Seasonal prediction of European Summer Heatwaves

Chloé Prodhomme
Stefano Materia, Constantin Ardilouze, Rachel H. White, Lauriane Batté, Virginie Guemas, Georgios Fragkoulidis and Javier Garcia Serrano

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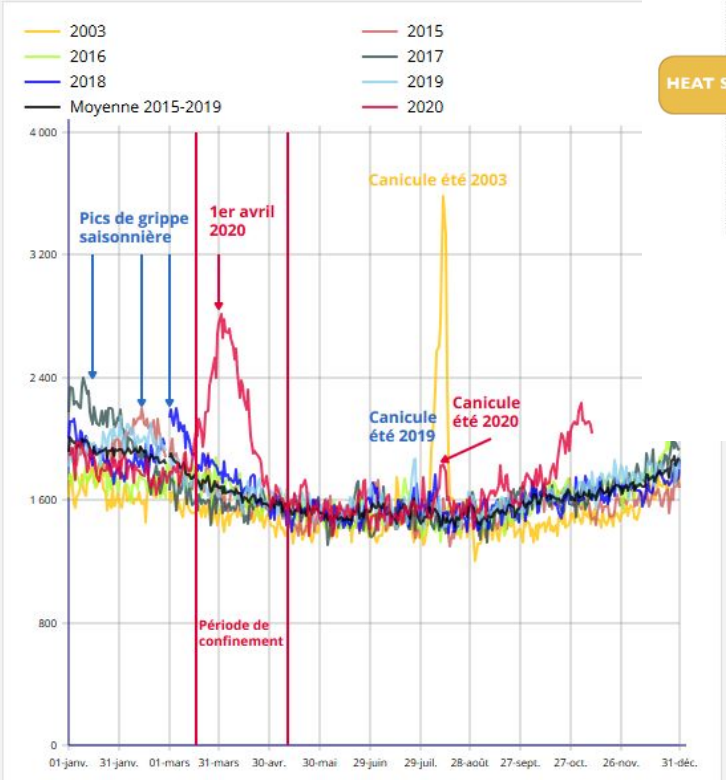
MEDSCOPE
MEDiterranean Services Chain based On climate PrEdictions

Heatwaves and health

Décès quotidiens en 2020 comparés aux cinq dernières années (2015-2019) et à la canicule de 2003

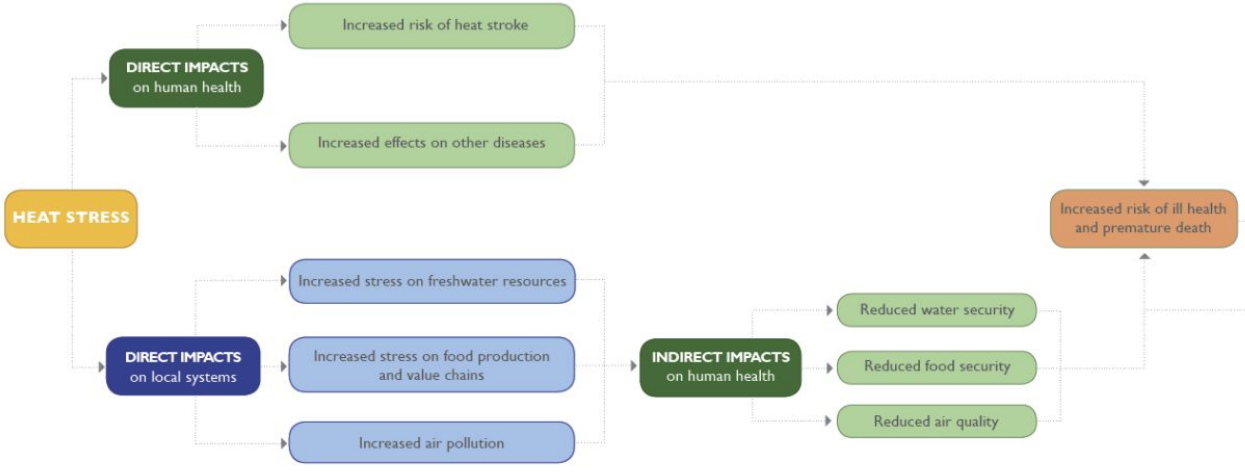


Lecture : le 1er avril 2020, 2 810 décès ont eu lieu en France, contre 1 684 en moyenne à la même date au cours des cinq années précédentes.

Champ : France

Source : Insee, statistiques de l'état civil

Figure 4. Direct and indirect effects of heat stress on health



Source: Adapted from Lucas et al. 2014

From USAID-ATLAS 2019: Heat Waves and Human Health

Heatwaves have a strong impact on human health through direct and indirects impacts, including droughts, decrease of food production, air quality….

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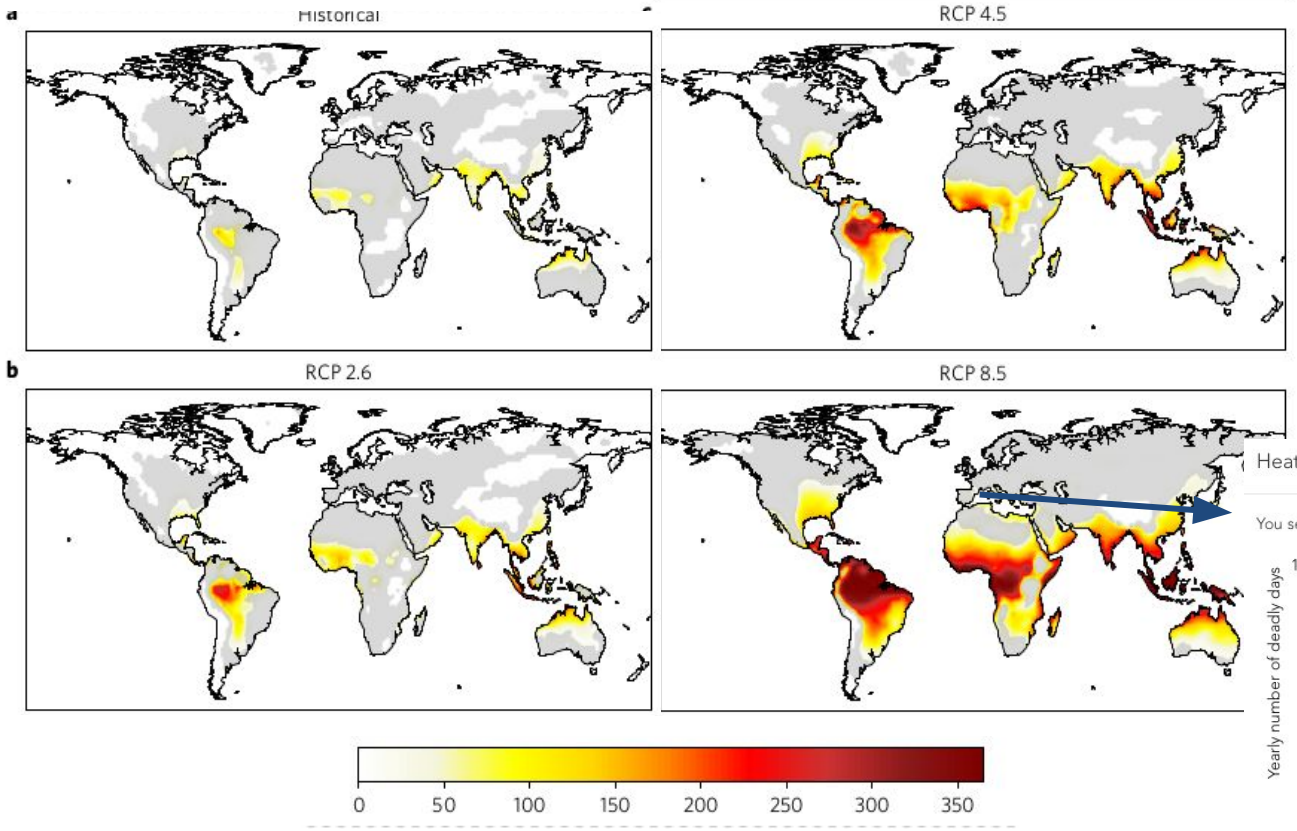
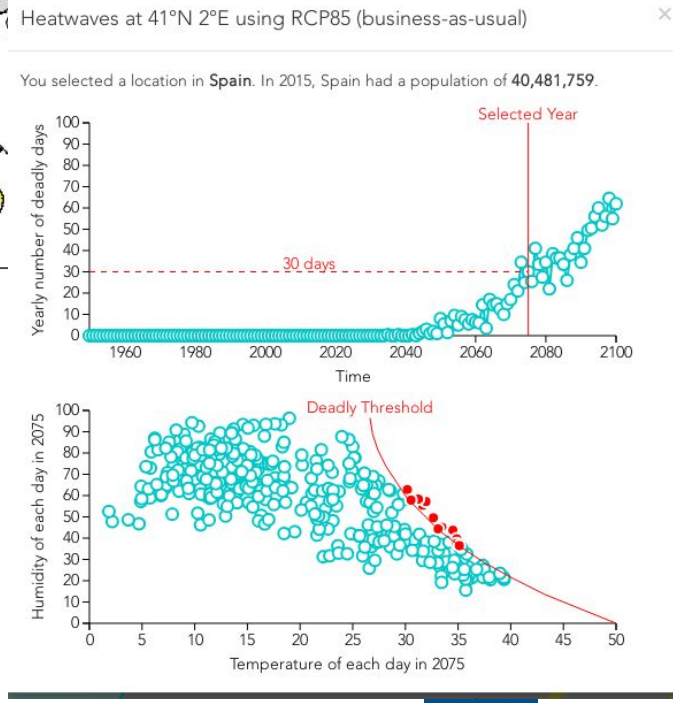
Heatwave in a changing climate



Heatwaves will become stronger and more frequent in the future, under the influence of global warming.



Number of days per year exceeding the threshold of temperature and humidity beyond which climatic conditions become deadly
Mora et al. (2017)

https://apl.esri.com/globalriskofdeadlyheat/#

Why predict heatwaves?

Predict heatwaves at seasonal scale

Better understand heatwaves mechanisms

Warming trend

Large-scale teleconnections
- Rossby wave packet
- Rossby wave guide

Land-atmosphere interaction
- vegetation
- soil moisture

Climate change adaptation

Preparation for health services

Water management

Power management

Agriculture

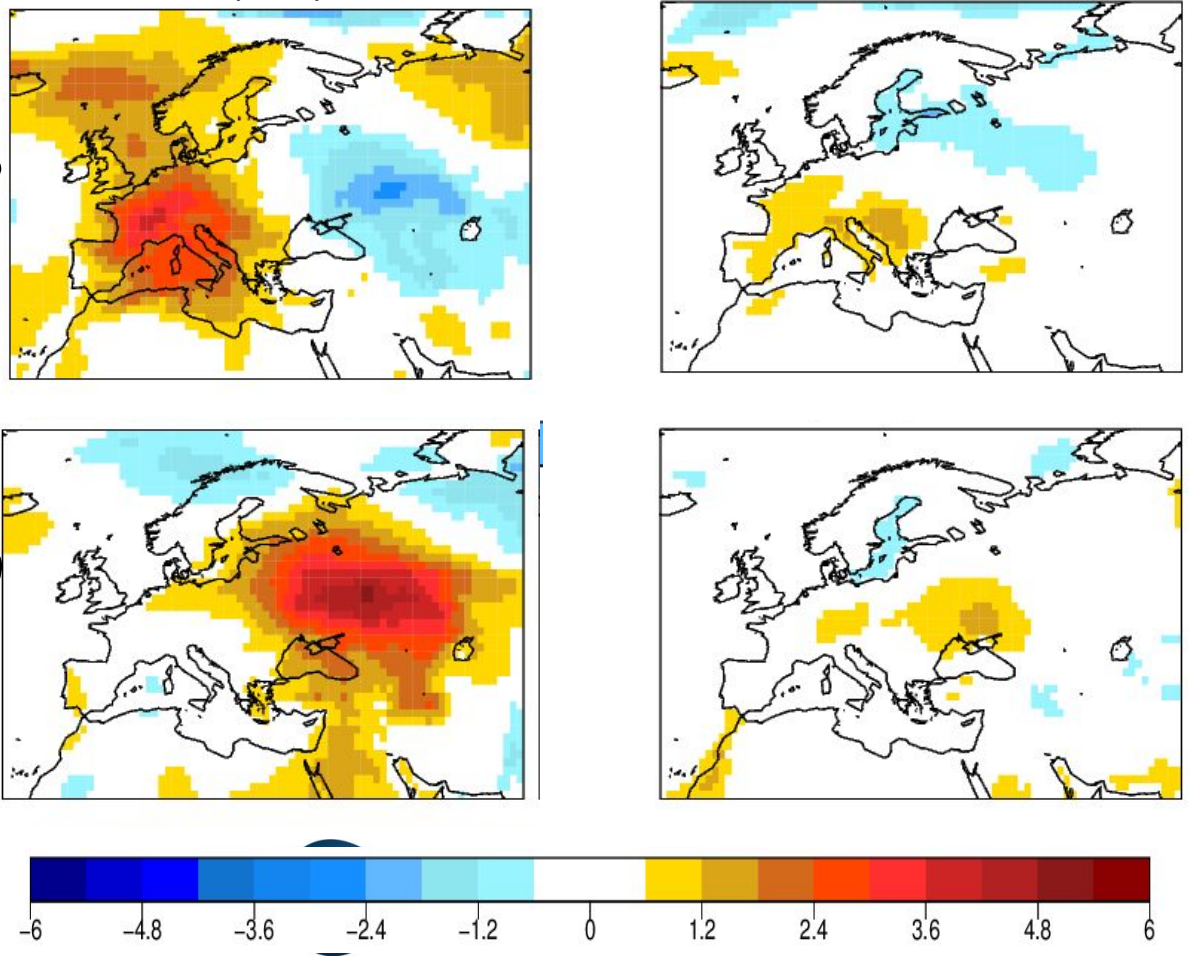
Heatwaves might be predictable

ERAint: 2m-temperature (JJA)

EC-Earth: 2m-temperature (JJA ensemble mean)

2003

2010



- 2003 and 2010 seems to be predictable from May 1st

- Using ensemble mean anomaly smooths the signal and is not adequate to assess heatwave.

Adapted from Prodhomme et al. (2016)

Data

Operational seasonal forecast:

- ECMWF SEAS5
- period: 1981-2016 (hindcast) + 2017-2019 (operational forecast)
- Initialized on May 1st
- 25 members
- Considered season: From May 15th to August 31st

Reference data: EOBS and ERA5

Statistical model:

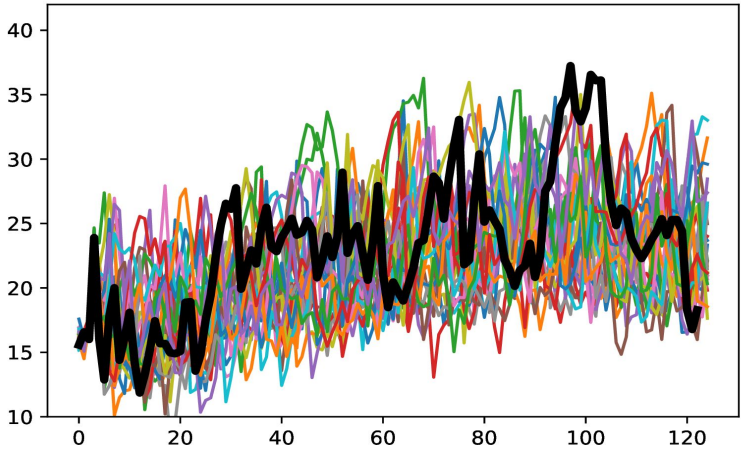
- ModTrend: Constructed using linear trend in cross-validation, estimated for each grid point with ERA5

All calculations (anomalies, scaling....) are done in cross-validation (excluding the year we want to forecast).

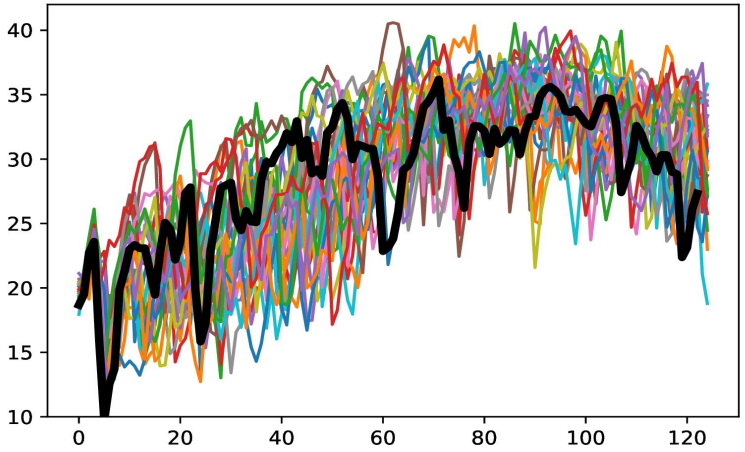
Challenges

tasmax in 2003

Paris

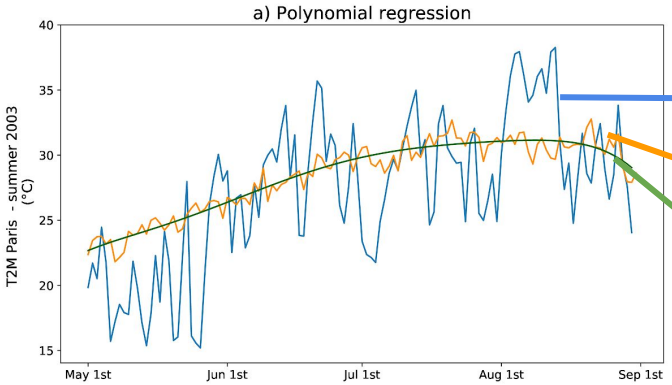


Madrid



- Detect heatwaves encompassing climatologically heterogeneous regions
- Exclude cold days for the calculation
- Account for the different members (different heatwave timing and spatial extent)
- Model biases

Indices



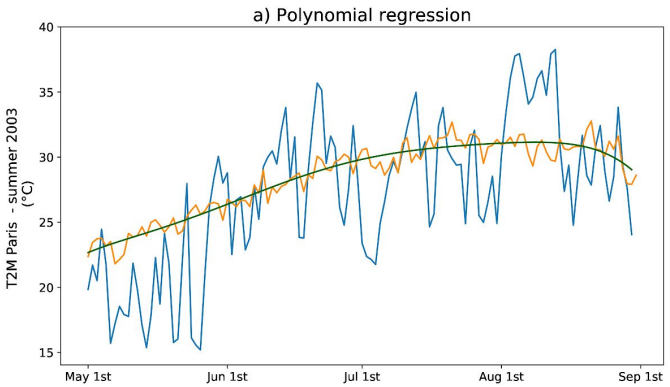
daily time serie of tasmax (2003 Paris)

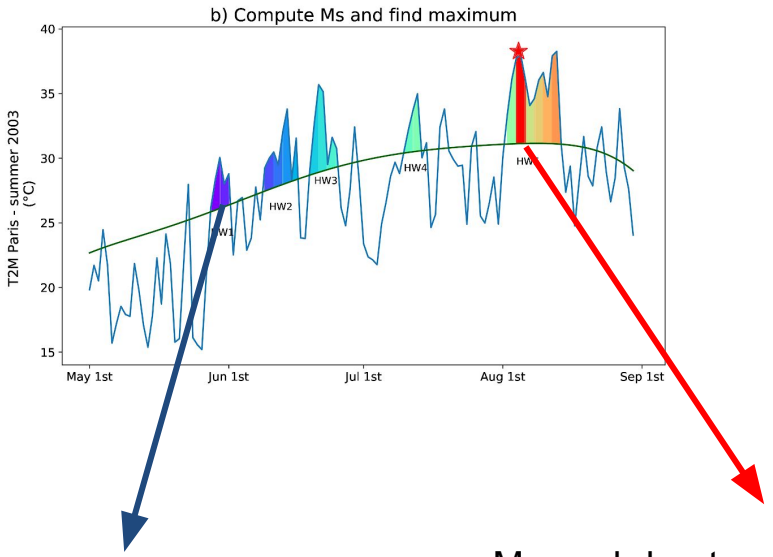
90th percentile

Polynomial regression of 90th percentile (order 6)

N90: Number of days above the smoothed 90th percentile

Indices

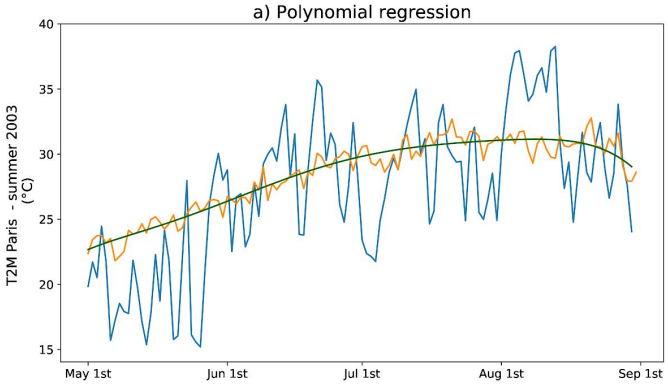


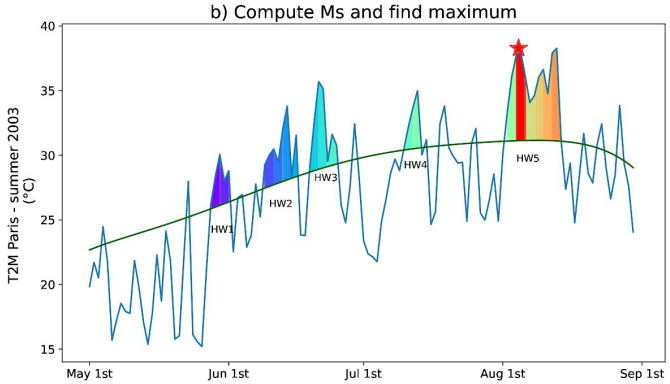


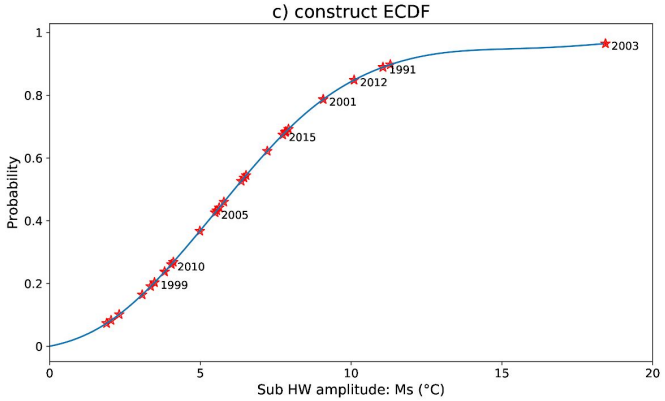
Sub-heatwave: 3 days above the smoothed 90th percentile.

Max sub-heatwave for the considered season

Indices

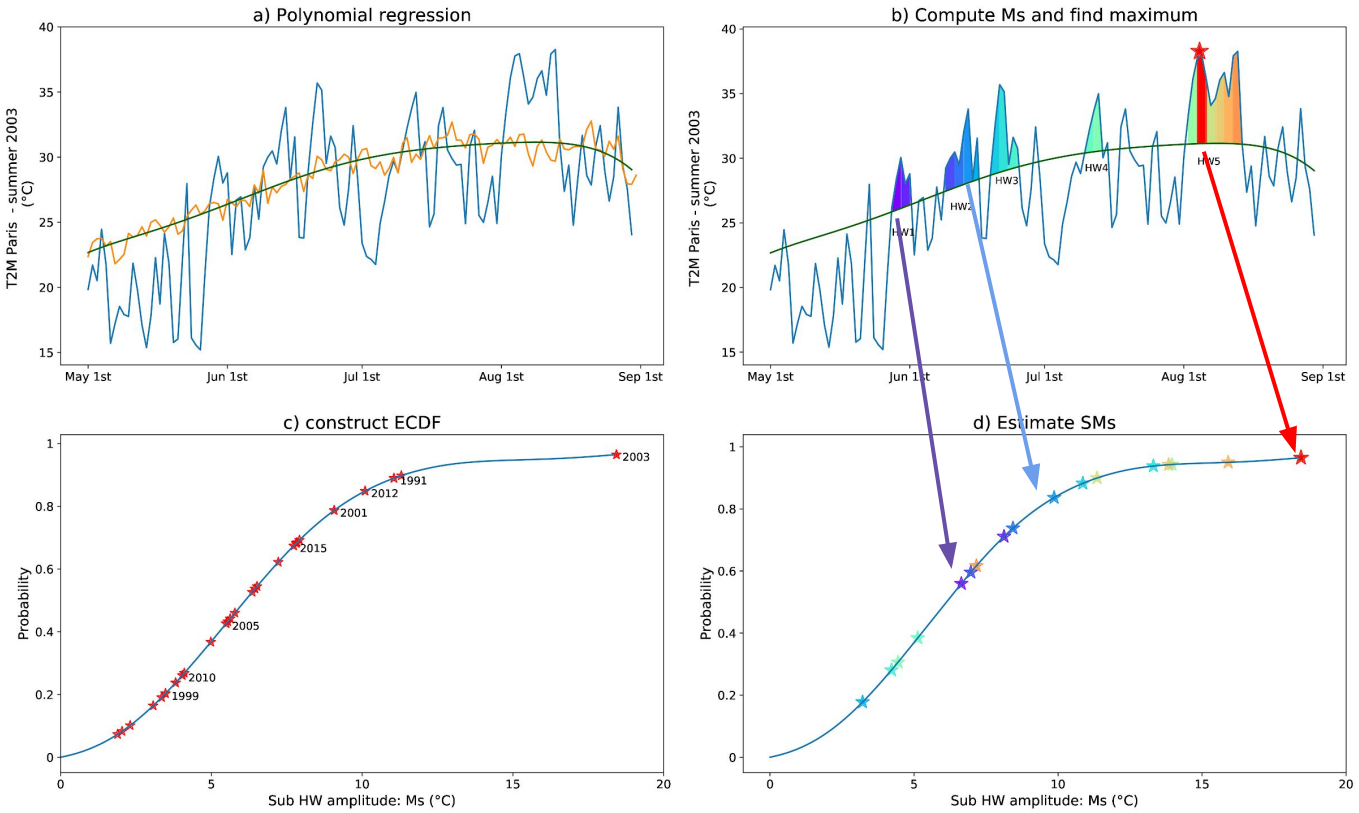






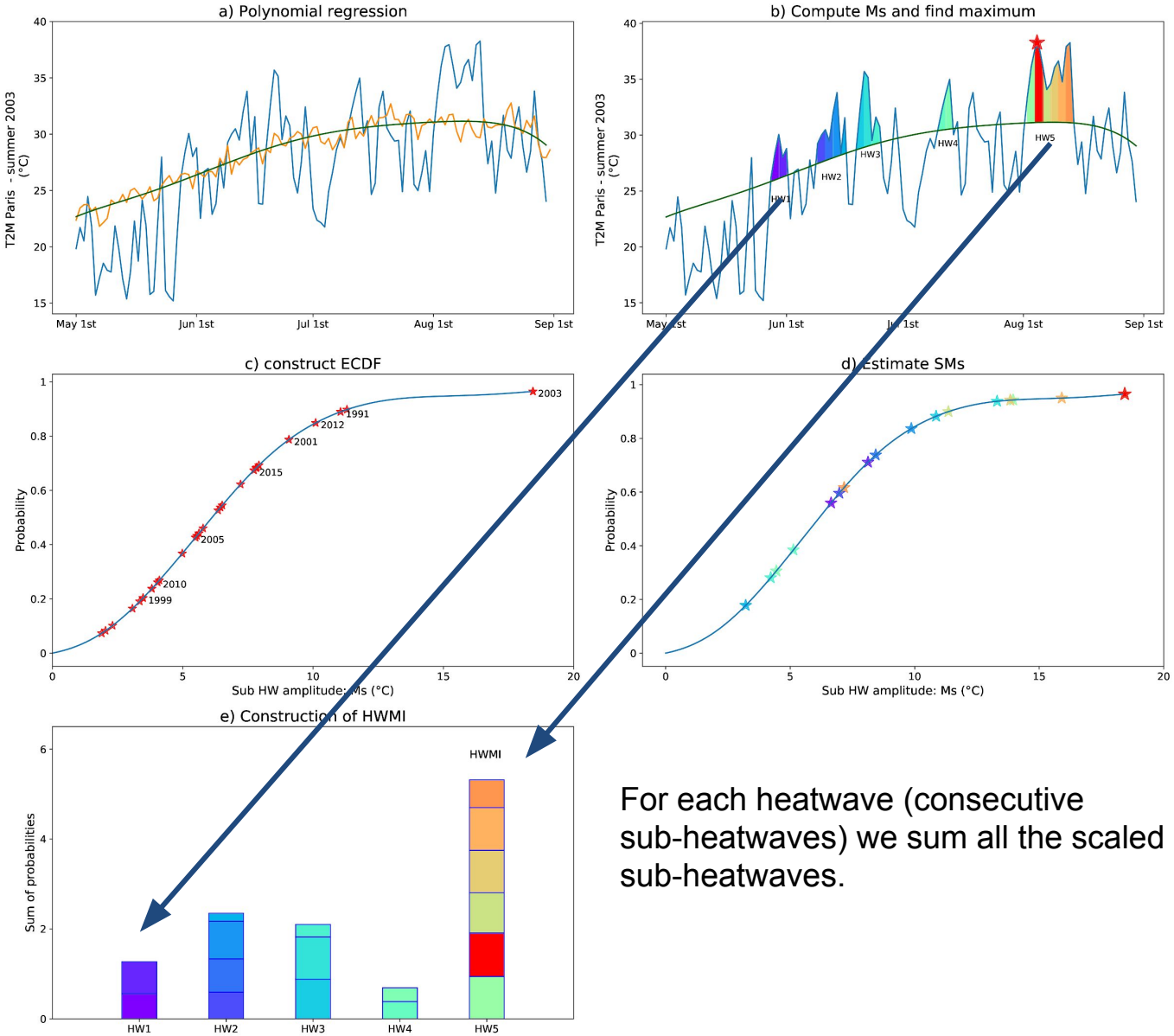
Construct ECDF with the maximum sub-heatwave of all years

Indices



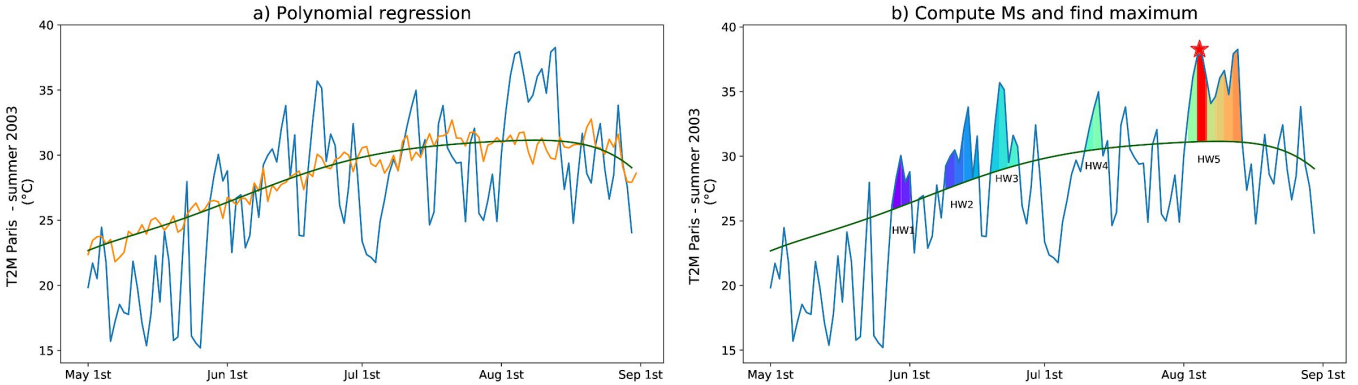
Scale all the sub-heatwave of the ECDF for the considered year

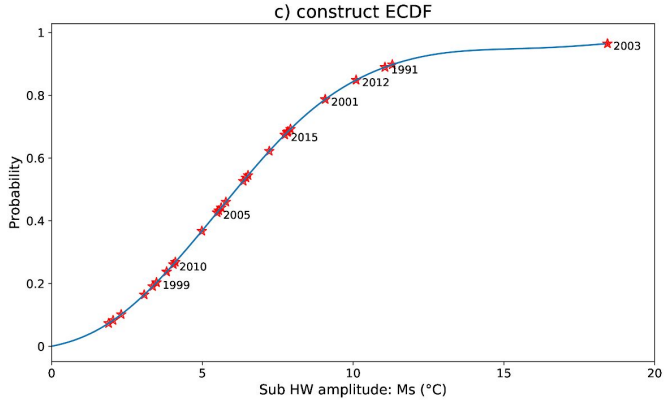
Indices

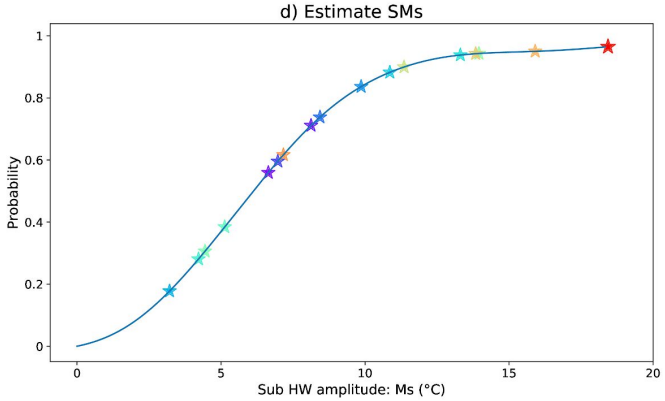


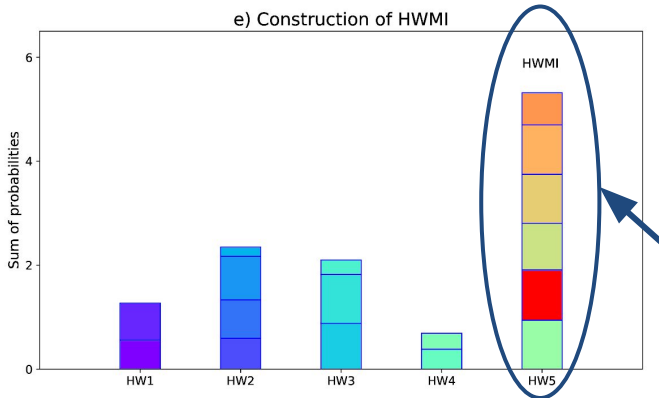
For each heatwave (consecutive sub-heatwaves) we sum all the scaled sub-heatwaves.

Indices





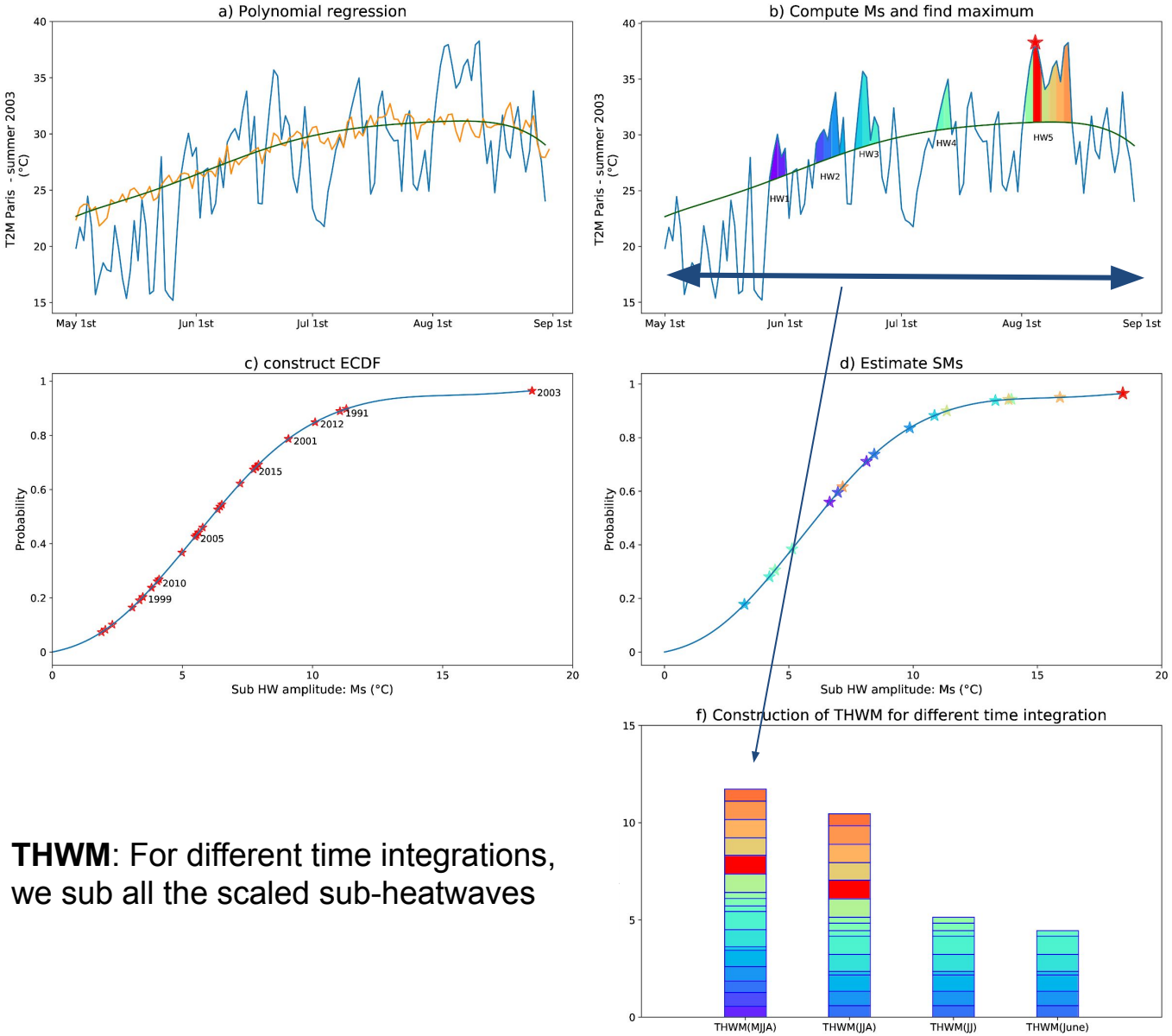




For each heatwave (consecutive sub-heatwave) we sum all the scaled sub-heatwave.

HWMI: Heatwave with the maximum magnitude
Russo et al. (2014)

Indices



THWM: For different time integrations, we sub all the scaled sub-heatwaves

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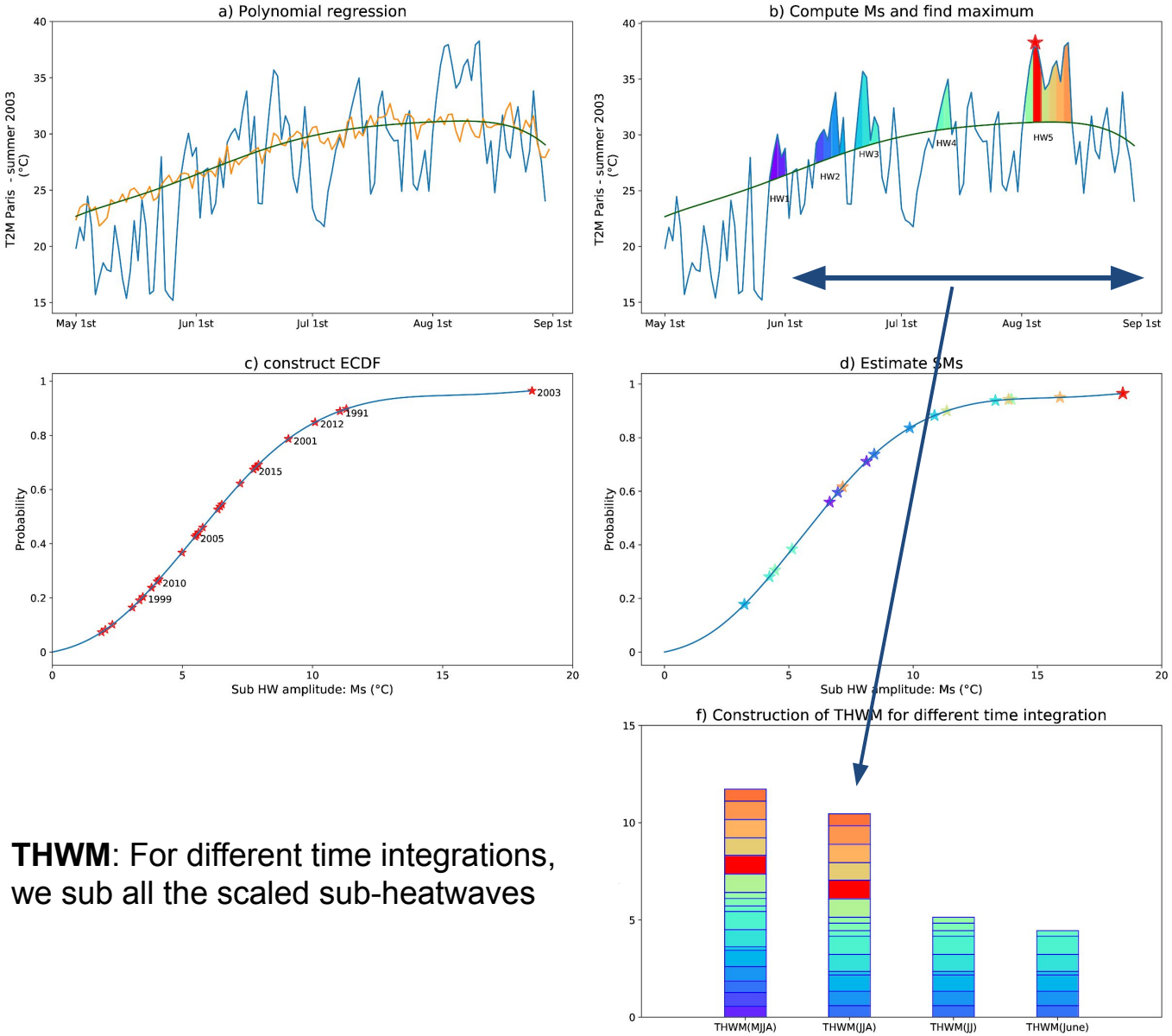
Indices



THWM: For different time integrations, we sub all the scaled sub-heatwaves

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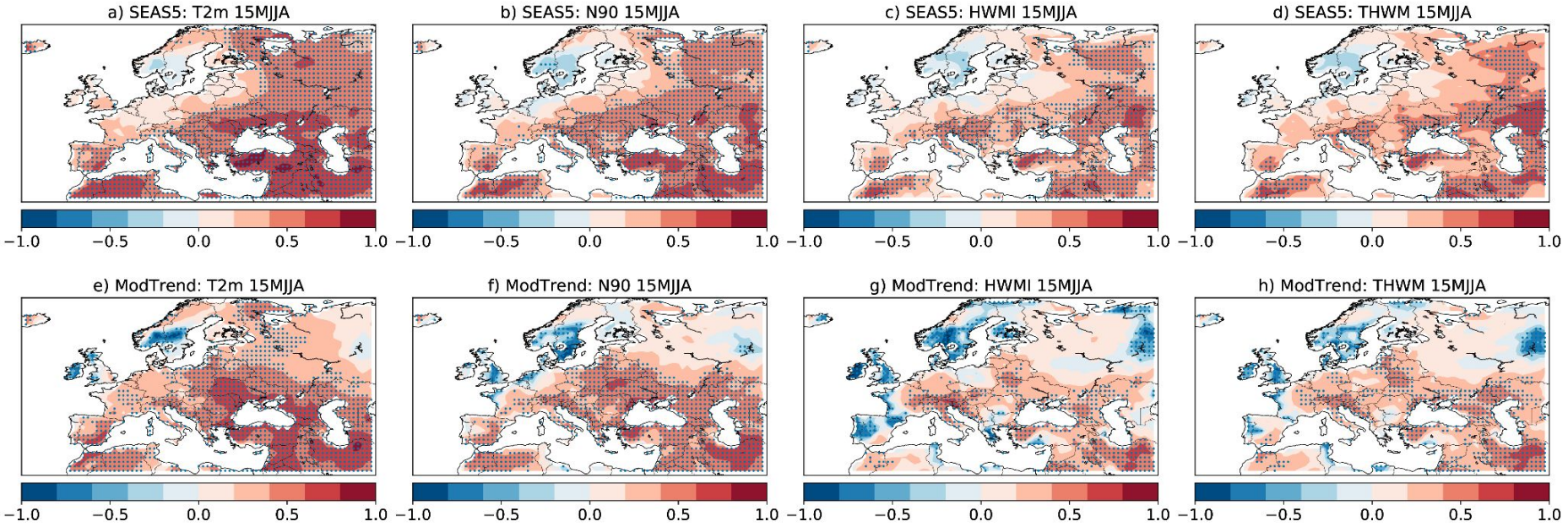
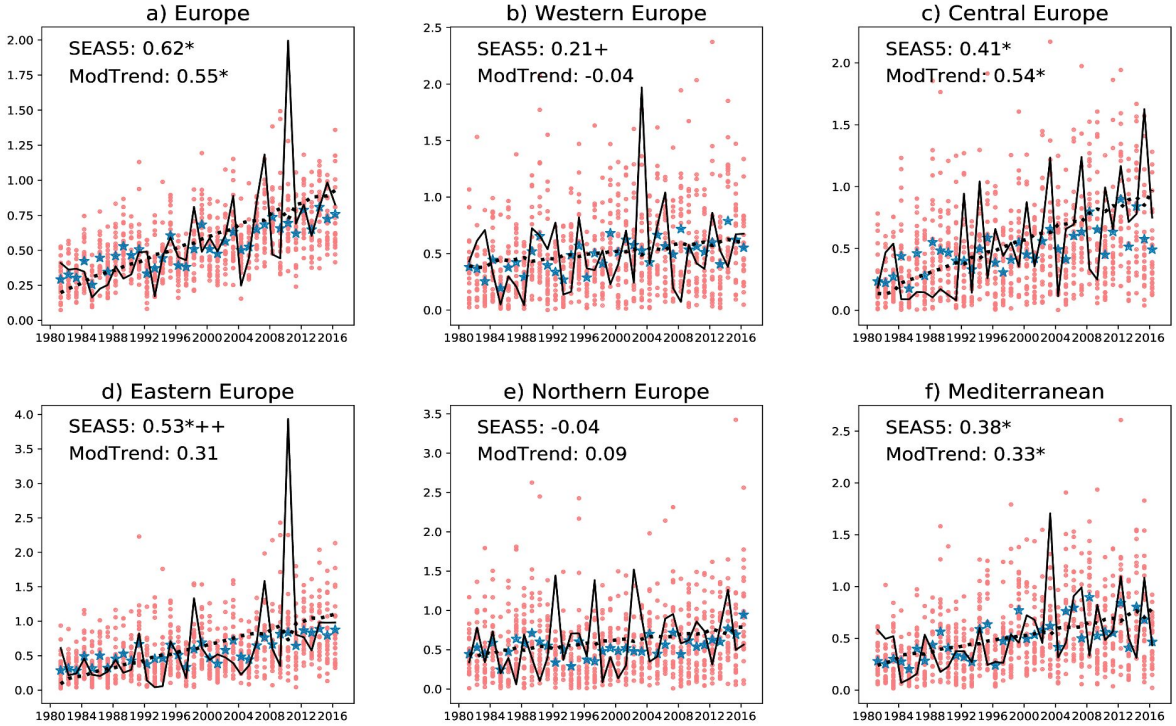
Correlation



Correlation obtained for the different heatwaves indices. Top: SEAS5 bottom: Statistical model ModTrend and right SEAS5 (dots shows correlation significant at the 95% confidence level)

- Skill of extreme indices is lower than mean 2m-temperature; consistently with previous studies
- Generally, SEAS5 performs better than the statistical model

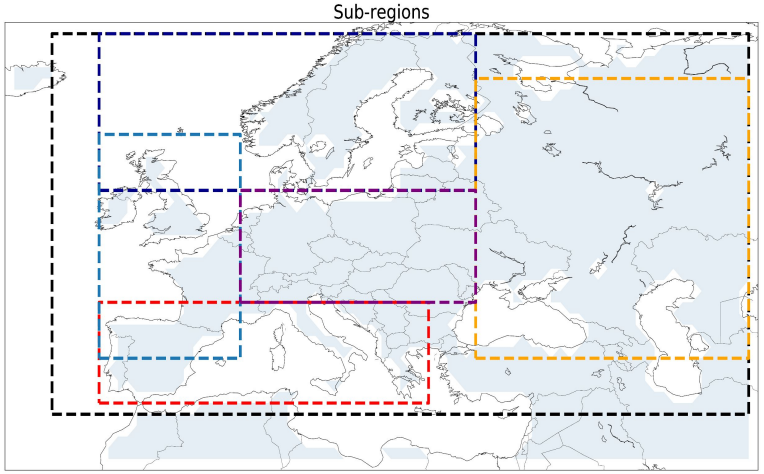
Sub-regions: THWM



HWMI averaged over different domains
- Plain Black line: ERA5
- Red dots: Different SEAS5 ensemble
- Blue stars: SEAS5 ensemble mean
- Dashed black line: Statistical prediction with ModTrend

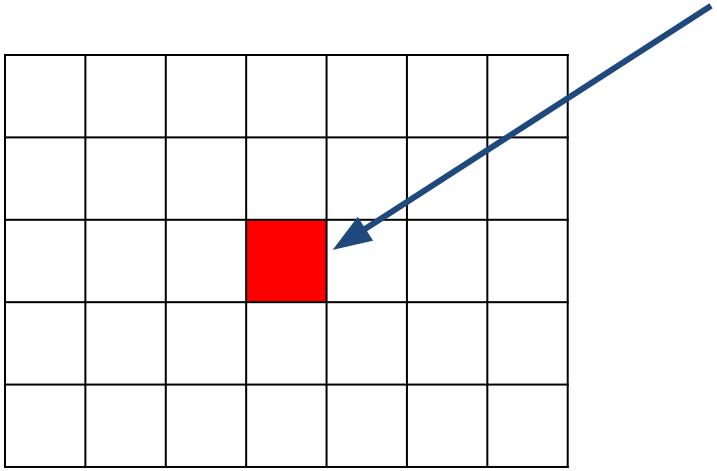
**: correlation significant at 95% confidence level*
+/++: correlation significantly higher than ModTrend at 90%/95% confidence level

SEAS5 tend to perform better than ModTrend for all sub-regions (except Central and Northern Europe) and the difference is significant at the 95% confidence level for the Eastern Europe.

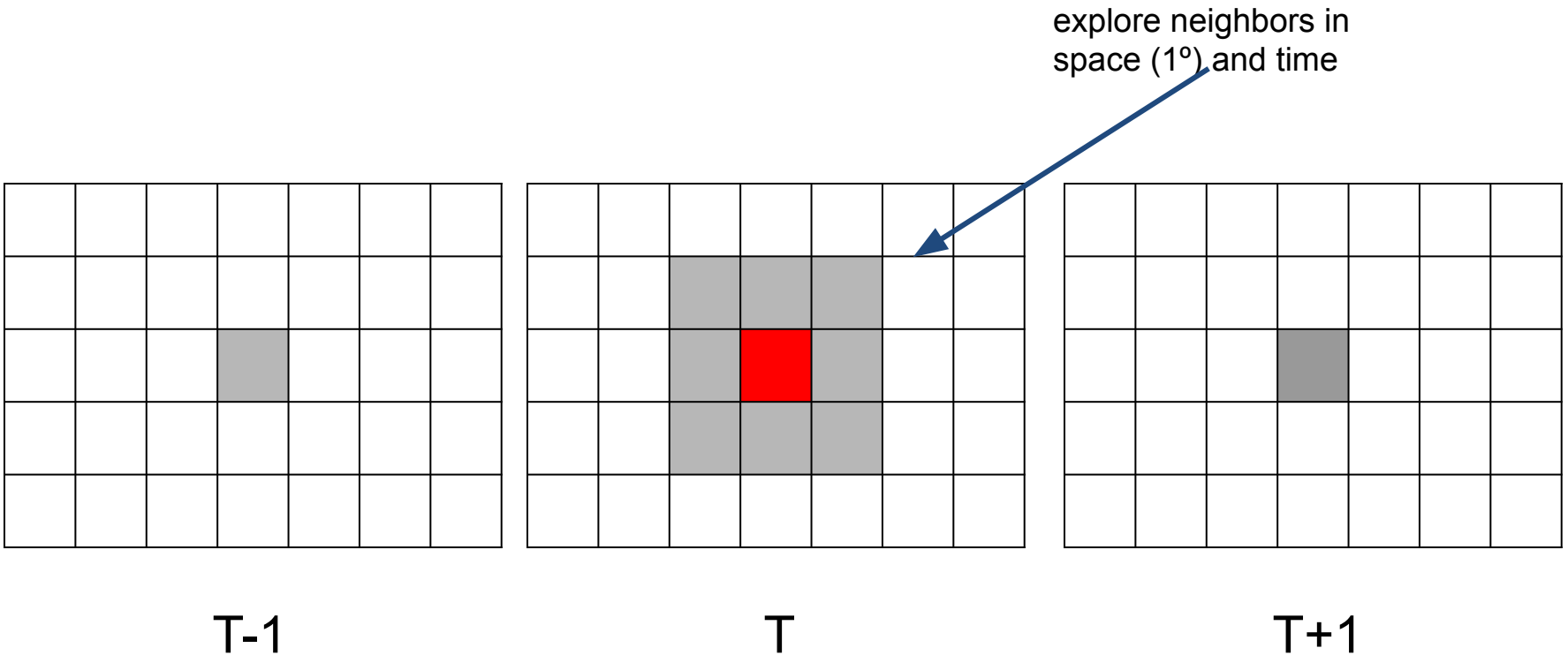


Heatwave detection - method

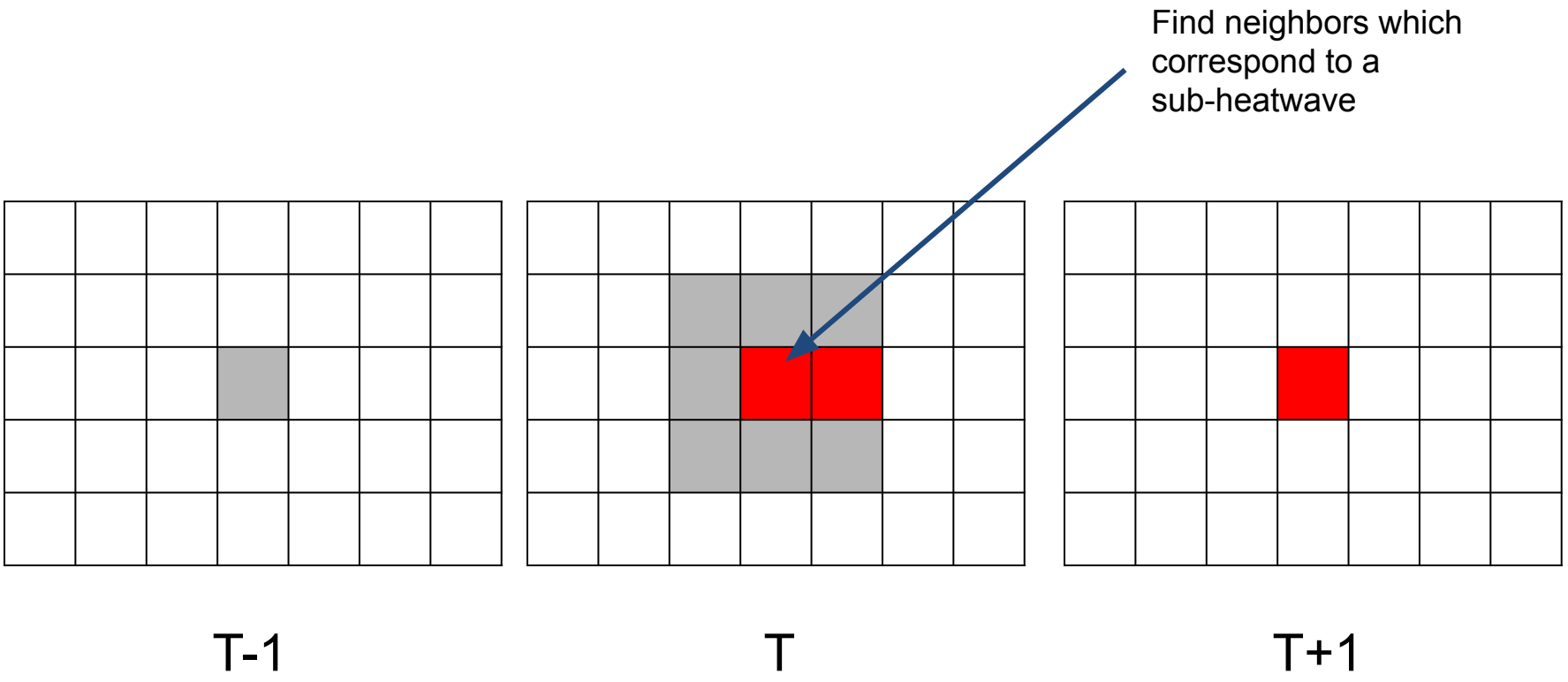
Find a sub-heatwave: seed



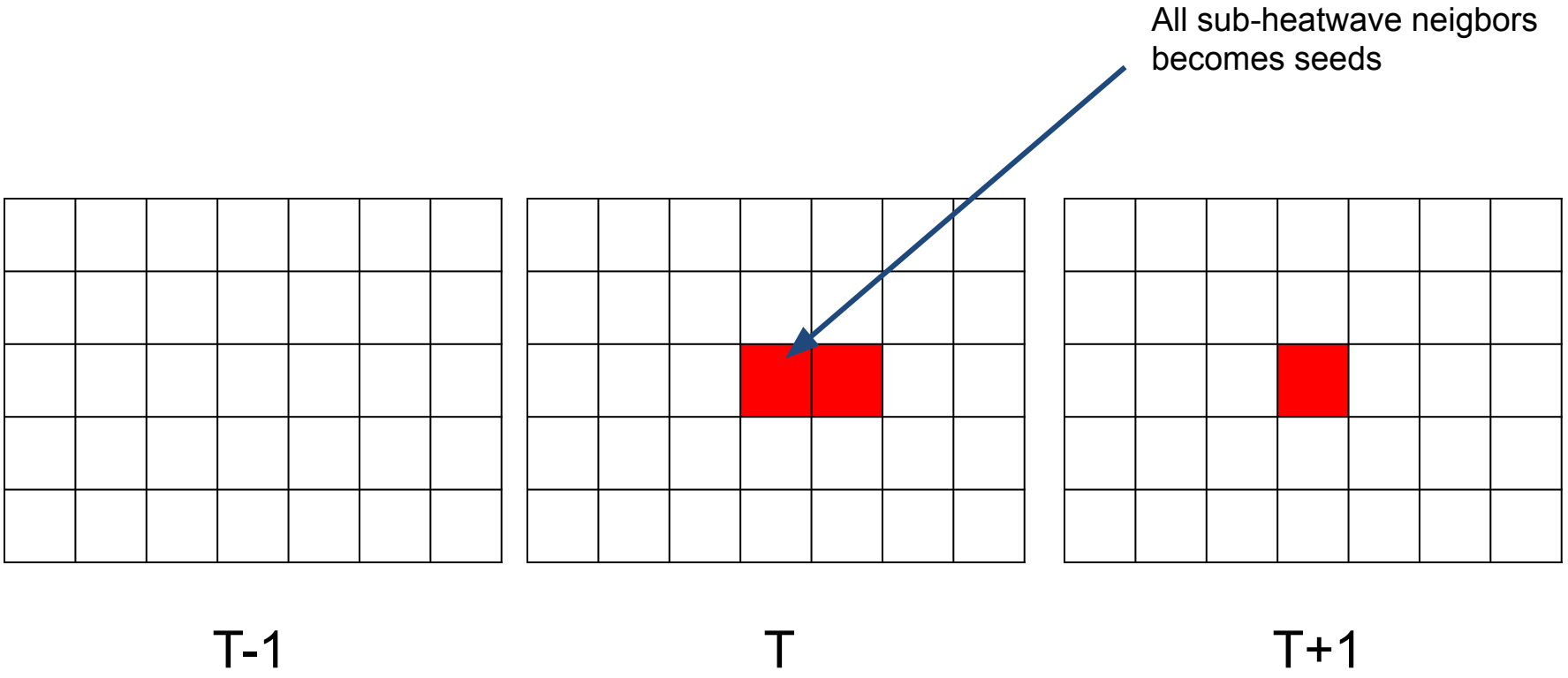
Heatwave detection - method



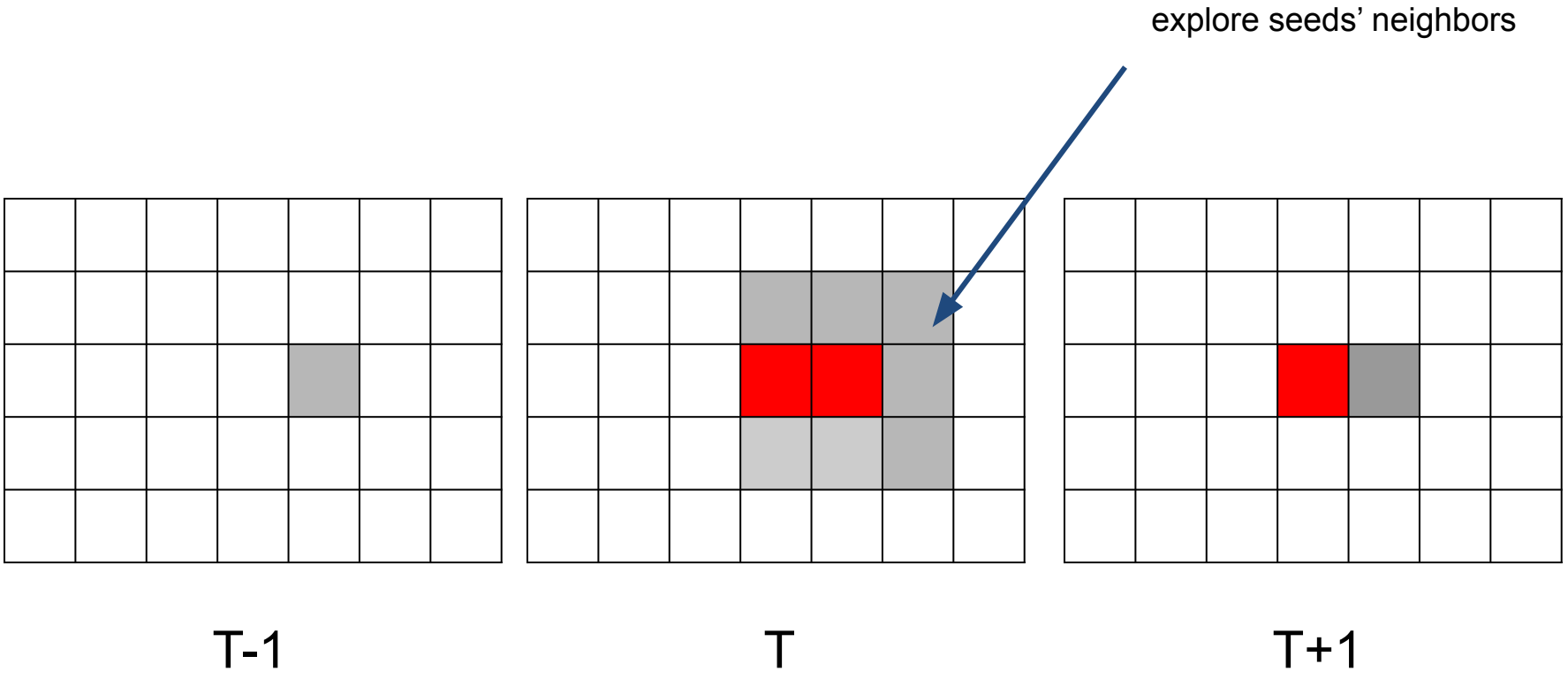
Heatwave detection - method



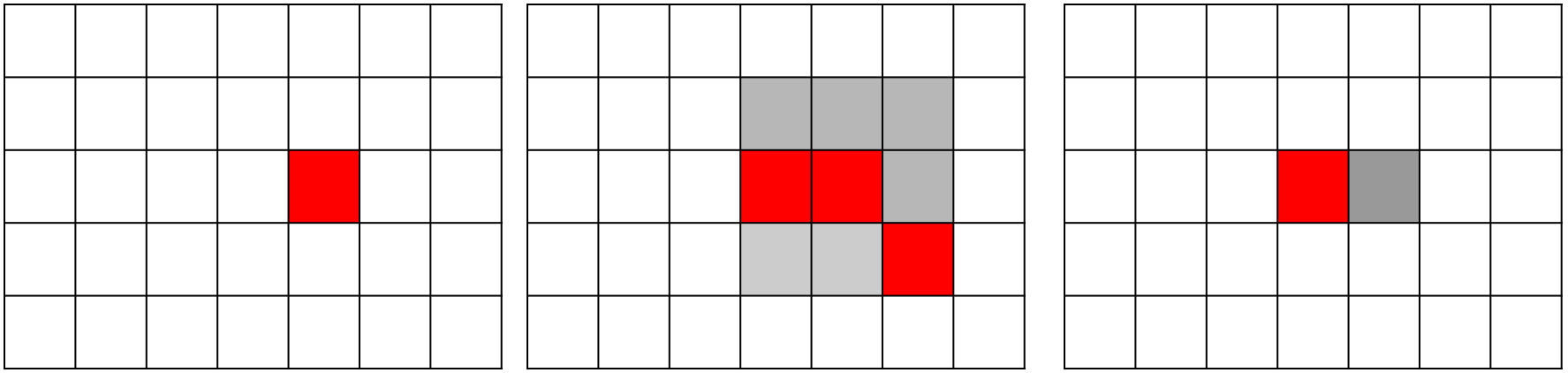
Heatwave detection - method



Heatwave detection - method



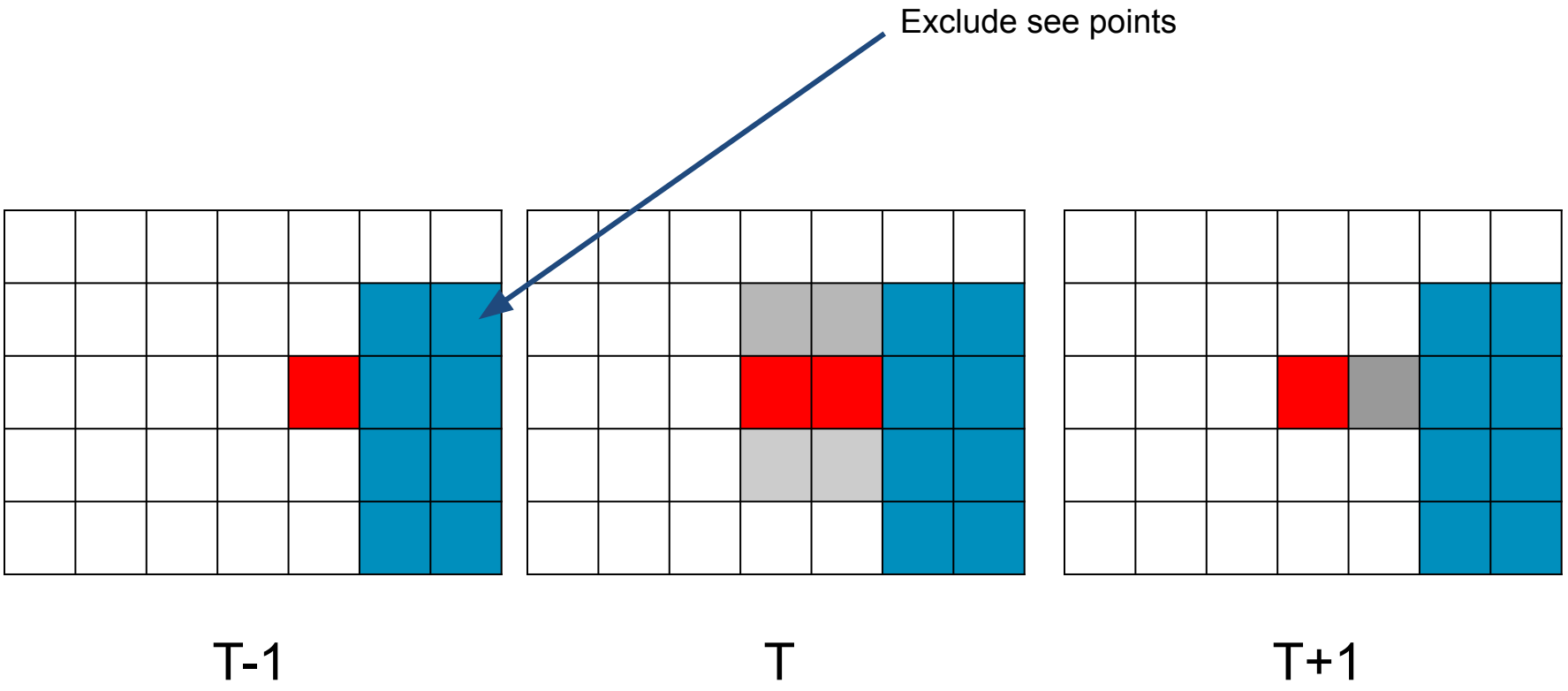
Heatwave detection - method



T-1 T T+1

And continue until finding all the points belonging to the heatwave

Heatwave detection - method



Compute its characteristics:

- **HW magnitude**: sum of all sub-heatwaves for a given time
- **HW total magnitude**: sum of all sub-heatwaves
- **HW spatial pattern**: sum of sub-heatwaves over time

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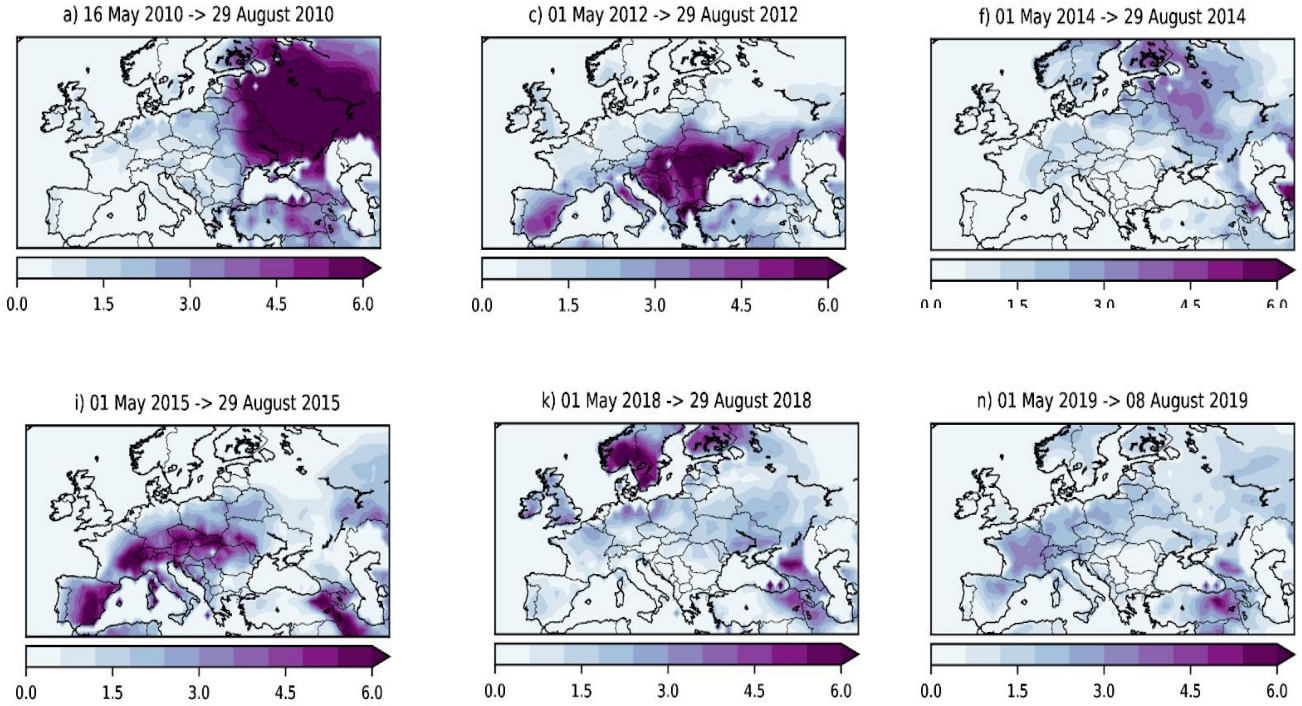
Heatwaves detection

Then, a threshold, hereafter **HST** corresponding to the **N** largest heatwave is estimated in cross-validation (excluding the year we want to predict). In this case, **HST=5**, but 6 heatwave are detected because of cross-validation.



Heatwave detection - score

model \ observation	heatwave	no heatwave
heatwave	hit	False Alarm (FA)
no heatwave	miss	Correct Rejection (CR)

$$accuracy = \frac{hit + CR}{nyear}$$

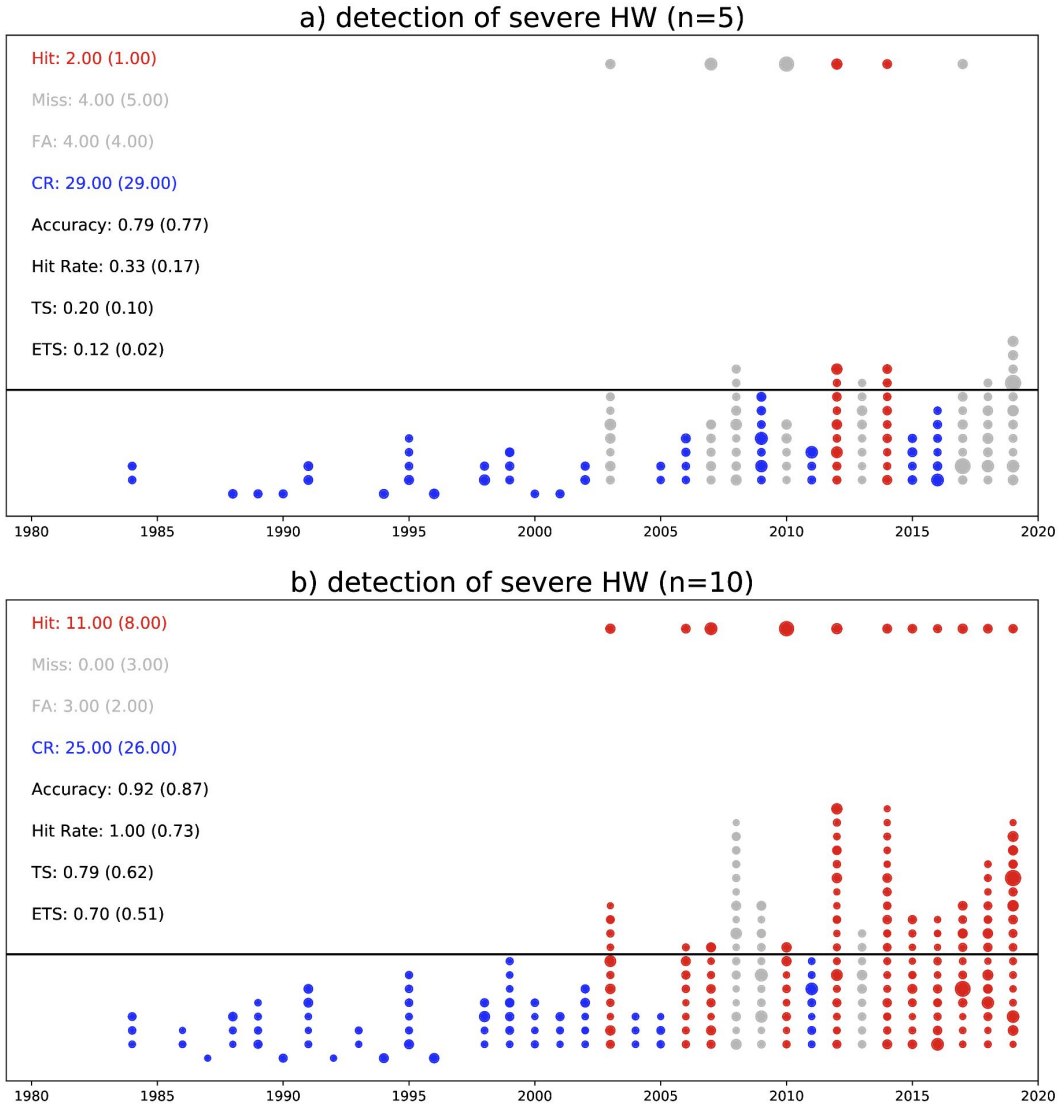
$$hitrate = \frac{hit}{hit + miss}$$

$$TS = \frac{hit}{hit + miss + FA}$$

$$ETS = \frac{hit - hitrandom}{hit + miss + FA - hitrandom}$$

$$hitrandom = \frac{(hit + miss)(hit + FA)}{nyear}$$

Heatwave detection



Severe heatwave detection, defining with Heatwave Severity Threshold (HST=10) (see attached presentation for more details) Top circles indicate observed severe heatwaves.
The bottom circles indicate the severe heatwaves that were predicted.
lack line corresponds to the percentage of members needed to detect an event (8 members).
The color corresponds to the contingency table, grey:False Alarm or missed event, red: hit, blue: correct rejection. The numbers show the score obtained by SEAS5 and by the simple statistical model in parentheses.

With our method, we can predict large heatwave using SEAS5, including 2010 heatwave.
However parameters should chosen carefully, SEAS5 is better than ModTrend for 5<HST<20.

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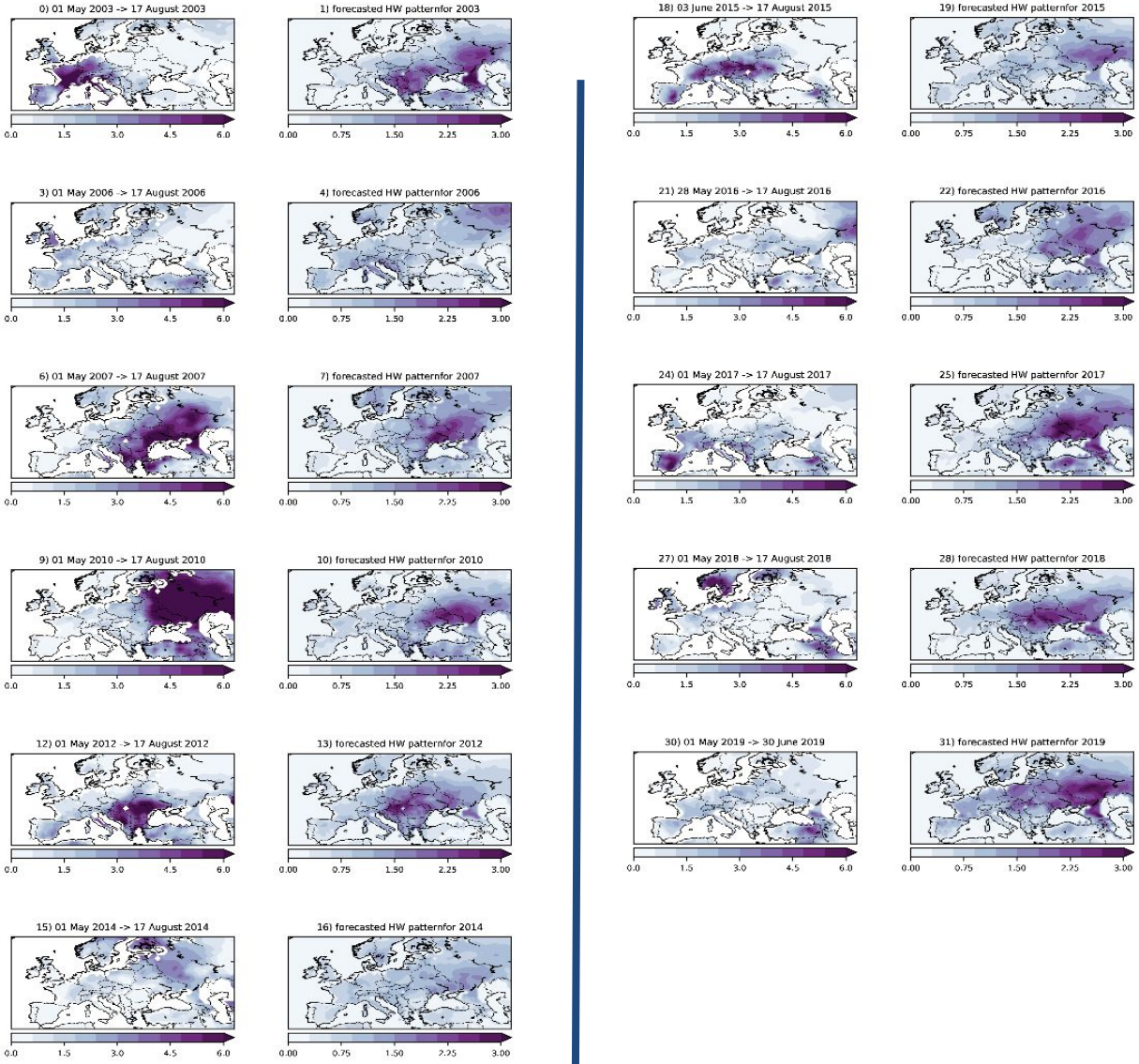
Heatwaves detection



Severe Heatwave Spatial pattern observed (left column) and predicted by the model (right column), for HST=10

The spatial pattern predicted by the model does not necessarily match the observed pattern (same happen for the timing, not shown).

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Conclusions

- Seasonal forecasts predict skilfully several local heatwave indices, especially over eastern and southern Europe.

- The skill of extreme indices is bounded by the skill of mean temperature.

- Dynamical forecast system performs better than a simple statistical model based on linear trend.

- Dynamical forecasts also provide potentially useful information at the regional scale up to three-months ahead for the THWM for the whole European domain, Mediterranean region and Eastern Europe.

- Seasonal forecasts are able to provide reliable information about the propensity of occurrence of individual severe heatwaves, performing better than random or a simple statistical model based on linear trend.

- The prediction system does not seem able to give reliable information about the timing of the heatwave peak nor about the heatwave spatial pattern

C. Prodhomme, S. Materia, C. Ardilouze, R. H. White,L. Batté, V. Guemas, G. Fragkoulidis, J. Garcia Serrano: Seasonal prediction of European Summer Heatwaves (under review to climate dynamics)

Why predict heatwaves?

Predict heatwaves at seasonal scale

Better understand heatwaves mechanisms

Climate change adaptation

Construct improved statistical model
Analyse multi-model prediction

Investigate predictability of Rossby wave (on-going)

Sensitivity experiments (soil conditions, SST...)

Interactive vegetation

Improve skill (multi-model combinaison, improved initialization….)

Construct operational product

Relate heatwave predictability with the predictability of its impact