



Model evaluation of compound precipitation and wind extremes over Europe

Laura E. Owen¹

Jennifer L. Catto¹, David B. Stephenson¹ and Nick J. Dunstone²

¹The University of Exeter, ²Met Office



Motivation & Problem

- The risk of very rare and unprecedented precipitation and wind events is largely unknown.
- These events hard to look at from the observational record due to the small sample size.

GloSea5

- The Global Seasonal forecast system version 5 (GloSea5) from the UK Met Office is an ‘experimental’ high resolution version of the climate model HadGEM3, with a resolution of 25 km (for details of the model setup see MacLachlan et al. [2015]).
- We use the high horizontal resolution version of GloSea5 (for details see Scaife et al. [2019]).
- 24 times more data than observations for 1993-2016.
- 24 seasons with 3 start dates (25th October and the 1st and 11th of November).
- Each season has 8 ensembles for each of these start dates.

But how well can GloSea5 simulate compound precipitation and wind extremes?

- We generate 24 timeseries of 3h total precipitation and 10m wind speed by drawing from each of the ensemble members.
- These are compared against 3h total precipitation and 10 m wind speed from the reanalysis dataset ERA5.
- All datasets in this study are from the period 1993 to 2016, for the winter season, December to February.

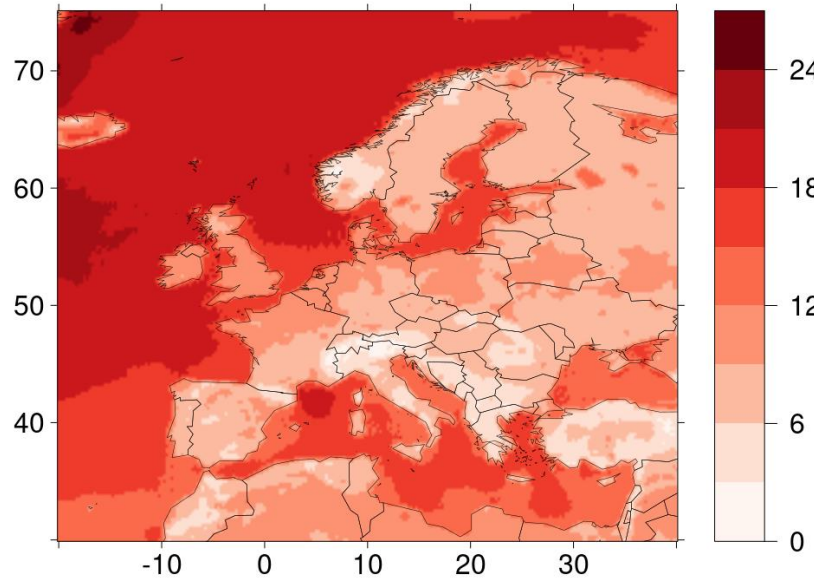


Wind extremes

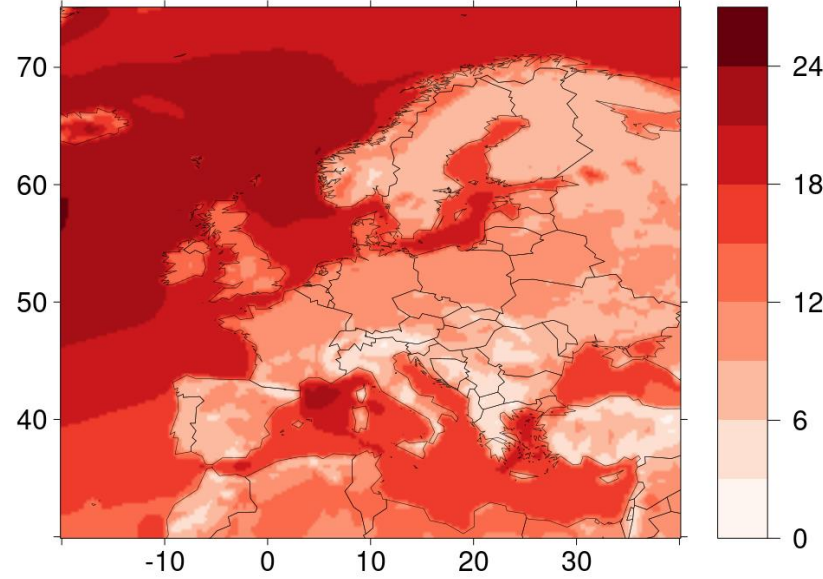
Wind speed above the 99th percentile for each gridpoint, for DJF, are taken as extreme. The GloSea5 mean 99th percentiles of wind speed are created by taking the mean of the 99th percentiles from each of the 24 GloSea5 model timeseries.

99th percentile 3 hourly 10 m wind speed (m/s)

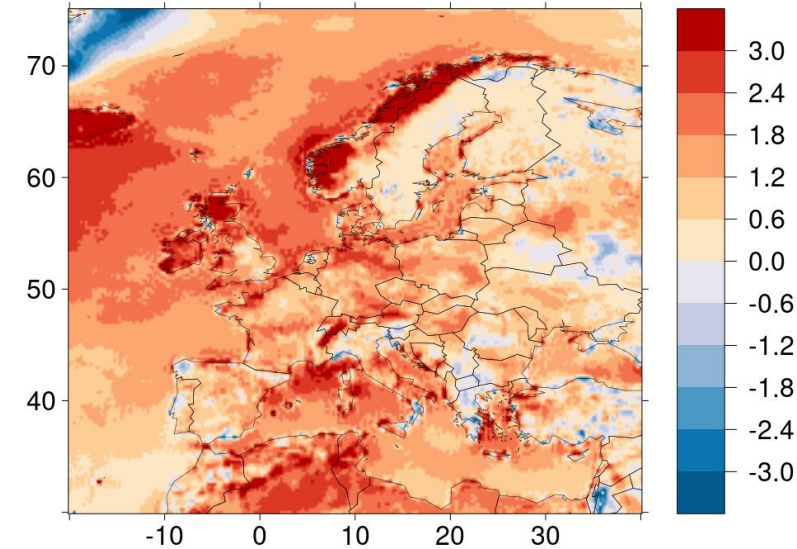
ERA5



GloSea5



wind difference



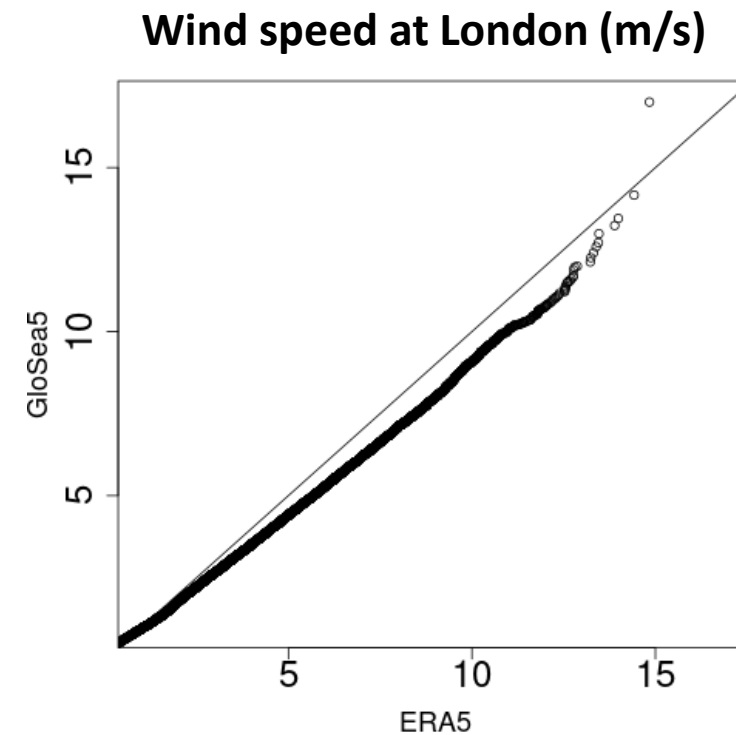
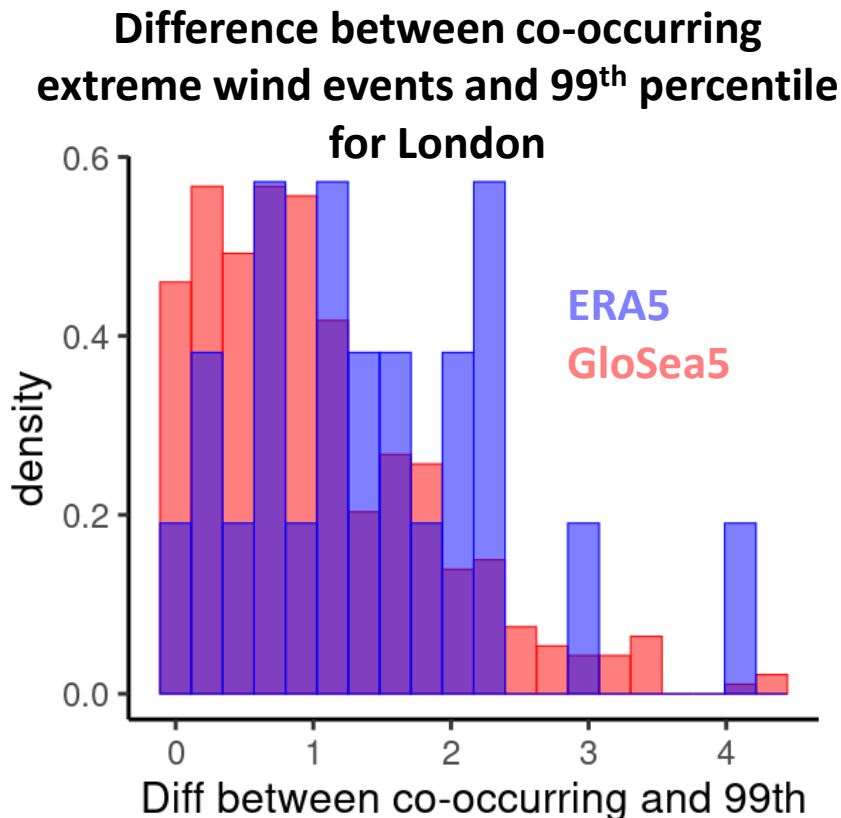
- The spatial pattern between ERA5 and GloSea5 compare well over Europe.
- However for most of Europe the magnitude of extreme wind in the model is overestimated. This is particularly true over areas of high topography.



Wind extremes: London

The model under and over estimates extreme wind and the number of extreme co-occurring wind events depending on location.

At London, GloSea5 underestimates wind speeds, except at the very extremes where wind speed is overestimated.



The histogram shows the distributions of the co-occurring wind and precipitation events larger than the 99th percentile wind.

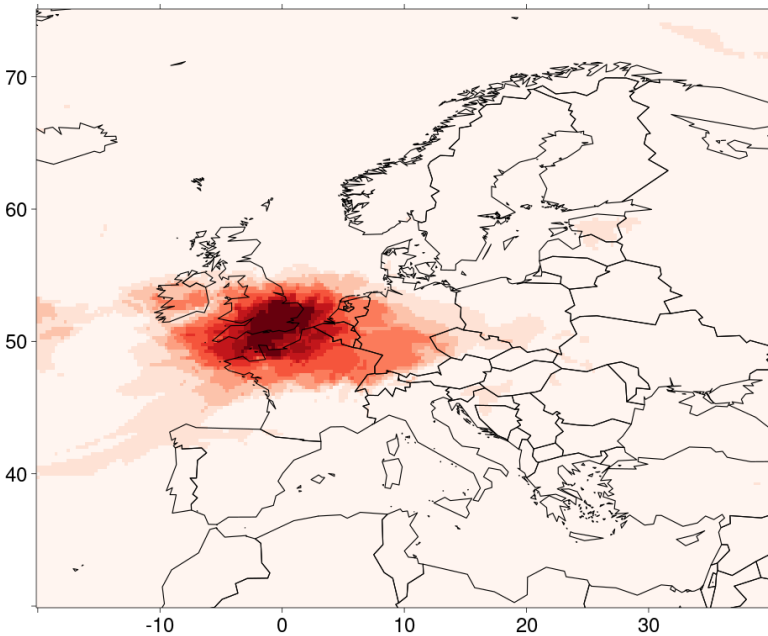
The distributions of the co-occurring wind events larger than the 99th percentile are very similar between the model and observations



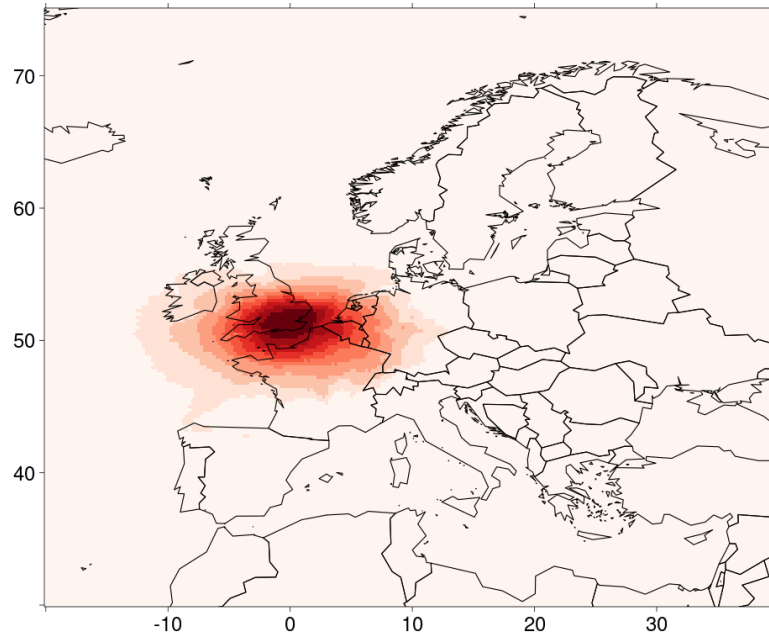
Wind extremes: London

Mean percentage of extreme (99th percentile) wind speed events when a 99.9th percentile wind speed event occurs at London

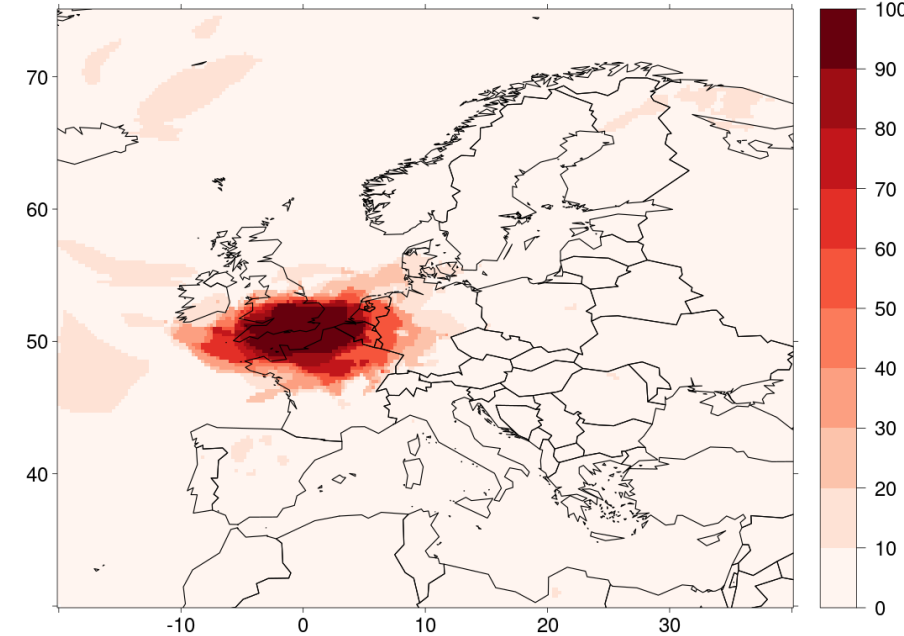
ERA5 17 events



GloSea5 408 events



GloSea5 top 10 most extreme events



- When a 99.9th percentile wind event occurs in London the majority of south east England and much of the English channel experiences a extreme 99th percentile event. A large footprint of extreme wind events is also found covering a circular area from southern England to Germany from North England to central France, the percentage of events slowly decreases as you travel away from London.
- The size and frequency matches well between GloSea5 and ERA5.
- The most extreme (top 10) wind events have a larger spatial footprint.

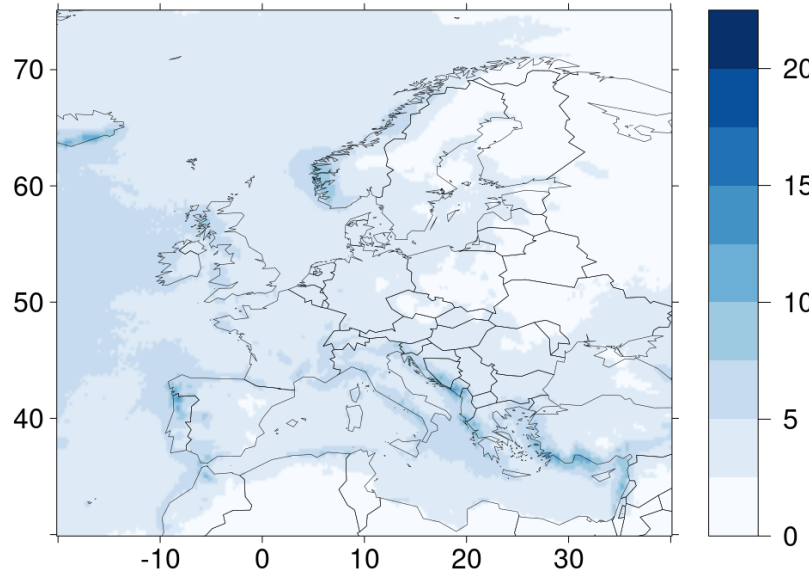


Precipitation extremes

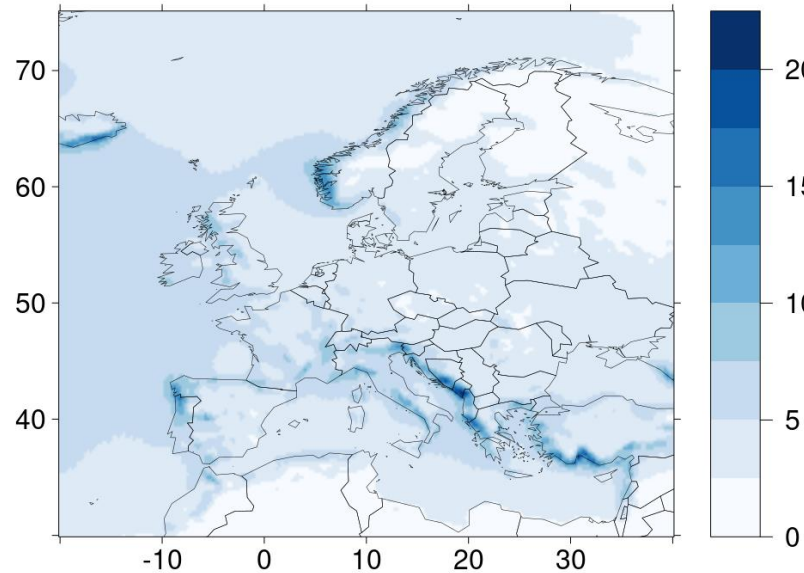
Precipitation above the 99th percentile for each gridpoint, for DJF, are taken as extreme. The GloSea5 mean 99th percentiles of precipitation are created by taking the mean of the 99th percentiles from each of the 24 GloSea5 model timeseries.

99th percentile 3 hourly precipitation (mm)

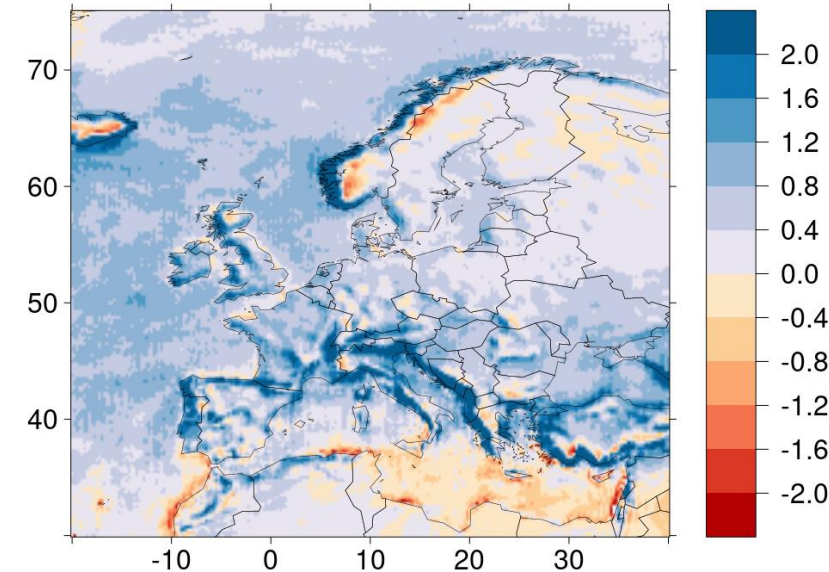
ERA5



GloSea5



precipitation difference



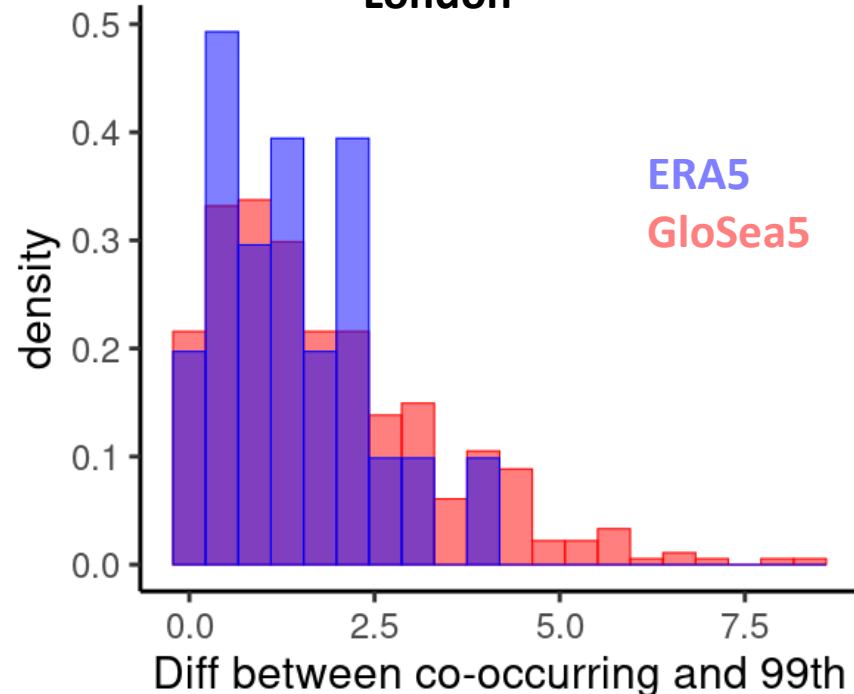
- The spatial pattern between ERA5 and GloSea5 compare well over Europe.
- Although the magnitude of extreme precipitation is overestimated in the model for most of Europe.



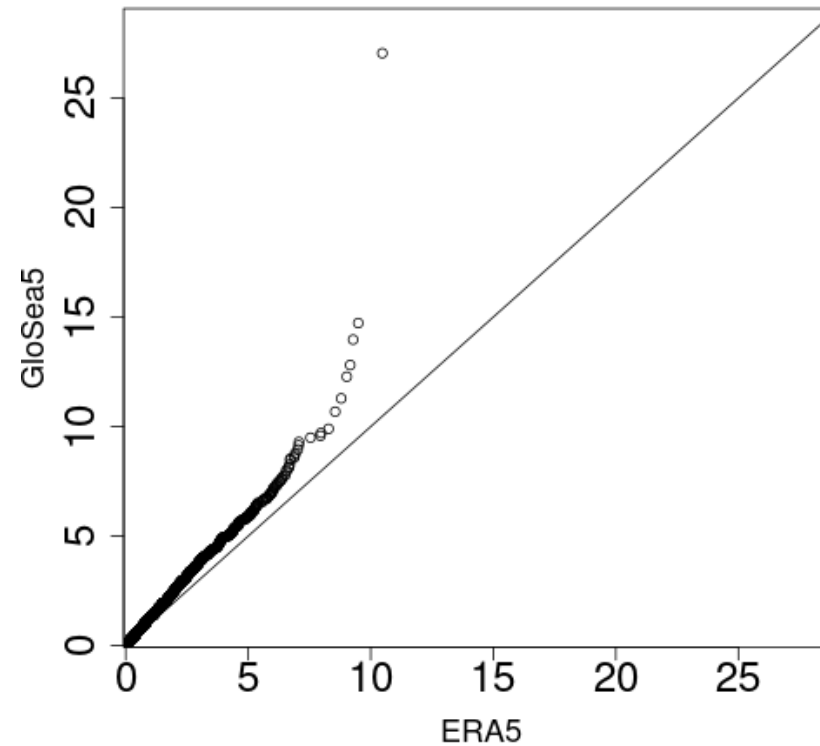
Precipitation extremes: London

GloSea5 overestimates all quantiles of precipitation for all locations, with overestimation increasing largely in the upper tails.

Difference between co-occurring extreme precipitation events and 99th percentile for London



Precipitation at London (mm)



The histogram shows the distributions of the co-occurring wind and precipitation events larger than the 99th percentile precipitation.

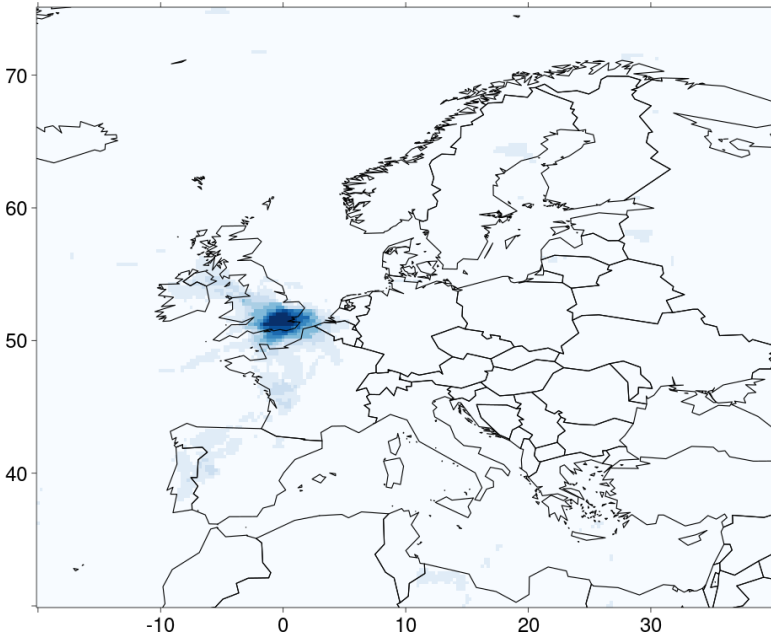
Co-occurring precipitation events above the 99th percentile are more extreme in the model.



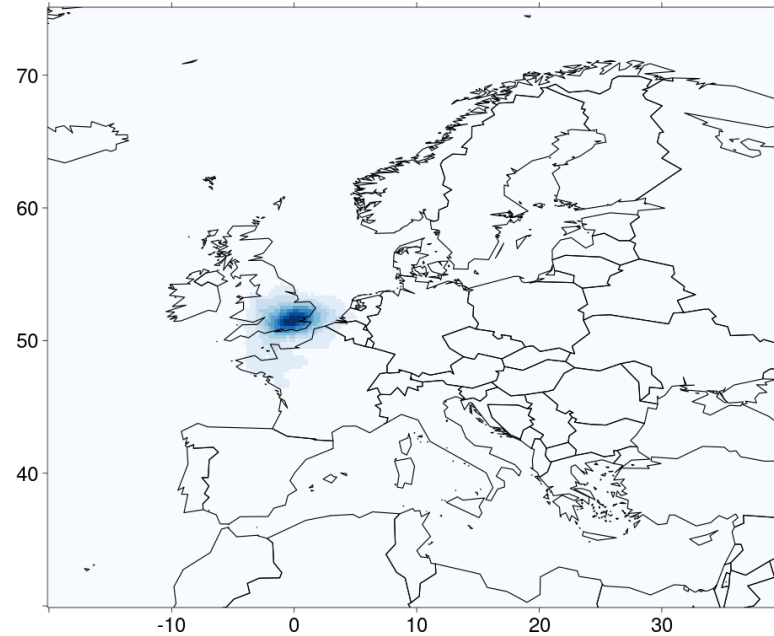
Precipitation extremes: London

Mean percentage of extreme (99th percentile) precipitation events when a 99.9th percentile precipitation event occurs in London

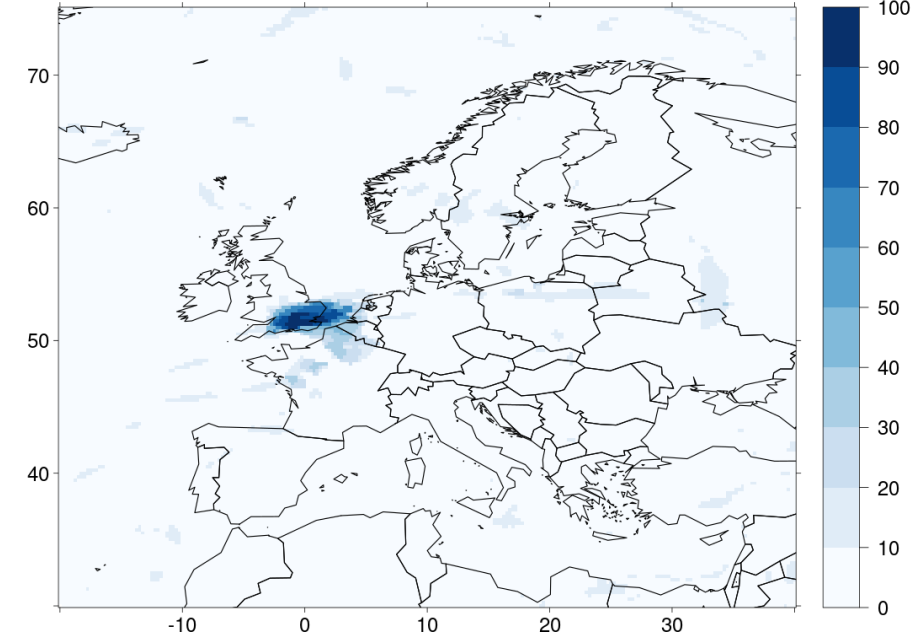
ERA5 17 events



GloSea5 408 events



GloSea5 top 10 most extreme events



- When a 99.9th percentile precipitation event occurs in London much of the surrounding area of south east England experiences 99th percentile extreme precipitation events 100% of the time. Much of the English channel, Wales, southern England and the Midlands also experience such precipitation events less than 30% of the time.
- The size and frequency match well between GloSea5 and ERA5.
- The most extreme (top 10) precipitation events have a larger spatial footprint.



Co-occurring extremes

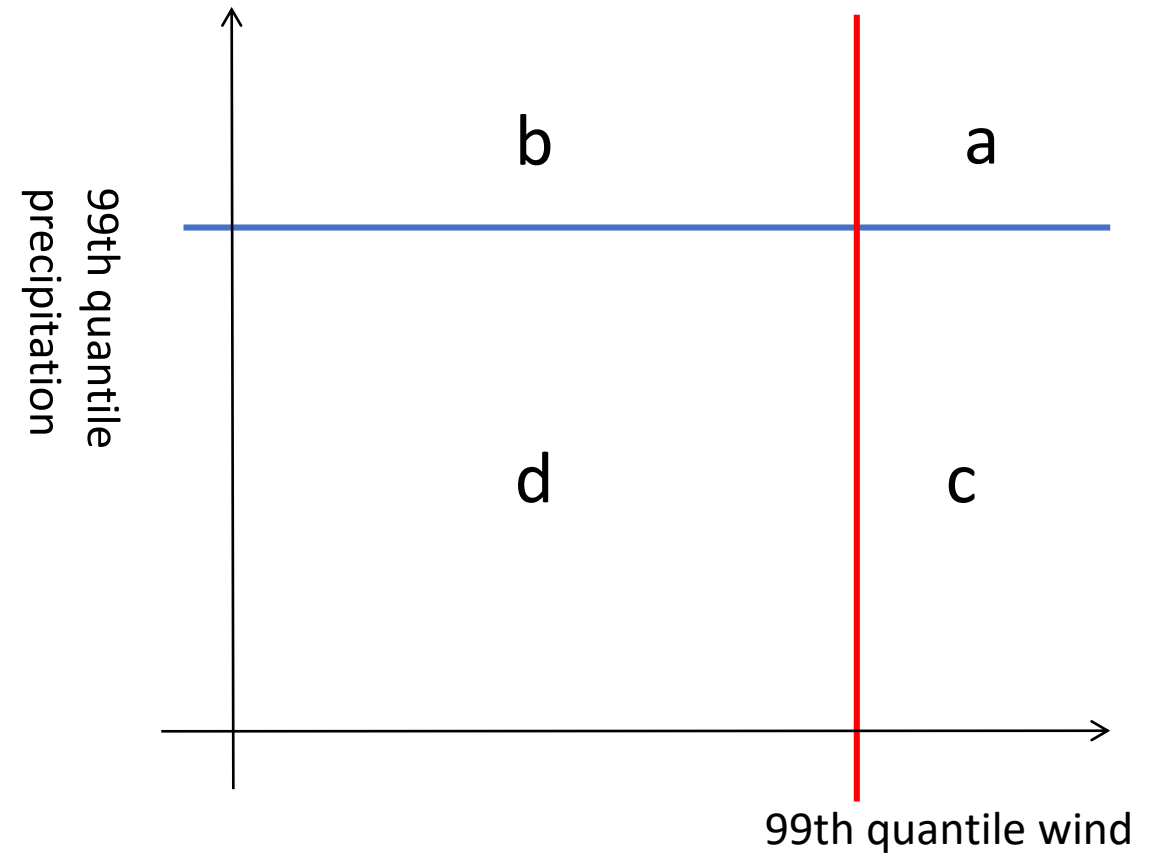
χ is the **chance** of an **compound extreme** event occurring **given** either a **precipitation** or **wind extreme** is occurring.

$$\chi(p) = Pr(Y(t) > y_p \mid X(t) > x_p)$$

where Y is precipitation, X is wind gust and y_p and x_p are the corresponding quantiles

$$\hat{\chi} = \frac{n_a}{(1 - p)n}$$

where n is the total number of timesteps, n_a are the number of co-occurring events and p is 0.99



A co-occurrence is recorded if the precipitation and the wind speed occur:
at the **same 3 hourly timestep**,
at the **same gridpoint**
and are **each above the 99th percentile**.

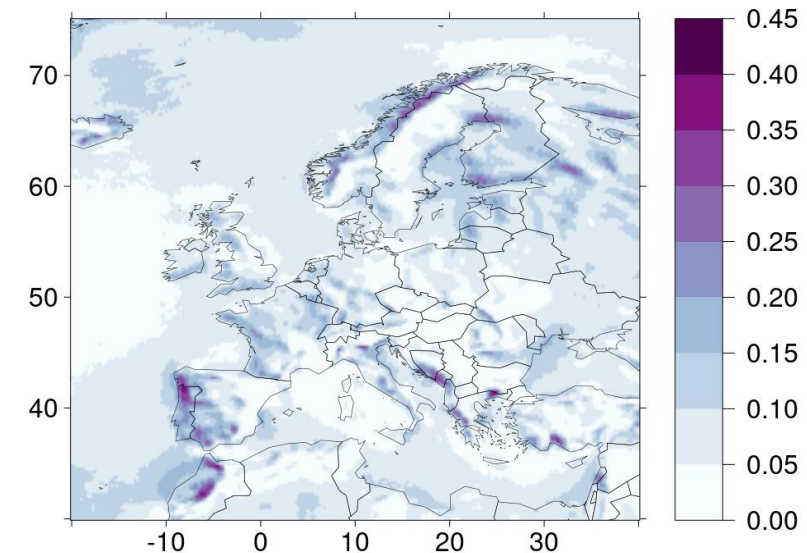
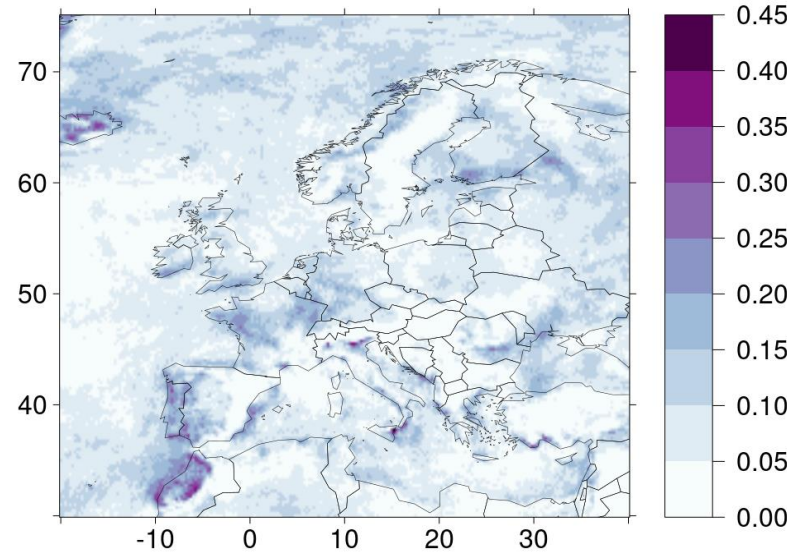


Co-occurring extremes

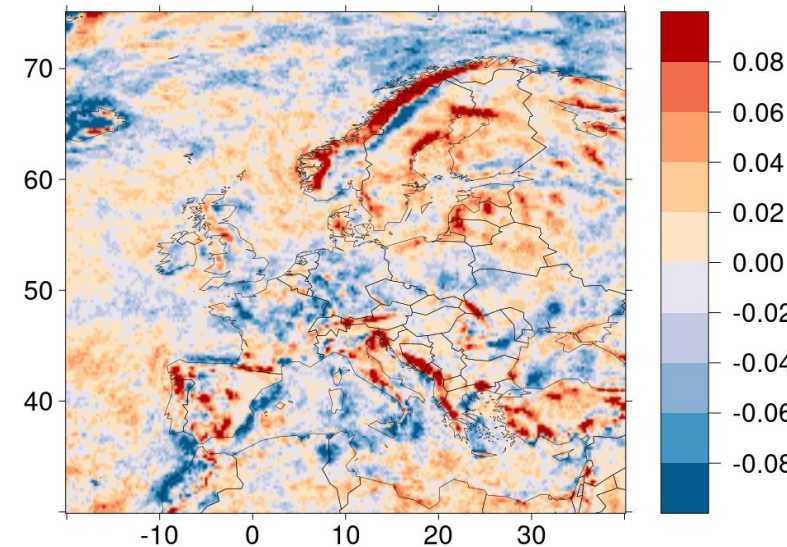
At every gridpoint $\hat{\chi}$ is calculated for each of the 24 GloSea5 timeseries, the mean at each gridpoint is then calculated from all 24 to create the GloSea5 mean $\hat{\chi}$

- The GloSea5 model gives the correct spatial pattern of 3 hourly extreme co-occurring wind and precipitation events over Europe.
- Although significant differences in frequency are found around and over some areas of high topography, particularly over Scandinavia, and the Norwegian Sea.

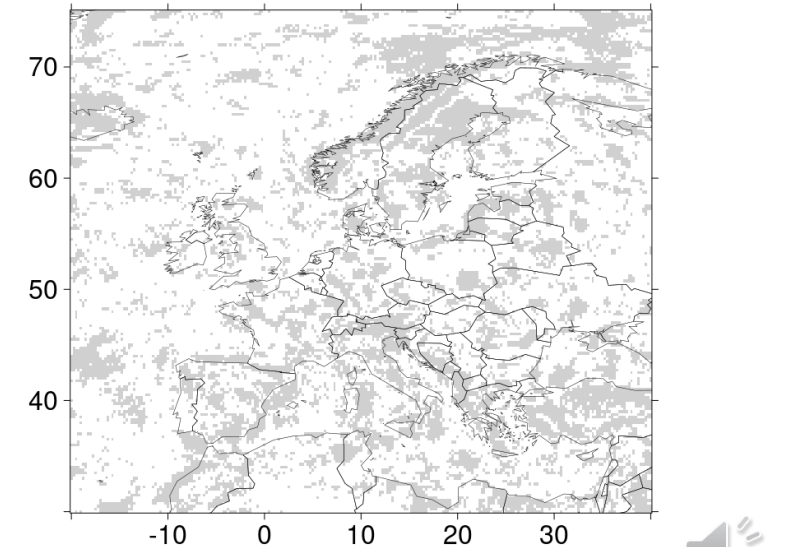
$\hat{\chi}$ maps for the 99th percentile 3 hourly extremes
ERA5 $\hat{\chi}$ GloSea5 $\hat{\chi}$



$\hat{\chi}$ difference



significance

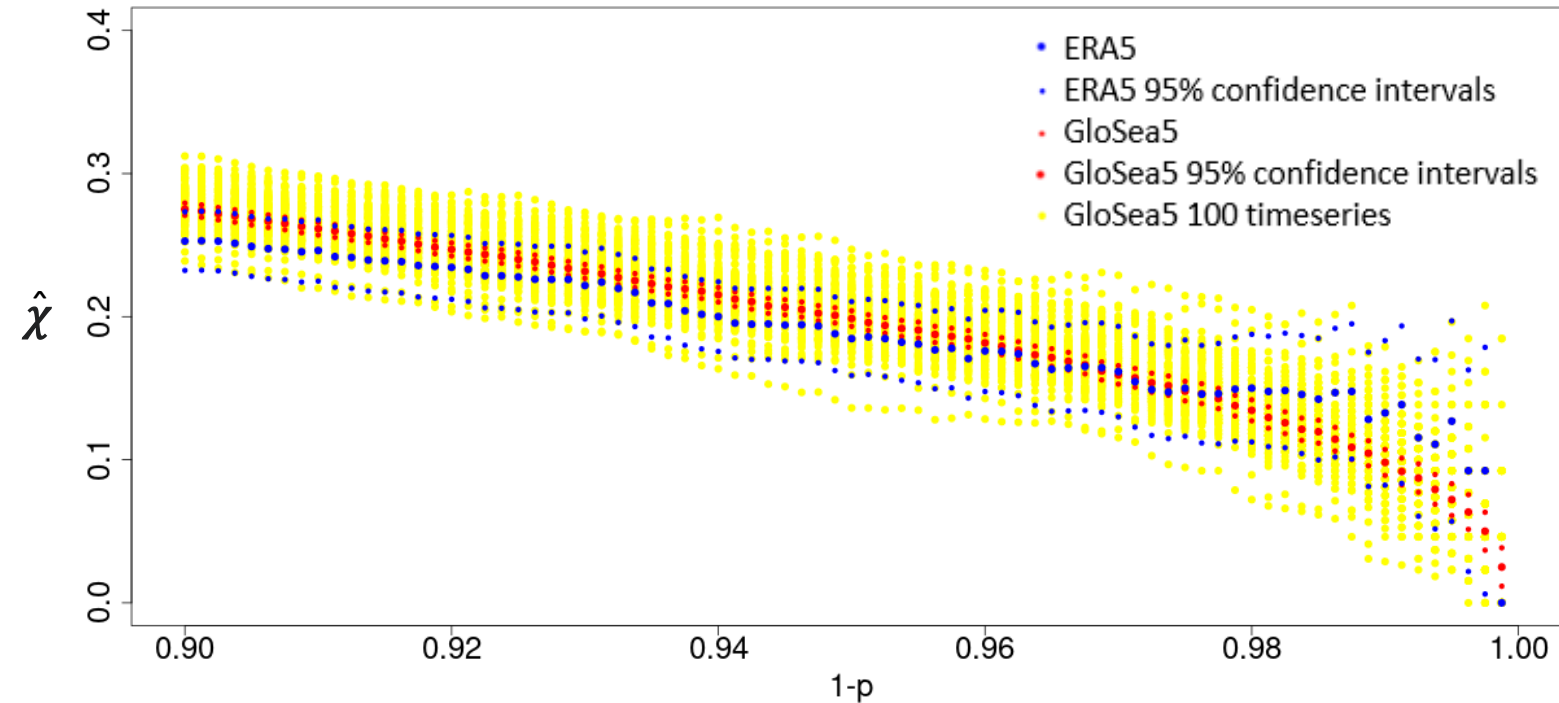


Significantly different



Co-occurring extremes: London

How does $\hat{\chi}$ vary with threshold for London?



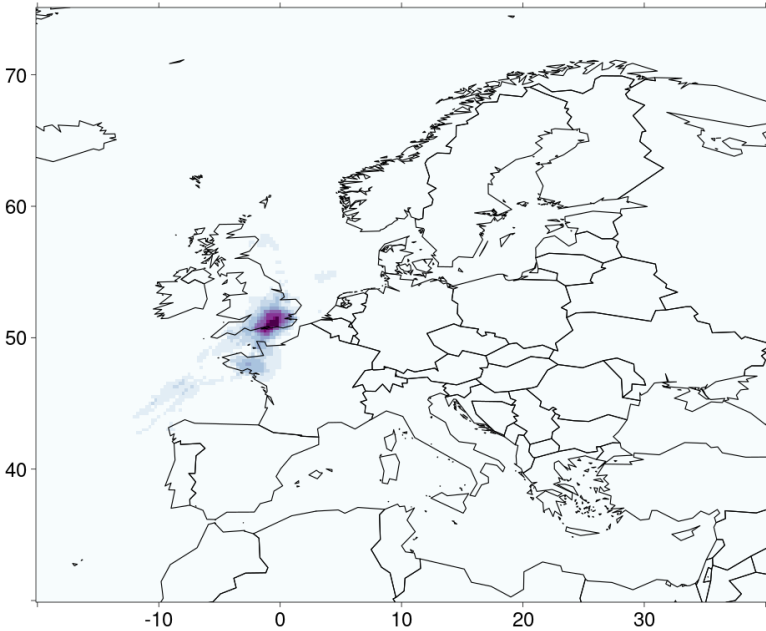
- The model $\hat{\chi}$ values are larger for almost all thresholds (0.9 to 0.999).
- Although for much of these the model is still within the ERA5 95% confidence intervals.



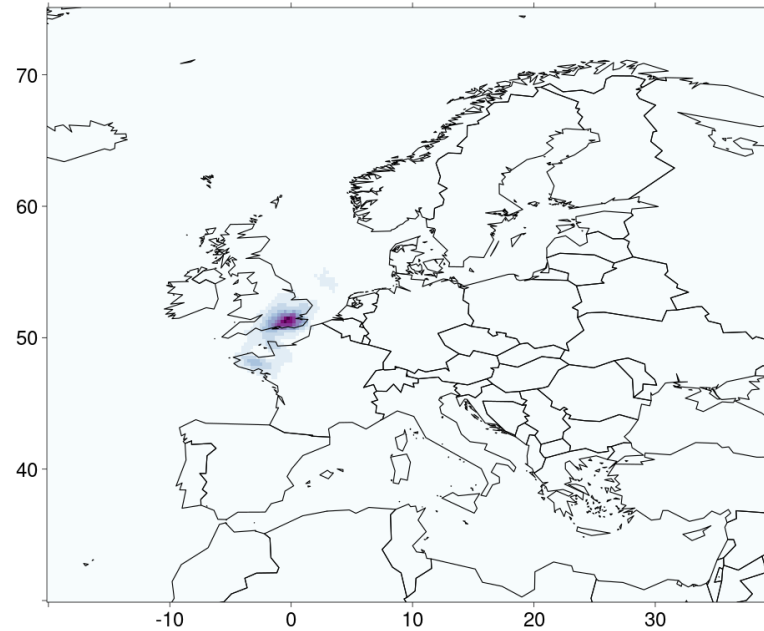
Co-occurring extremes: London

Mean percentage of extreme co-occurring events when extreme co-occurring events occur in London

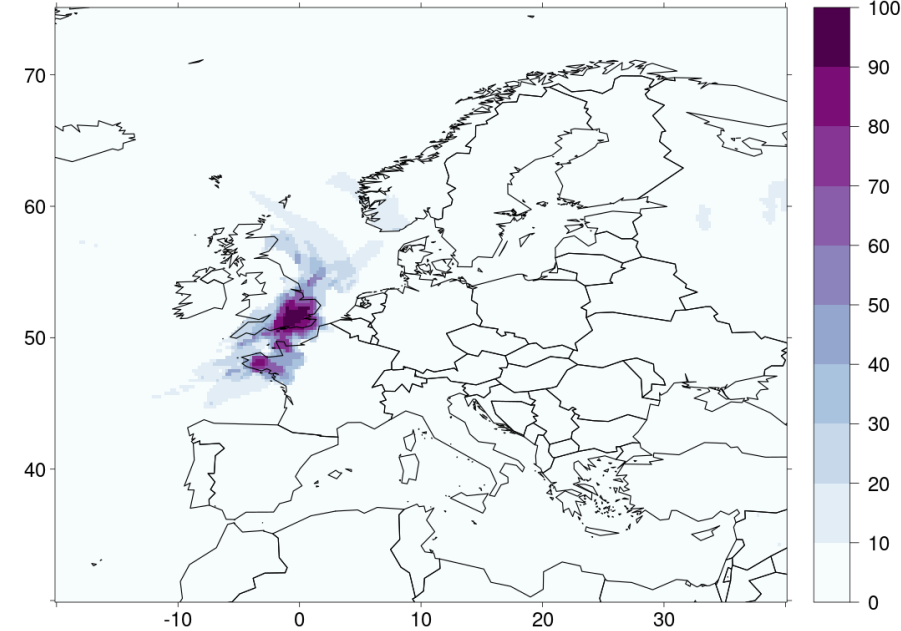
ERA5 23 events



GloSea5 410 events $M=17.1$, $R=8-25$



GloSea5 top 10 most extreme events



- When a compound event occurs in London the south east of England and the English channel experience compound events 100-60% of the time. This trails off over north western France (10-50%) and the north Atlantic (up to 30%).
- The size and frequency match well between GloSea5 and ERA5.
- The most extreme (top 10) compound events have a larger spatial footprint.

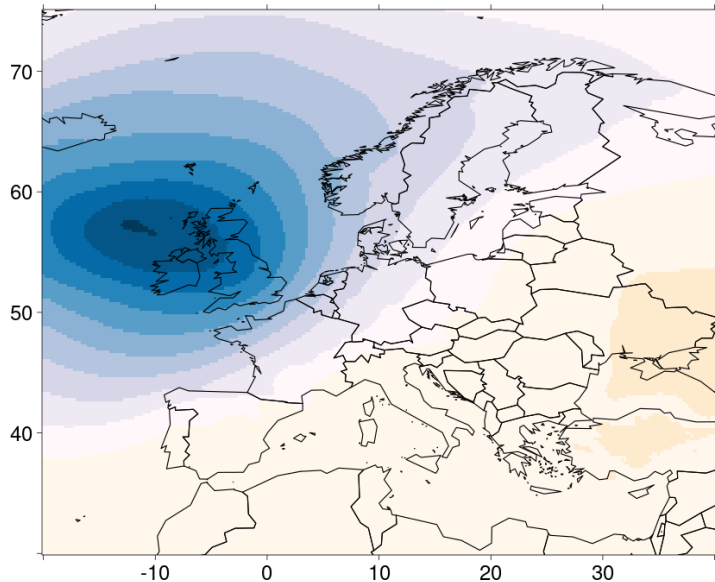


Synoptic patterns: London

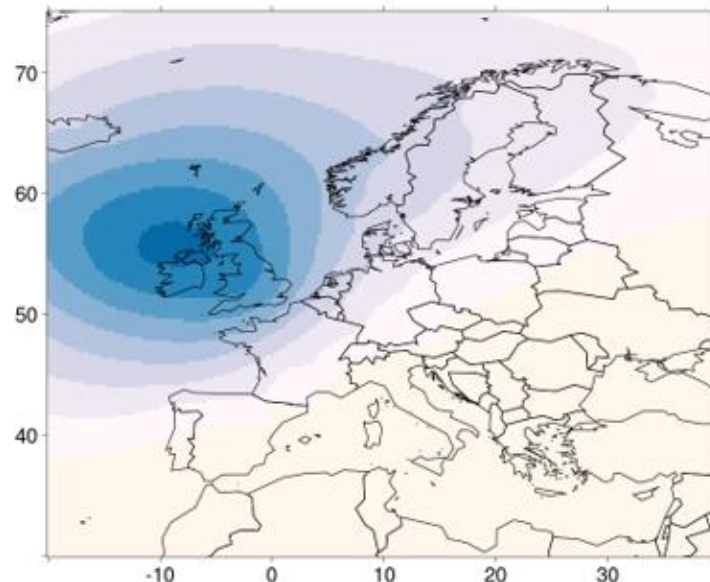
- Previous studies have shown that cyclones play an important role in the co-occurrence of wind and precipitation extremes.

Mean mslp winter anomaly when extreme co-occurring events occur in London (hPa)

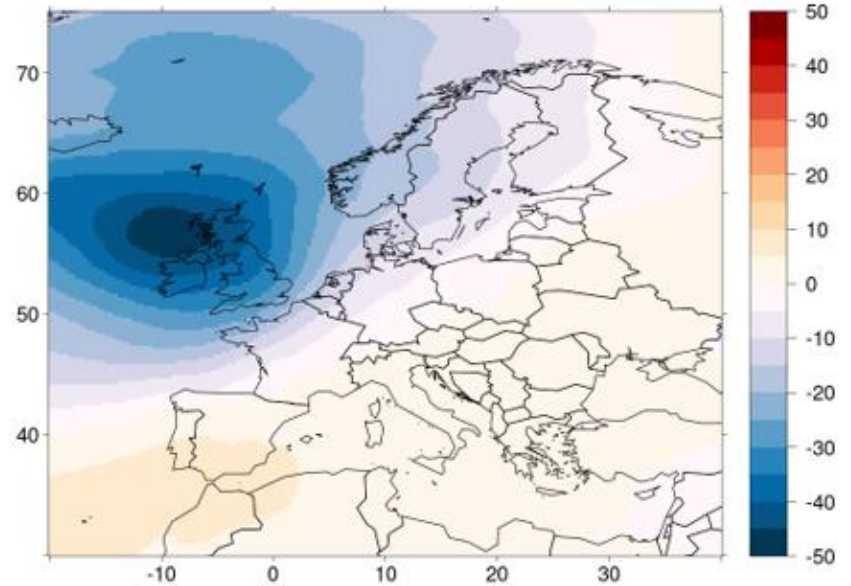
ERA5 23 events



GloSea5 410 events M=17.1, R=8-25



GloSea5 top 10 most extreme events



- Co-occurring extremes are located to the south east of the cyclone, 90 degrees to the direction of travel, where the steepest gradient in the isobars occurs.
- The GloSea5 model reproduces the correct synoptic situations leading to 3 hourly co-occurring extreme precipitation and wind events. This is seen in the spatial pattern of the MSLP anomaly as well as the magnitude.
- The most extreme (top 10) compound events are associated with cyclones with the same spatial structure but with greater minima in MSLP (up to 10 hPa difference)

Conclusions

How well can GloSea5 simulate precipitation and wind extremes?

- Although substantial differences in magnitude are found between the precipitation and wind extremes, the co-occurrence between the two extremes compares well spatially over Europe.
- However, significant differences in frequency are found around and over some areas of high topography.
- The model is producing the correct spatial structure and size of wind, precipitation and co-occurring extreme events.
- The model's co-occurring events at individual locations investigated occur with very similar synoptic patterns to ERA5, indicating that the compound extremes are produced for the correct reasons.

What does the model tell us that observations cannot?

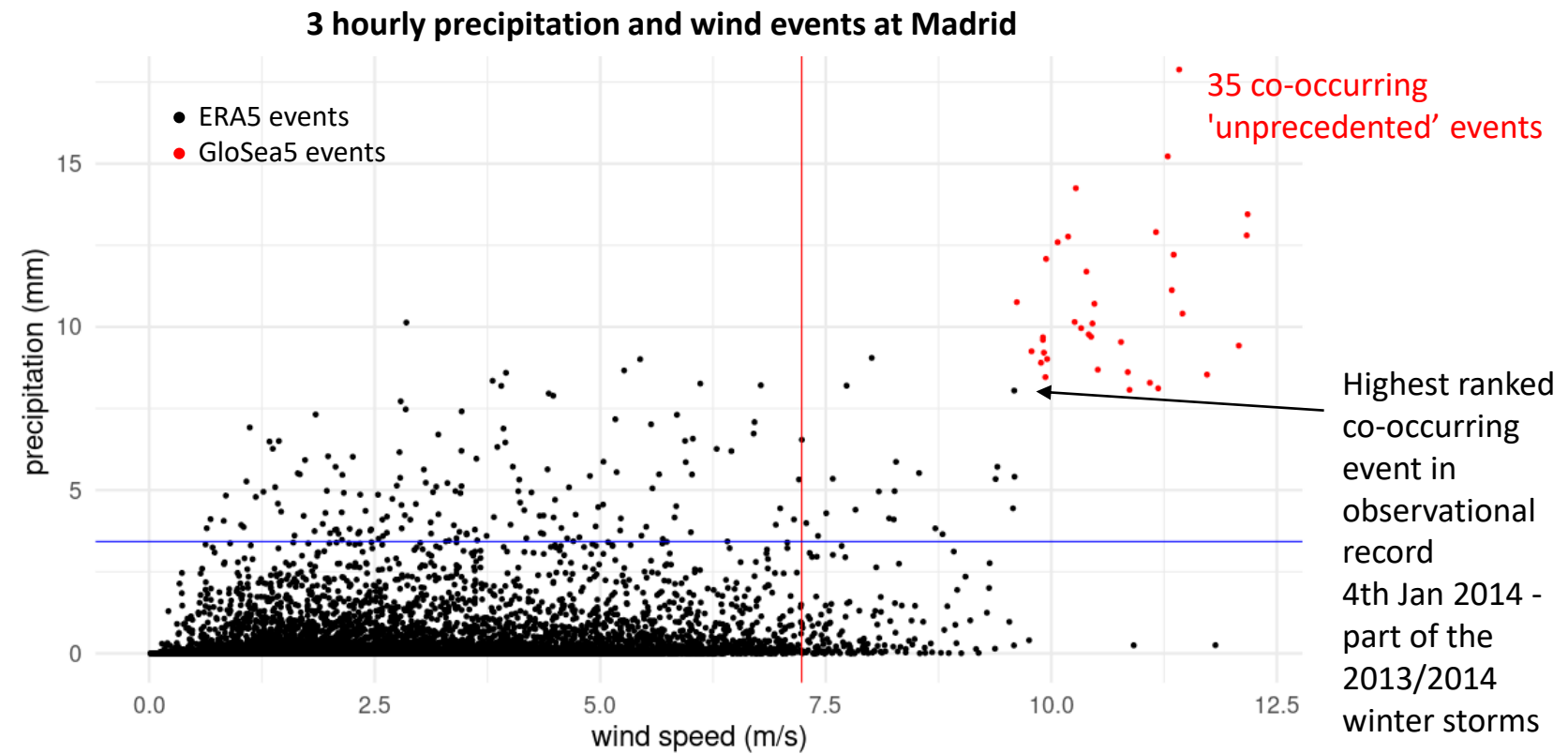
- The more extreme an wind, precipitation and co-occurring event at a location the larger the surrounding associated spatial regions of such events. This is particularly true for the co-occurring events.
- The more extreme an co-occurring event at a location the lower the associated MSLP minima. Suggesting the most extreme events are associated with cyclones with the deepest lows in MSLP.



Future work

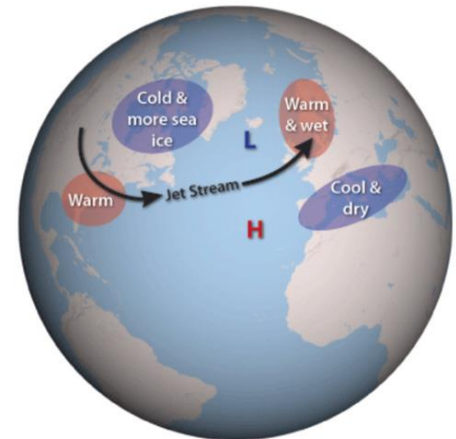
Unprecedented events

- What is the risk of an unprecedented precipitation and wind event happening over Europe?

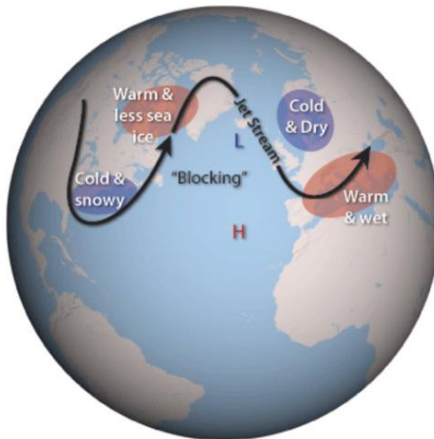


The North Atlantic Oscillation

Positive NAO phase



Negative NAO phase



- Does the NAO index affect the frequency of co-occurring events over Europe?
- How does the NAO index affect the spatial footprint of extreme precipitation, wind and compound events?





Thank you

If you have any questions or comments please contact me at:
lb663@exeter.ac.uk



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