Subseasonal Prediction of European Extreme Temperature Events in S2S hindcasts

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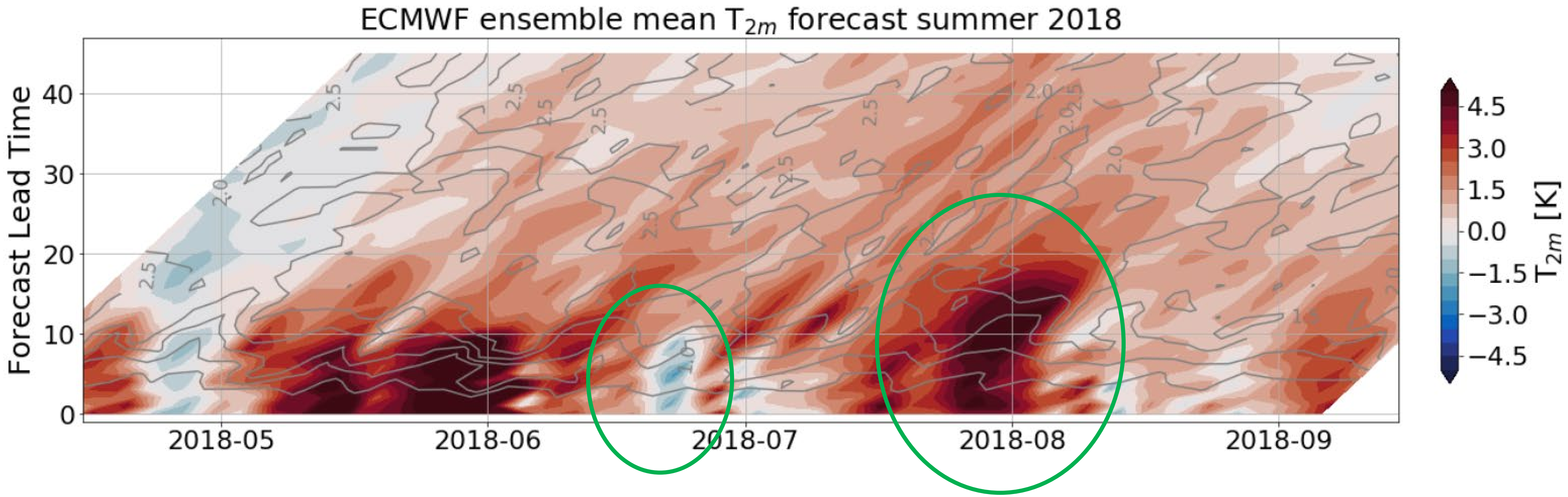


ECMWF Ensemble mean 2m temperature anomaly forecast (shading) and ensemble spread (contours) averaged over Scandinavia

Objectives

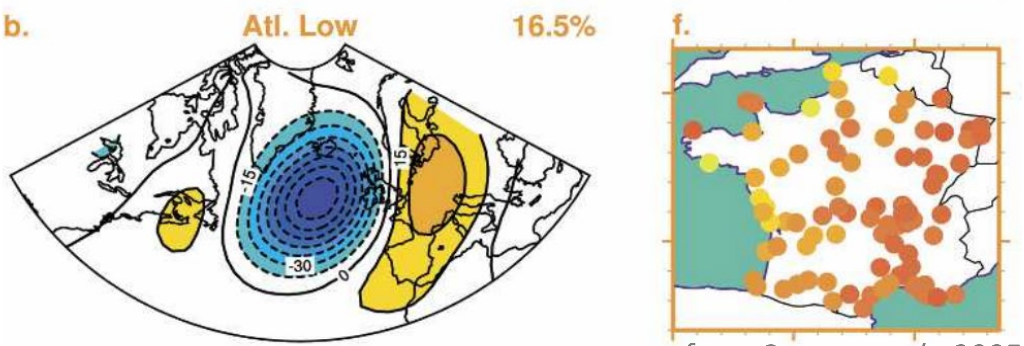
Is there extended prediction skill for extreme surface temperature events (compared to climatologically average ones)?

What is the role of persistence?

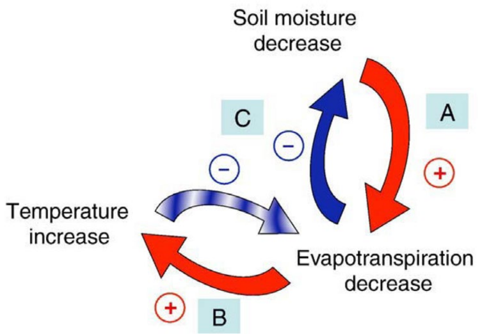
Verification of S2S ensemble hindcasts

Surface temperature variability can be determined by components with predictability potential on S2S time scales:

- low-frequency atmospheric variability (possibly influenced by ocean variability, *Cassou et al., 2005; Wulff et al., 2017*)
- land-atmosphere interactions (soil moisture memory, *Seneviratne et al., 2010*)



from Cassou et al., 2005



from Seneviratne et al., 2010

Data & Methods

Data:

Hindcasts: S2S ensembles (*Vitart et al., 2016*)

- mostly ECMWF: 11 members, initialized twice weekly, only model versions 2016+

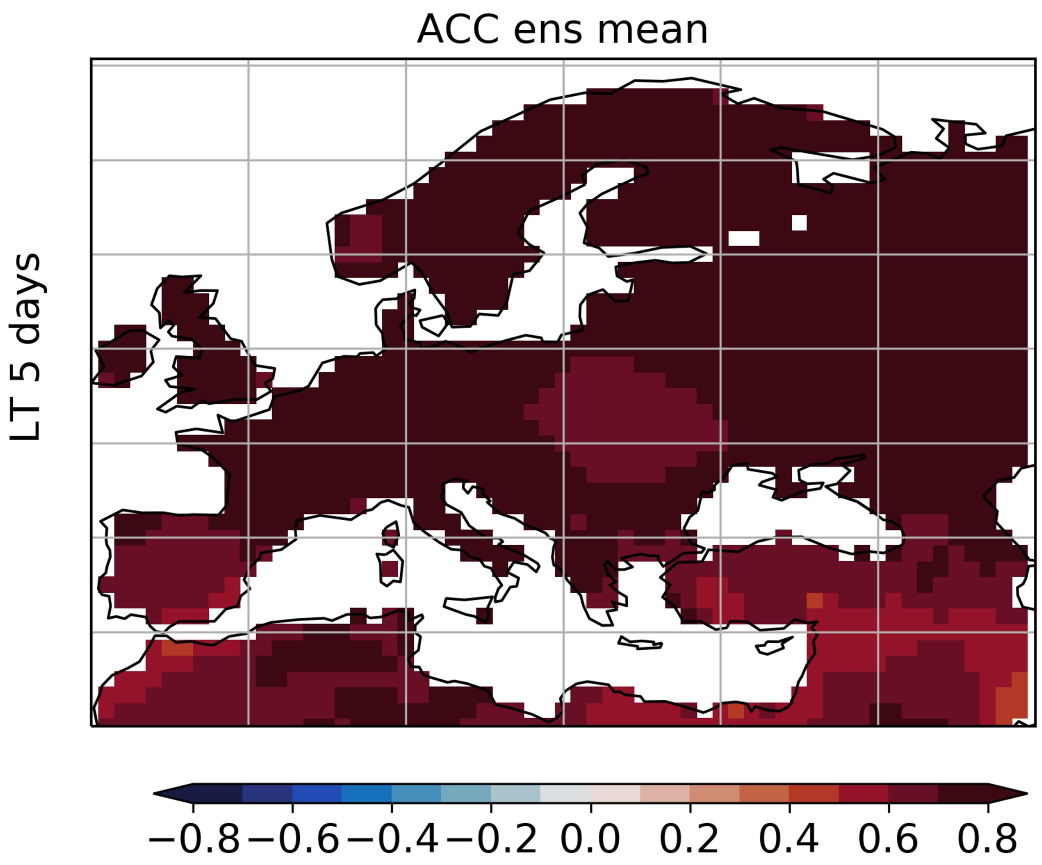
Verification: ERA-Interim reanalysis (*Dee et al., 2011*)

Methods:

Consider pentad mean anomalies of T_{2m} in JJA with respect to the 1999-2010 lead time-dependent climatology

Extreme temperature event: exceedance of the 95$^{\text{th}}$ percentile of the T_{2m}^{5d} distribution (again lead time-dependent)

Surface temperature prediction skill

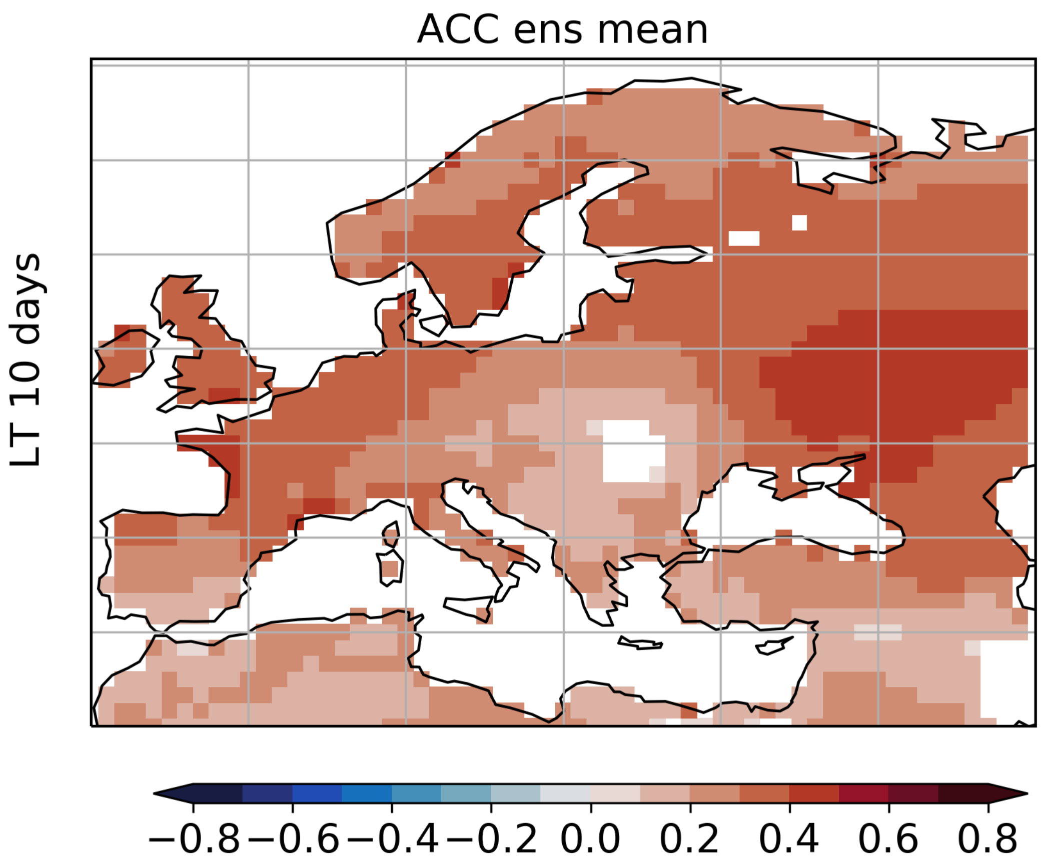


5 days lead time

Anomaly correlation coefficient (ACC)

At each grid point & for each lead time:
→ correlation over dimension of initialization time

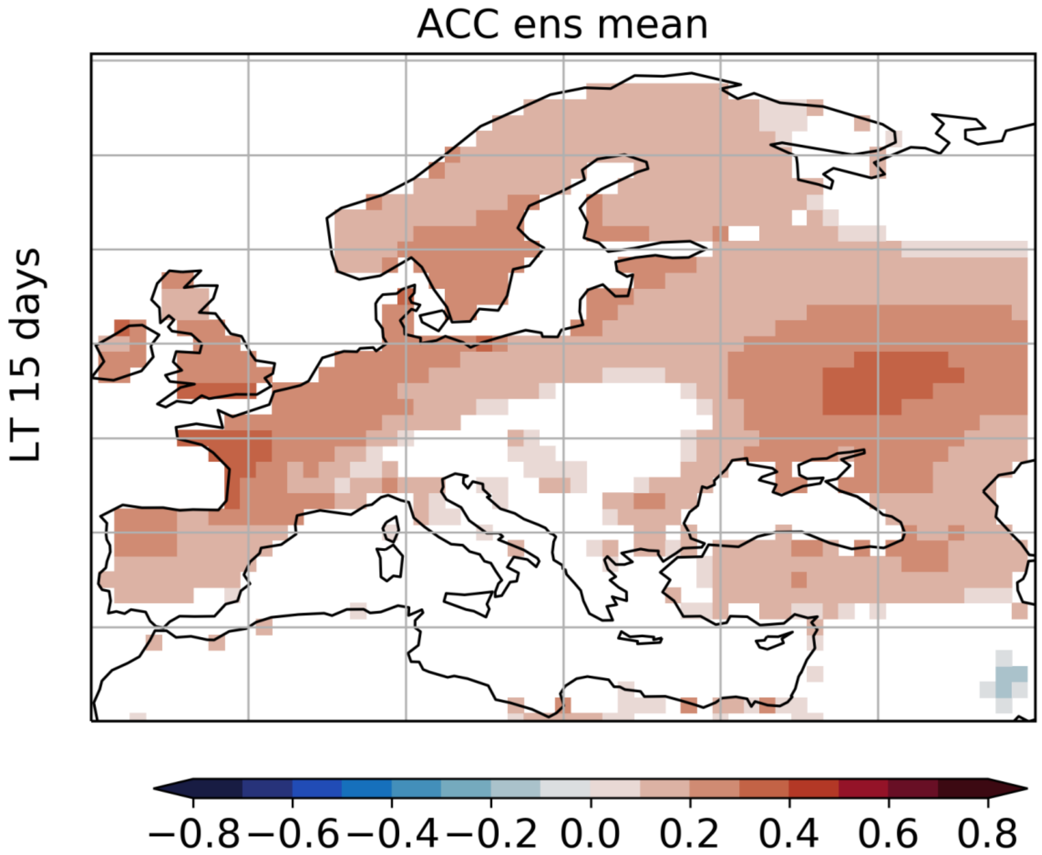
Surface temperature prediction skill



10 days lead time

ACC < 0.5 over whole domain

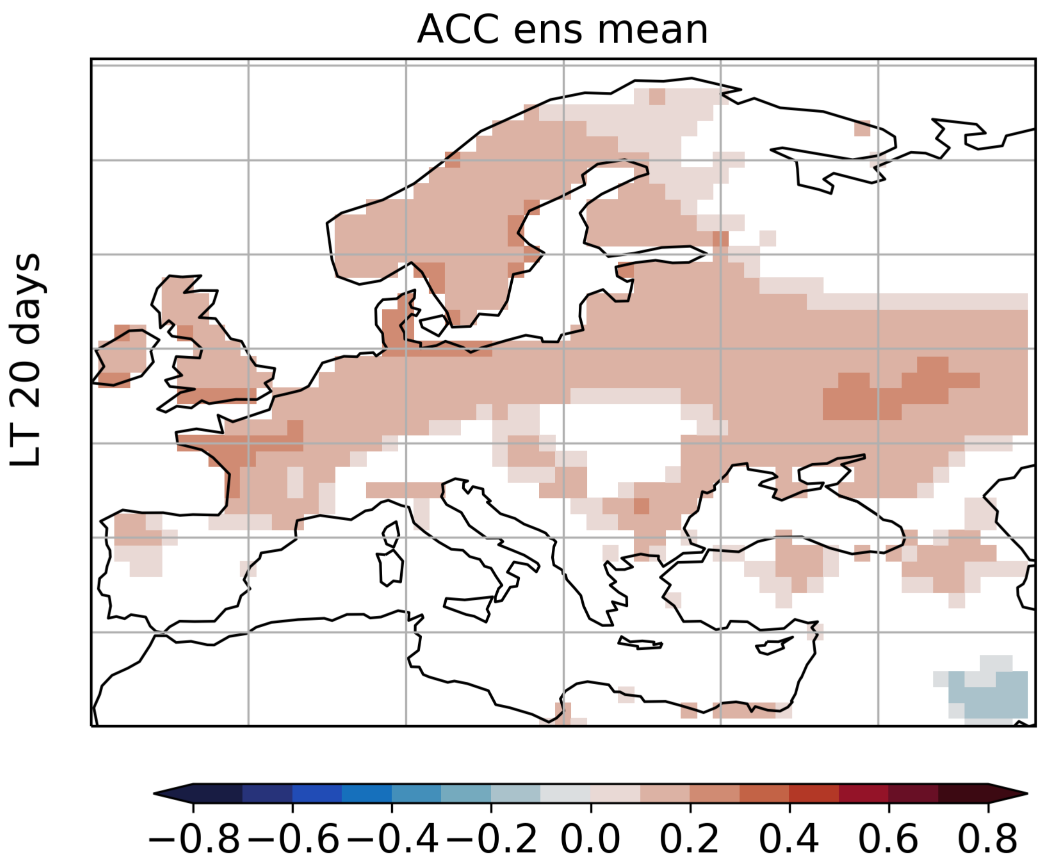
Surface temperature prediction skill



15 days lead time

ACC < 0.4 over whole domain

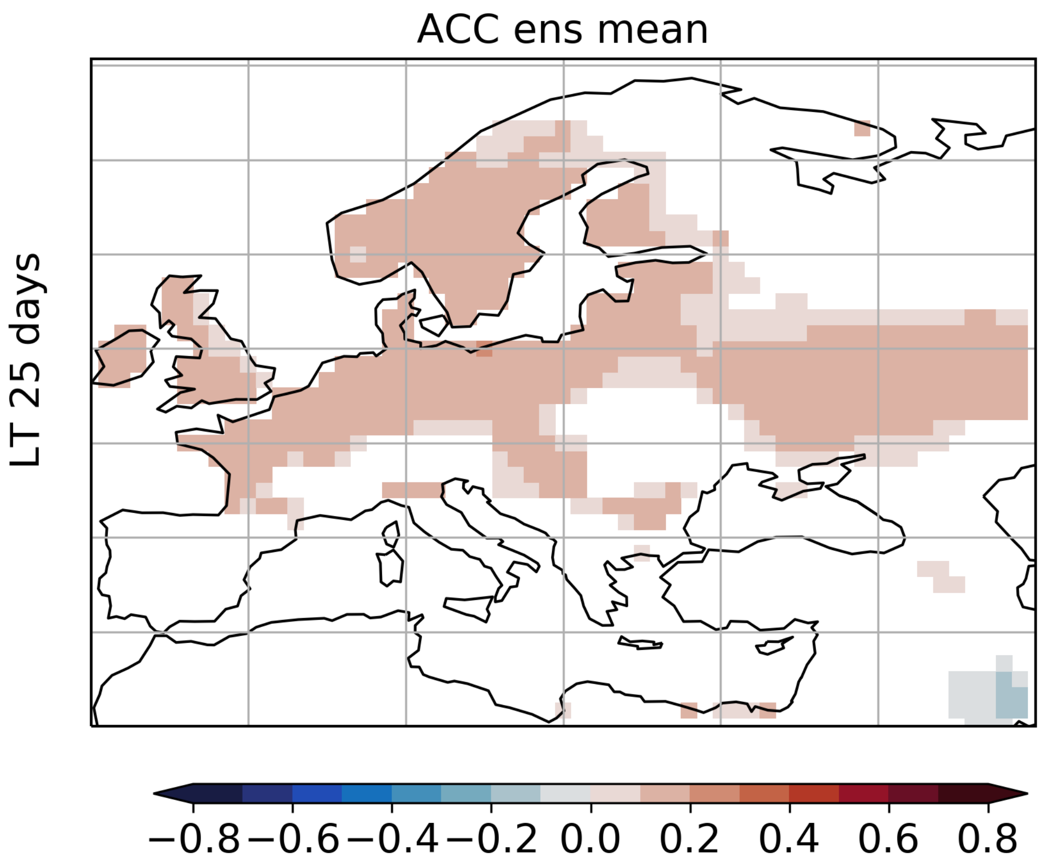
Surface temperature prediction skill



20 days lead time

ACC < 0.3 over whole domain

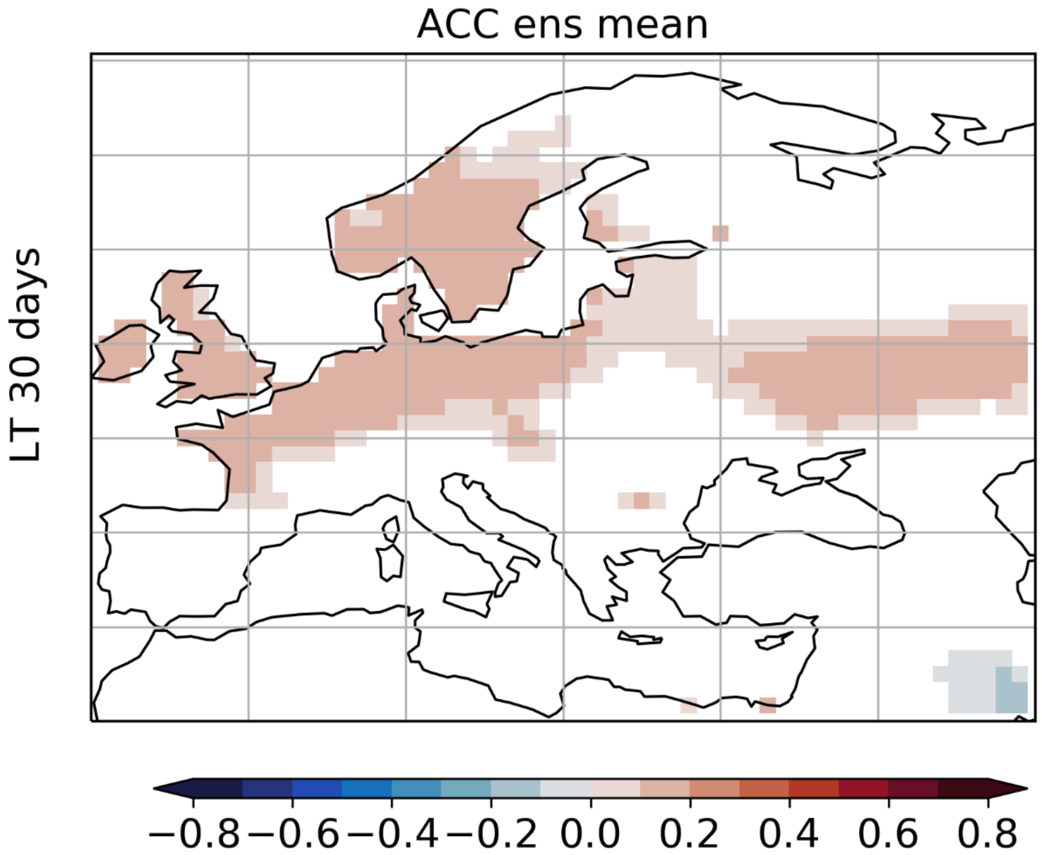
Surface temperature prediction skill



25 days lead time

ACC < 0.2 over whole domain

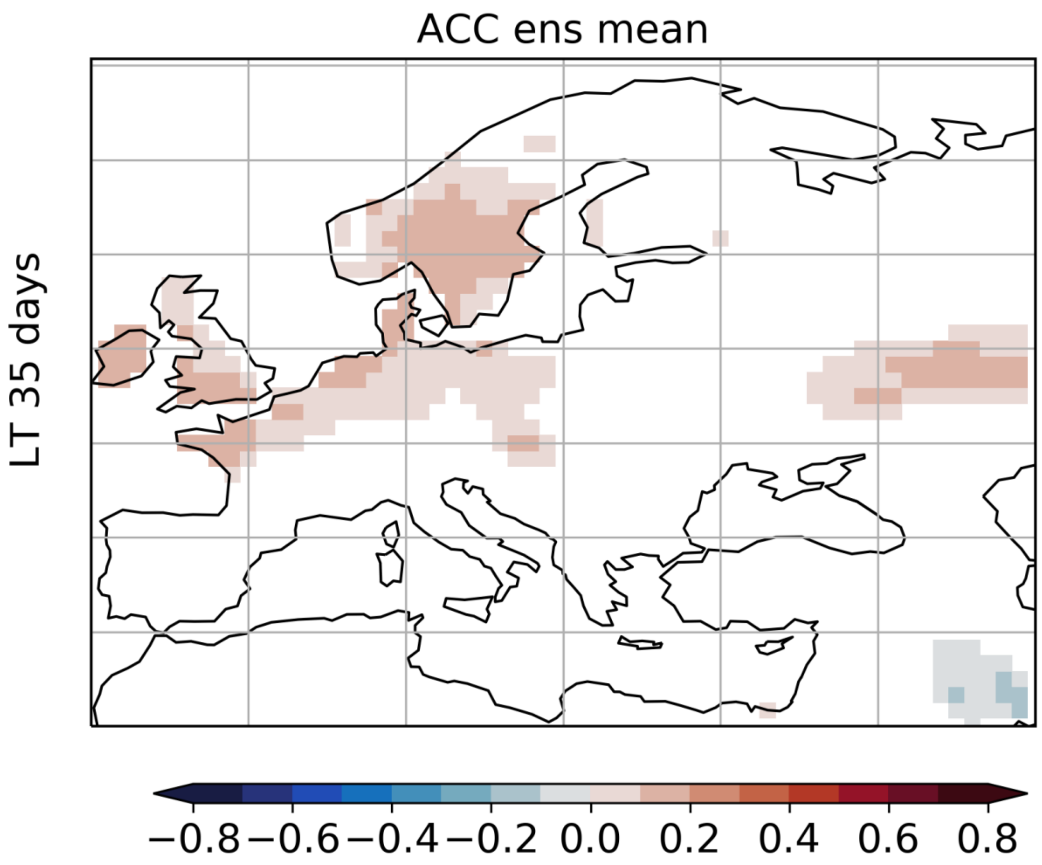
Surface temperature prediction skill



30 days lead time

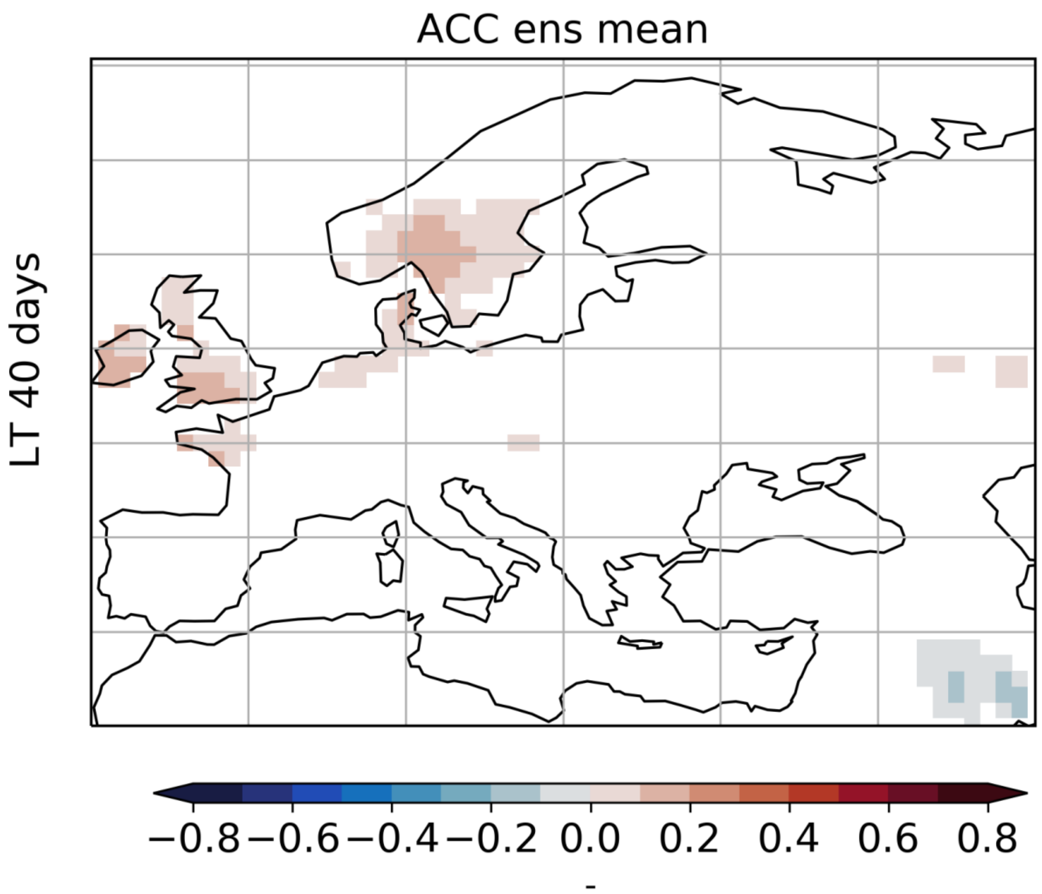
Small but significant predictable signal remains

Surface temperature prediction skill



35 days lead time

Surface temperature prediction skill



40 days lead time

Are extremes more predictable than climatology?

- Need a **base rate independent** measure for the prediction skill → the Odds Ratio (**OR**, *Stephenson, 2000*)
  - Ratio of odds of making a hit to the odds of making a false alarm

$$OR = \left(\frac{H}{1-H}\right)\left(\frac{F}{1-F}\right)^{-1}$$

- Transform to Skill Score: OR Improvement over **random** forecast → the **ORSS**
  - Compare forecasts of 50th vs. 95th percentile events

$$ORSS = \frac{OR - 1}{OR + 1}$$

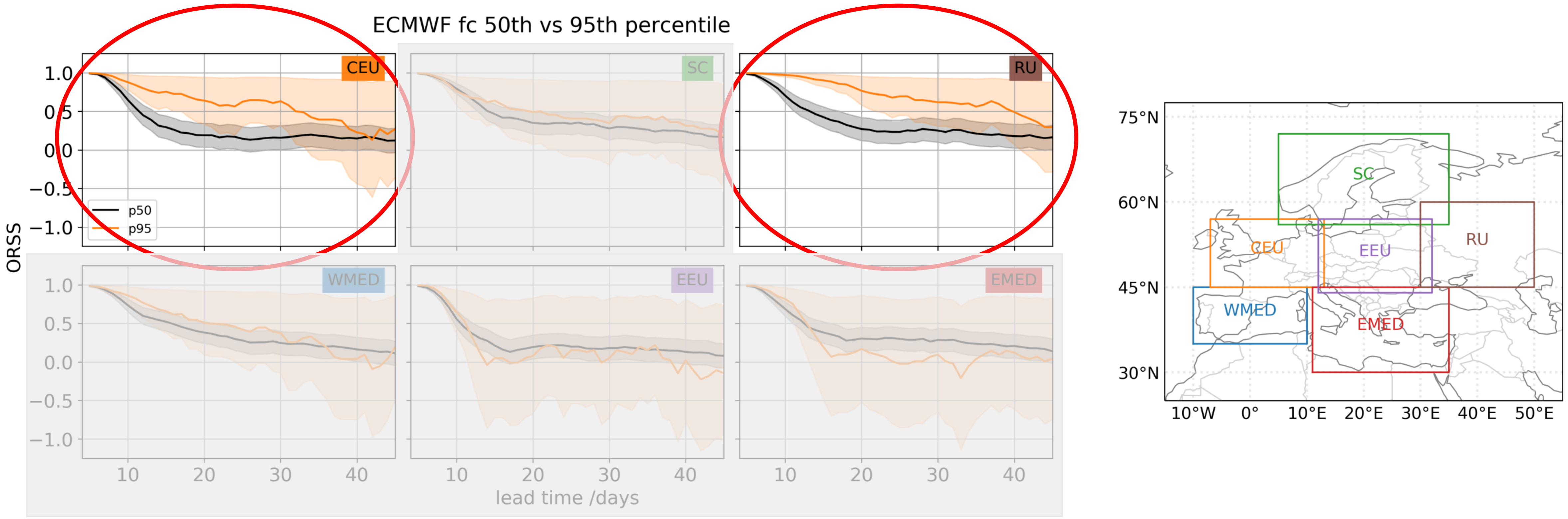
- Skill Score relative to **persistence**

  → OR Benefit Skill Score (**ORBSS**, *Mittermaier, 2008*)

$$ORBSS = \frac{OR - OR_p}{OR + OR_p}$$

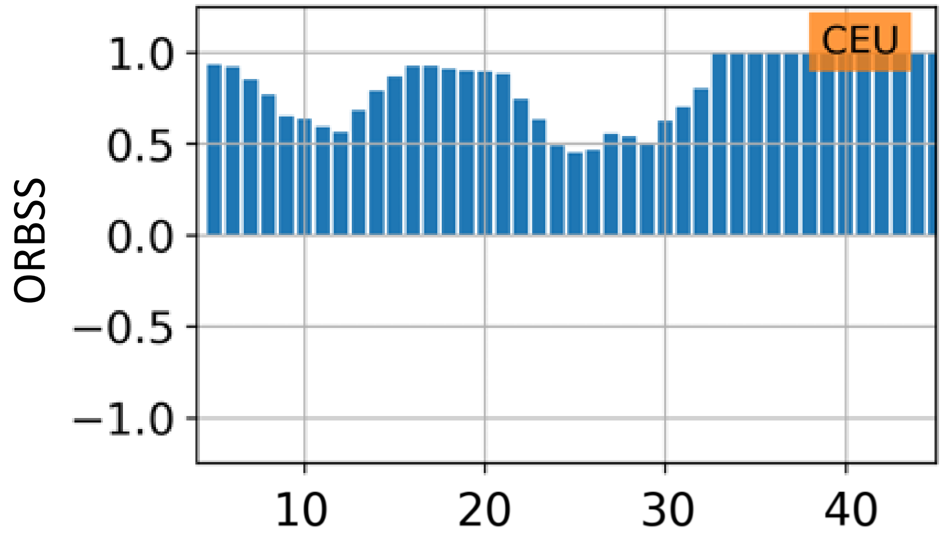
H: hit rate; F: false alarm rate

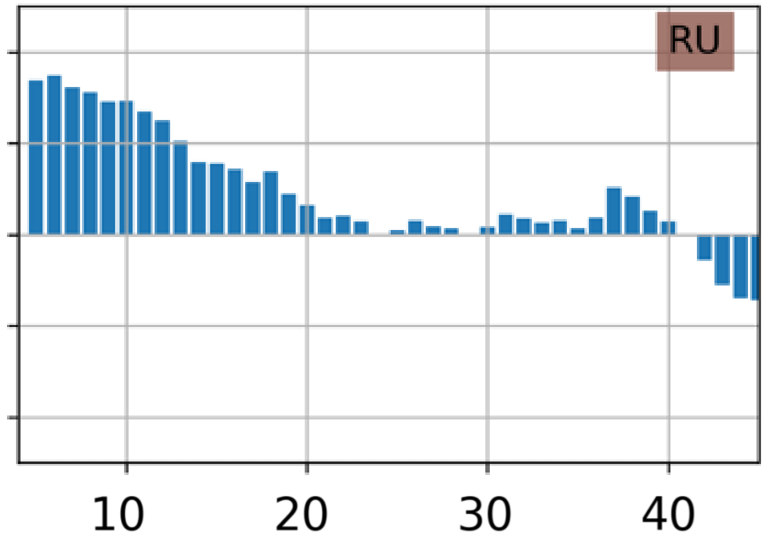
Extended predictability of extremes in CEU & RU regions



ORSS indicates extended predictability of extreme temperatures in western Europe (CEU) and western Russia and the Ukraine (RU)

Extreme temperature skill through persistence?



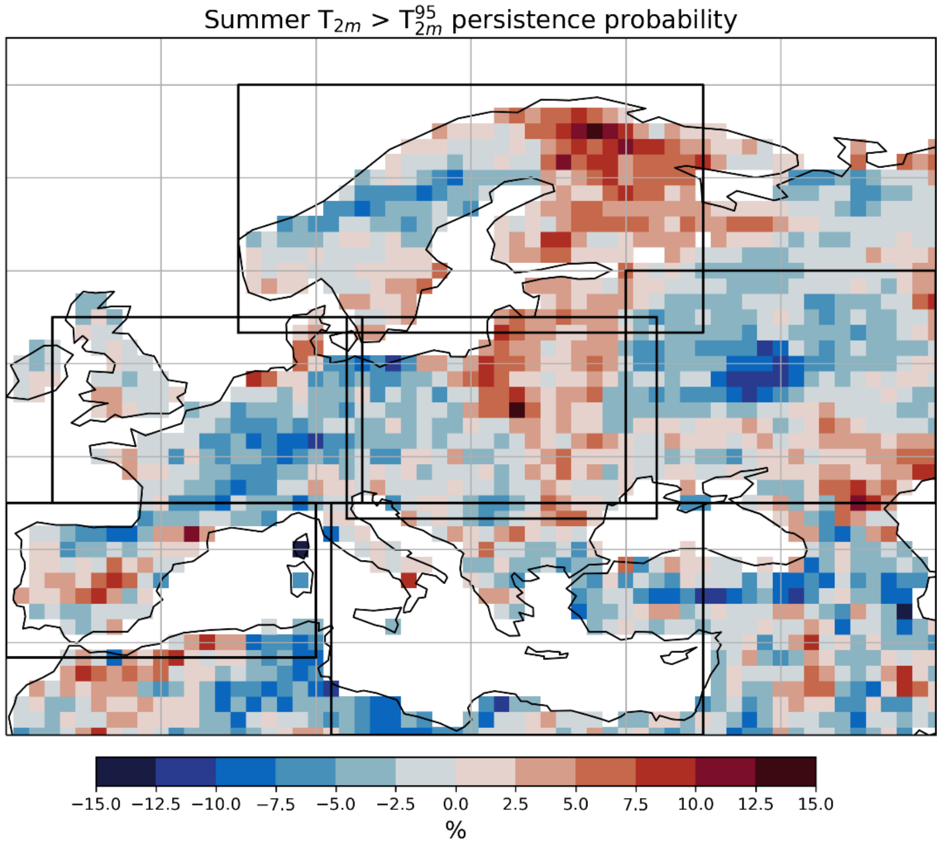


Persistence cannot explain the skill in the CEU region

Large part of the skill at sub-seasonal lead time in RU region comes from persistence

Extreme temperature persistence in ECMWF model

ERA-Interim - ECMWF hindcasts lead time 18-22 days

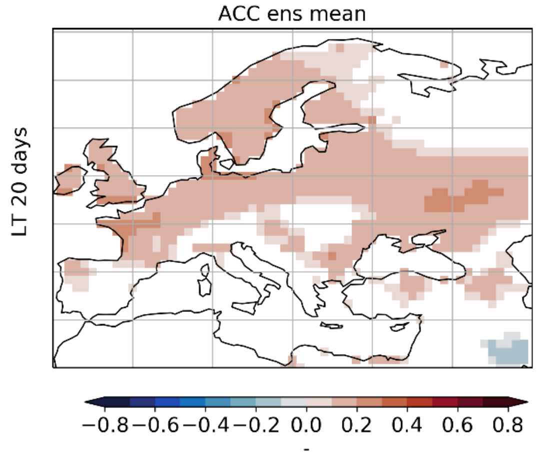


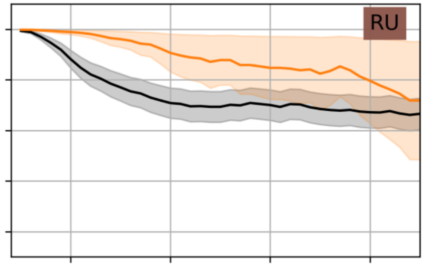
Difference in persistence probability for 95th percentile events between ERA-Interim and ECMWF model

In RU region rather underpersistence for subseasonal lead times
→ The model does not just predict persistence all the time

Conclusions

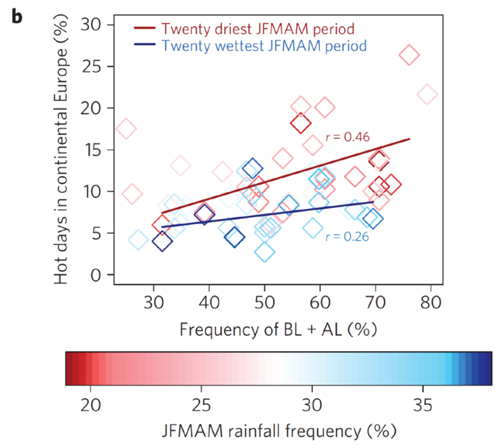
- There are predictable signals in weekly surface temperature at subseasonal lead times in some European regions
- In north-western Europe (CEU) and western Russia and the Ukraine (RU), **prediction skill for surface temperature extremes is larger than for average temperatures**
- In RU, large part of the skill can be attributed to persistence of extreme temperatures (especially during the 2010 event)





Outlook

- How strongly is persistence determined by land-atmosphere interactions?
- What is the role of atmospheric circulation regimes in extreme temperature forecast skill at S2S lead times?
- What is the influence of a drift of the main modes of circulation?
- How do different S2S hindcast products compare?



from Quesada et al. (2012)

Thank you for your attention!

References

Cassou et al., *Tropical Atlantic influence on European heat waves,* 2005, Weather 59 (8)

Duchez et al., *Drivers of exceptionally cold North Atlantic Ocean temperatures and their link to the 2015 European heat wave*, 2016, Environ. Res. Lett. 11 (20)

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Stephenson, *Use of the "Odds Ratio" for Diagnosing Forecast Skill,* 2000, Weather and Forecasting 15 (2)

Vitart et al., *The subseasonal-to-seasonal (S2S) prediction project database*, 2016, Bull. Amer. Meteorol. Soc. 98 (1)

Wulff et al., *Tropical Forcing of the Summer East Atlantic Pattern*, 2017, GRL 44 (21)

Odds Ratio

$$OR = \frac{\left(\frac{H}{1-H}\right)}{\left(\frac{F}{1-F}\right)}$$

$$H = \frac{hits}{hits + misses}$$

$$F = \frac{false\ alarms}{false\ alarms + correct\ negatives}$$

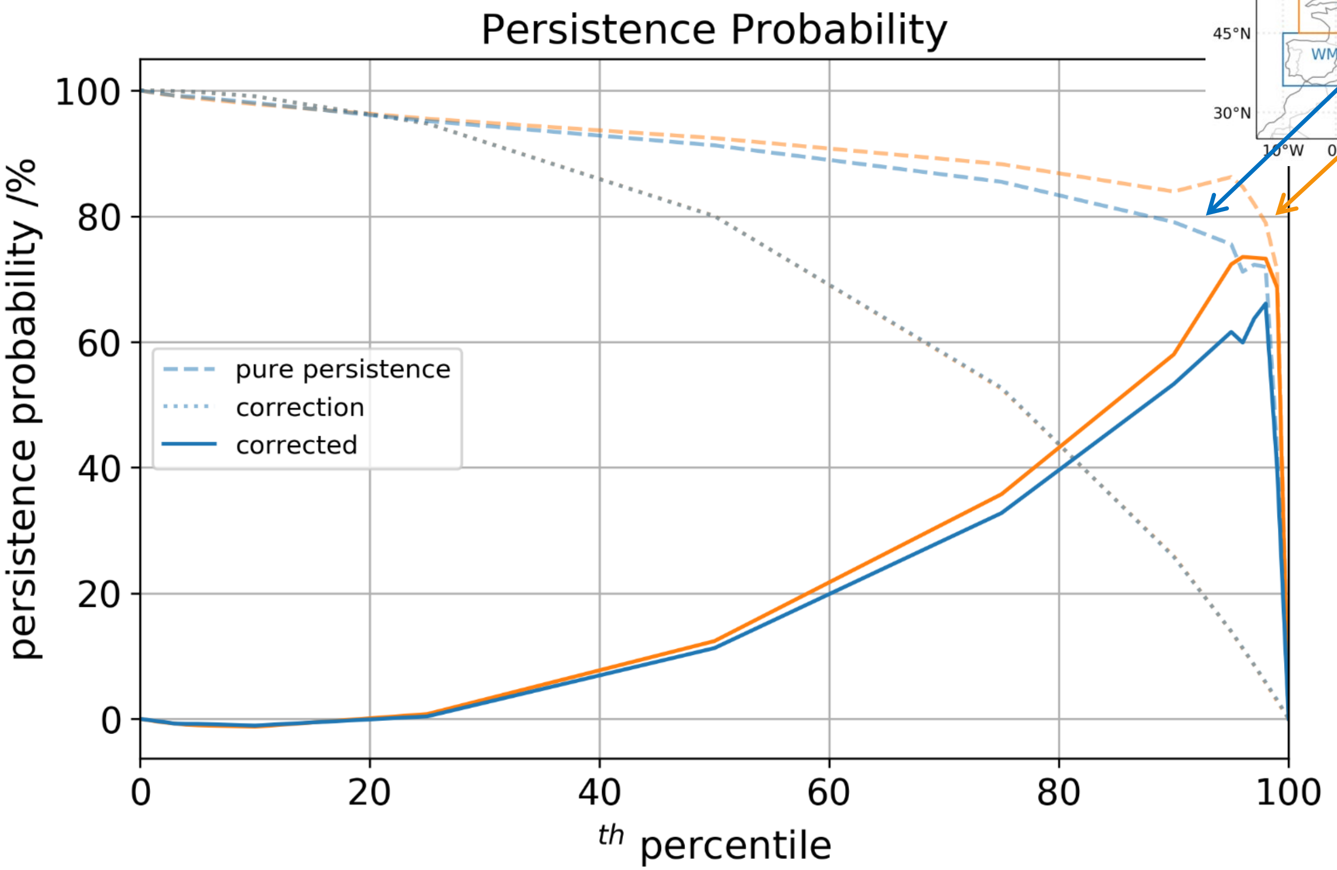
OR is the ratio of the odds of a “yes” forecast being correct to the odds of a “yes” forecast being wrong

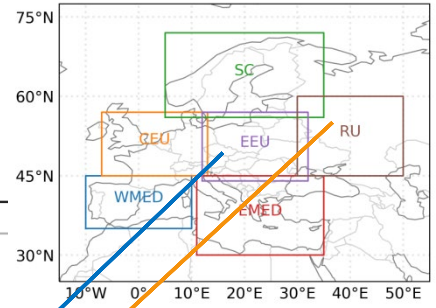
(see http://www.cawcr.gov.au/projects/verification/)

Persistence probability dependence on threshold

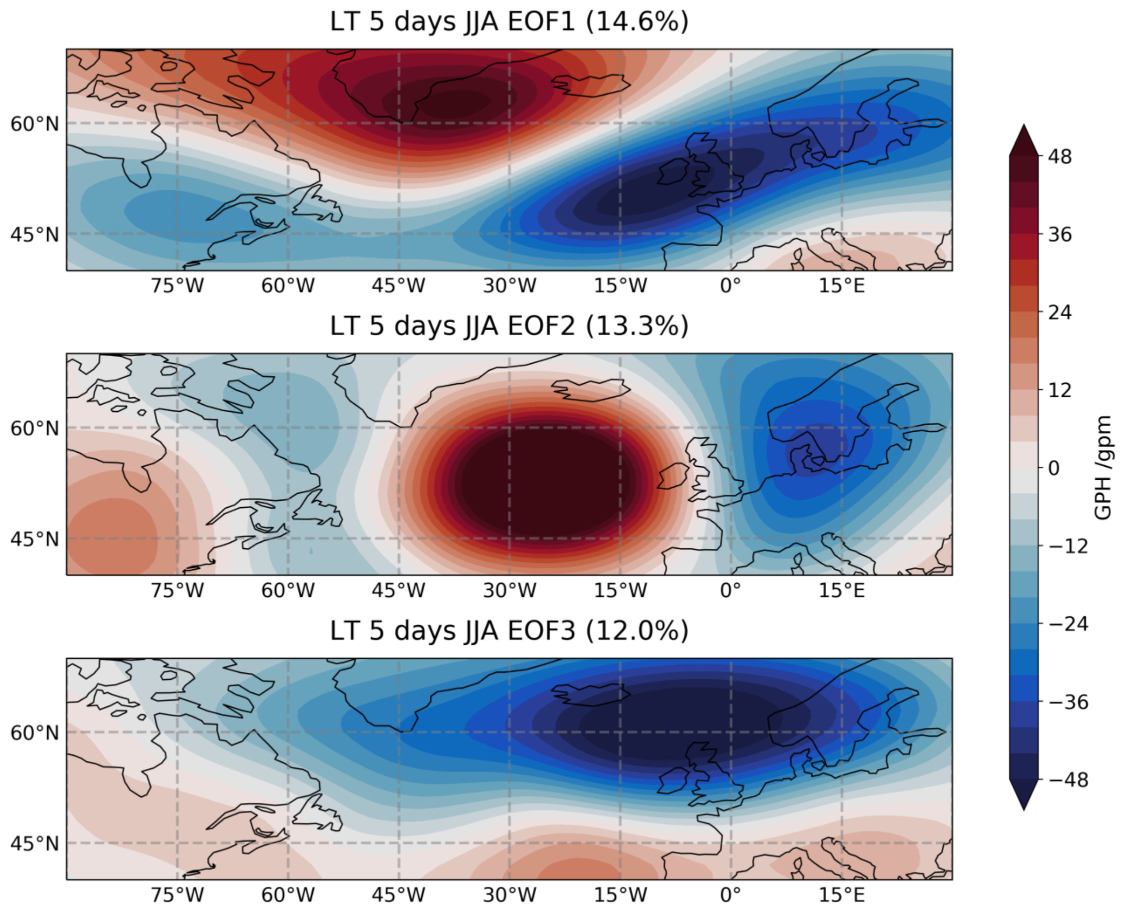
Strong dependence on chosen percentile threshold remains after correcting

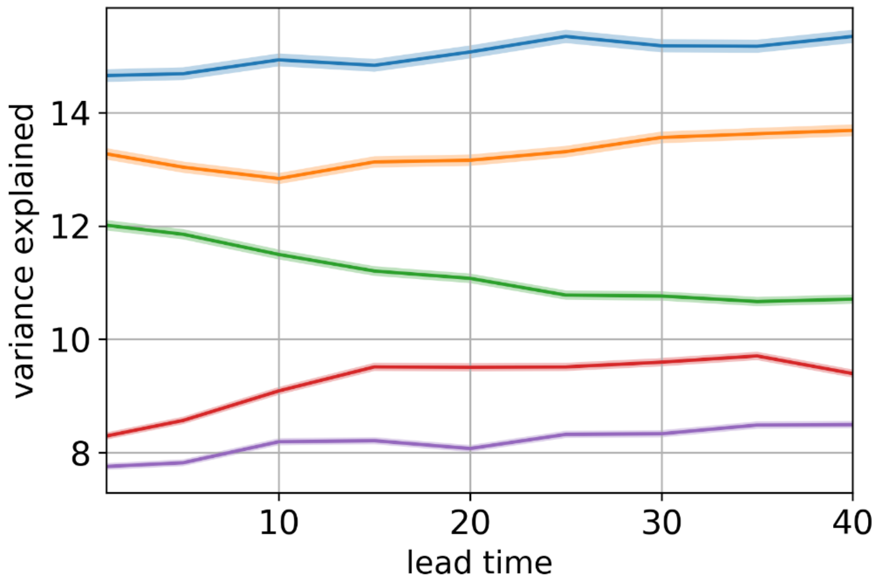
Persistence probability for high temperatures exceeds what is expected for a random time series more strongly than for average temperatures





How are SNAO and SEA predicted?





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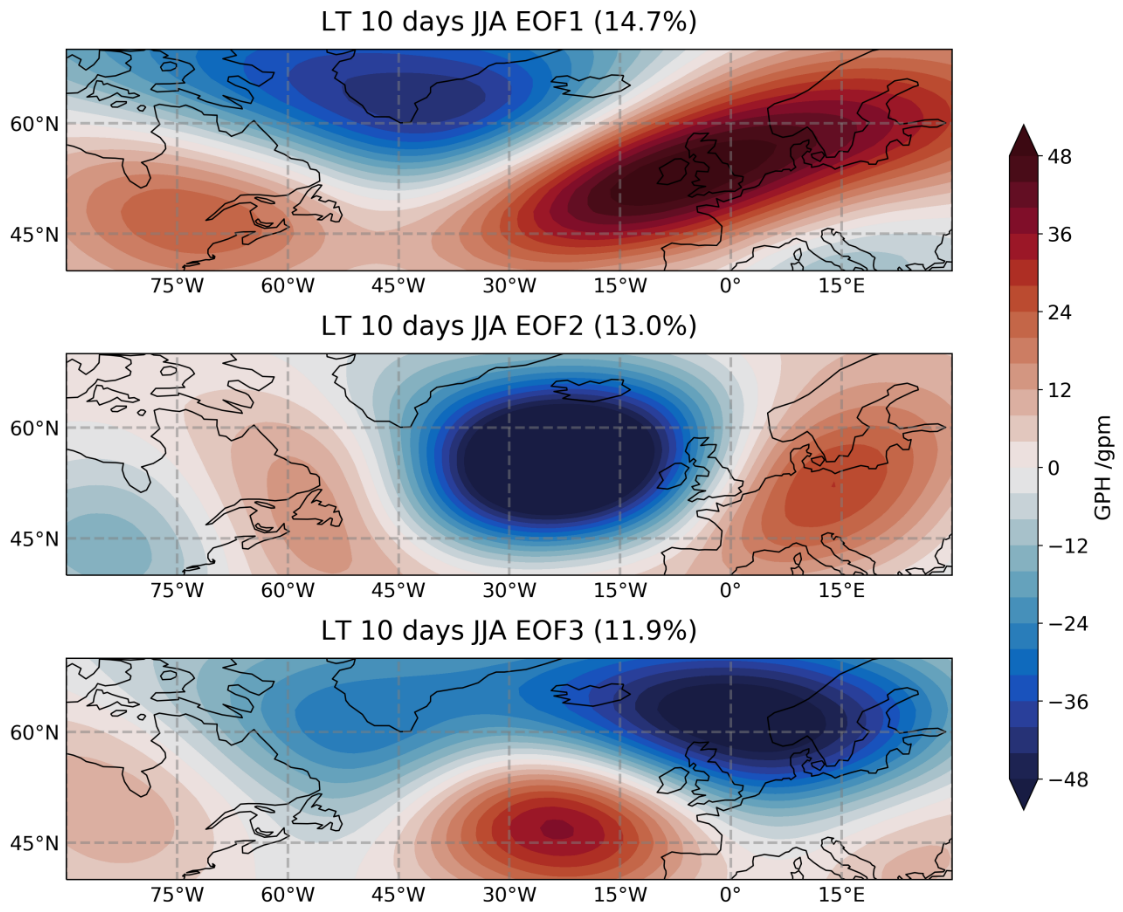

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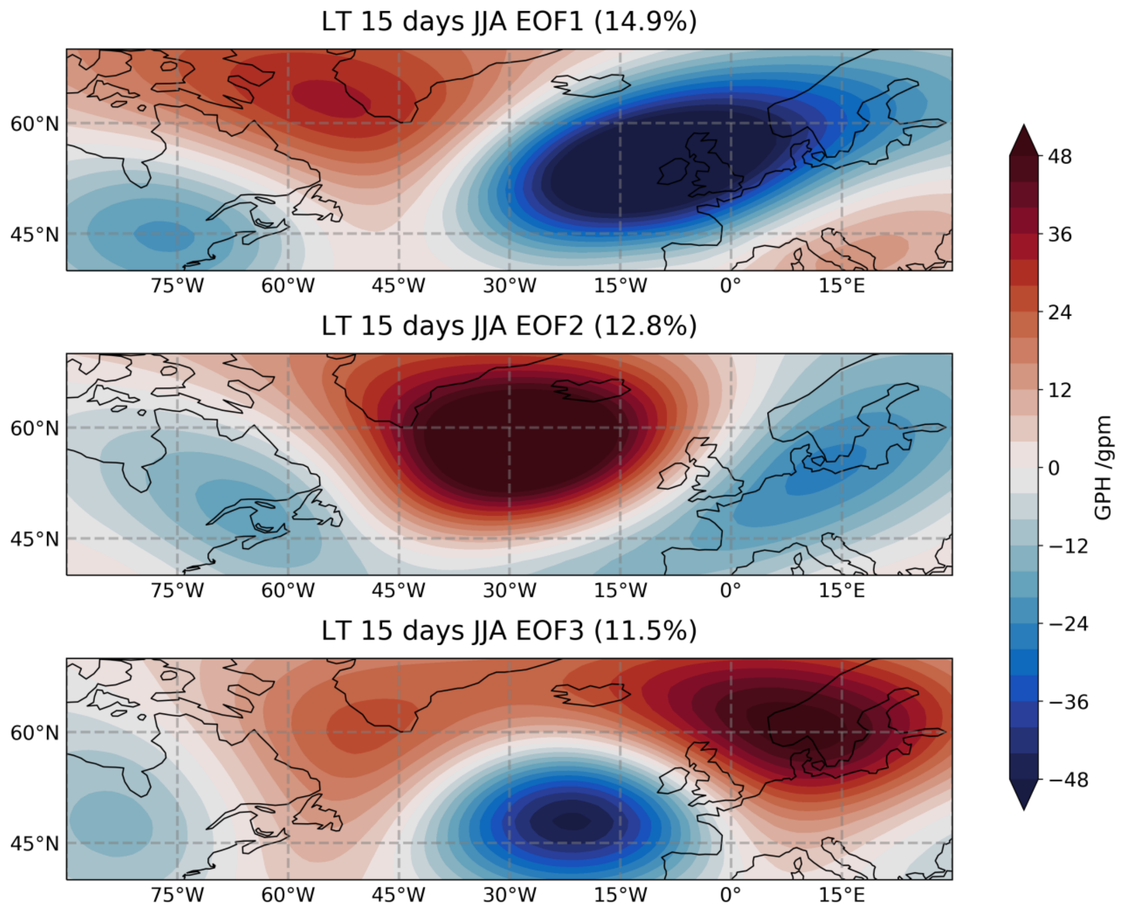

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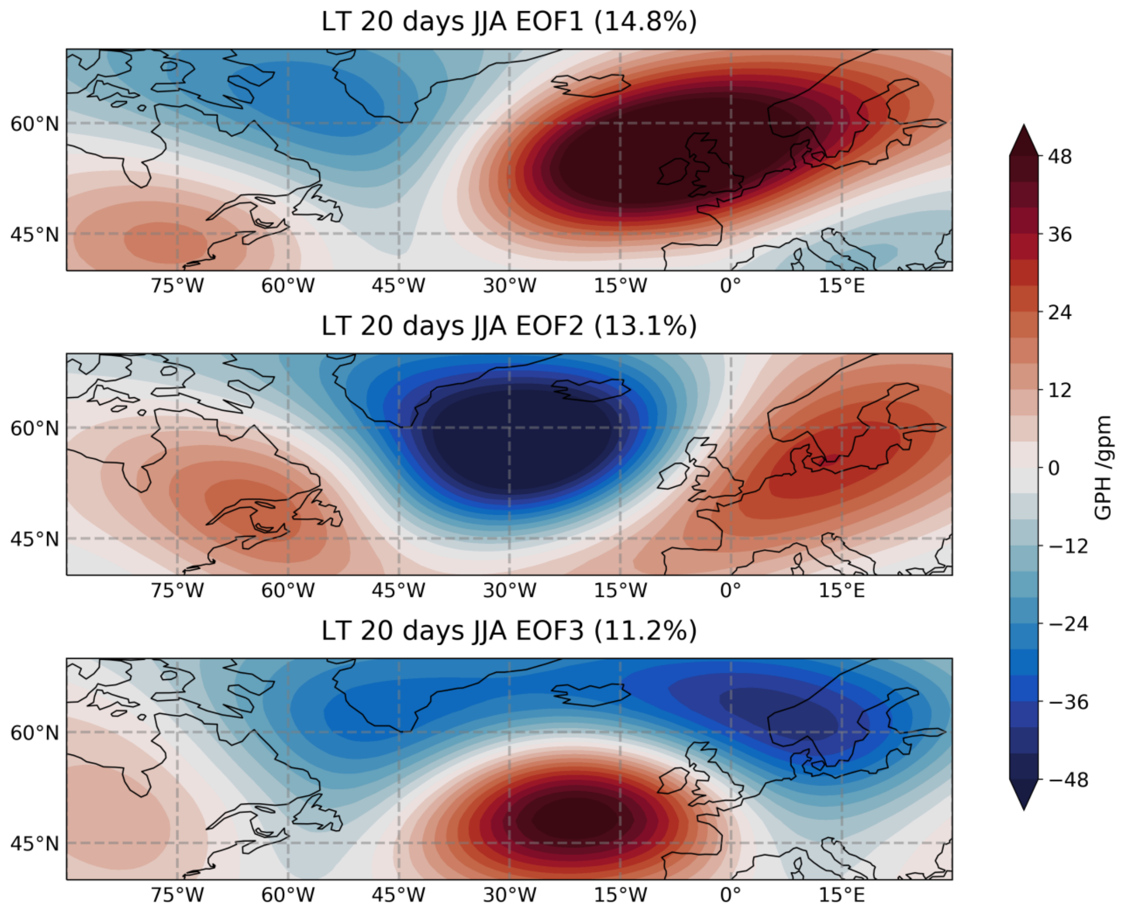

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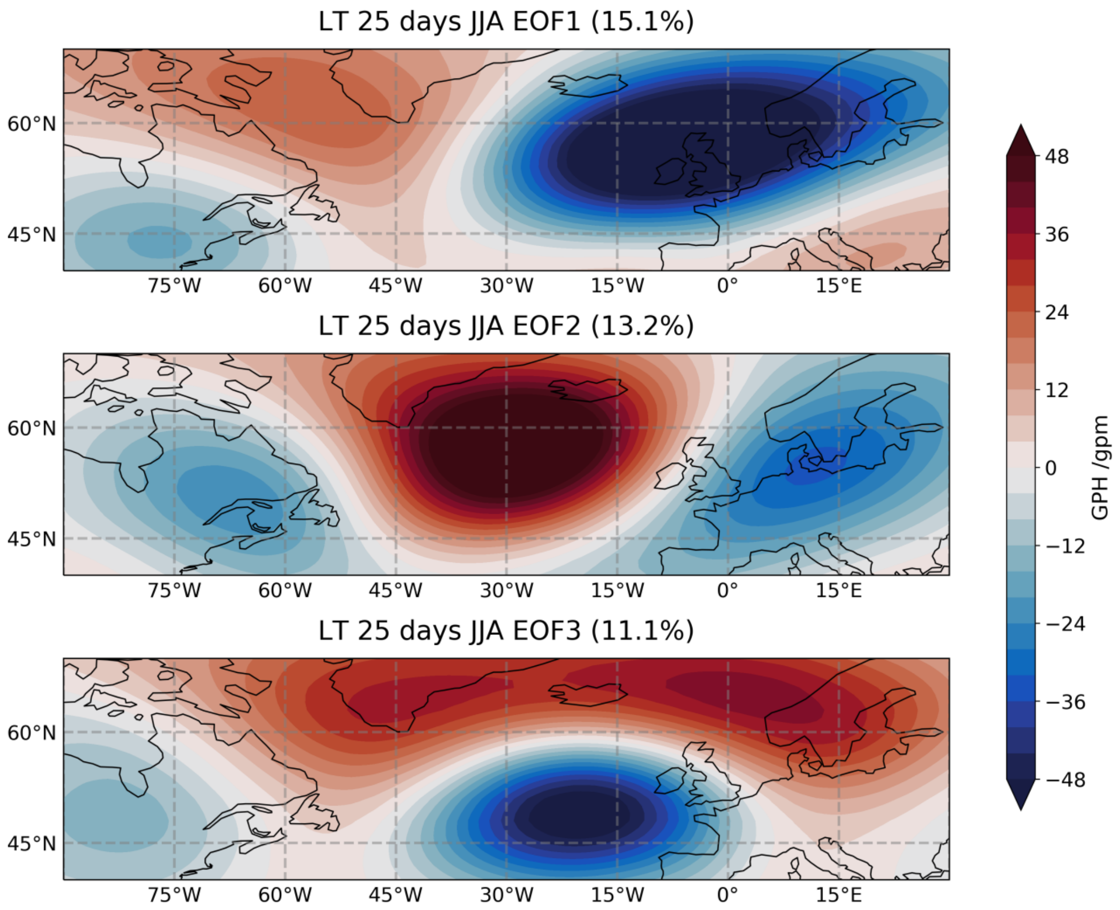

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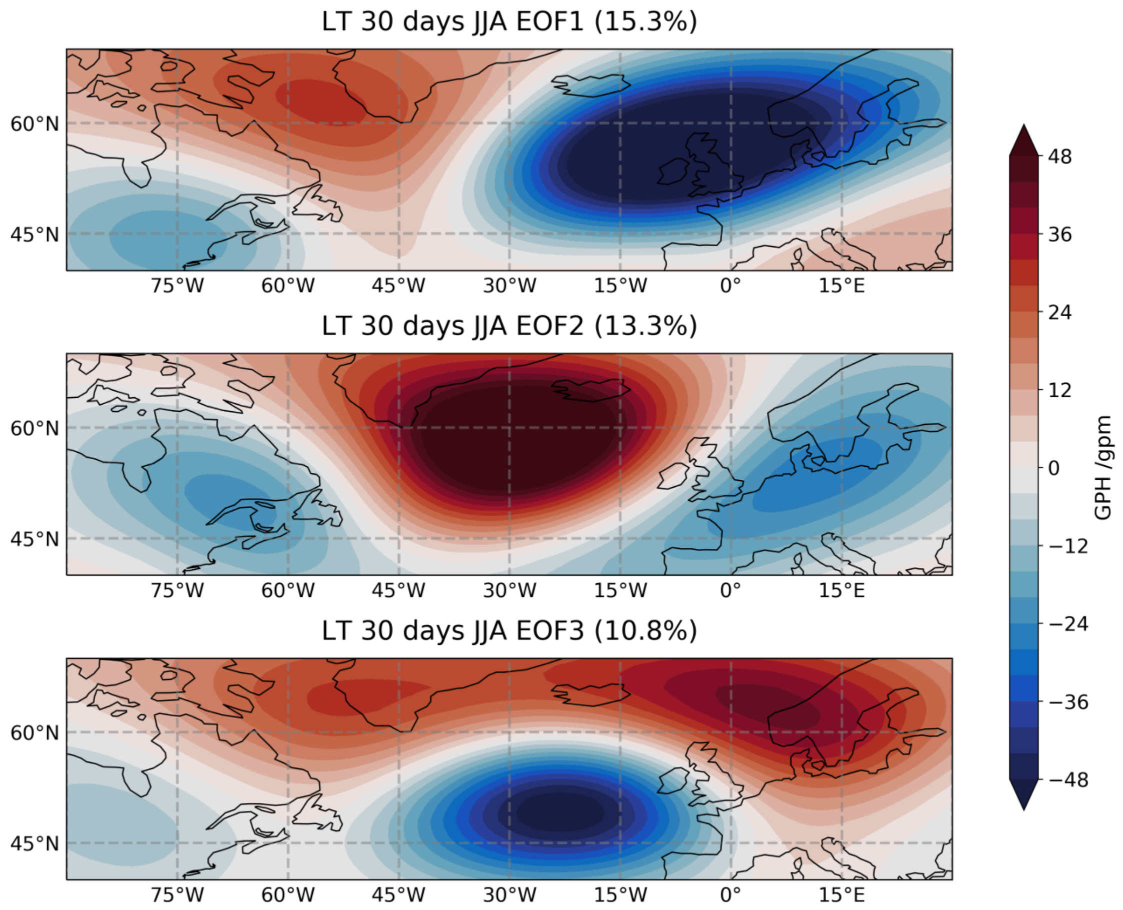

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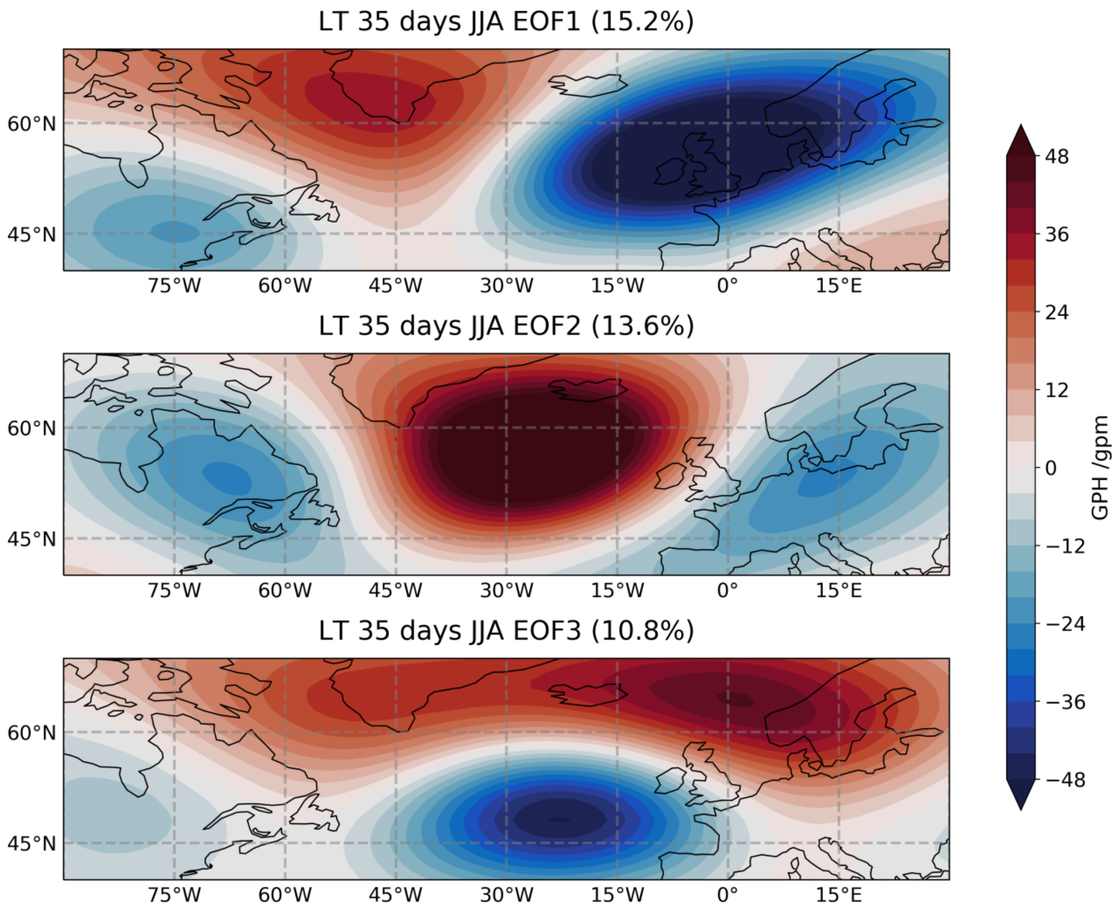

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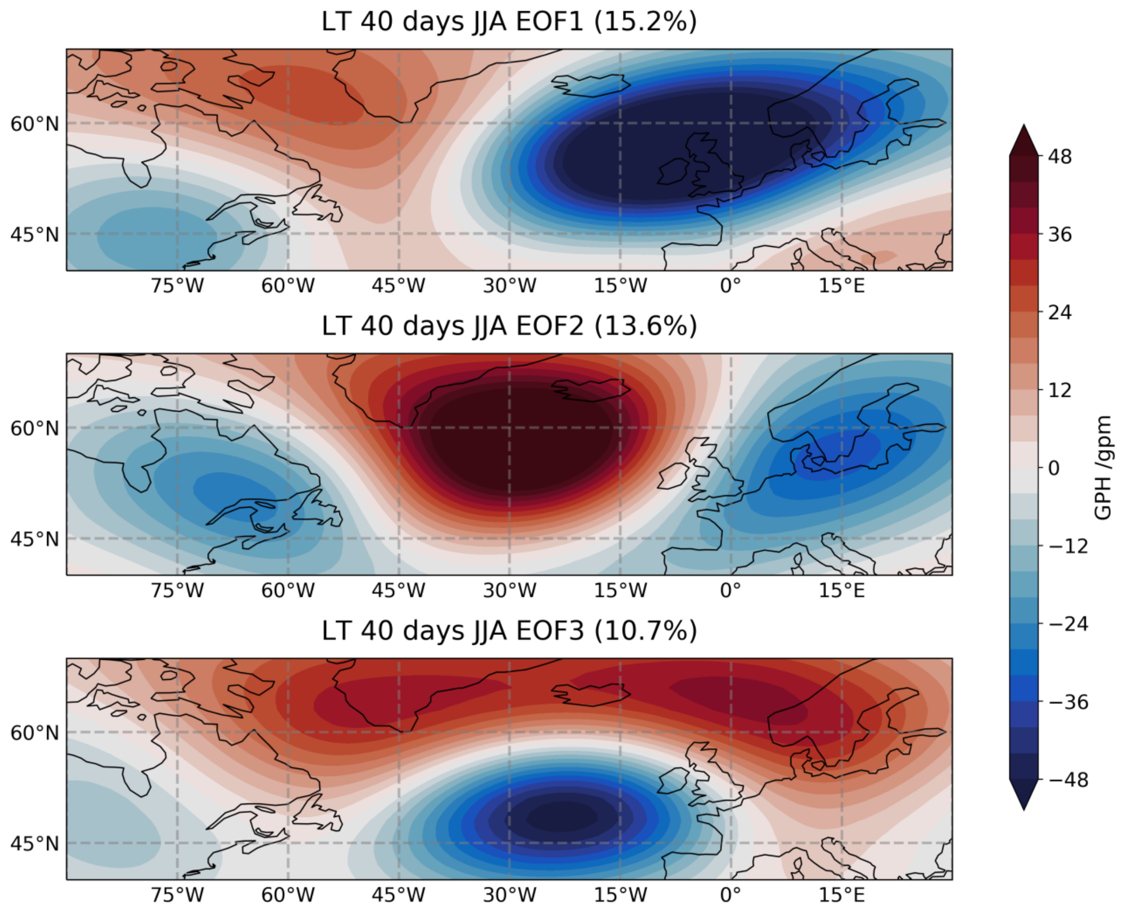
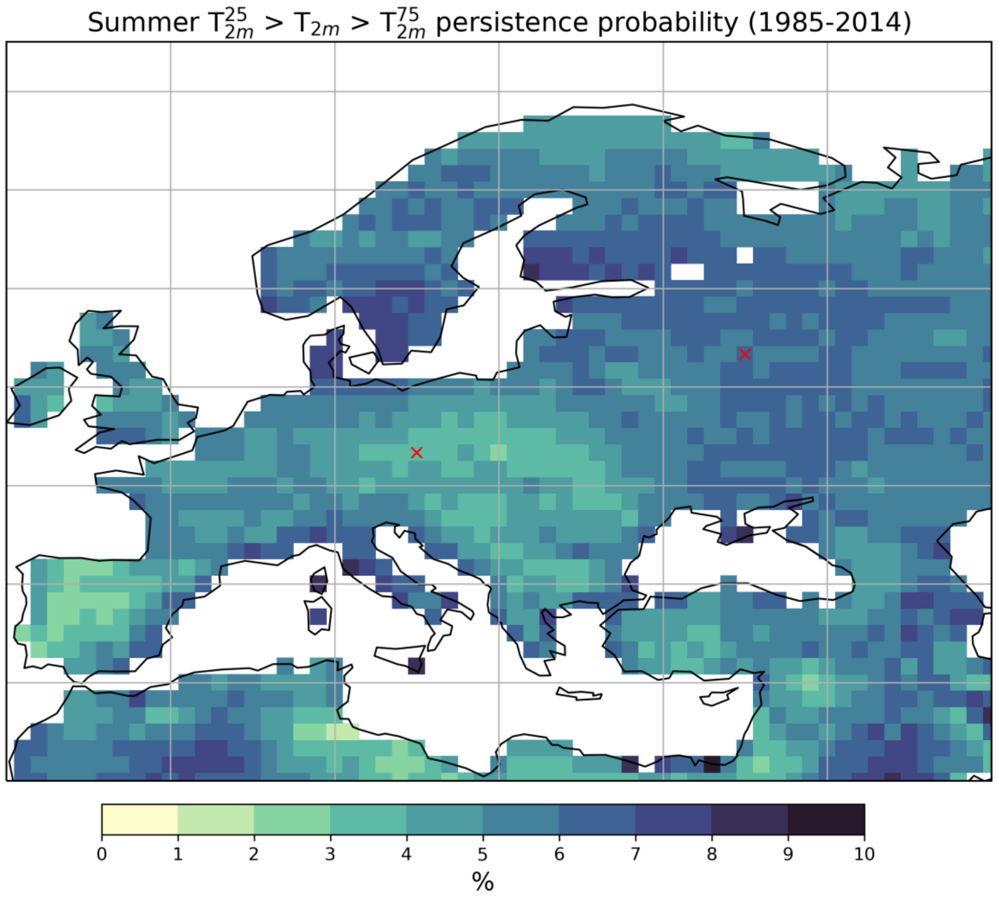
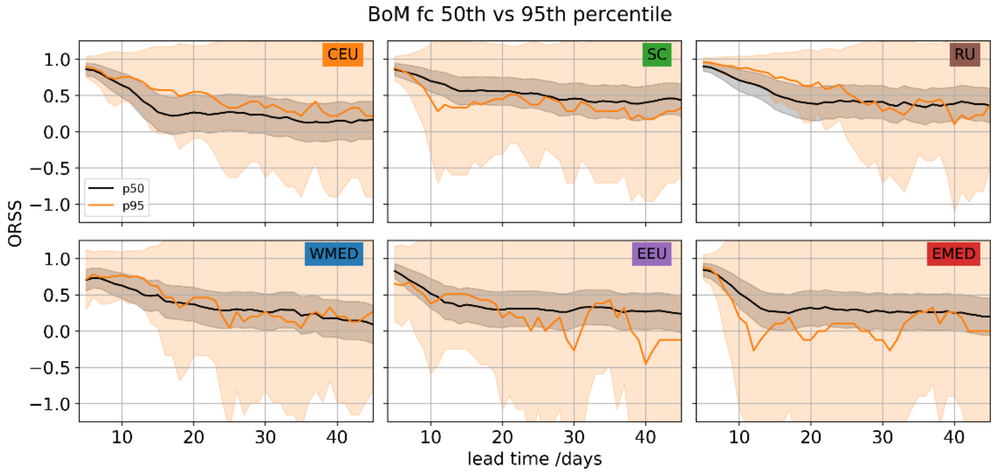


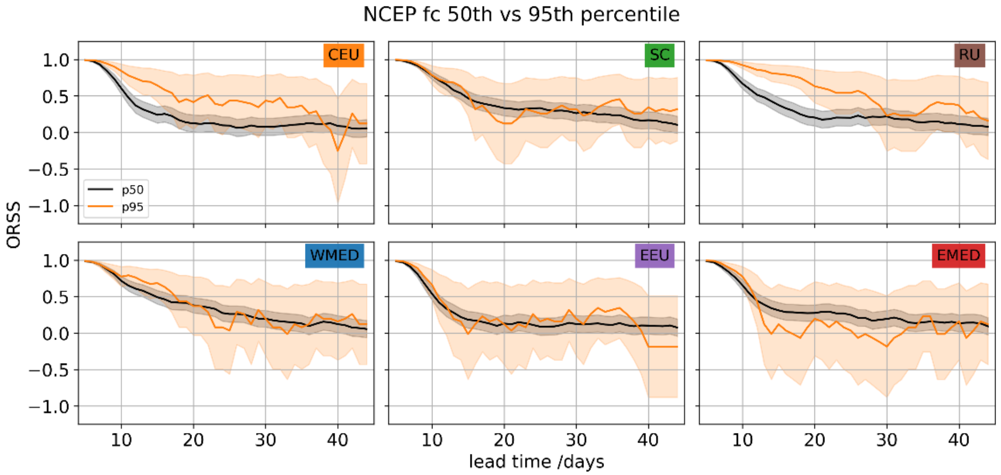
Similar for all models but some (CMA, NCEP) do not separate EOF2 and 3 anymore at longer leads

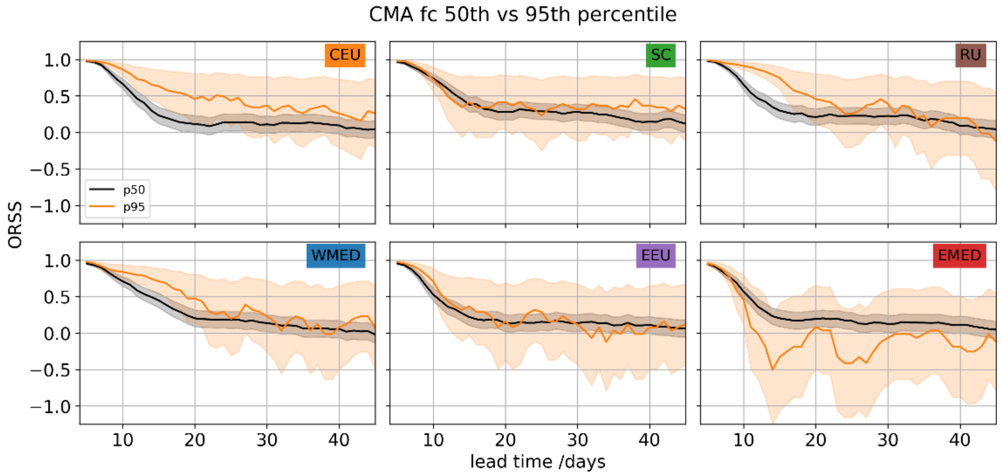


ERA-Interim persistence of inner quartile temperatures

50^{th} vs 95^{th} percentile forecast skill other models







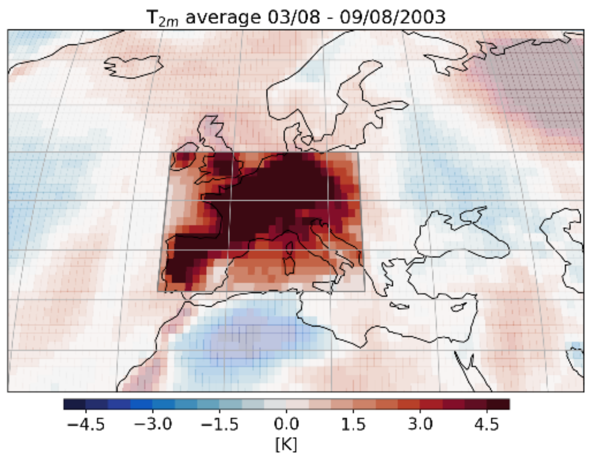
Extreme temperature events

Extreme temperature event

Defined as a period of at least 3 days in which **2m temperature exceeds the 95th percentile of the monthly climatology**. Each event must be separated from the previous by at least 3 days.

Here limited to **JJA** and **land areas** in the region indicated to the right

→ **11 events** in the period of 1999-2010 obtained from daily **ERA-Interim** reanalysis



Ensemble hindcasts

From 4 forecasting systems (ECMWF, BoM, CMA, NCEP) in the S2S data base (Vitart et al., 2016) with:

- Different ensemble sizes
- Different initialization strategies (frequency, ensemble generation)
- Common period covered: 1999-2010
- Ocean and sea ice coupled
- …