CGFI UK Centre for Greening Finance & Investment

University of BRISTOL

Compound wind and flood risk over Europe

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Motivation

Strong winds and extremes in precipitation can produce devastating socio-economic impacts.

Wind storms are the main cause: e.g. Storm Kyrill (2007) had estimated insured losses for Europe of £6.3 billion (Fink et al., 2009).

The 2013/14 winter UK floods caused economic damages of £1.3 billion (Environmental Agency, 2016).

Compound effects of multiple drivers, such as precipitation and wind together, cause most of the weather and climate related catastrophes (Zscheischler et al., 2018).

Is there correlation between extreme wind damage and flooding over Europe?

Source: Air Worldwide

Source:The independent

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Key literature

Short timescales: hours to days

When a compound wind/rain event happens over Europe there is a >80% chance that a wind storm is present

(Owen et al., 2021)

Longer timescales: seasons

In years which are wetter you've got a substantially increased chance of their being a large wind hazard over parts of Europe

(Hillier and Dixon, 2020)

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Gaps

Studies are focused on precipitation rather than on river flow.

- The timescale of the response may be quite different for river flow within a catchment

Studies are not easily translatable to an industry useable compound metric.

- Focus on grids is a useful starting point but real users may wish to know about country specific metrics.

Model resolution is quite coarse when you're interested in a catchment level

- Higher resolution data is available (either through observation stations, high resolution reanalysis or UKCP)

Focused on present day

- Commonly using reanalysis like ERA5 (~30km)

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Input dataset's characteristics

1. **Data type**: site-based observational, reanalysis, climate model.
2. **Spatio-temporal granularity**.
3. **Length of time-series** analysed.

Timeframes

4. **Time window** (e.g. day, season).
5. **Wintertime definition**
6. **Time period examined** (current, future)

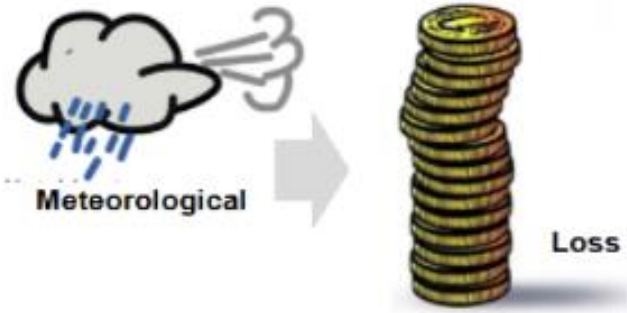
Spatial domain

7. **Unit of Aggregation**

Analytical choices for correlation analysis

Metrics & hazard/risk proxies

8. **Quantity analysed**, i.e. which proxy for hazard or risk. Meteorological (e.g. seasonal precipitation), hazard (e.g. gust v^3), or an estimate of impact (e.g. rail losses).
9. **Correlation metric**, r, occurrence ratio, tail dependency (χ, χ), AEP effect.



Data

Wind Data	Precipitation Data	River flow Data
ERA5 Reanalysis (1980-present)	ERA5 Reanalysis (1980-present)	Glofas historical run (1980-2018)
CHESS (1960-2017 10m wind speeds)	CHESS (1960-2017)	EFAS historical run (1991-present)
CAMELS-GB (1970-2015)	CAMELS-GB (1970-2015)	CAMELS-GB (1970-present)
UKCP 12km	**UKCP 12km**	**UKCP 12km (through CEH)**

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Metrics for wind/flood damage

Wind Damage Metric

Storm Severity Index

Exceedance of P98 max daily wind gust

$$\mathrm{SSI} = \sum_{i=1}^{N_i} \sum_{j=1}^{N_j} \left(\frac{V_{i,j}}{V_{i,j}^{98}} - 1 \right)^3 \cdot \mathrm{pop}_{i,j}$$

Flood Damage

Flood Severity Index

Exceedance of P99.5 total daily river discharge (twice year overtopping of river)

$$FSI = \sum_{i=1}^{N_i} \sum_{j=1}^{N_j} \left(\frac{Flow_{i,j}}{Flow_{i,j}^{99.5}} - 1 \right) \cdot \mathrm{pop}_{i,j}$$

Start with a GB focus

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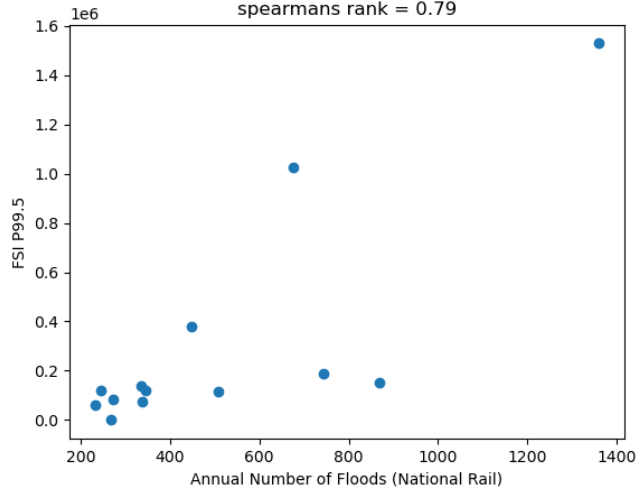
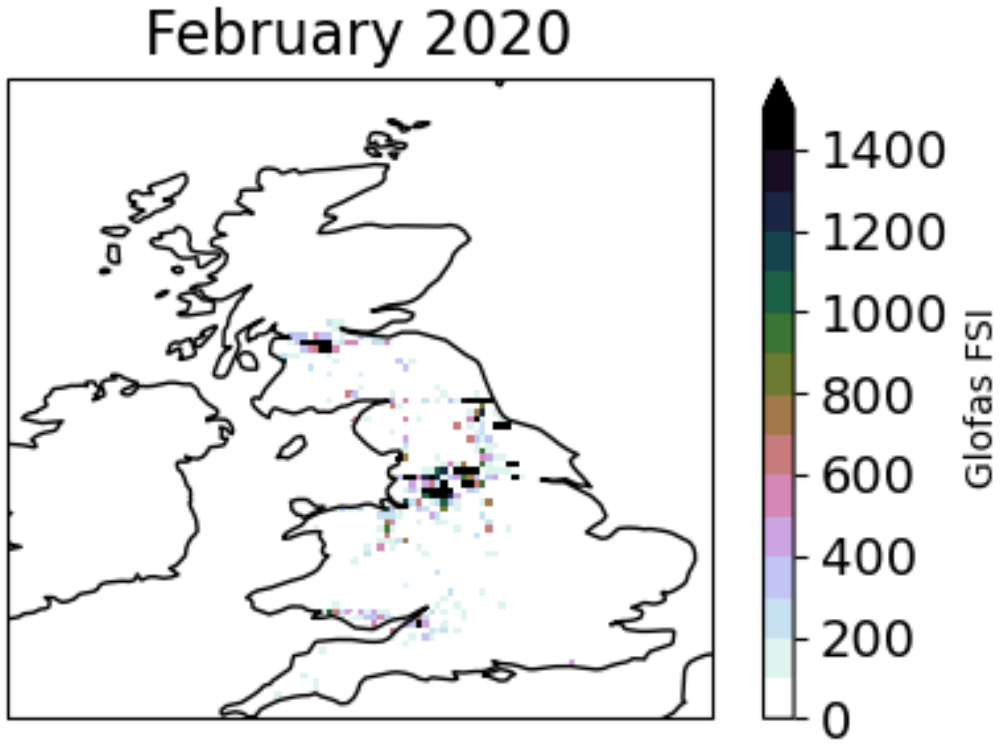
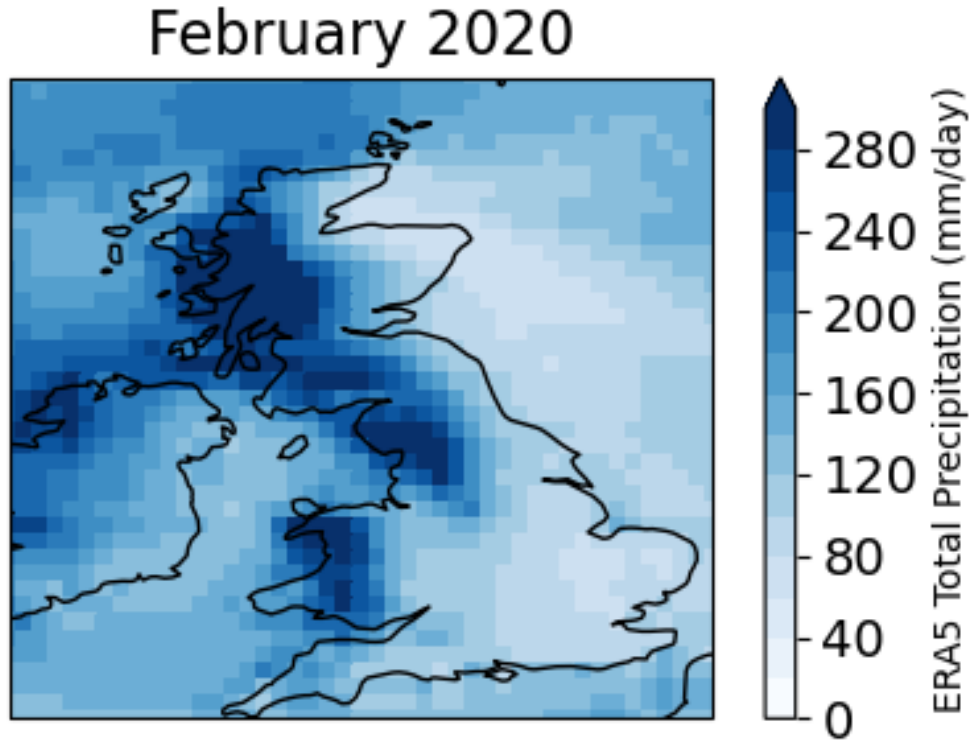
FSI example
Ciara and Dennis (2020)







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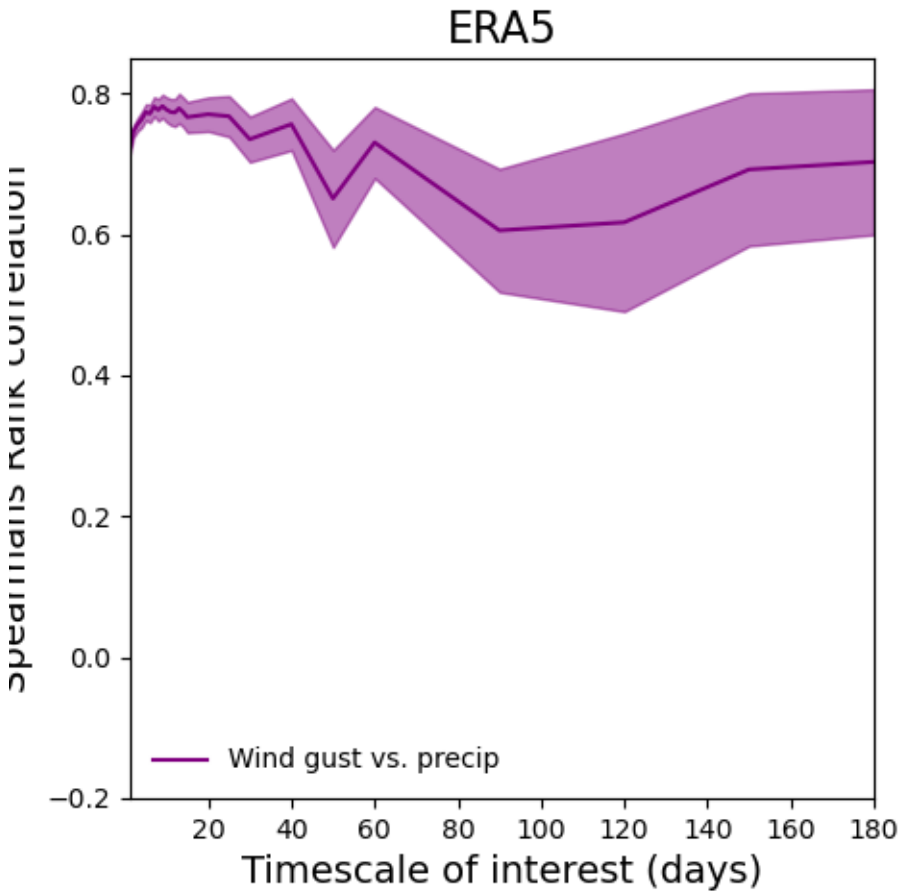
Correlation analysis: observations



- GB national aggregate data
- October-March
- 1980-2020

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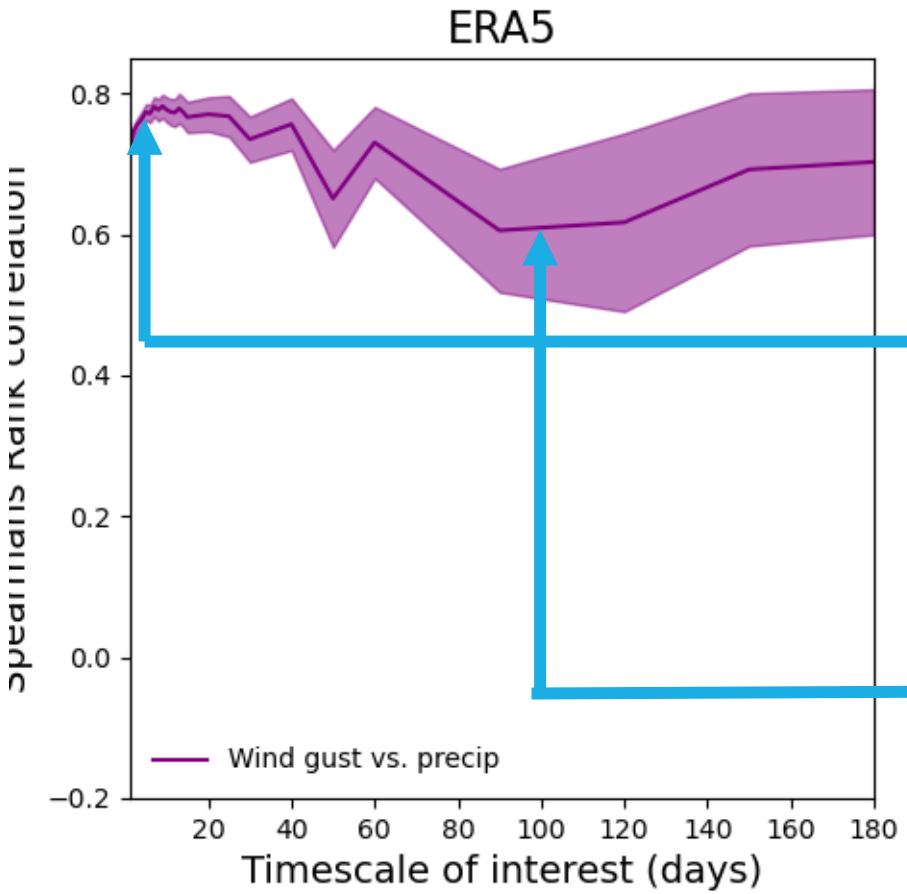
Correlation analysis: observations



Correlation between 3-day mean daily-max gust and 3-day accumulated precipitation, October-March 1980-2020

Correlation between 100-day mean daily-max gust and 100-day Accumulated precipitation, October-March 1980-2020

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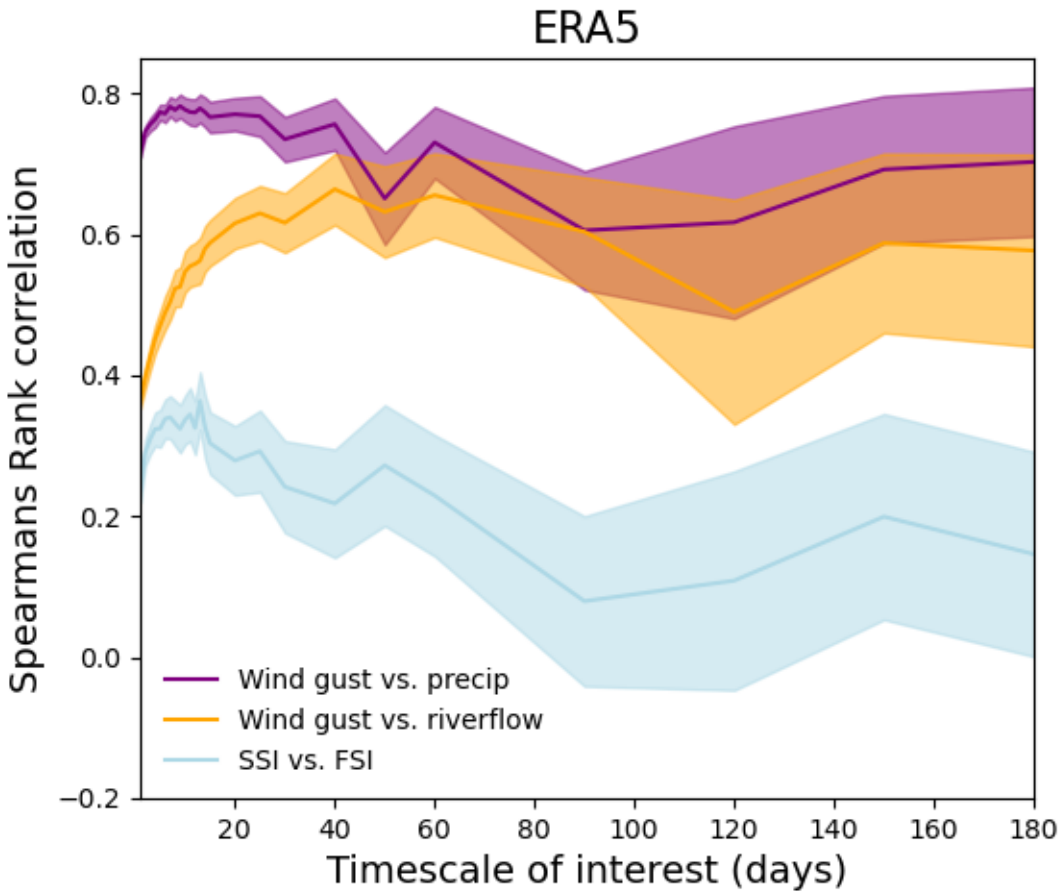
Correlation analysis: observations



1. Wind gusts vs. Precip correlation is relatively constant ~0.7 throughout all time periods
2. Wind gusts vs precip peaks at ~10 days
3. SSI vs. FSI has very low correlations
4. Correlation decays as we get closer to the final impact.
5. Puts previous studies into context

But ERA5/Glofas are not our only options for observations….

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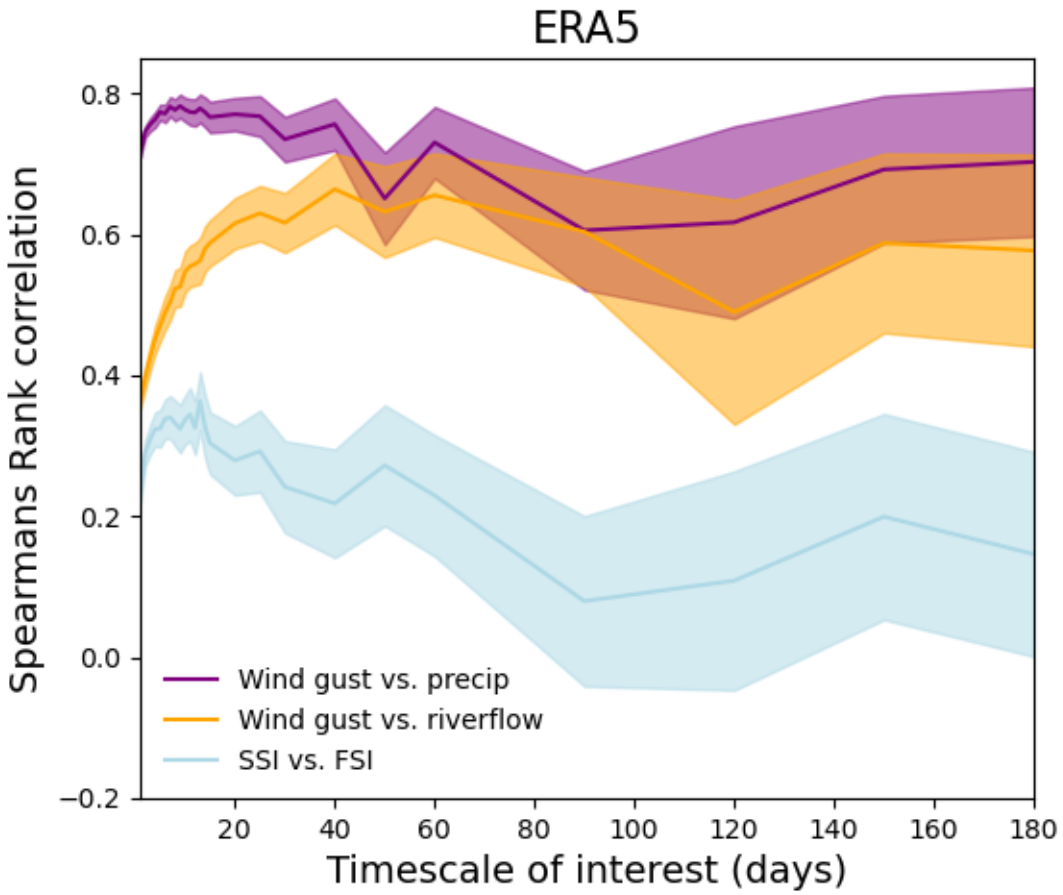
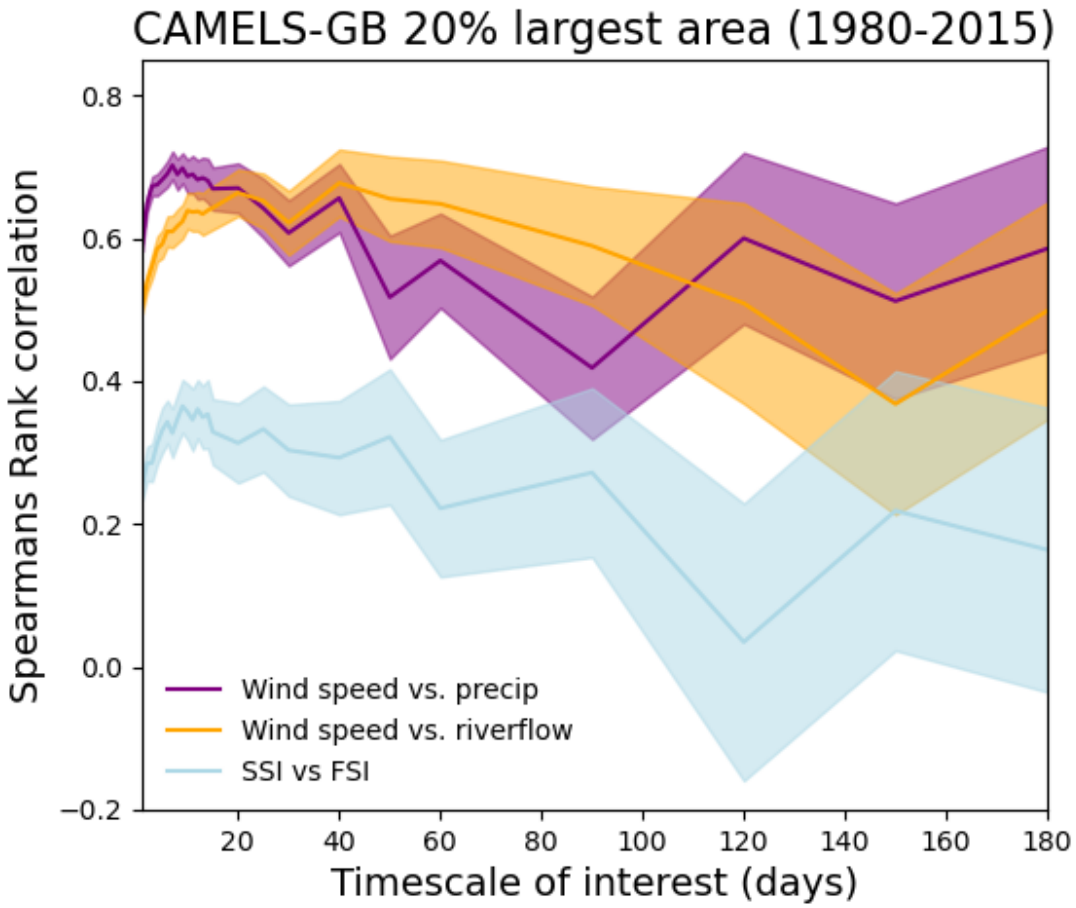
Correlation analysis: observations





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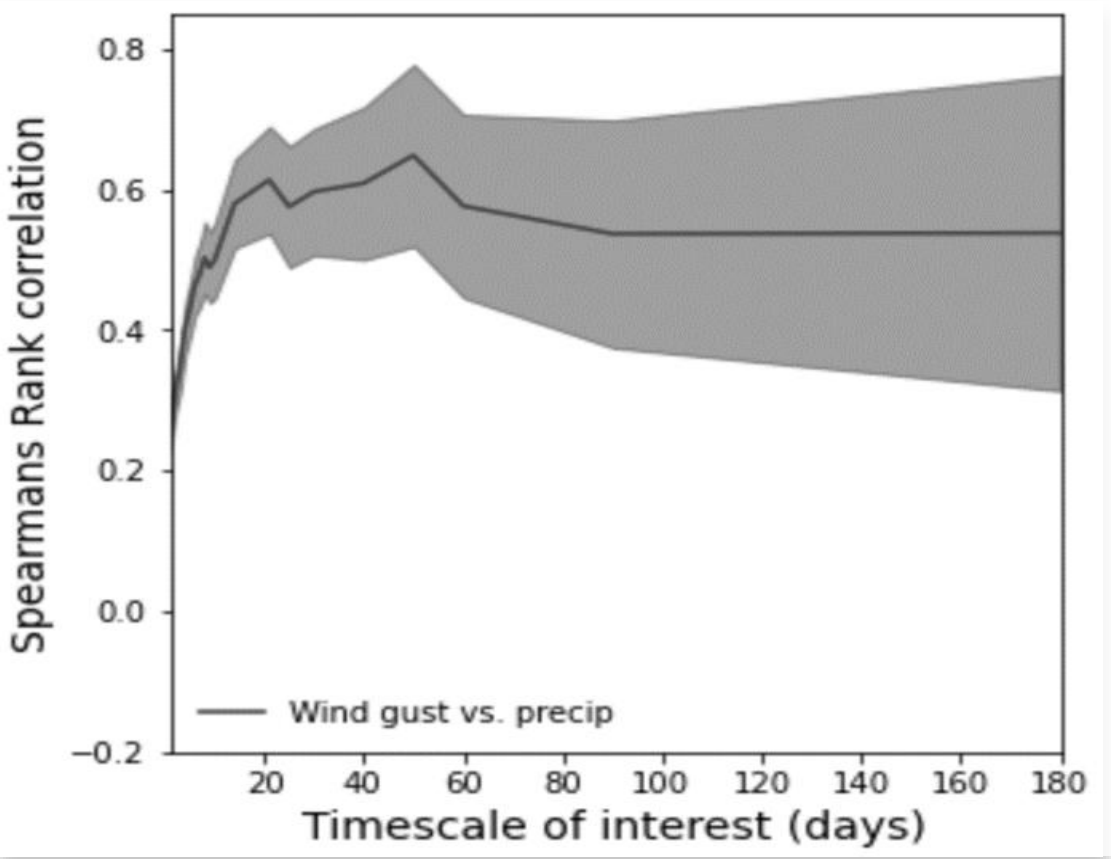
Within the impact data



1. Correlation between Network rail costs (flood vs. wind) are similar to that seen with ERA5 wind gusts and glofas river flows.
2. Suggests the relationships we are capturing are real ☺
3. NR losses are likely related to water ponding on saturated ground rather than excess river flows so makes sense that the NR correlations are closer to the purple/yellow lines.

Network rail losses (cost), correlation between flooding and wind.

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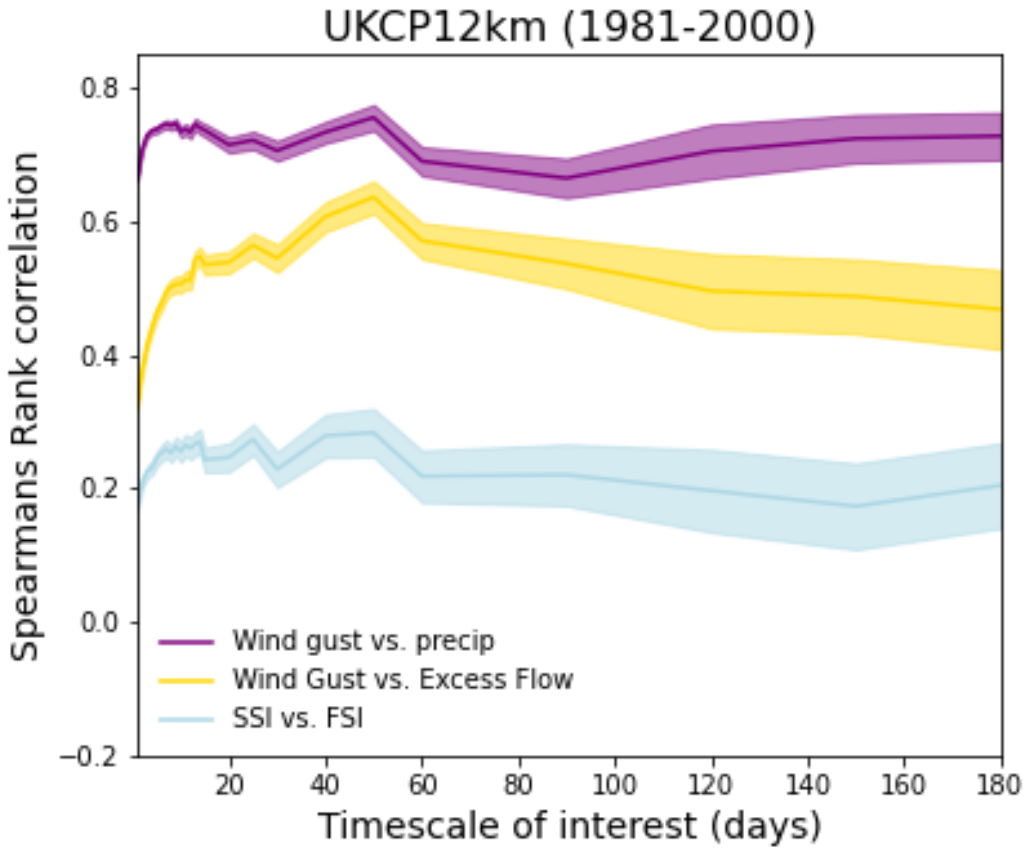
Correlation analysis UKCP 12km model



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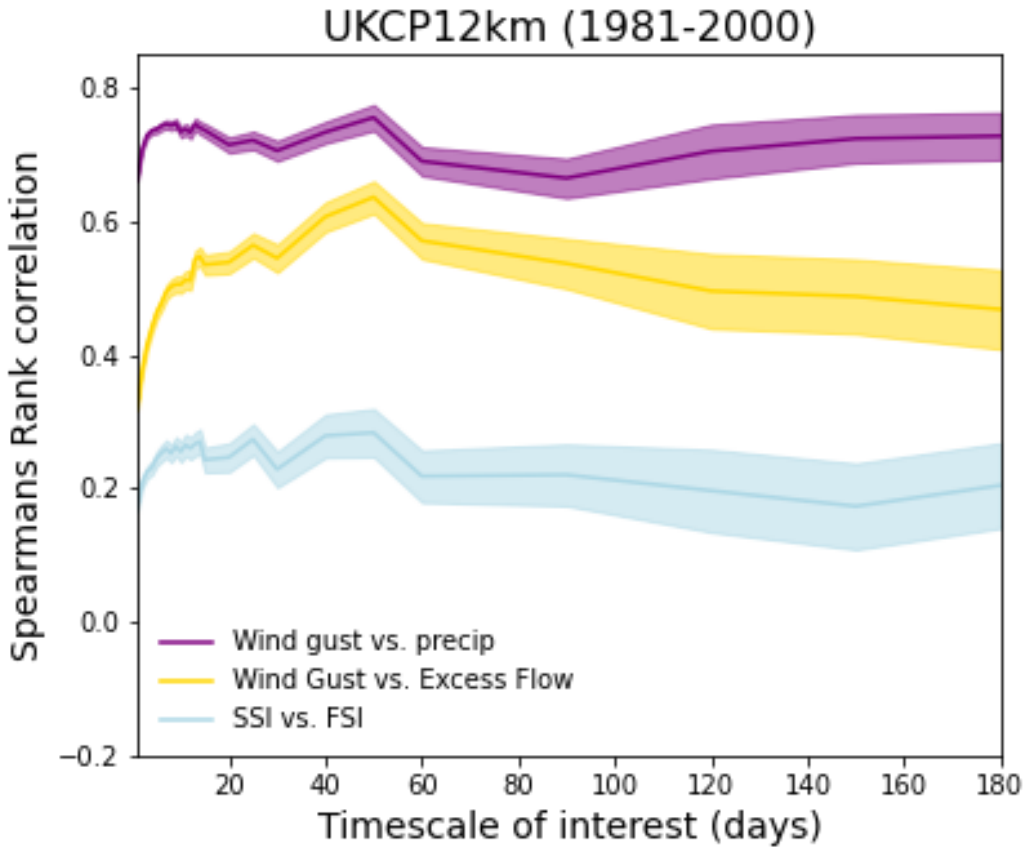

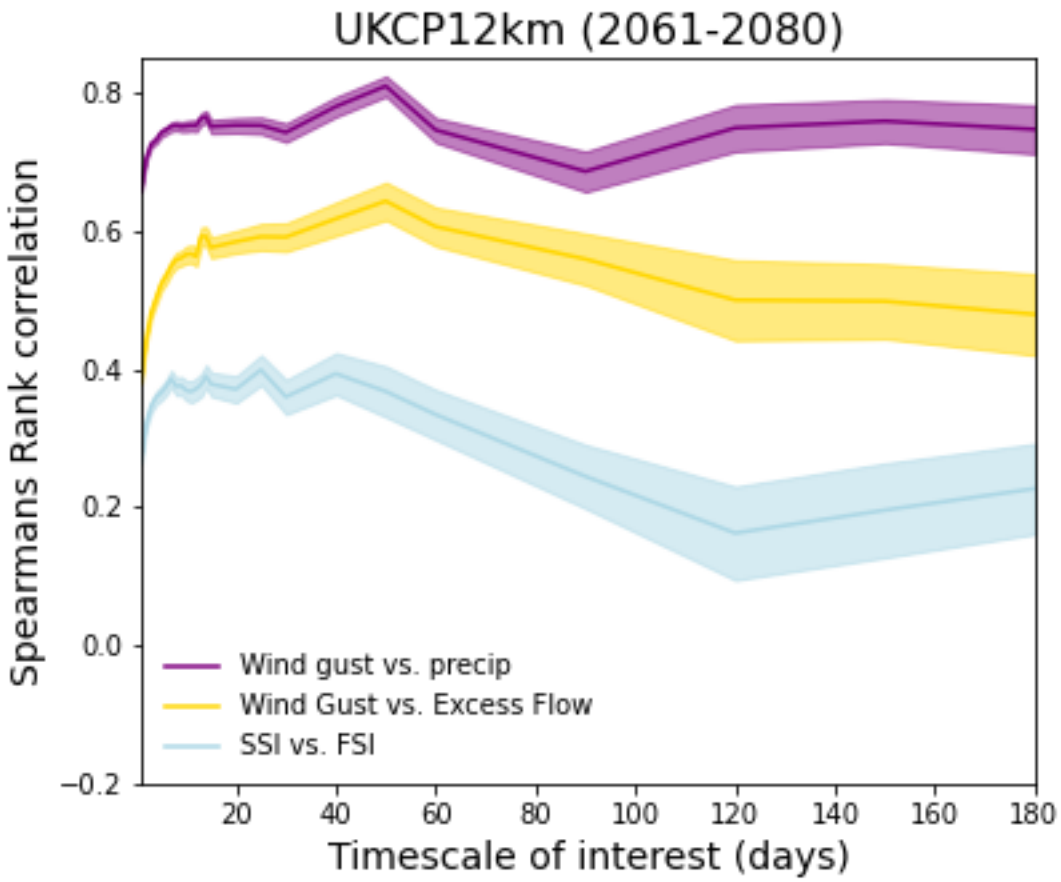

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Correlation analysis UKCP18 12km model

- In the UKCP-derived FSI there are a lot more occurrences in general than for SSI (due to the higher grid resolution (1km vs. 12km)

- In a future climate there are less occurrences of SSI, but more occurrences of SSI.
- Associated with slightly reducing extreme gusts, but slightly increasing extreme river flows/rain.

- In total this doubles the occurrence of very extreme, co-occurring FSI/SSI events in a future climate from 0.5 → 1.2% of days.
- These extreme SSI/FSI are likely to be associated with loss/damage 'somewhere'.

	ERA5 (1981-2020) (1981-2000)	UKCP hist (1981-2000)	UKCP future (2061-2080)
Days with SSI (%)	16 % 17%	22 %	20 %
Days with FSI (%)	26 % 24%	39 %	42 %
FSI > P95, SSI > P95	0.7% 0.6%	0.5 %	1.2%

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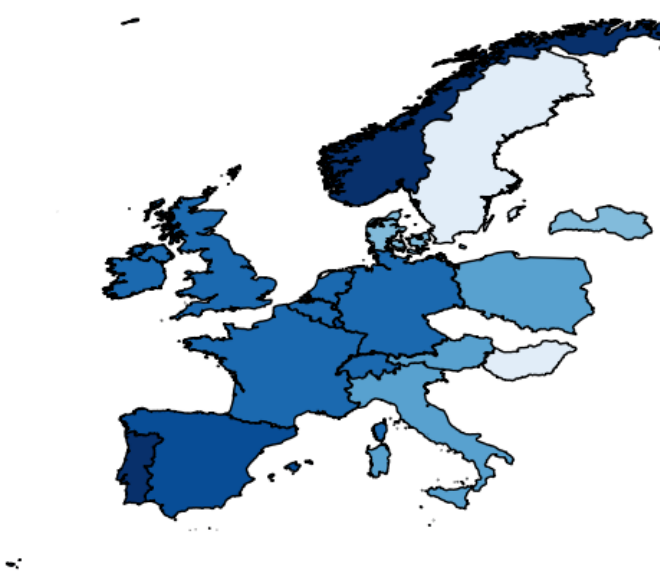
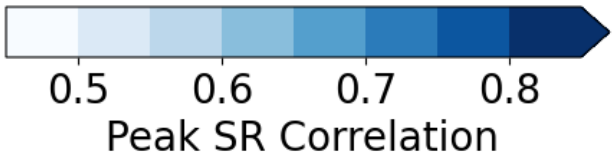
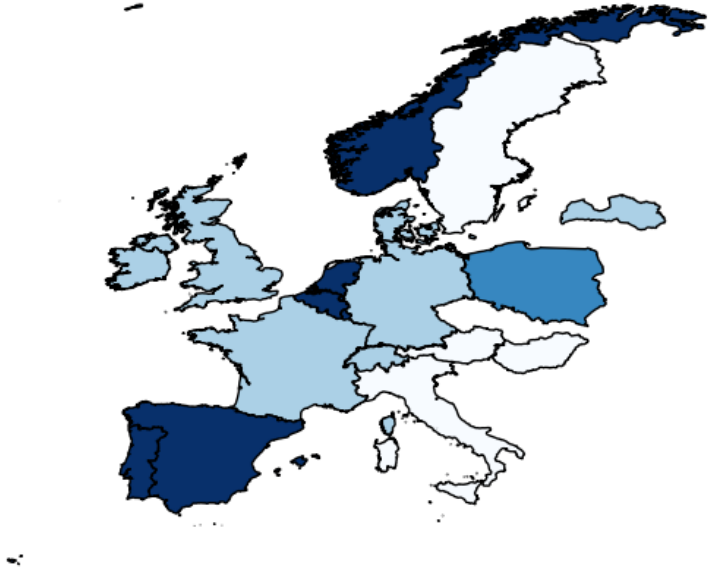
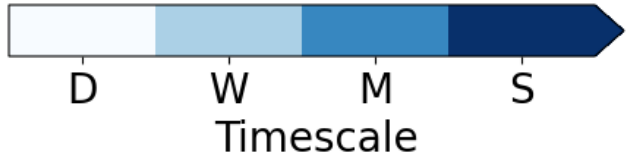
Extending Across Europe

Daily Precip vs wind gusts... progressing this to SSI vs FSI









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Highlights

- We have investigated the correlation between wind and flood damage over GB using metrics of varying complexity.
  - We have developed a novel Flood Severity metric (FSI) which can be used to model GB-wide flood damage in a similar way to the Storm Severity Index (SSI).
- Correlation present between GB winter wind gusts and precipitation totals at all timescales ranging from daily to seasonal (~0.7).
  - Correlations are weaker when river flows are considered instead of precipitation as a proxy for flood damage.
  - The correlation decays further when using damage metrics of SSI and FSI.
  - Similar results are seen in UKCP 12km simulations to within observational products.

- Climate change expected to double the occurrence of extreme compound wind/flood events compared to those seen in the historical period.

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Next Steps

Short-term

Combined flood/wind risk

- Complete analysis, submit paper on national-level relationships
- Develop process-based understanding of the relationships
- Expand to Northern-Europe
- Rigorous uncertainty assessment of current climate

Medium-term

Developing useful ingredients for an open source CAT model

- High quality stochastic flood and wind event.
- Storylines for industry to understand future climate risk.

Thank you for listening ☺

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Next Steps

Short-term

Combined flood/wind risk

- Complete analysis, submit paper to ERL on national-level relationships
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Medium-term

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Extras

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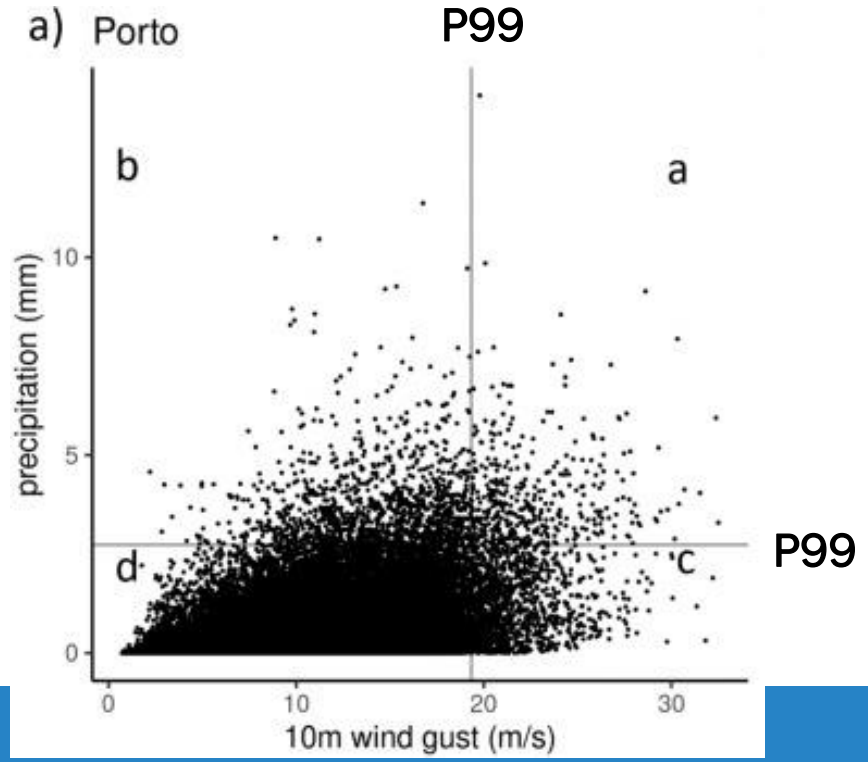
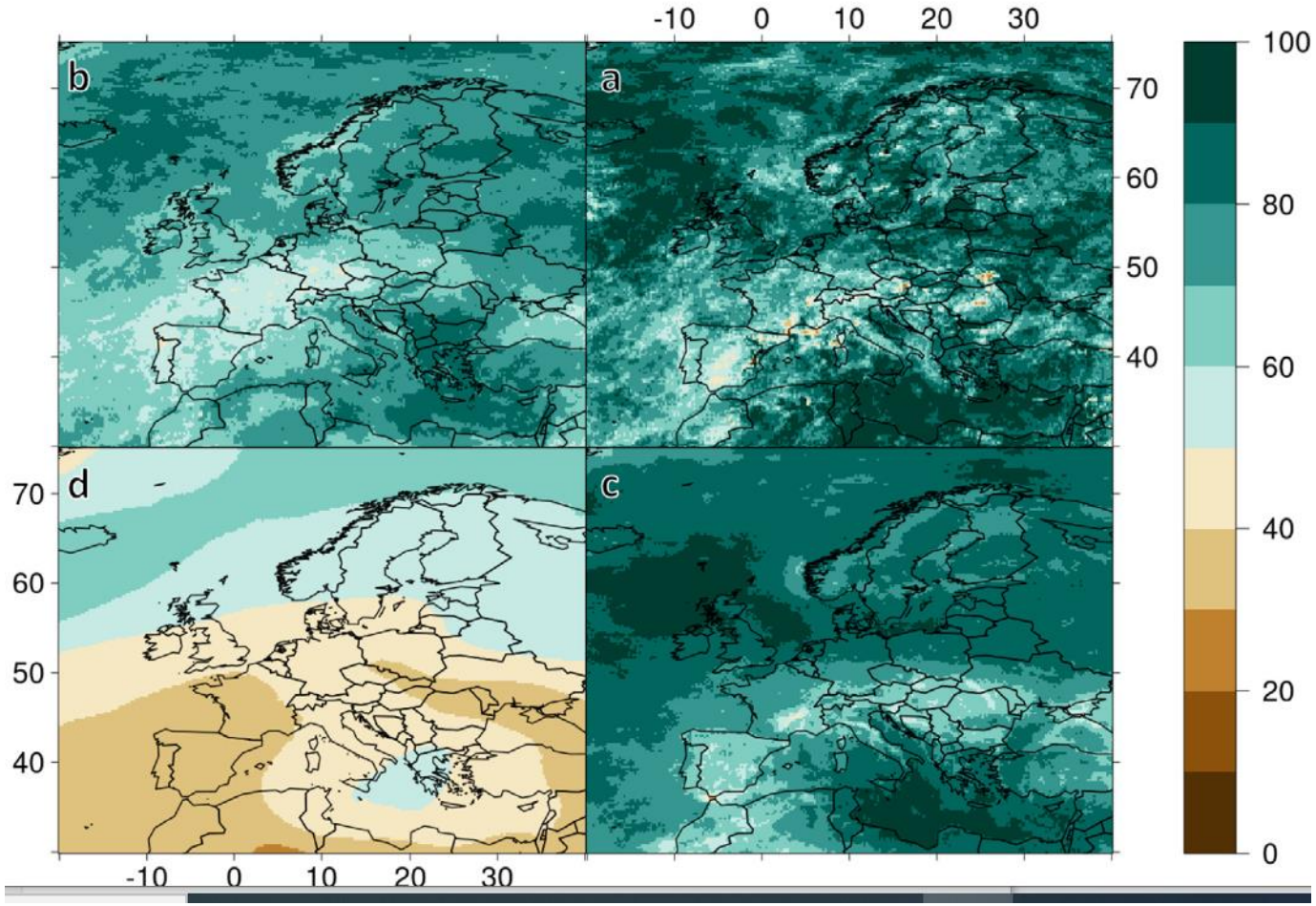
Previous work (1/2)

When a compound wind/rain event happens over Europe there is a >80% chance that a wind storm is present

- Owen et al., (2021)



Probability of a cyclone within 1100km



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Previous work (2/2)

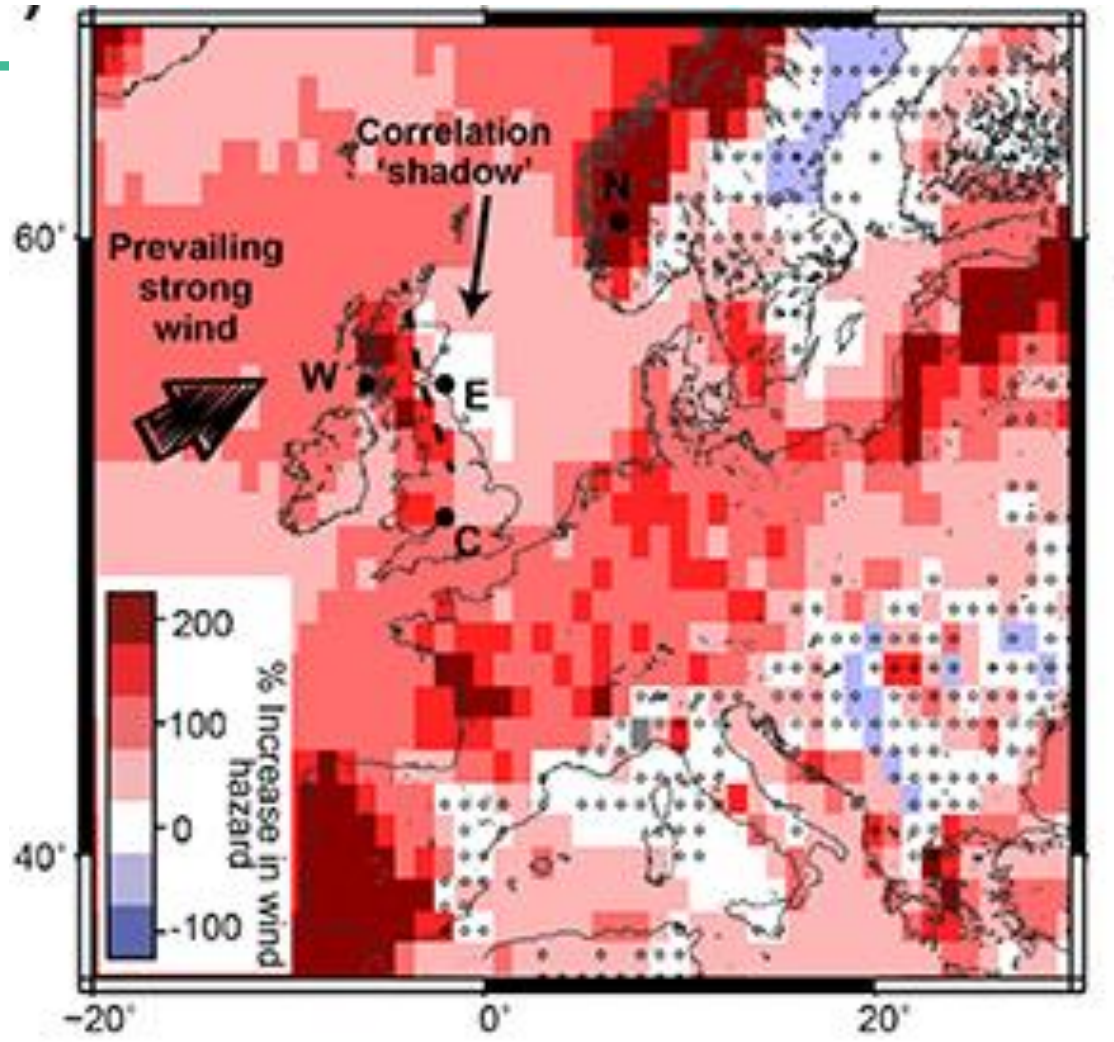
In years which are wetter, there is a substantially increased chance of their being a large wind hazard over parts of Europe

- 600 simulations of seasonal weather forecast data from the Met Office decadal prediction system (Oct-Mar, 1993-2016)

- $H_W = \sum (v_{max} - c)^3$ for $v_{max} > c$

- Total precipitation accumilation

- Hillier and Dixon (2020)



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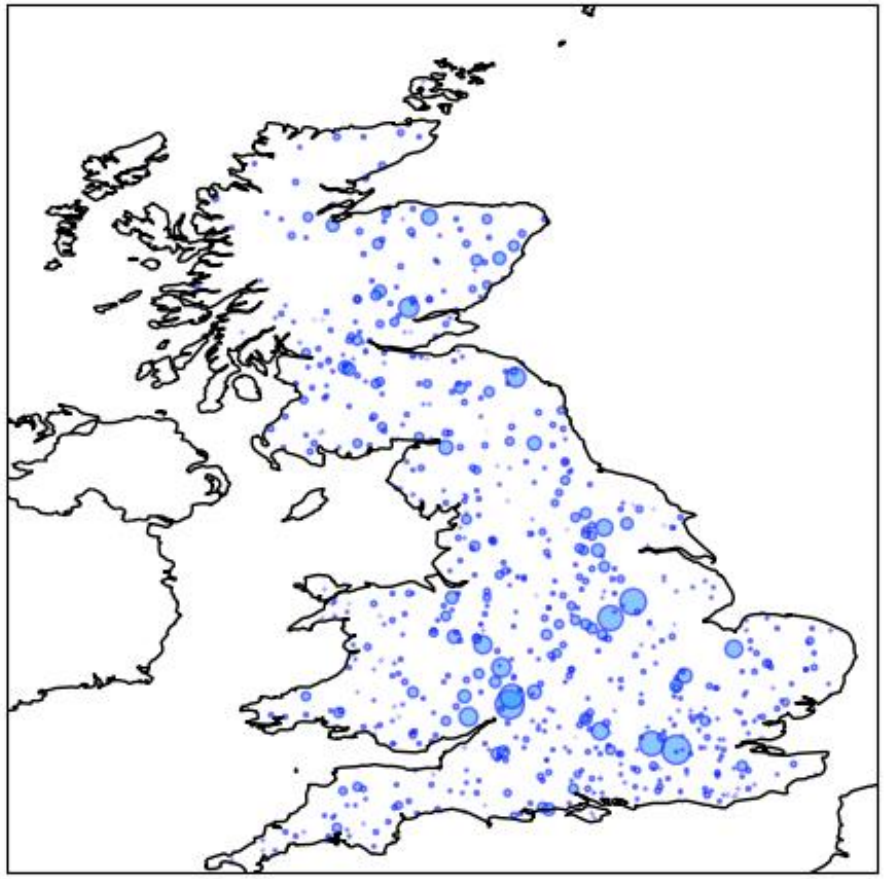
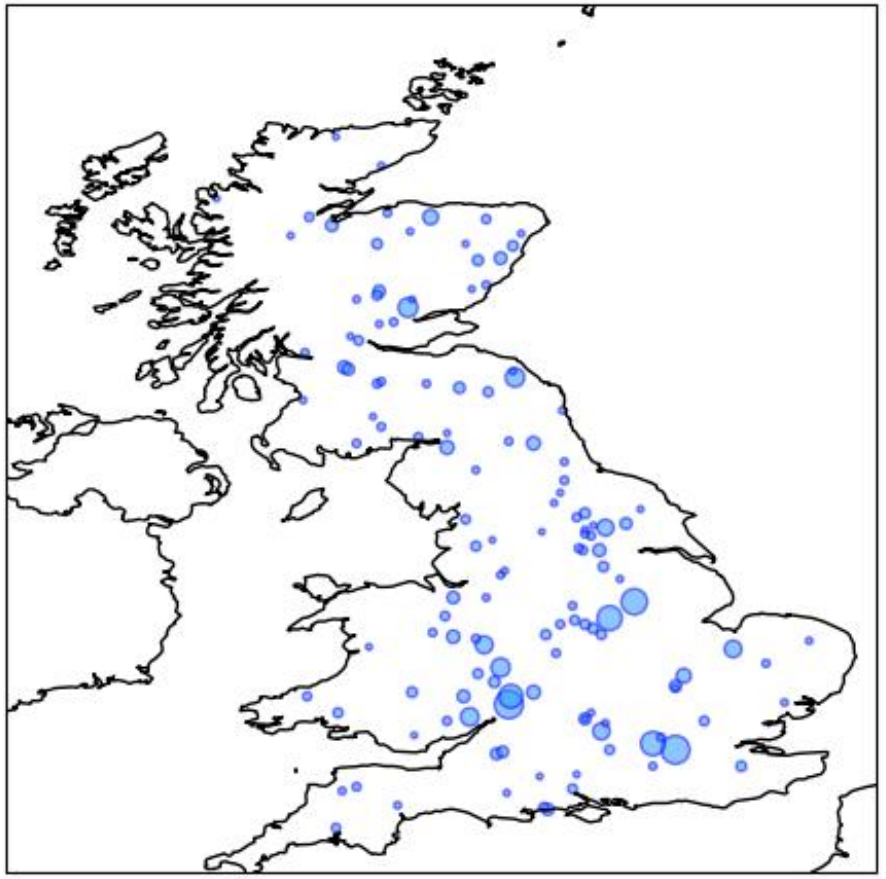
CAMELS-GB 671 stations



Top 20%



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Weather

Strongest co-occurrence (**r = 0.7-0.8**) for weather related variables is over a few days, related to individual atmospheric events.

Storm (e.g. ETC)

~Daily (**2-3 days**)

Precipitation, V_{max}

Notable storm

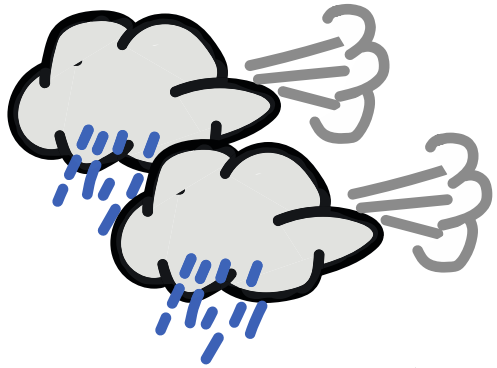
Hazard & Impact

River flow and wind extremes co-occur most strongly (**r = 0.6-0.7**) over a few weeks, involving clusters of storms.

Storm sequences

10-15 days

Flow, V_{max}^3



Storm 'cluster', each event may have a different character

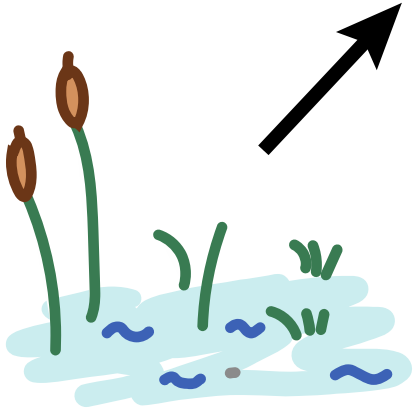
Implications

Impacts co-occur most strongly (**r = 0.4-0.5**) on a monthly time-scale, with catchment saturation increasingly important

'Memory' in catchment saturation

30-90 days

Impact & impact proxies - SSI, FSI



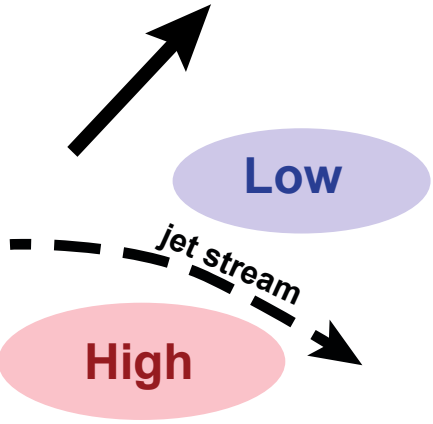
Catchment saturation

Less well understood

Large -scale drivers?

Seasonal

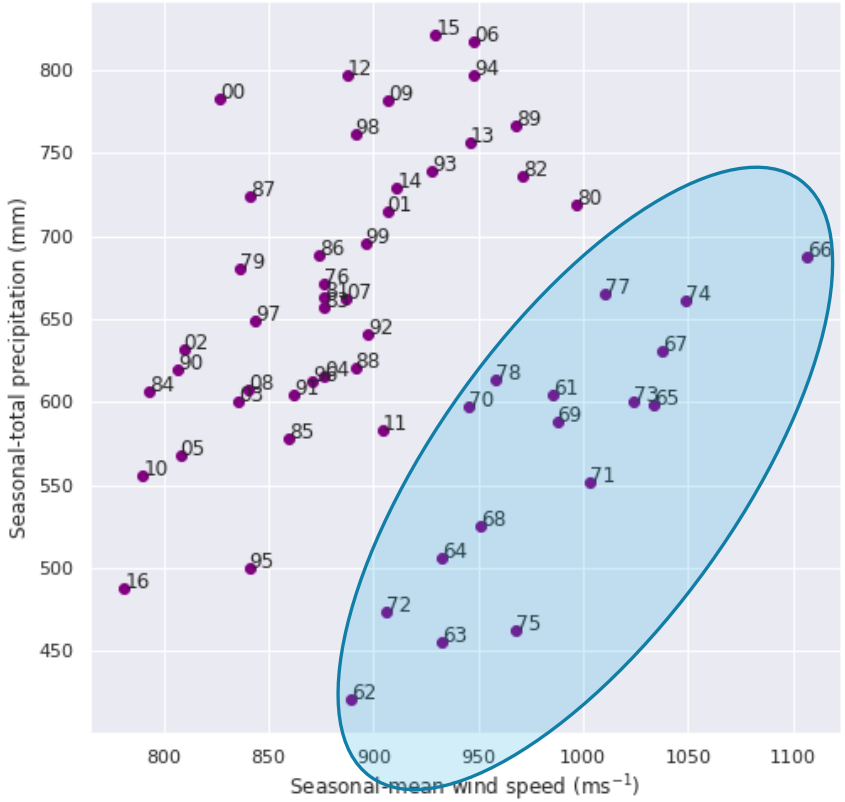
e.g. solvency

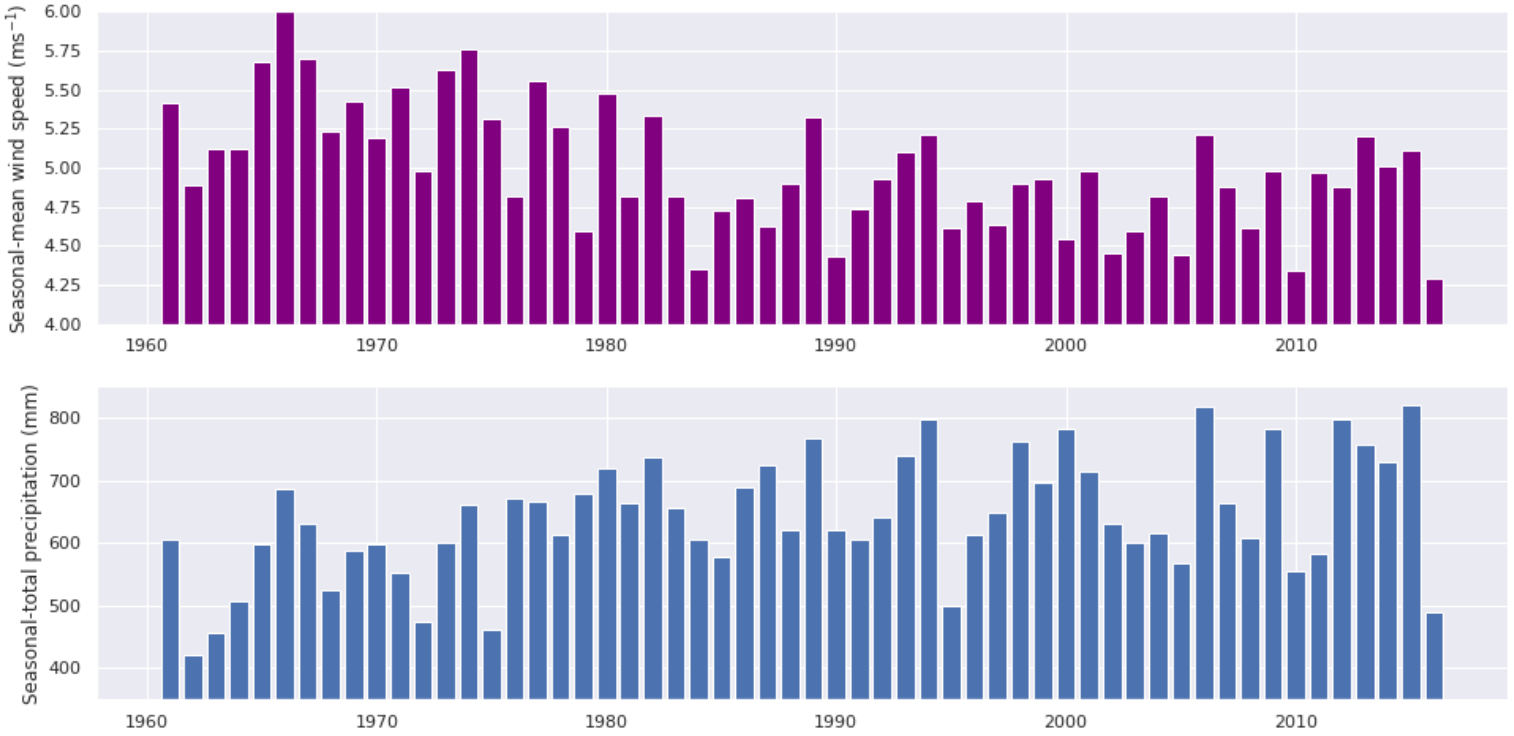


Large-scale drivers (e.g. teleconnections)

Potential issues with long datasets

- Motivates the need for high quality ensemble, cliamte model simulations (scrapped 1960-1980 in CAMELS/CHESS-MET as trends are lurking)





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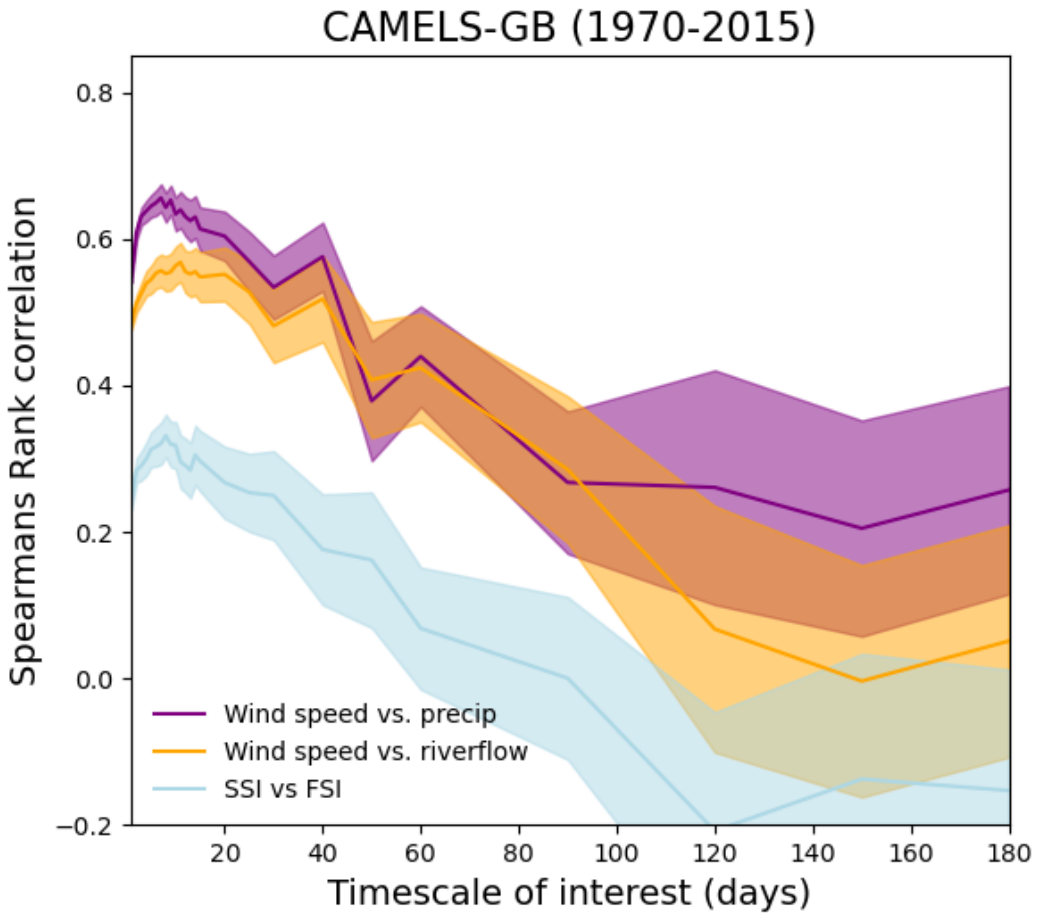
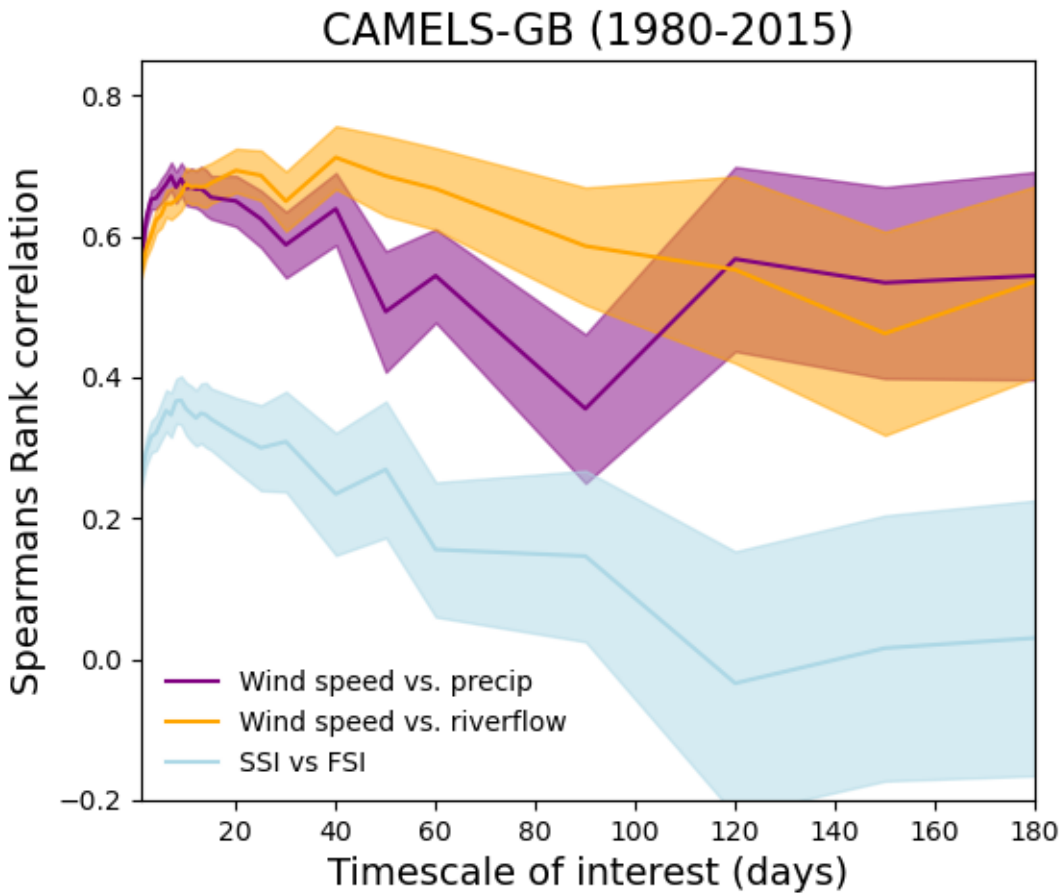
Correlation analysis: observations





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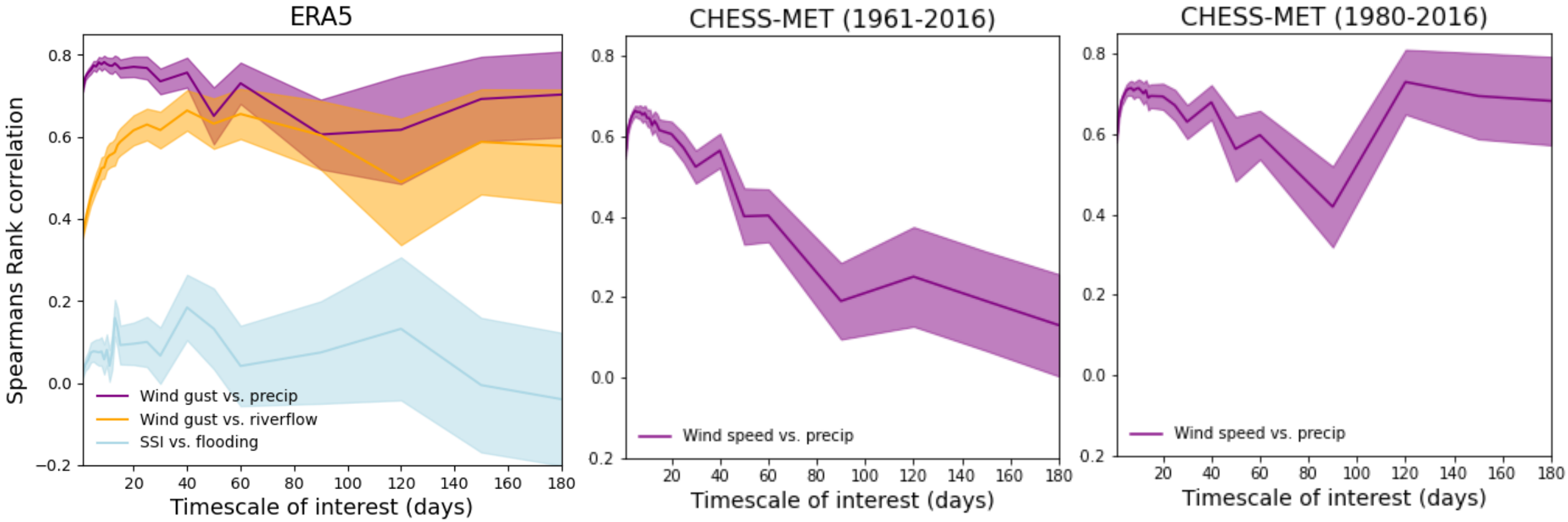

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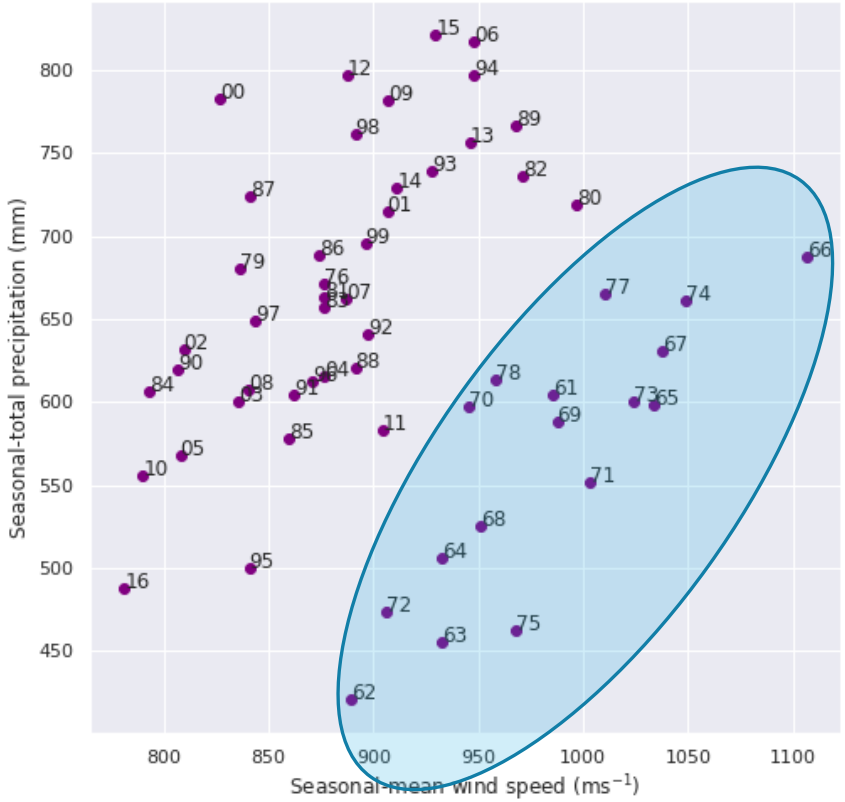

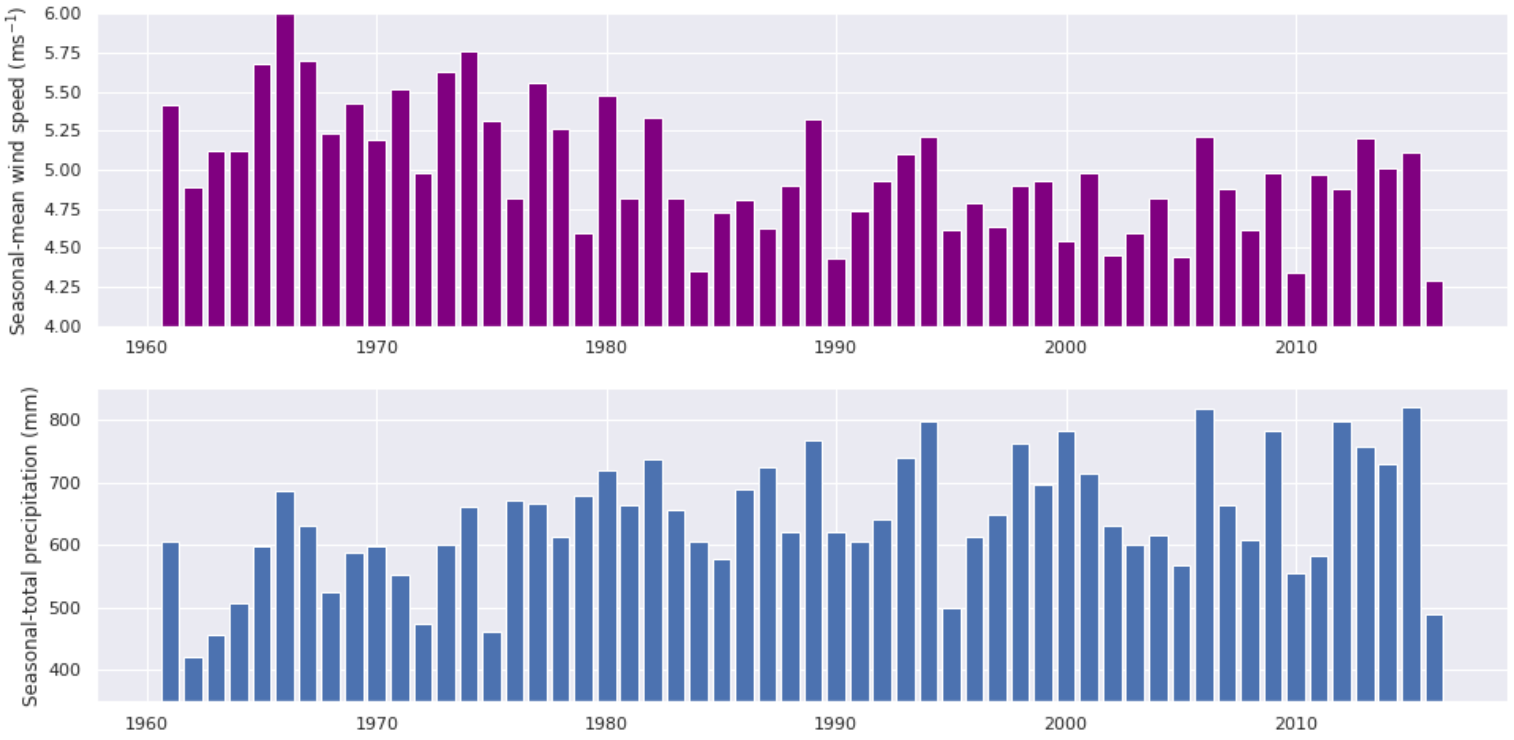

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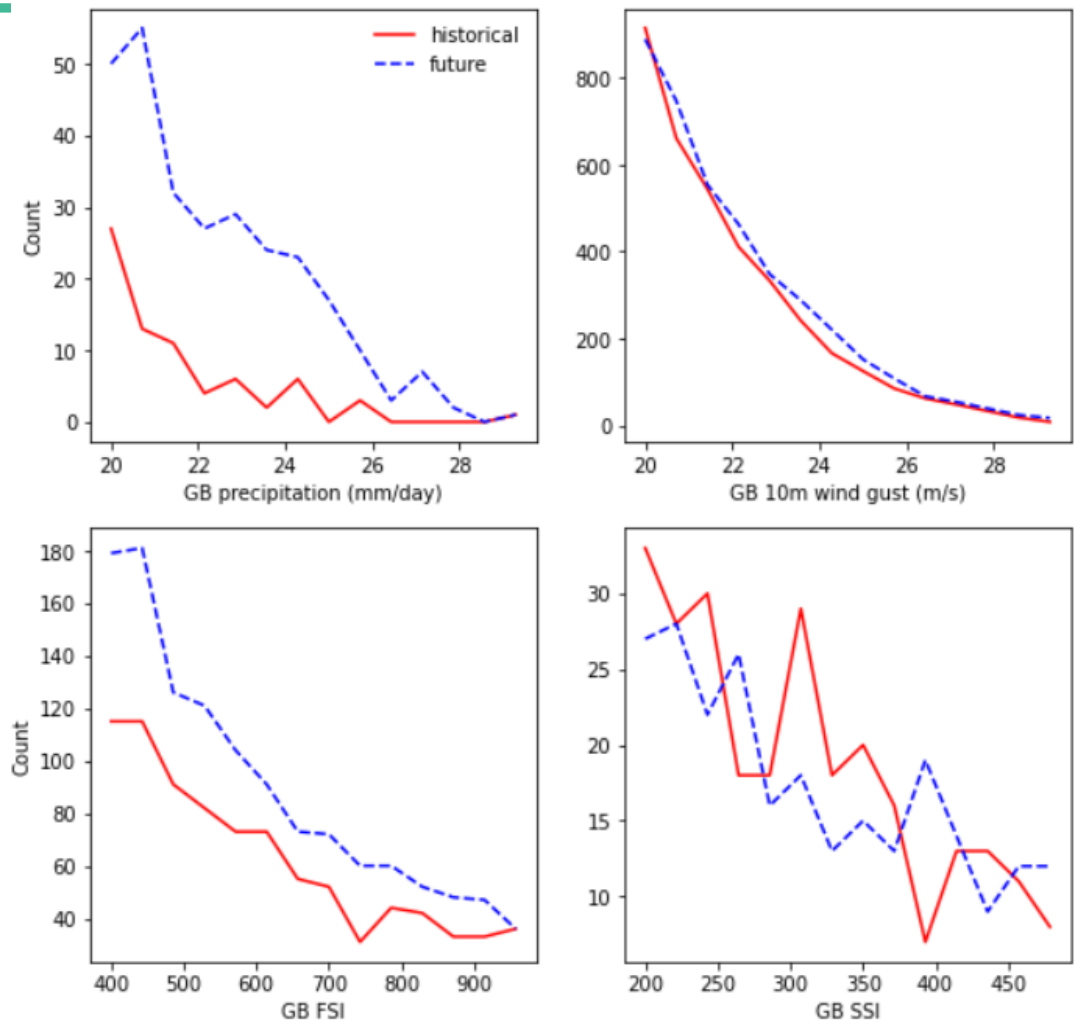
Correlation analysis UKCP18 12km model

- If we zoom in on the tails of distributions we see differences in the FSI and precipitation metrics
  - More extreme precip over GB in a future climate and more large FSI events.

  - Much less obvious what's happening for wind gusts



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UKCP12km model SSI/FSI

UKCP hist 1 day	Hit SSI	Miss SSI
Hit FSI	12 %	27%
Miss FSI	10%	51%

UKCP hist 3 day	Hit SSI	Miss SSI
Hit FSI	21 %	27 %
Miss FSI	13 %	39 %

UKCP hist 7 day	Hit SSI	Miss SSI
Hit FSI	48 %	21 %
Miss FSI	15 %	16 %

UKCP fut 1 day	Hit SSI	Miss SSI
Hit FSI	13 %	29 %
Miss FSI	7 %	51 %

UKCP fut 3 day	Hit SSI	Miss SSI
Hit FSI	22 %	29 %
Miss FSI	9 %	40 %

UKCP fut 7 day	Hit SSI	Miss SSI
Hit FSI	47 %	24 %
Miss FSI	11 %	18 %

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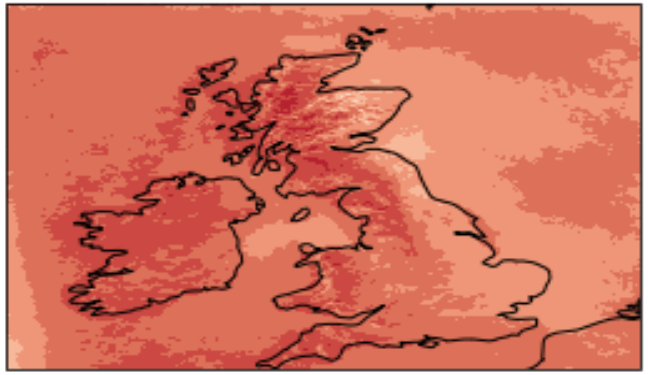
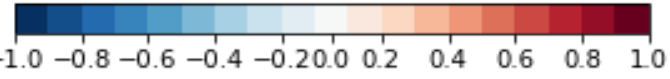
UKCP2.2km data slices (correct fields) Daily correlations, 1 ens member

UKCP2.2km DJF 1980-2000

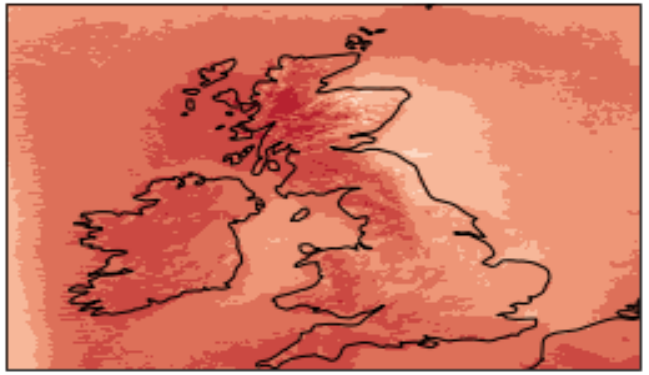


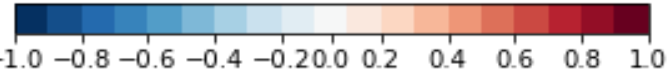


Correlation Coefficient

aily max 10m wind gust vs total precip

UKCP2.2km DJF 2020-2040

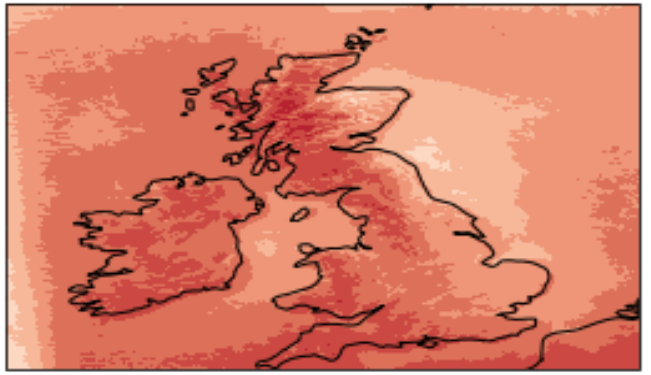


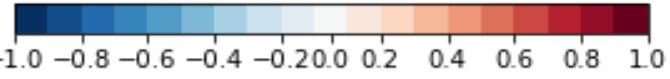


Correlation Coefficient

Daily max 10m wind gust vs total precip

UKCP2.2km DJF 2060-2080





Correlation Coefficient

Daily max 10m wind gust vs total precip

Daily comparison ERA5 vs. UKCP2.2km