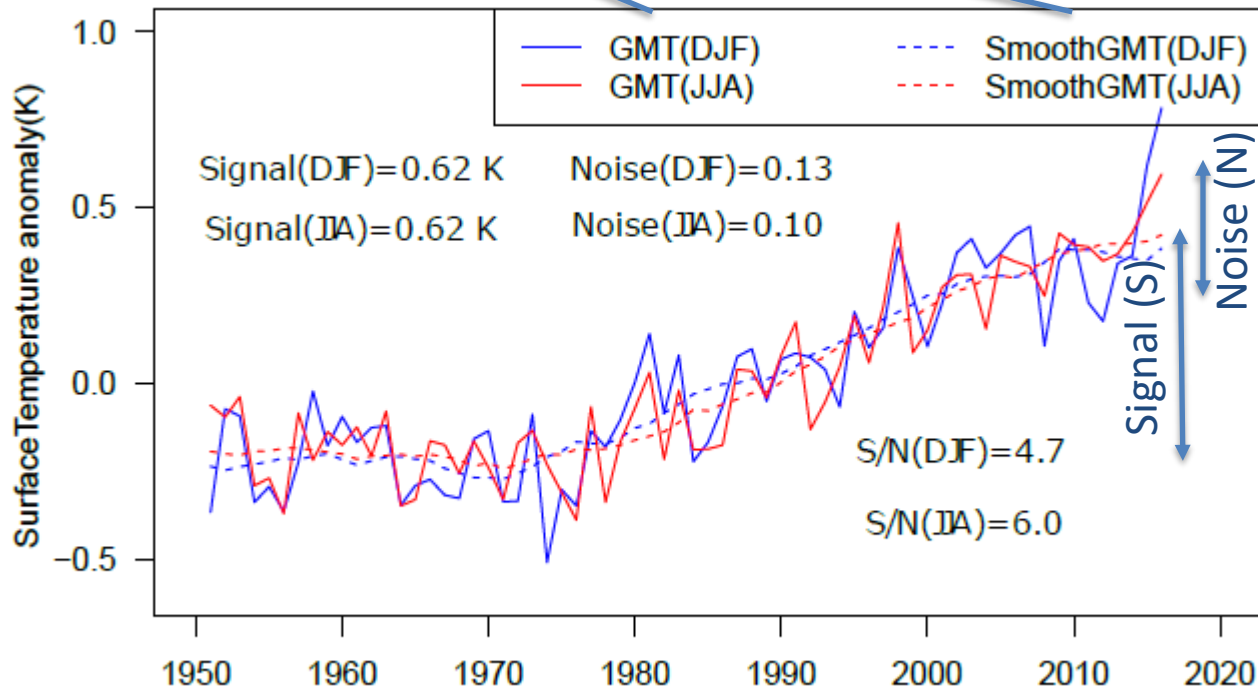
- NAO- linked to late GBI onset (e.g. 2010)
- EA- contributes to earlier onset central Europe

# Increasing EA pattern contributes to warmer growing season ( $ta_o$ ) in S Europe Spurious changes identified in Romania & N Bulgaria (1950-60s)



# Time of Emergence of INDECIS variables (Albert Osso et al, Univ Reading/Univ Graz)

- Time of emergence of INDECIS variables (e.g. [Hawkins et al. 2020 GRL](#))
- $OBS(t) = aG(t) + b$ ;  $N = StDev(OBS - aG)$
- Emergence of extreme precipitation signal in N Europe (e.g. Scandinavia & Scotland)
- Emergence of Extreme Daily Temperature over much of Europe ( $S/N > 2$  Iberia)





# Recent record-breaking temperature events in Europe



Weather and Climate Extremes 26 (2019) 100224

Contents lists available at ScienceDirect

Weather and Climate Extremes

Journal homepage: <http://www.elsevier.com/locate/wace>

Saharan air intrusions as a relevant mechanism for Iberian heatwaves: The record breaking events of August 2018 and June 2019

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<sup>d</sup> Instituto Português do Mar e da Atmosfera, Portugal  
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**ABSTRACT**

The summer of 2018 and 2019 were characterized by unusually warm conditions over Europe. Here, we describe the intense heatwaves striking the Iberian Peninsula in early August 2018 and late June 2019. The 2018 episode was relatively short-lived but outstanding in amplitude, particularly in western Iberia. Similar to previous mega-heatwaves, the 2019 event was long-lasting and affected large areas of western and central Europe, including eastern Iberia. During these events, many absolute temperature records were broken in western and eastern Iberia, respectively (some of them standing since 2005). In both cases, a cyclonic circulation off the coast in the northeastern Atlantic and a strong subtropical ridge pattern over the affected area promoted the advection of an anomalously warm air mass. This paper highlights the role of these very warm, stable and dry air intrusions of Saharan origin in the western and eastern Iberia heatwave events. Using a thermodynamical classification based on the geopotential height thickness and potential temperature, we show how the magnitude and poleward extension of these Saharan intrusions were unprecedented in the period since 1948. The relationship between Iberian heatwaves and Saharan warm air intrusions is discussed in the long-term context, showing a close link in southern sectors of the Peninsula. However, a consistent poleward trend in the latitudinal extension of these subtropical intrusions reveals their increasing relevance for heatwaves in northern sectors of Iberia and western Europe. This overall trend is accompanied by an apparent “see-saw” in the occurrence of subtropical intrusions between eastern and western Iberia on multi-decadal scales.

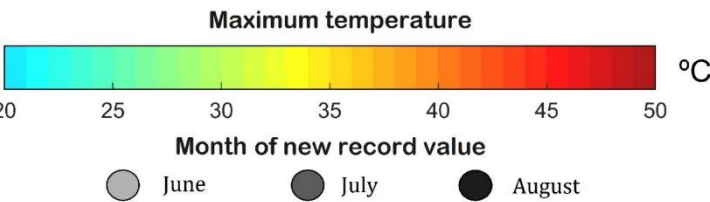
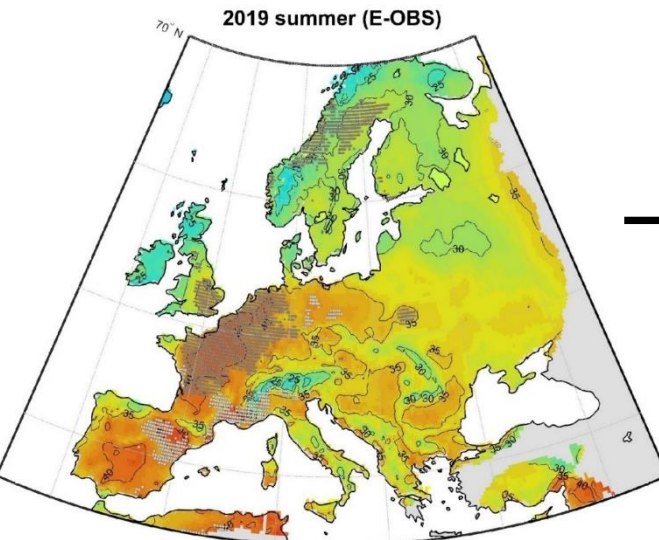
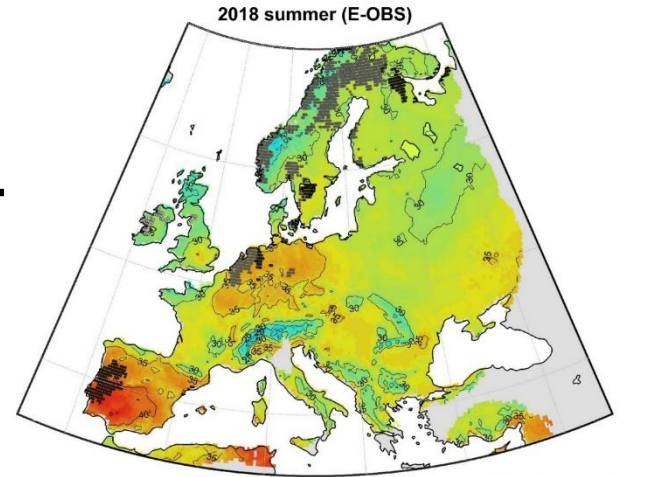
**1. Introduction**

Some of the most well studied exceptionally hot summers in recent years in Europe have been those of 2003 (Gohar et al., 2004; García-Herrera et al., 2010) and 2010 (Barriopedro et al., 2011; Dole et al., 2011). In both cases, widespread above-average temperature anomalies were registered, and many new all-time temperature records were set at the time. They were associated with “mega-heatwaves” (Barriopedro et al., 2011; Miralles et al., 2014), which refer to outstanding heatwave (HW) events in terms of duration, intensity and spatial extent. The recent European HW event of June 2017 was the earliest summer mega-HW in the reanalysis period since 1948 (Gaudet-Szeiler et al., 2019). The end of June 2019 also saw an exceptional HW in central and western Europe. Despite occurring in the very early summer, large areas of France and Spain exceeded the temperatures registered during previous mega-HWs. The June 2019 HW had large repercussion on the media and, as it evolved before summer holidays, national governments activated contingency plans and deployed resources to minimize impacts (e.g. The Guardian, 2019). Over Iberia, the event was particularly severe in the eastern part, where some regions recorded absolute temperature records, whereas western Iberia experienced relatively milder conditions. Other recent summers, such as 2015 (Russo et al., 2015) and 2018, did not feature European mega-HWs, but did feature regional extreme events. During the summer of 2018, media coverage was particularly focused on persistent record-breaking temperatures in northernmost sectors of Europe. However, southwestern Europe was also struck by the occurrence of unprecedented temperature values during the first week of August. The intensity and relevance of the early August Iberian HW was masked by relatively wet and cool conditions in June and July 2018, resulting in near-average seasonal mean temperature anomalies in the region. Unprecedented absolute temperatures were recorded, particularly over Portugal, where all-time records were broken in many places, including most of those standing since the 2003 mega-HW (Instituto Português do Mar e da Atmosfera, hereafter IPMA, 2018).

Unlike the prolonged mega-HW events that occurred in August 2003

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COMMUNICATIONS EARTH & ENVIRONMENT

ARTICLE

<https://doi.org/10.1038/s43247-020-00048-9> OPEN

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Distinct influences of large-scale circulation and regional feedbacks in two exceptional 2019 European heatwaves

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Two separate heatwaves affected western Europe in June and July 2019, in particular France, Belgium, the Netherlands, western Germany and northeastern Spain. Here we compare the European 2019 summer temperatures to multi-proxy reconstructions of temperatures since 1500, and analyze the relative influence of synoptic conditions and soil-atmosphere feedbacks on both heatwave events. We find that a subtropical ridge was a common synoptic set-up to both heatwaves. However, whereas the June heatwave was mostly associated with warm advection of a Saharan air mass intrusion, land surface processes were relevant for the magnitude of the July heatwave. Enhanced radiative fluxes and precipitation reduction during early July added to the soil moisture deficit that had been initiated by the June heatwave. We show this deficit was larger than it would have been in the past decades, pointing to climate change imprint. We conclude that land-atmosphere feedbacks as well as remote influences through northward propagation of dryness contributed to the exceptional intensity of the July heatwave.

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Sousa et al. (2019)

Weather and Climate Extremes

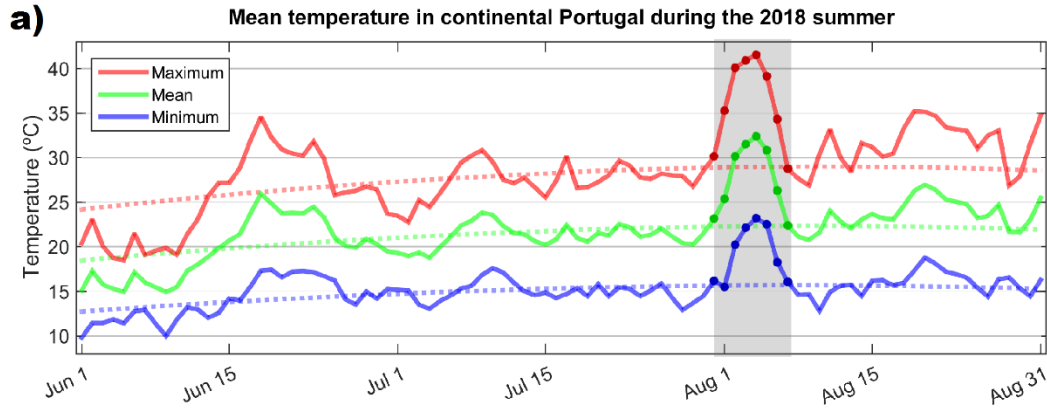
<https://doi.org/10.1016/j.wace.2019.100224>

Sousa et al. (2020)

Communications Earth & Environment

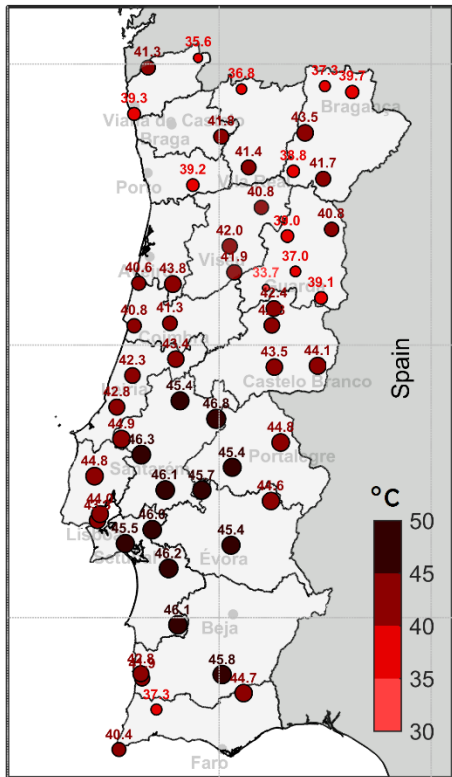
<https://doi.org/10.1038/s43247-020-00048-9>

# Extreme heat episode in SW Europe – August 2018

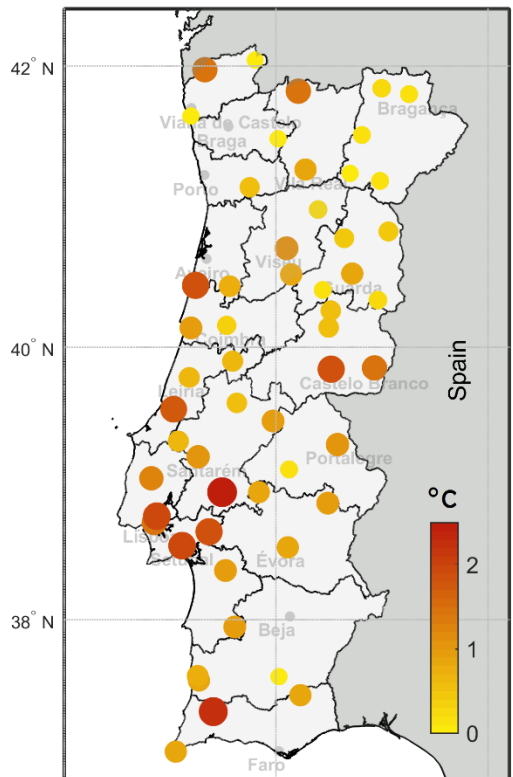


- i) More than 50% of the country with  $T_{max} > 40^{\circ}\text{C}$
- ii) 17 stations with  $T_{max} > 45^{\circ}\text{C}$
- iii) 40% of stations broke all-time records

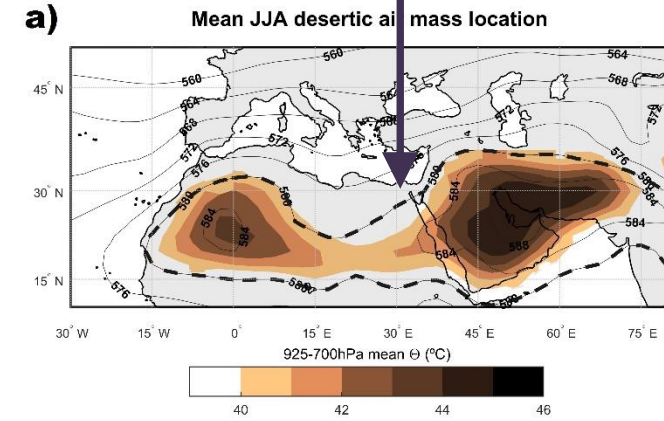
**b) New all time station records in Portugal**



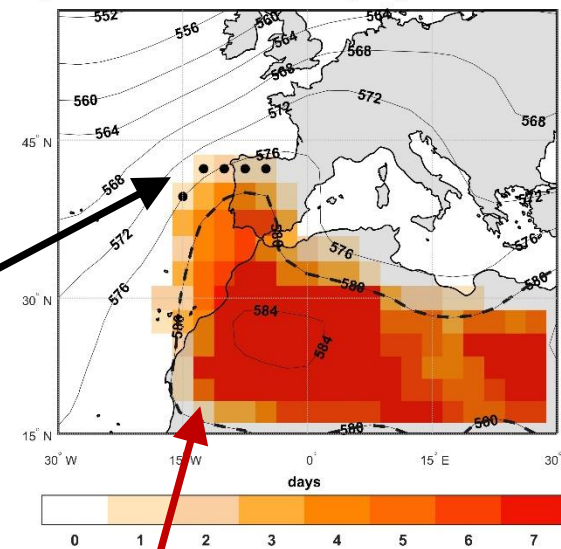
**c) Difference to previous records**



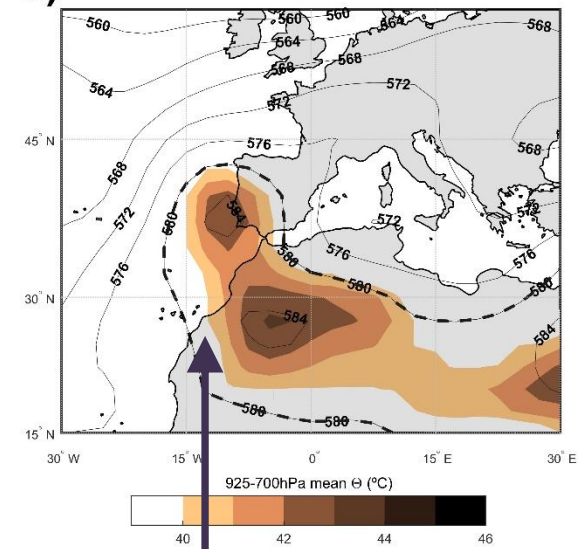
## Typical location of desert air masses



**b) Saharian intrusion early August 2018**



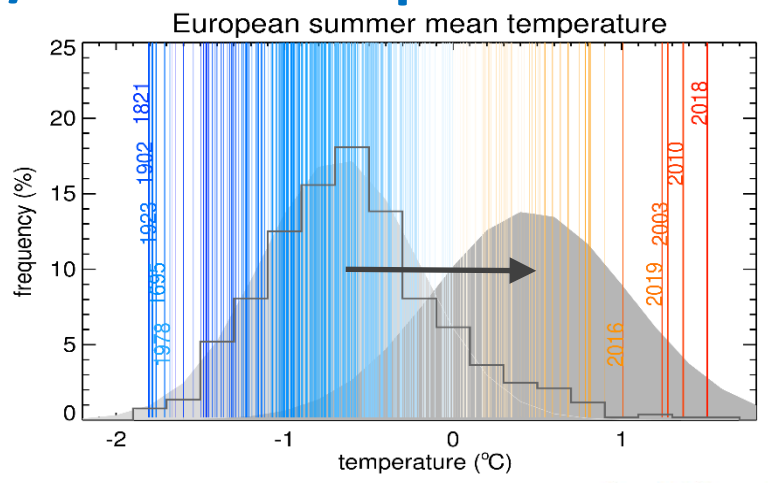
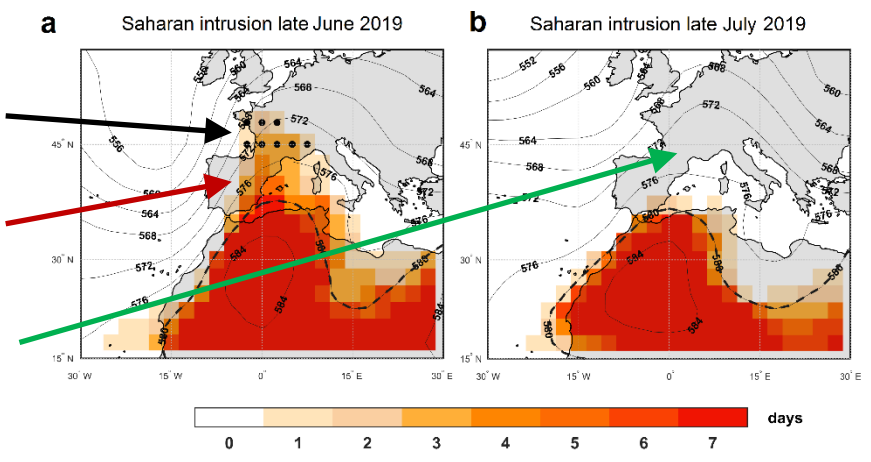
**c) 2018-08-04**



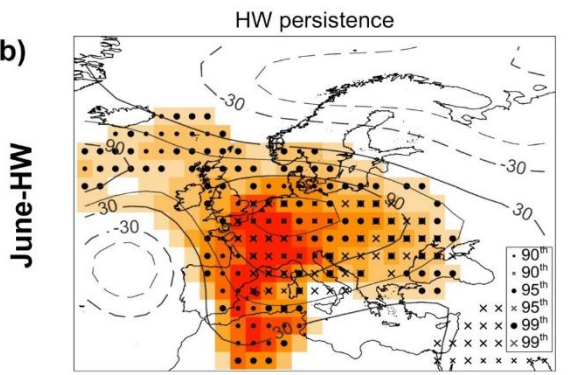
# Extreme heat episodes in Western/Central Europe – June & July 2019



First time ever here  
 Significant intrusion (June HW)  
 No intrusion (July HW)

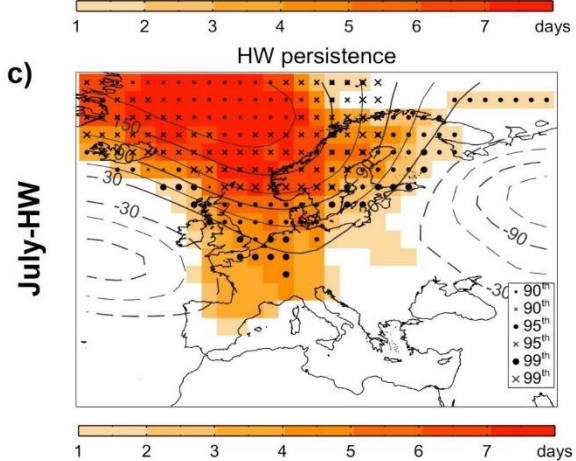


Very significant shift in temperature distributions in recent decades!



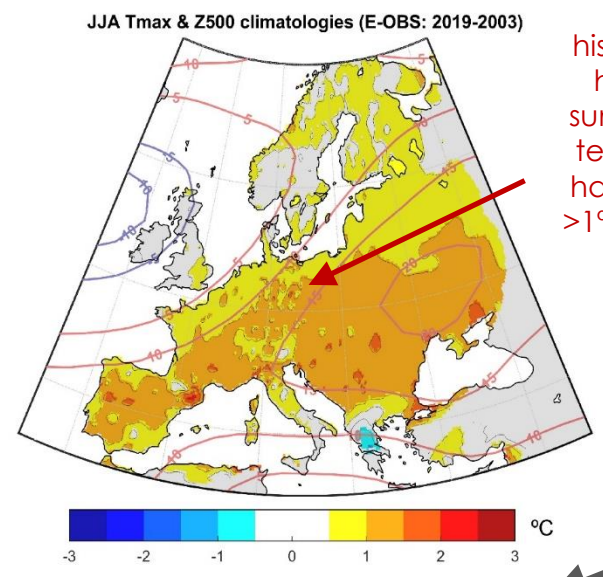
**June 2019**

First time ever that France registered >45°C



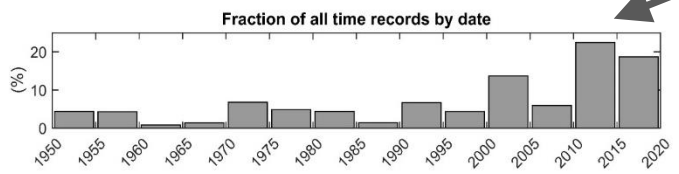
**July 2019**

First time ever that Belgium & Netherlands registered >40°C

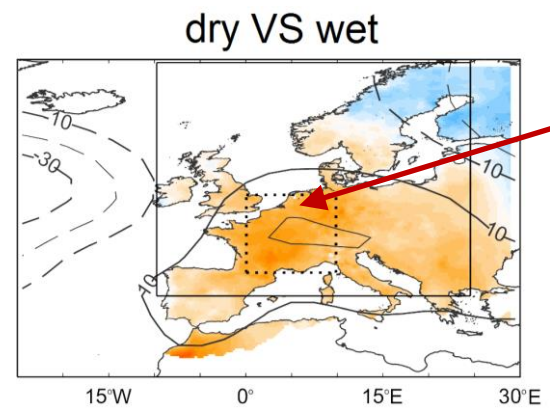


Since the historical 2003 heatwave, summer mean temperatures have increase >1°C in Europe.

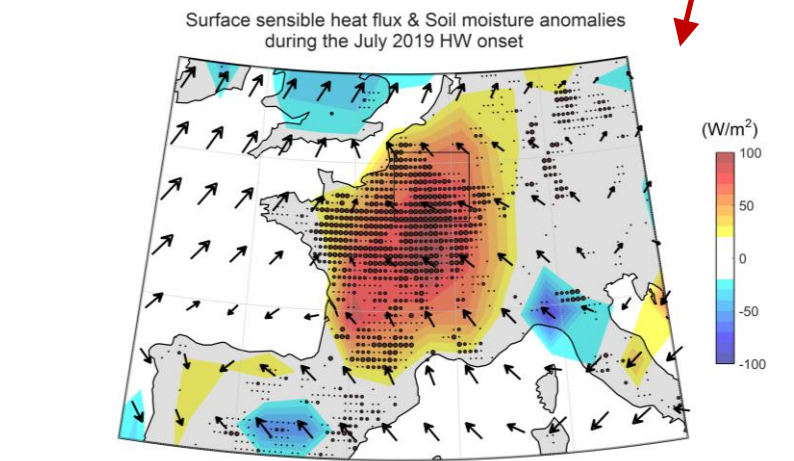
**In just 15 years!!!**



Frequency of new records has been increasing systematically



Amplified surface temperature anomalies during the July HW due to drought conditions.

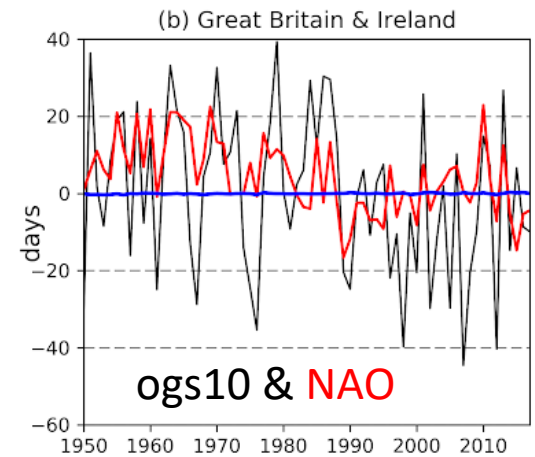


## WP5.3 – some key results: Relation between INDECIS metrics/atmospheric circulation patterns

[URead/UCantab/ULisbon/CNR-IRPI/CNR-ISAFOM/EHI-Cantab]

- Changes in INDECIS variables & links with teleconnection patterns (NAO & EA, also SCA & EA/WR)
- Development of statistical models to link INDECIS metrics with circulation patterns
- Improved representation of weather regimes in CMIP6 simulations
- Non-stationary relationship between teleconnection patterns & regional metrics (Southern Italy case studies)
- Trends in circulation can combine with climate change to determine changes
- NAO+ and EA+ contributes to earlier growing season onset in NW Europe
- NAO+, EA/WR+, SCA-, EA- increase wind power production in N Europe
- Heat extremes in Europe linked to anomalous circulation patterns

<http://www.indecis.eu/wp5.php>



# WP5 Status & plans

- WP5.1, WP5.2, WP5.3 delivered
- Success: Strong cross-institute contribution to deliverables
- Challenge: moving from individual contributions to collaboration between partners
- Continued activities at University of Reading:
  - Albert Osso continues to contribute from University of Graz on Time of Emergence work (submitted paper)
  - Philip Craig works until project end on publishing results from WP5.3
  - BSc project on biophysical indices (e.g. UTCI)
  - Collaboration on 1921 drought paper led by Gerard van der Schrier
  - Possible further study on dynamic/thermodynamic components of change in INDECIS metrics