NCAS Climate
Department of Meteorology

Indecis
Sectorial Climate Services
www.indecis.eu

University of Reading

WP5 - INDICES TIME EVOLUTION & RELATIONS WITH ATMOSPHERE

ERA4CS
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

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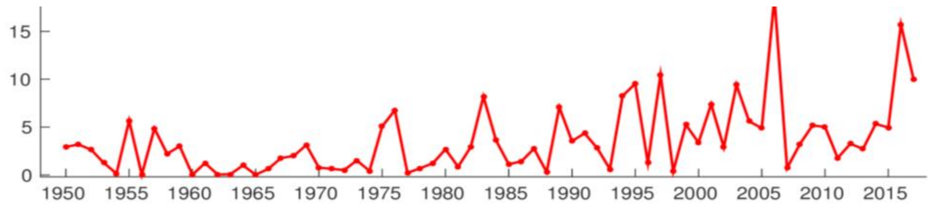
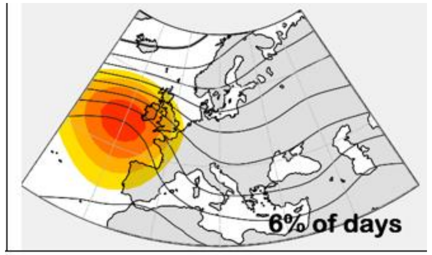
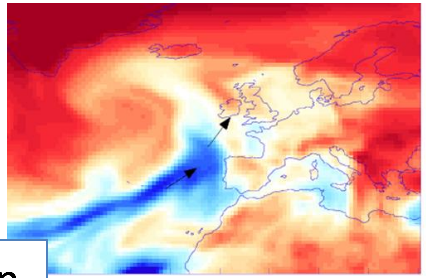
Aim: quantify variability/change in indices and establish link to atmospheric circulation patterns



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

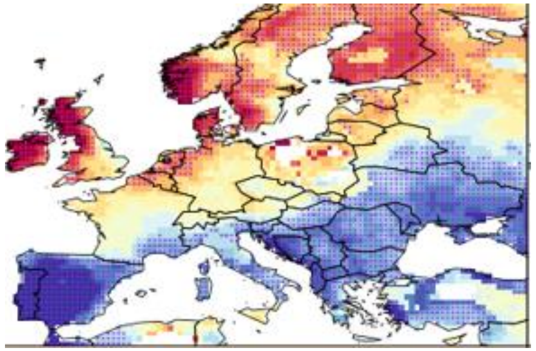
Analyse temporal evolution of INDECIS-QCHDS/ISDs

WP 2,3,4

Investigate time-emergence of observed climate change signal

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 precipition: 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

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NOAA NCAR UCAR

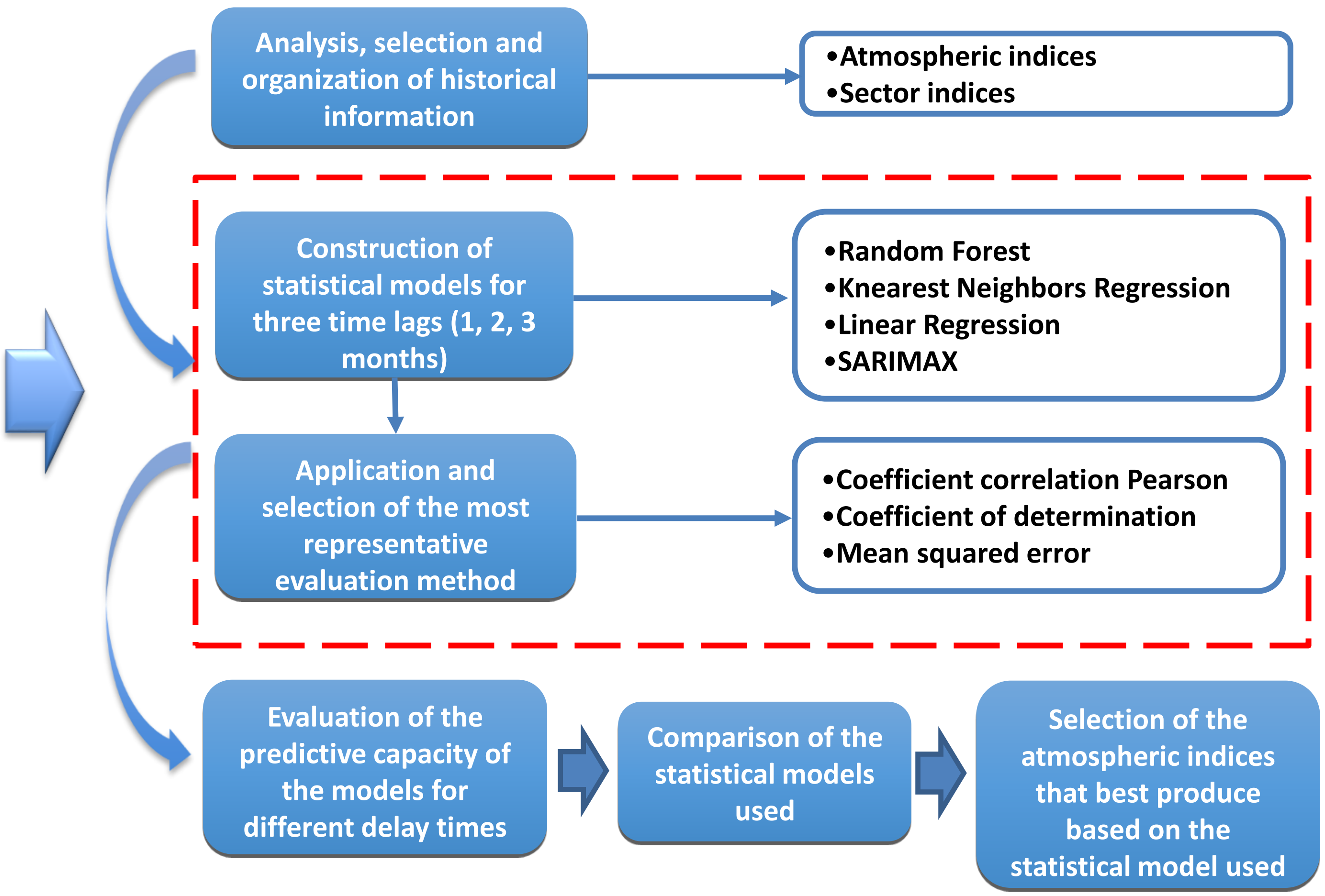
Atmospheric indices

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

SARIMAX

Lag time	M. Evaluation
1 Month	MSE
2 Months	R^2
3 Months	R

Predictors	Predictands
NIÑO - ONI	Bioclimatic, Precipitation
SCA - PNA	Snow, Cloud radiation
EA-POL-EP/NP	Aridity continentality, Fire
WP – EA/WR	Temperature

$R^2 = 0.83 - 0.99$

RANDOM FOREST

Lag time	M. Evaluation
1 Month	MSE
2 Months	R^2
3 Months	R

Predictors	Predictands (R^2)
NIÑO - ONI	1. Snow
SCA - PNA	2. Bioclimatic
EA-POL-EP/NP	3. Aridity continentality
WP – EA/WR	4. Temperature

$R^2 = 0.80 - 0.99$

K-nearest Neighbors

Lag time	M. Evaluation
1 Month	MSE
2 Months	R^2
3 Months	R

Predictors	Predictands (R^2)
NIÑO - ONI	1. Snow
SCA - PNA	2. Aridity continentality
EA - POL	3. Fire
WP – EA/WR	4. Bioclimatic

$R^2 = 0.82 - 0.99$

Linear Regression

The linear regression model did not obtain good results

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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%.

AIM OF THE STUDY

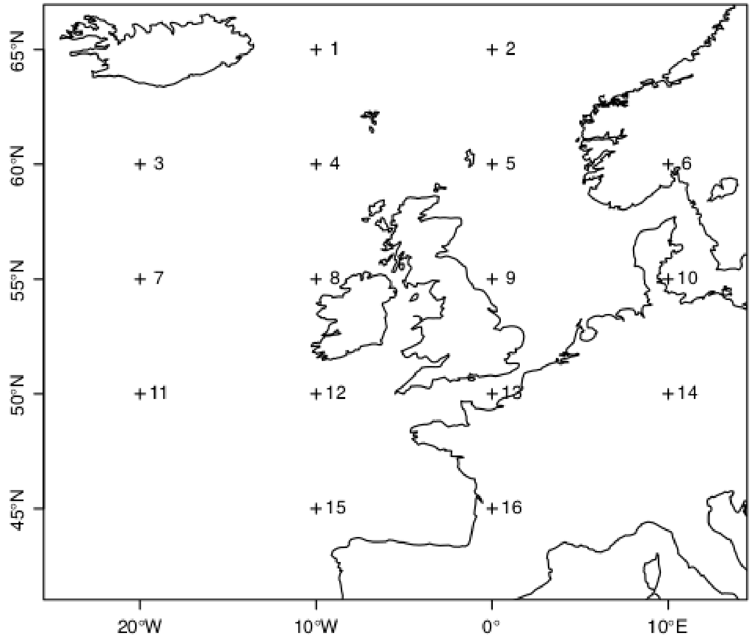
- Assess the potential improvement of CMIP6 over CMIP5 GCMs regarding the statistical analysis between circulation types in a process-based validation.
- Provide a quantitative ranking of models, to aid in the plausibility step of model selection over Europe for downscaling purposes.

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)

RELEVANT RESULTS

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

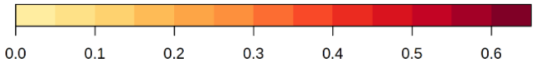
CONCLUSIONS:

- ✓ CMIP6 models in general yield better weather type reproducibiliy 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

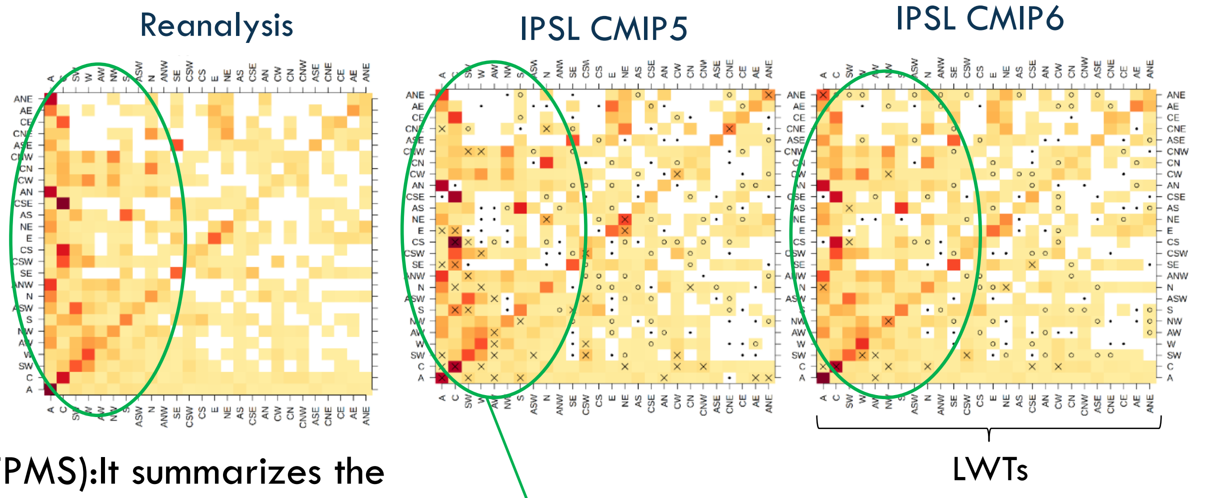
Fernandez-Granja, JA. et al. (2020) Improved atmospheric circulation over Europe by the new generation of CMIP6 Earth System Models. Climate Dynamics (Under review).

RELEVANT RESULTS

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



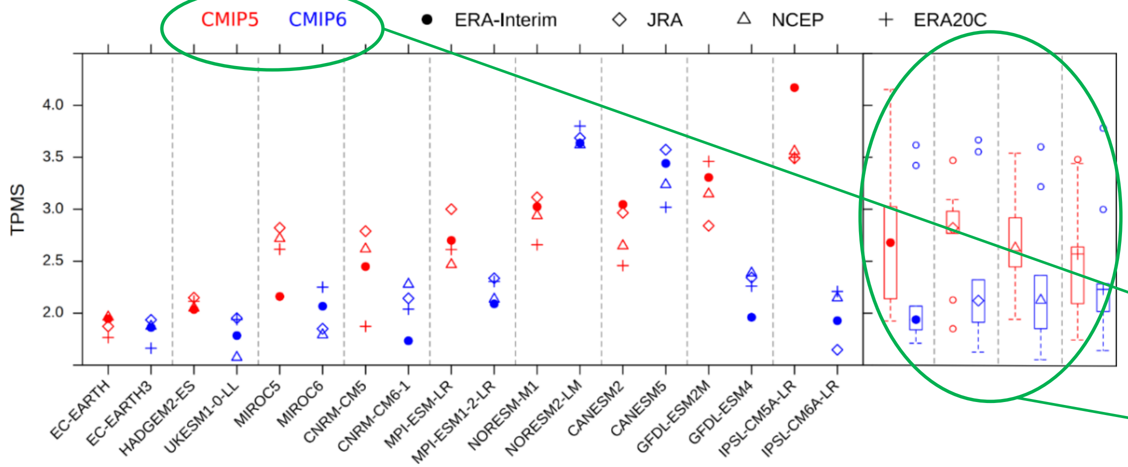
$$A_{ij} = p(X_t = j | X_{t-1} = i)$$



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

$$TPMS = \sum_{p \in A^*} |p_m - p_o|$$

p_m: GCM
p_o: Reanalysis



Order regarding CMIP5 TPMS from best to worst

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

Fernandez-Granja, JA. et al. (2020) Improved atmospheric circulation over Europe by the new generation of CMIP6 Earth System Models. Climate Dynamics (Under review).

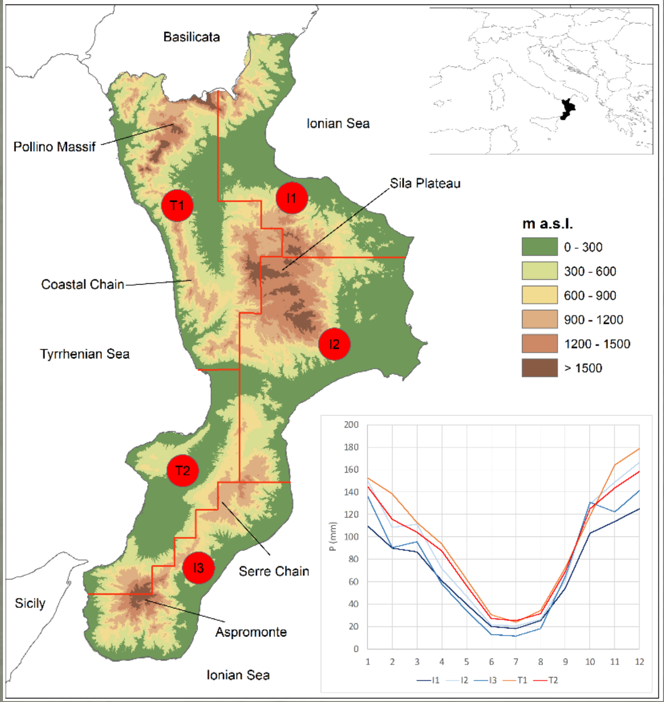
INDECIS data catalogue & new stations → WP5: finding relevant teleconnections for Europe/ Mediterranean → teleconnection/variables correlation analysis → **regional correlation analysis**

- 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

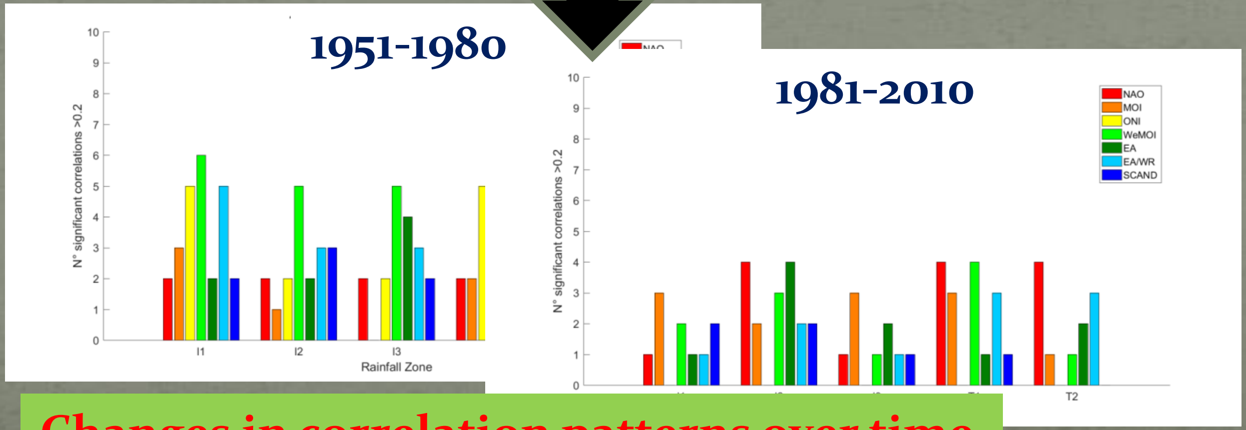
Caroletti, Coscarelli & Caloiero – CNR, Cosenza

- 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%
Calabria	**43%**

(1) Averaged over all the correlations in the study

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



Changes in correlation patterns over time

Caroletti, Coscarelli & Caloiero – CNR, Cosenza, Italy

Caroletti, Coscarelli & Caloiero: "A sub-regional approach for the analysis of atmospheric teleconnection influence on precipitation in Calabria", EGU2020-3078, EGU General Assembly 2020

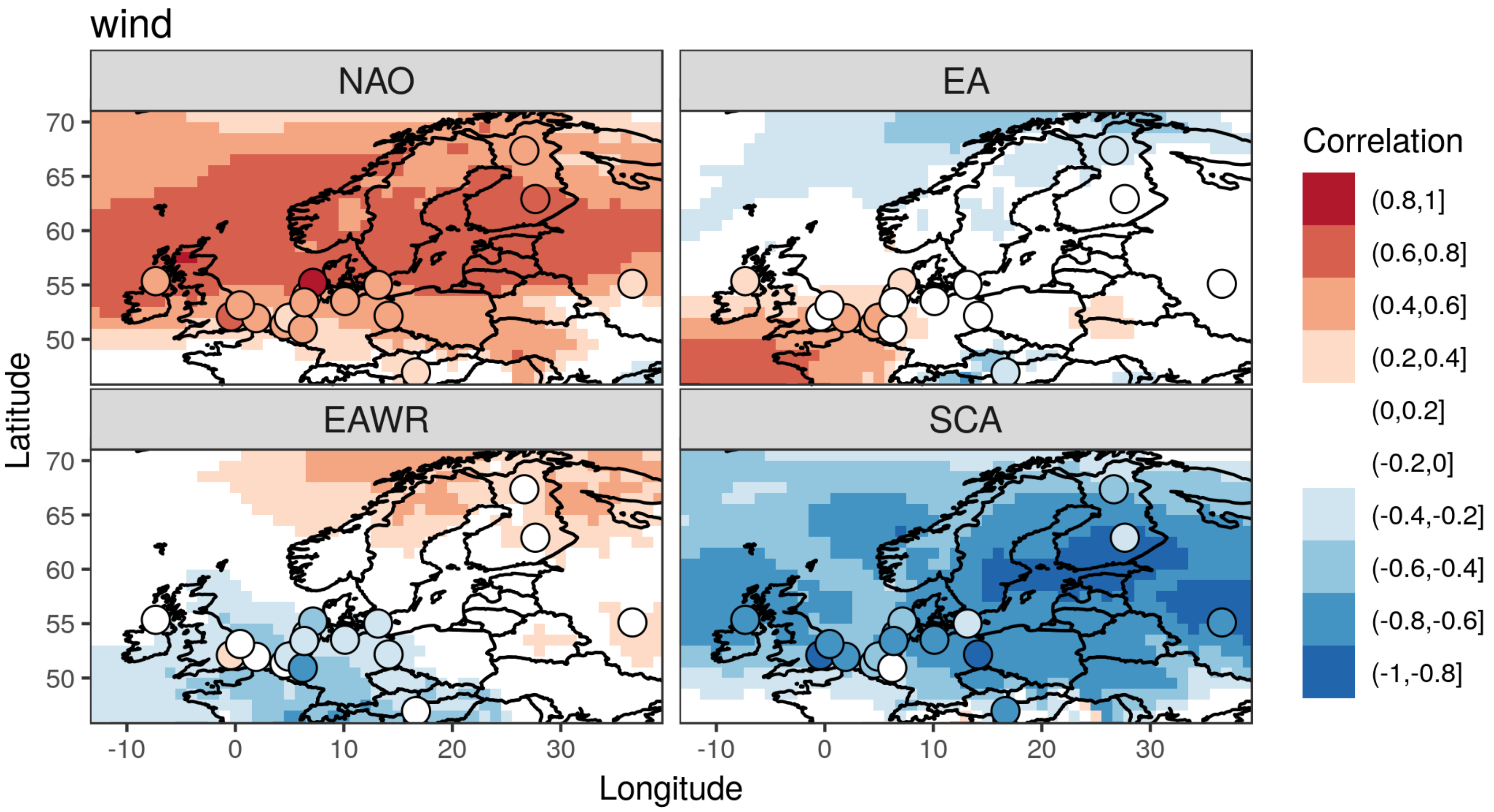
Caroletti, Coscarelli & Caloiero: "A micro-climatic regional approach to the influence analysis of teleconnection patterns on precipitation in Calabria (Southern Italy)" - submitted to International Journal of Climatology

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

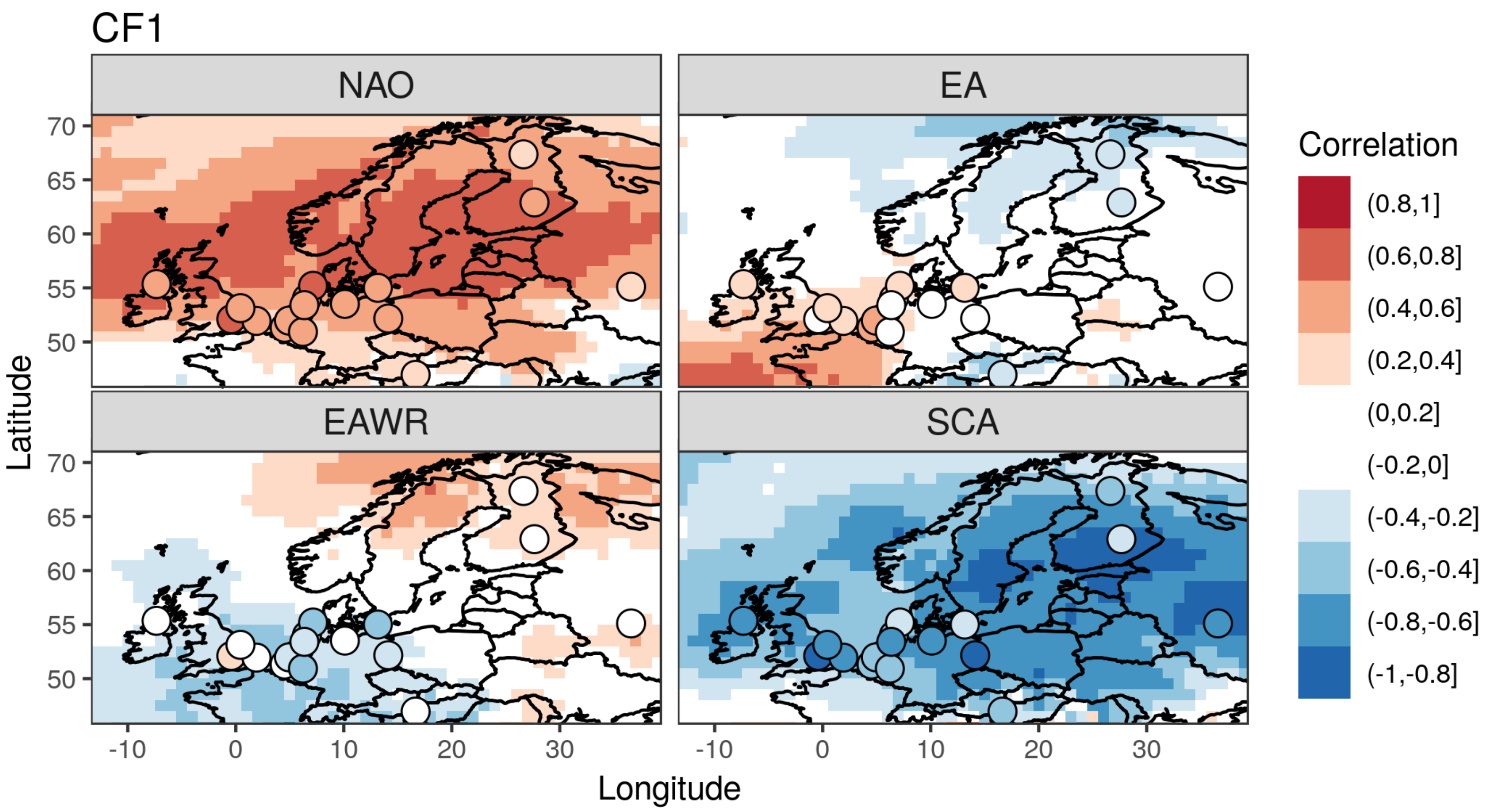
Key messages:

- 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

Barcelona Supercomputing Center
Centro Nacional de Supercomputación

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Sectorial Climate Services

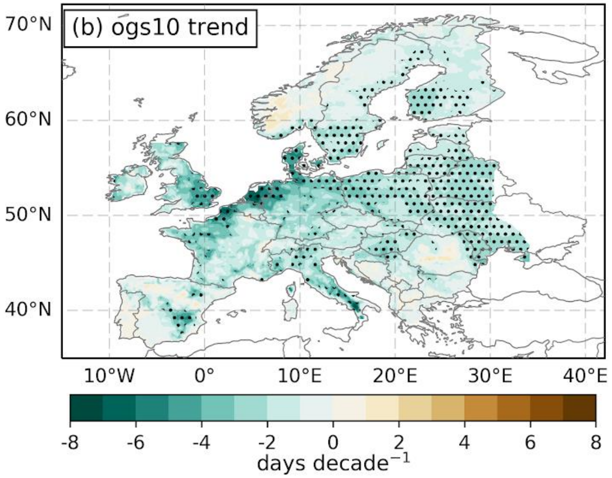
Linking growing season metrics to atmospheric circulation patterns

University of Reading

Focus on variables relevant to the agriculture sector:

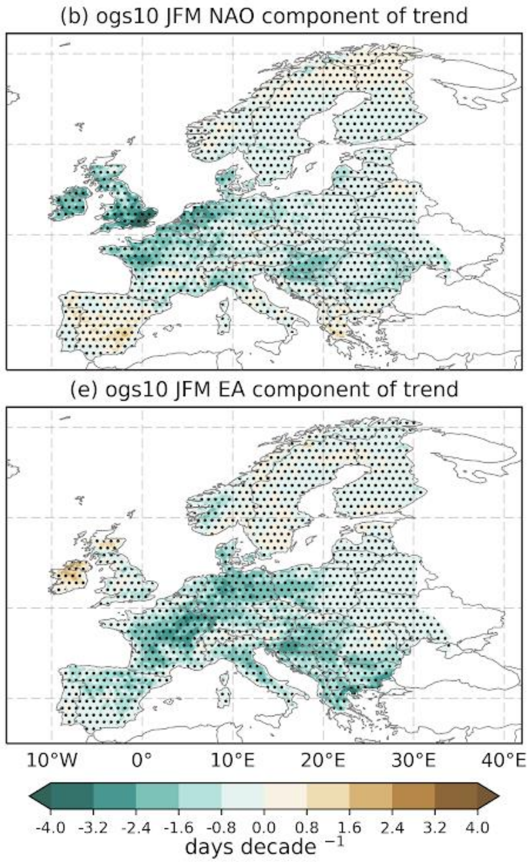
- Growing season onset (ogs10)
- Total growing season precipitation (gsr)
- Mean growing season temperature (ta_o)

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*)

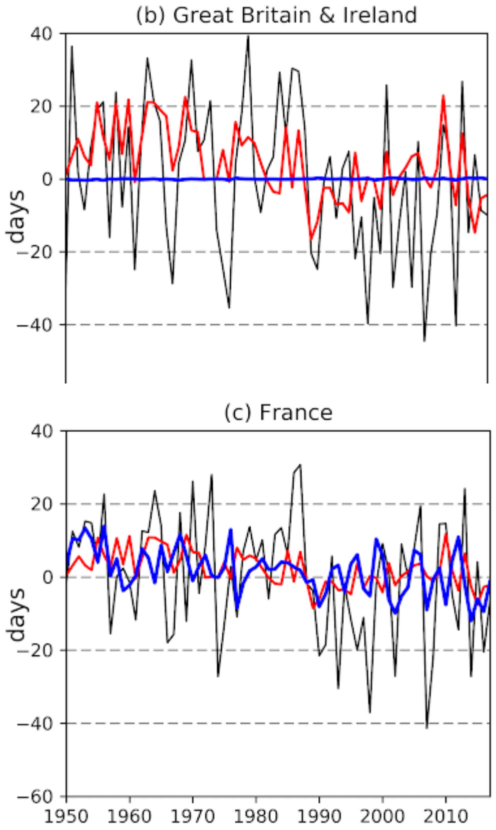


Early onset: NAO+ & EA+

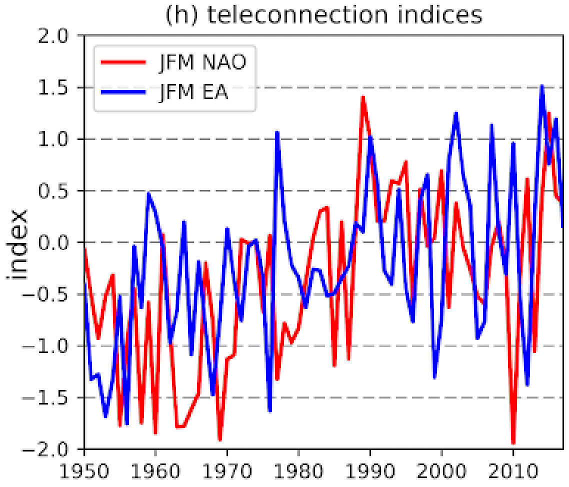
- NAO- linked to late GBI onset (e.g. 2010)
- EA- contributes to earlier onset central Europe



← early onset late onset →

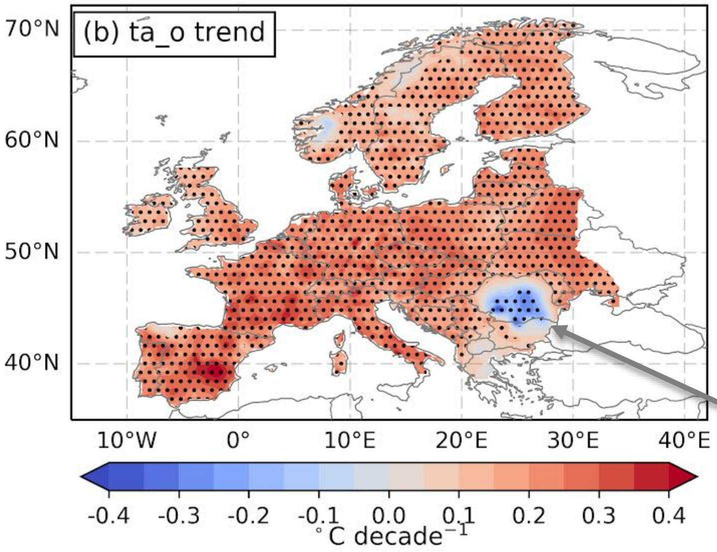


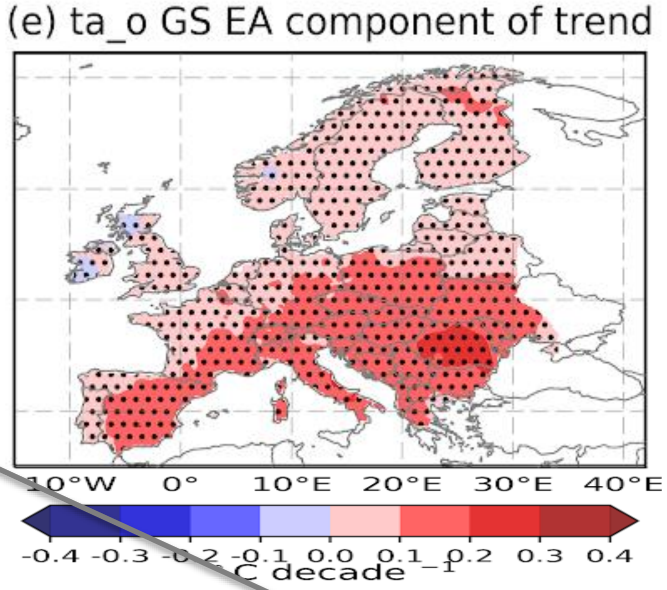
+ve trend in JFM NAO & EA

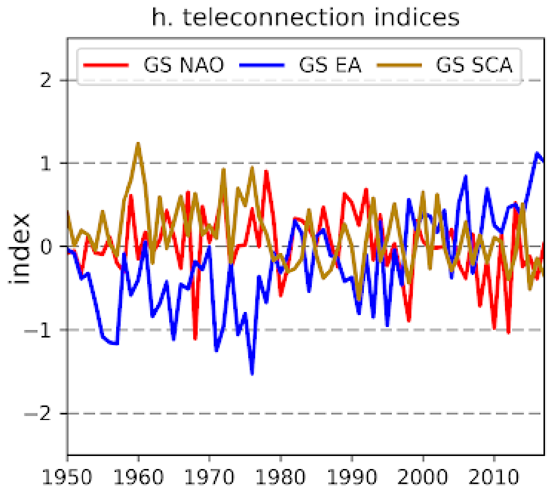


Work by Philip Craig

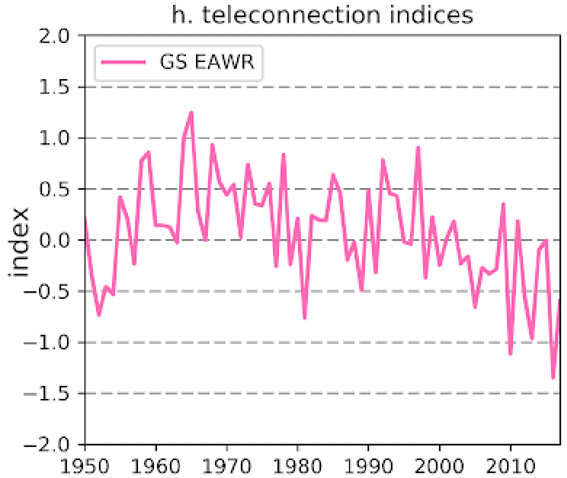
Increasing EA pattern contributes to warmer growing season (ta_o) in S Europe
Spurious changes identified in Romania & N Bulgaria (1950-60s)

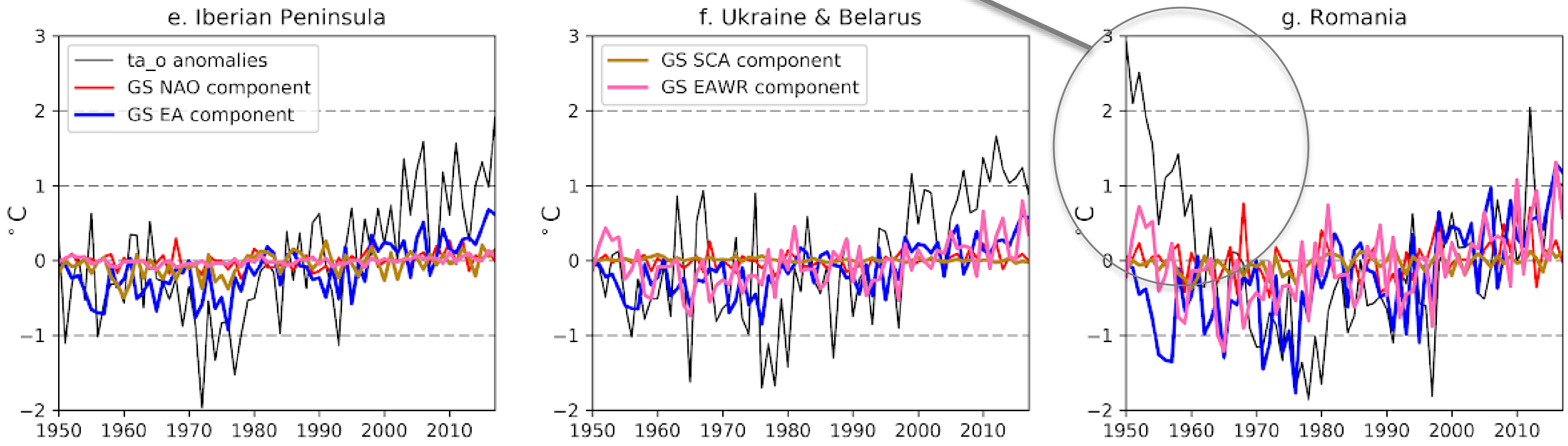






Work led by
Philip Craig





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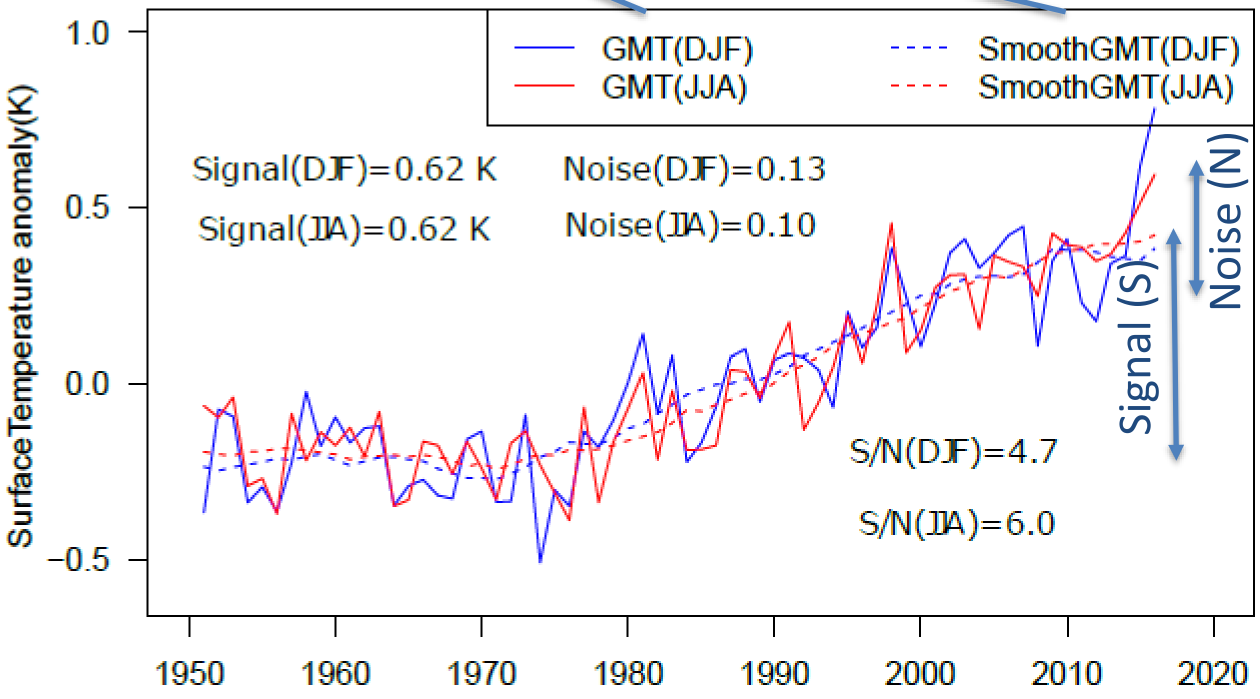
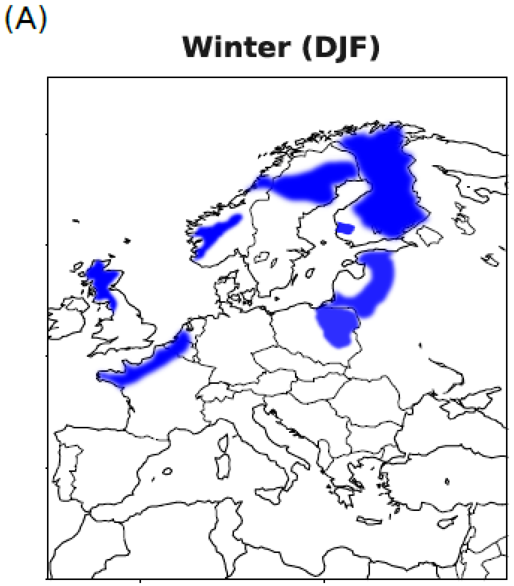
Time of Emergence of INDECIS variables

(Albert Osso et al, Univ Reading/Univ Graz)

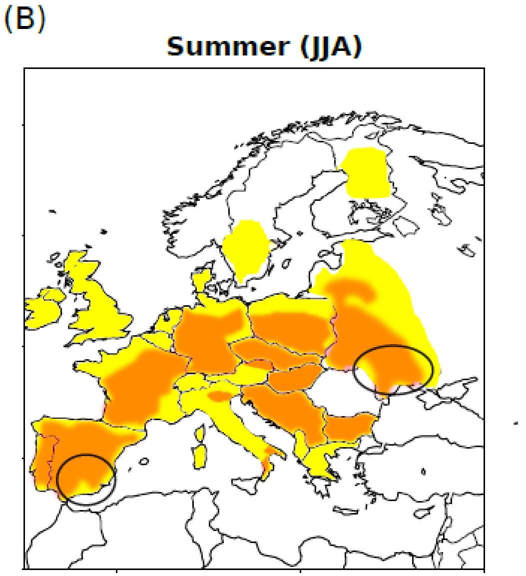
- Time of emergence of INDECIS variables (e.g. Hawkins et al. 2020 GRL)
- *OBS*(t) = a*G*(t) + b;   N=StDev(*OBS* – a*G*)

- 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)





Unusal and unfamiliar extreme precipitation events



Unusual and unfamiliar extreme maximum temperatures

Unusual, unfamiliar and unknown extreme night temperatures

Areas with unfamiliar drought-inducing conditions

Osso et al. (2021) Emerging new climate extremes over Europe, *submitted to Clim. Dyn.*

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

Pedro M. Sousa, David Barriopedro, Alexandre M. Ramos, Ricardo García-Herrera, Fátima Espírito-Santo, Ricardo M. Trigo

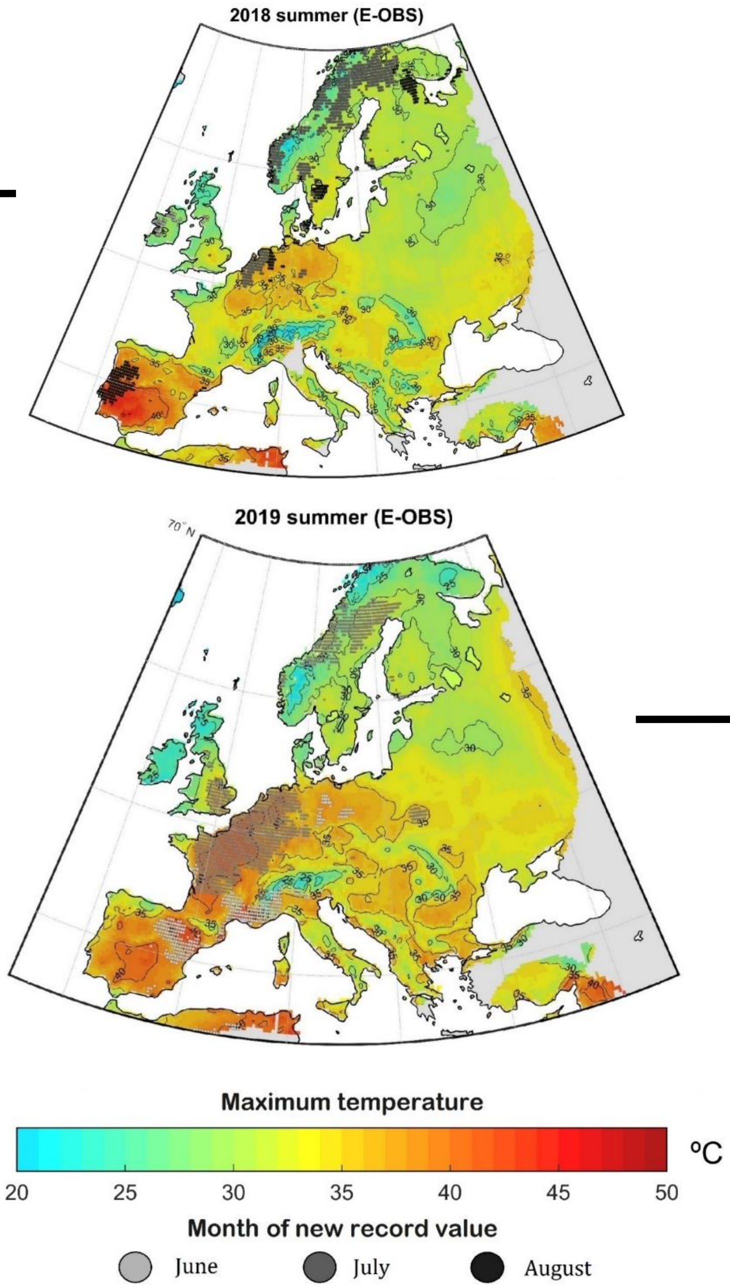
ABSTRACT

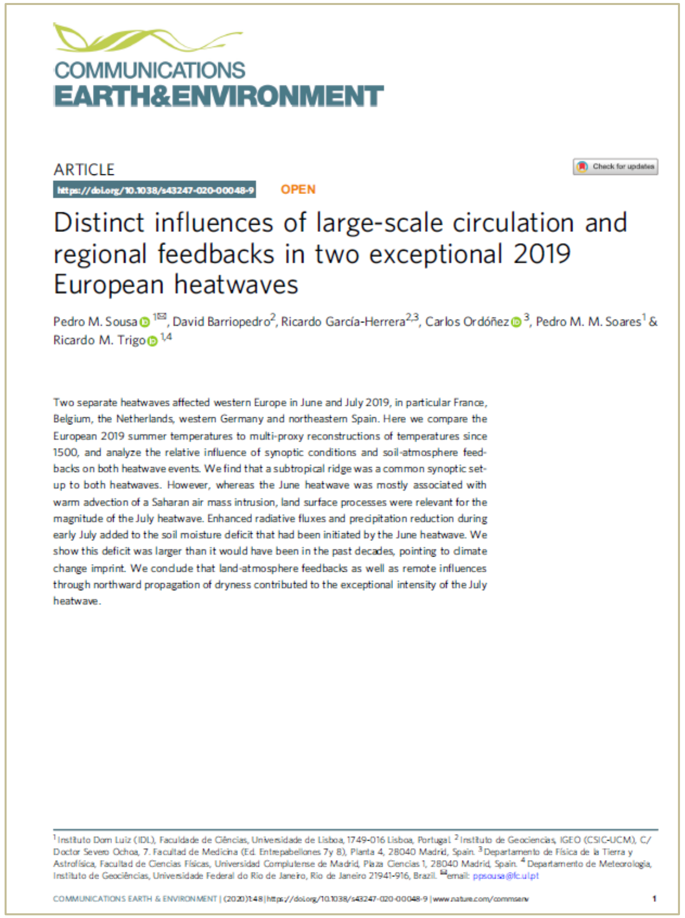
1. Introduction

Sousa et al. (2019)

Weather and Climate Extremes

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




COMMUNICATIONS EARTH&ENVIRONMENT

ARTICLE

OPEN

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

Pedro M. Sousa, David Barriopedro, Ricardo García-Herrera, Carlos Ordóñez, Pedro M. M. Soares & Ricardo M. Trigo

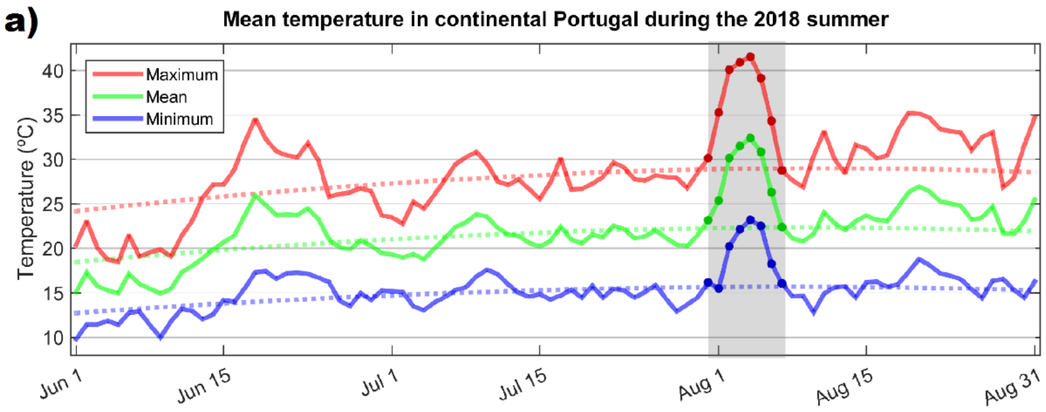
Two separate heatwaves affected western Europe in June and July 2019, in particular France, Belgium, the Netherlands, western Germany and northeastern Spain. Here we compare the European 2019 summer temperatures to multi-proxy reconstructions of temperatures since 1500, and analyze the relative influence 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.

Sousa et al. (2020)

Communications Earth & Environment

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

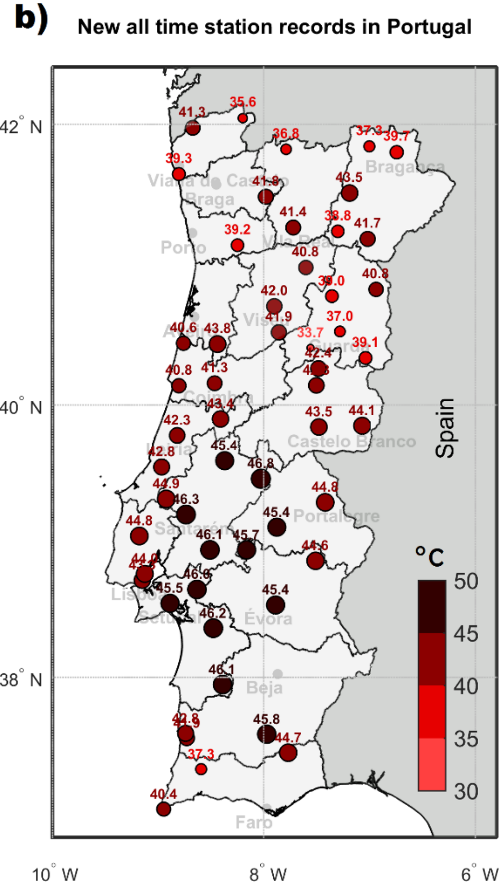
Extreme heat episode in SW Europe – August 2018

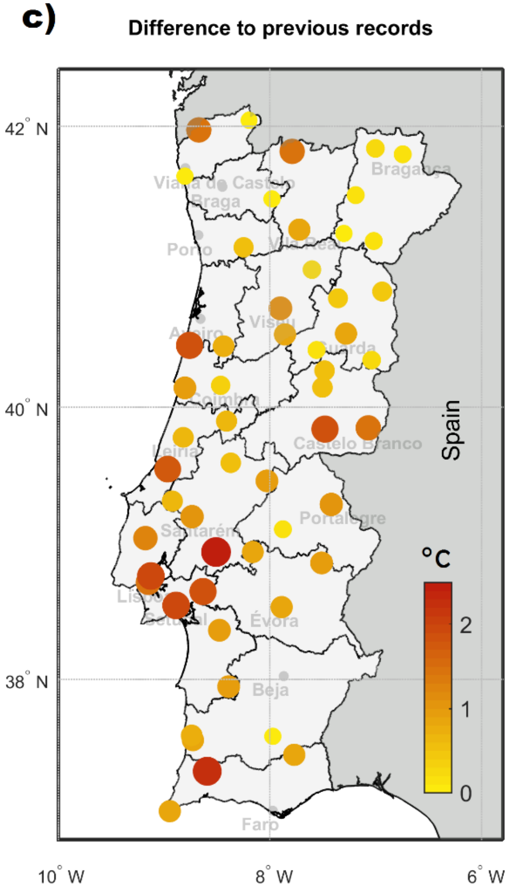


i) More than 50% of the country with Tmax>40°C

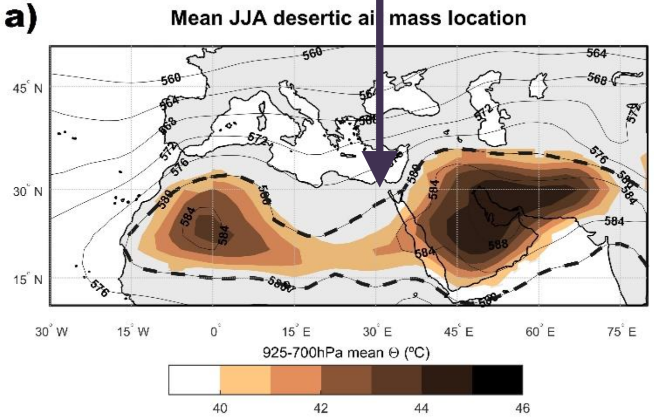
ii) 17 stations with Tmax>45°C

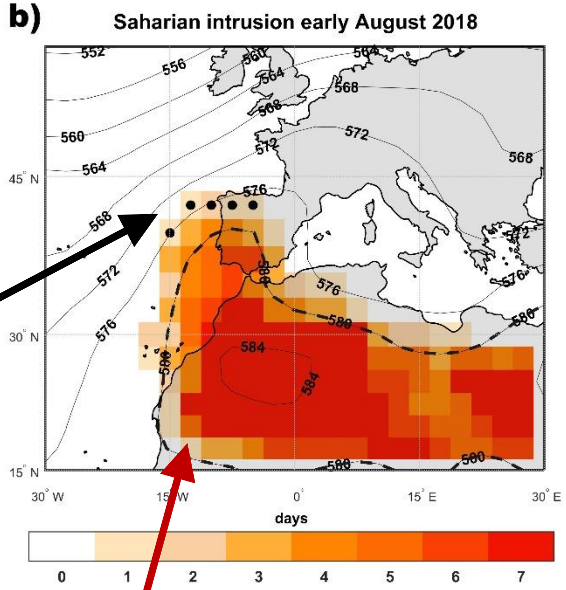
iii) 40% of stations broke all-time records

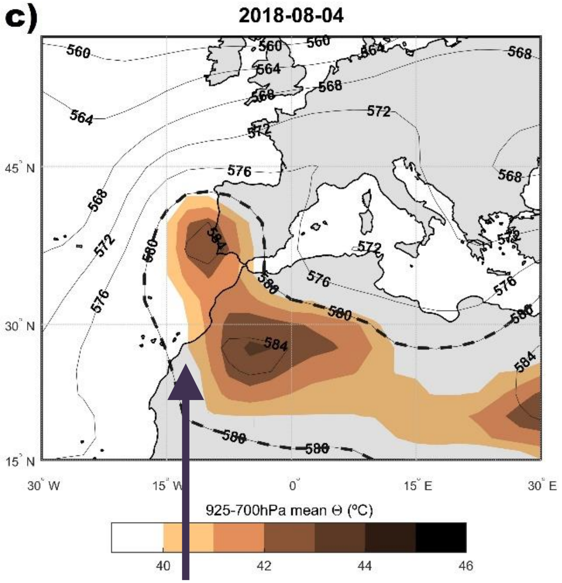




Typical location of desert air masses







First time ever here

Intrusion persistence

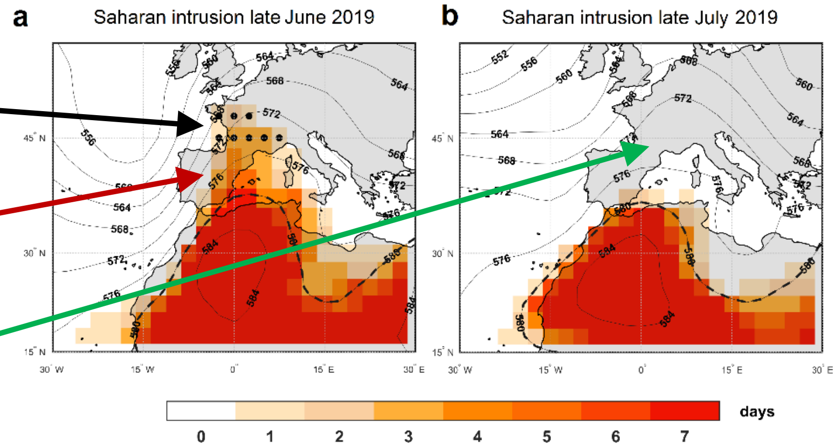
Subtropical ridge with Saharan intrusion

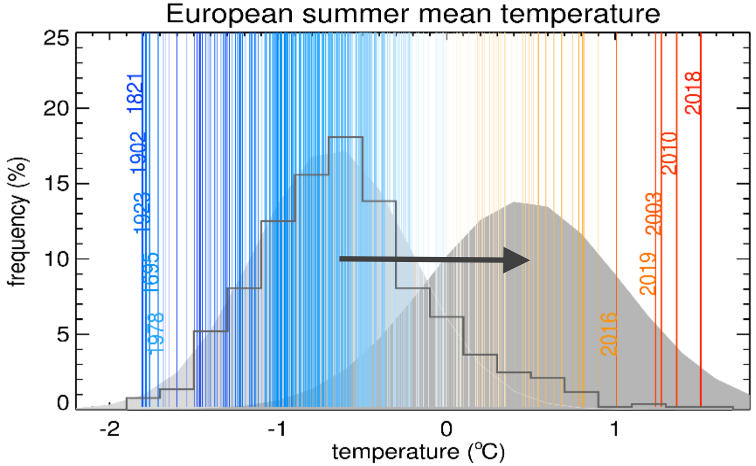
Extreme heat episodes in Western/Central Europe – June & July 2019

First time ever here

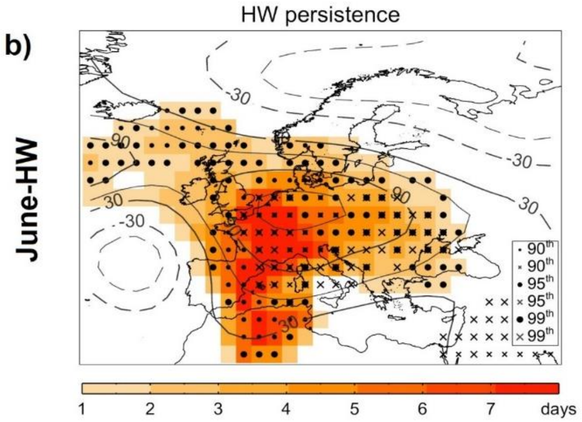
Significant intrusion (June HW)

No intrusion (July HW)



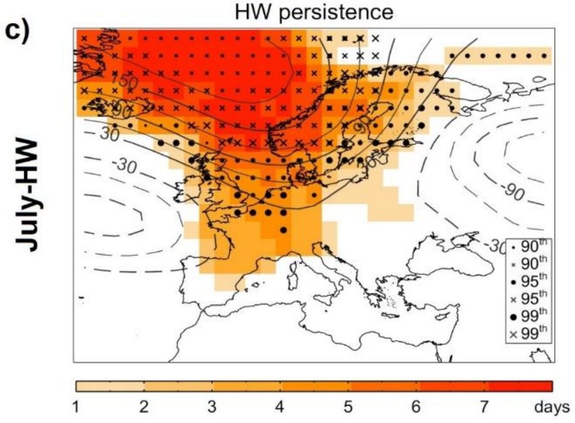


Very significant shift in temperature distributions in recent decades!



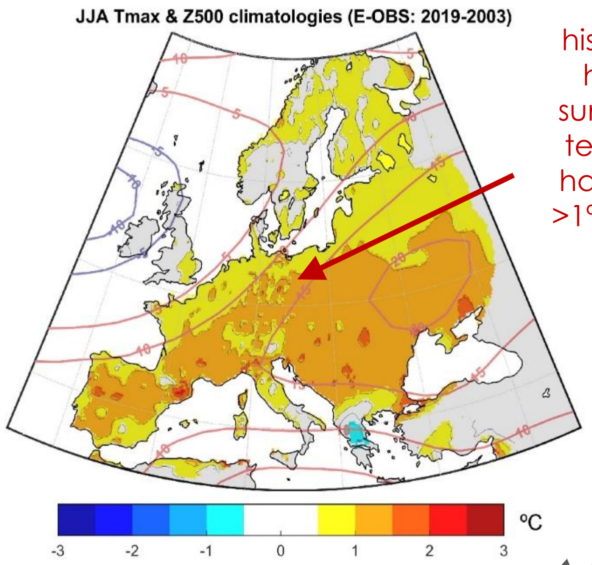
June 2019

First time ever that France registered >45°C



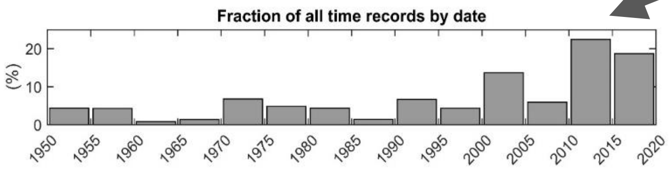
July 2019

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

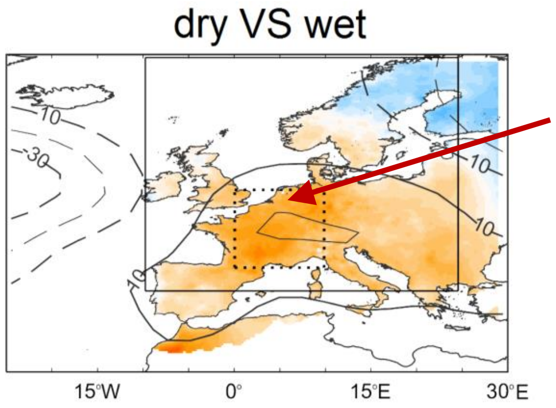


Since the historical 2003 heatwave, summer mean temperatures have increase >1°C in Europe.

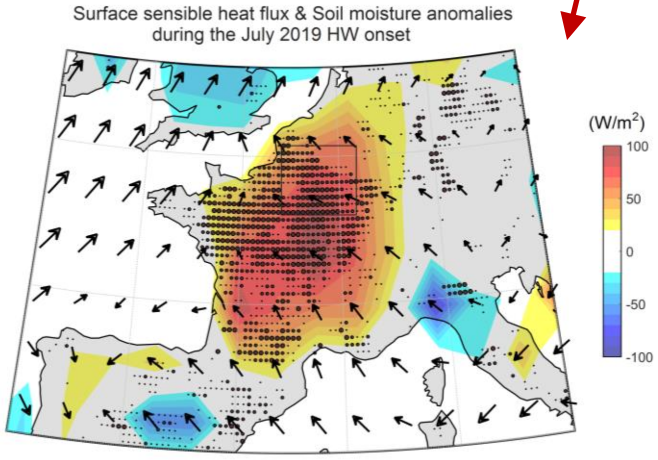
In just 15 years!!!



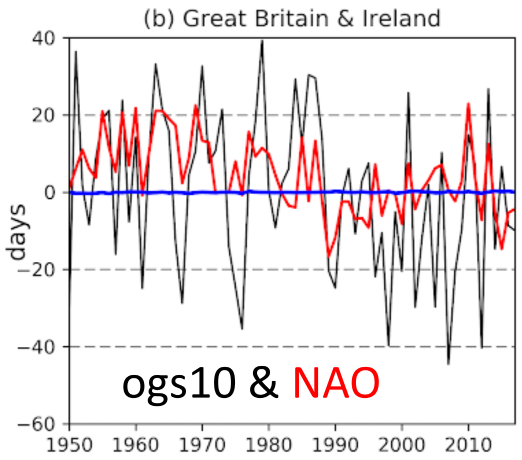
Frequency of new records has been increasing systematically



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