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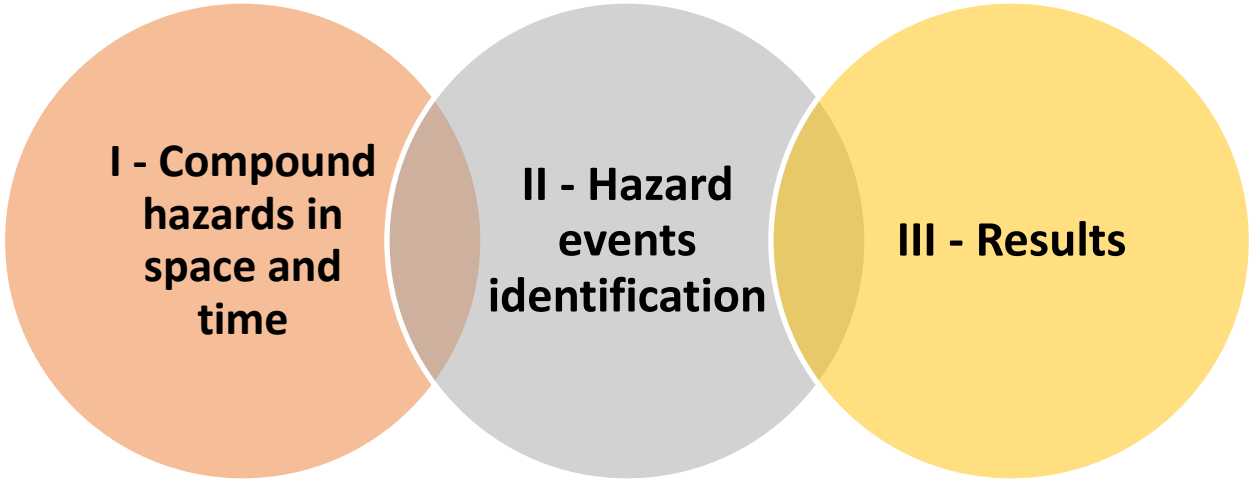
Spatiotemporal footprint of hydrometeorological compound events in Great Britain

EGU 2020 – Session ITS2.16 "Compound weather and climate events”

Context on hazard interrelations

- **Multiple natural hazards** pose different types of problems including:
  - How do hazards **relate**?
  - How to **model** interrelations between hazards?
  - On what **scales** hazard interrelations occur?

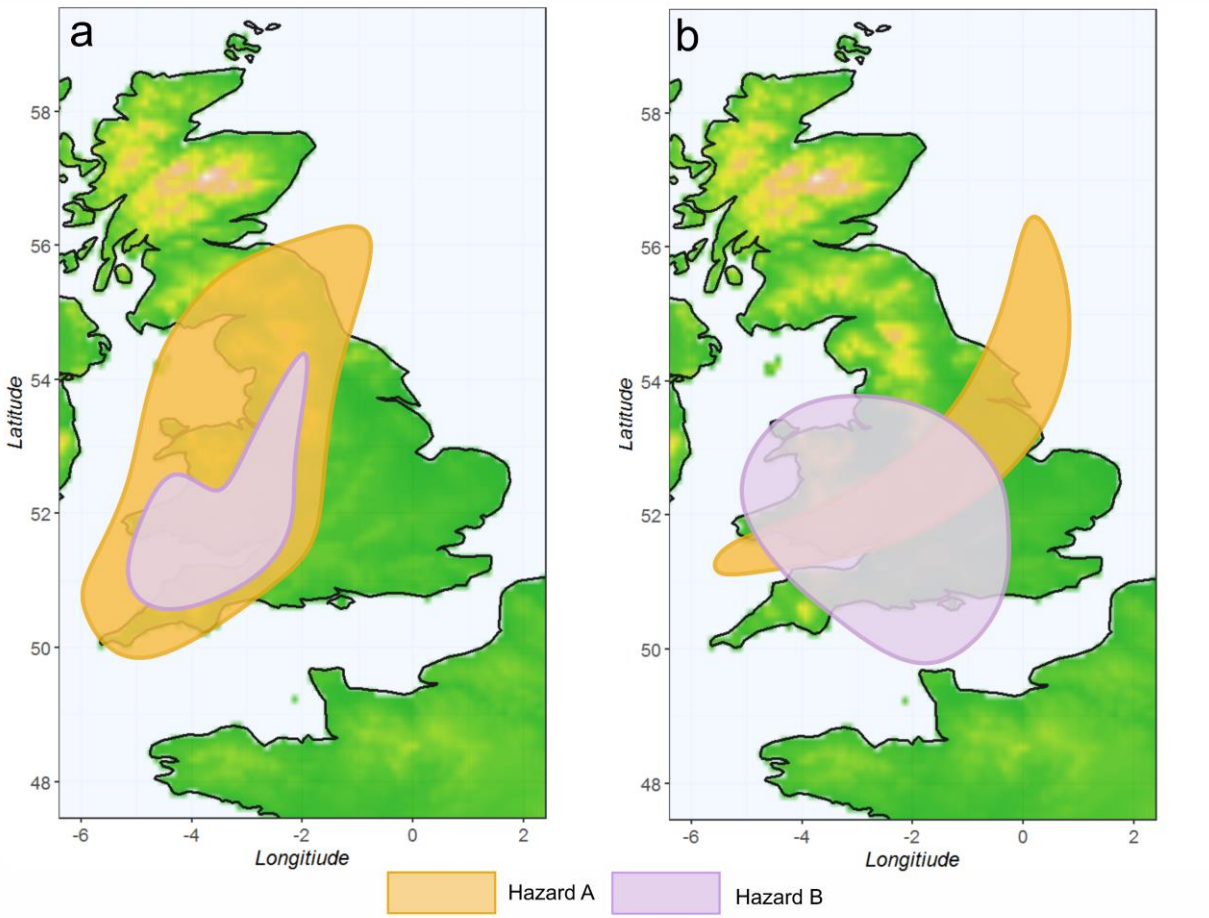
- Hazards **interrelations** in **space** and **time**:
  - **How long** does compound hazards events last?
  - **How many sites** can be affected by a single compound hazards event?
  - **When and where** does compound hazard events occur?



Approach aimed to be applicable to different natural hazards interrelations

Compound hazards/extremes events

- **Compound hazards/extremes**: two or more associated hazards/extreme events **impacting** the **same time and place**.
- Is it exactly **same location** at the **same time?**
- How to define and characterize compound hazards in time and space ?
  - **different time scales** (minute, hour, day, week)
  - **impact various sites** at the **same time** or **successively**
- *Hazard event* = a **cluster** in space and time representing the **footprint** of a **singular phenomenon**

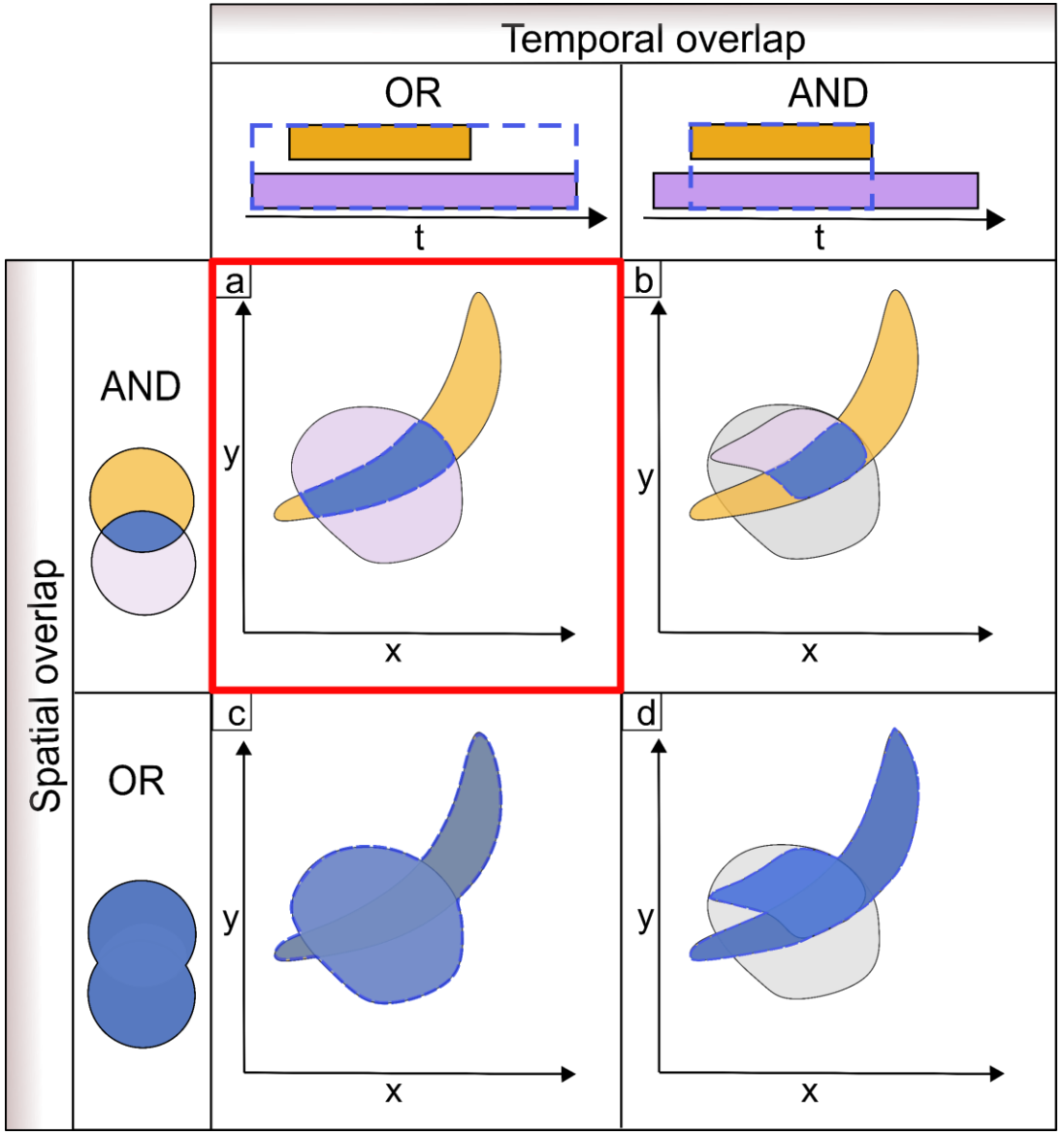


Defining compound hazards in time and space

Spatiotemporal Compound hazards *:* different hazards occur on the **same area** during the **duration** of **an event.**

(a) spatial overlap in aggregated time (AND-OR)
(b) spatiotemporal overlap (AND-AND)
(c) aggregated time and space (OR-OR)
(d) temporal overlap on aggregated space (OR-AND)

Spatiotemporal **footprint**: Area impacted by two(or more) hazards during the aggregated duration of a event (AND-OR).



Hazards, data & study area

Two storm-related hazards:

- **Extreme wind**
- **Extreme precipitation**

The interrelation of extreme wind and extreme precipitation can result in different impact than the addition of their impacts

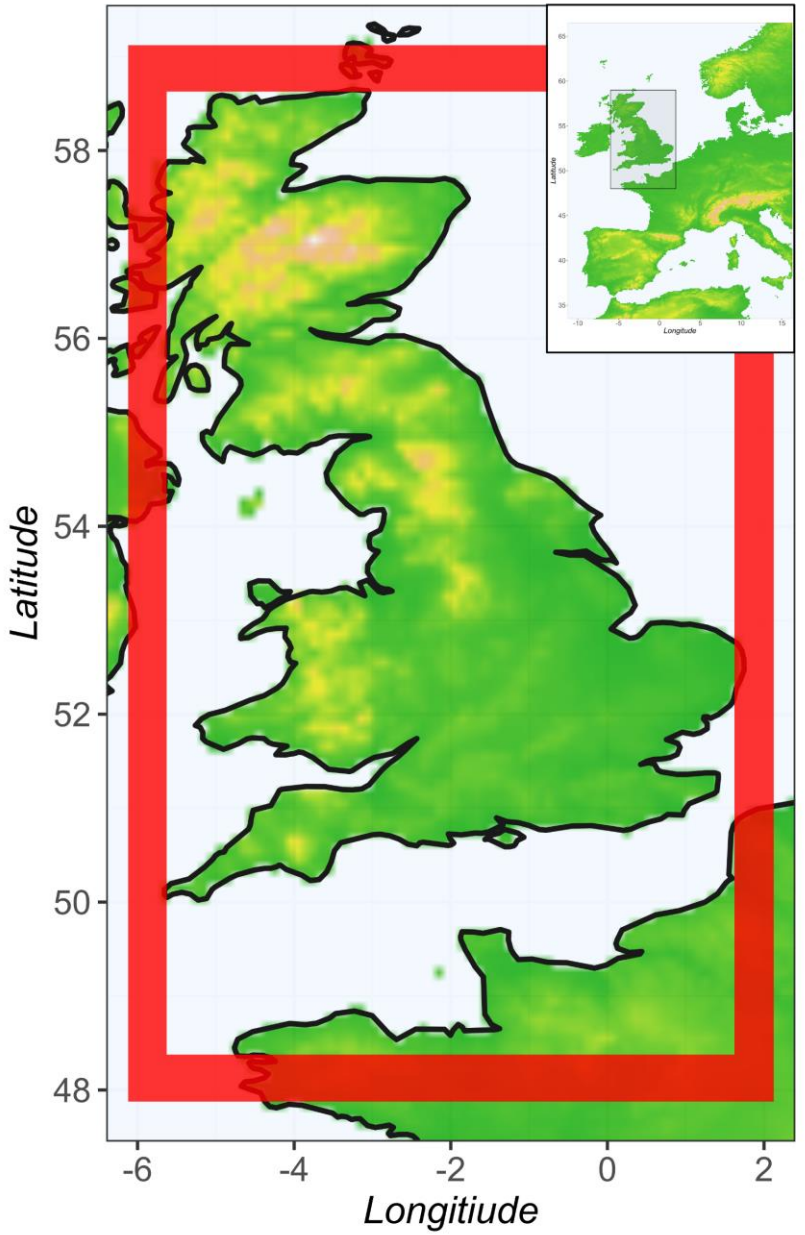
ERA 5 climate reanalysis (1979-2019)

- Spatial resolution = 0.25° x 0.25°
- Temporal resolution = 1 hour

Study area: Great Britain

Variables (averaged over a grid box):

- **Total hourly precipitation** (mm/h)
- **Maximum hourly wind gust** (m/s)



Guard area (red) around the study area to mitigate edge effects

Event identification

0.99 quantile on each cell:

- Above hazard ==TRUE
- Below hazard ==FALSE

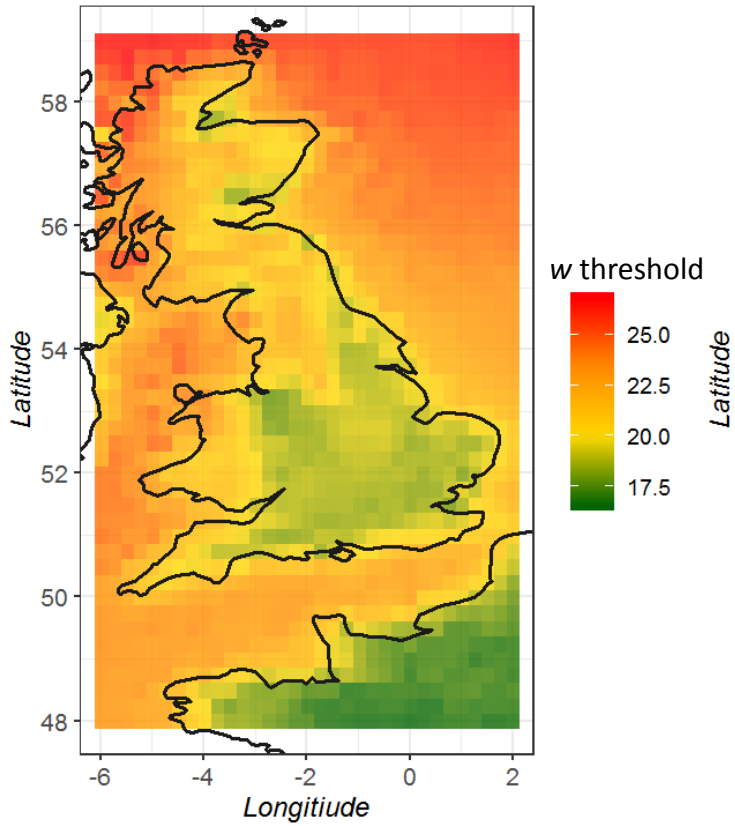
If a cell is above threshold, spatiotemporal coordinates are kept

Two sample of extreme events (hazards):

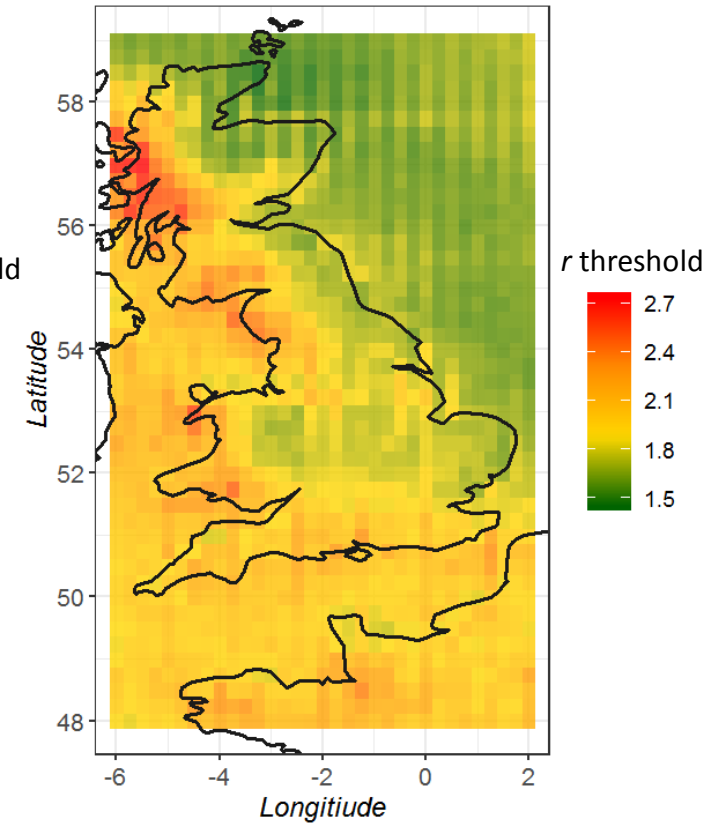
i. occurrences of wind gust above the threshold

ii. occurrences of precipitation above the threshold

wind gust (w) [m s^{-1}]

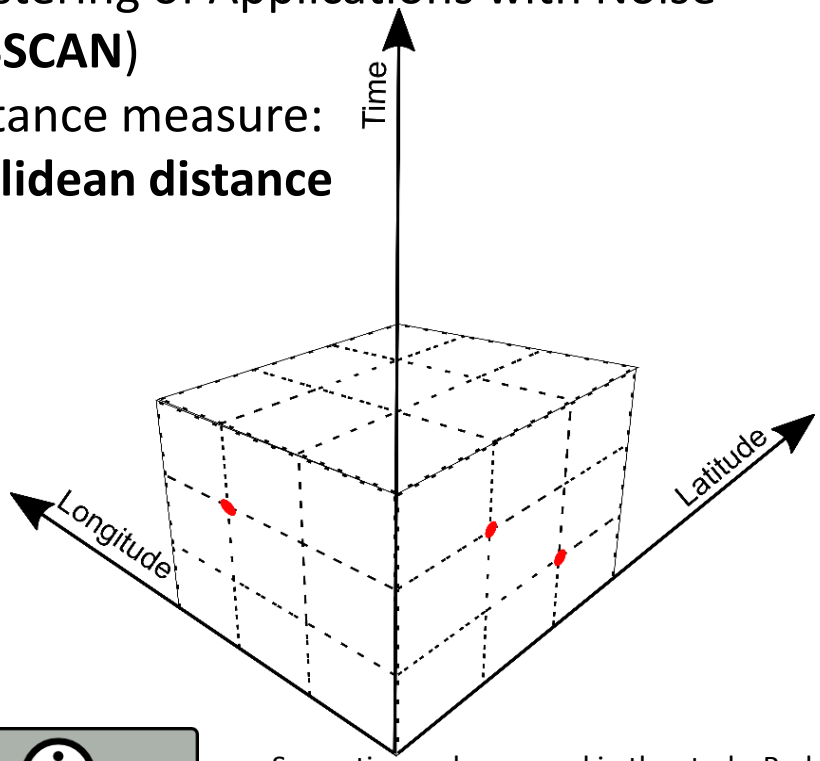


rain (r) [mm h^{-1}]



Clustering procedure

- Extreme events are point objects with coordinates in space (latitude and longitude) and time (date)
- Clustering algorithm: Density Based Spatial Clustering of Applications with Noise (**DBSCAN**)
- Distance measure: **Euclidean distance**



Space time cube as used in the study. Red dots are extreme events.
Each box is 0.25 deg x 0.25 x 1hour

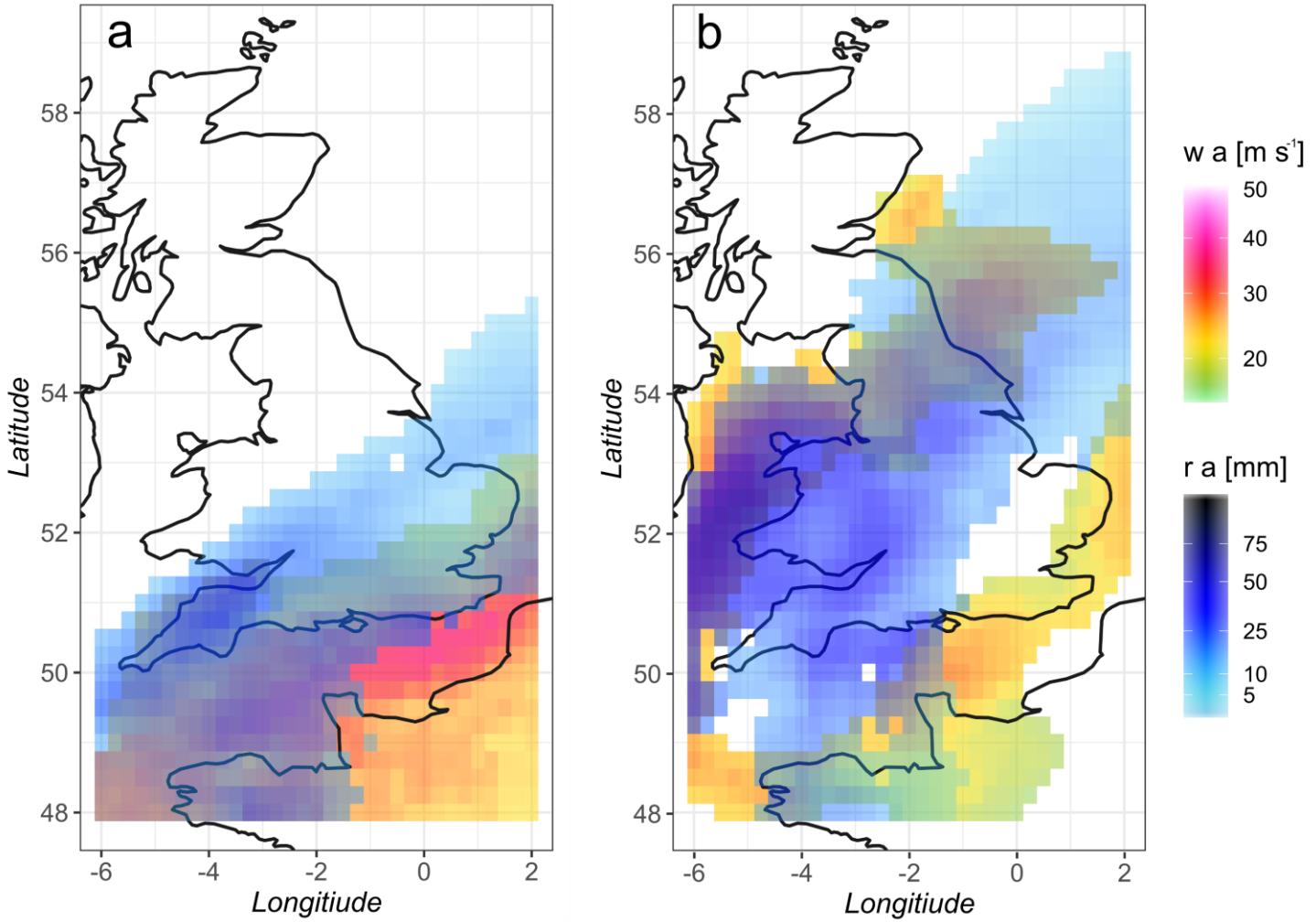
- DBSCAN finds clusters with **arbitrary shapes** and do not require the predetermination of the number of clusters
- Extreme events are clustered in time and space
- **Clusters** created are hazard events with attributes

Attributes of hazard events

	Attribute	*Wind events*	*Rain events*	*Compound hazard events*
Intensity	r_a *(mm)*		✓	✓
	w_a *(m* s^{-1}*)*	✓		✓
Scales	*Spatial extend (# cells)*	✓	✓	✓
	Duration (h)	✓	✓	✓
	Event center	✓	✓	

Output example: Storm Angus

- Storm Angus occurred on November 19th 2016 (a). A consecutive depression occurred 36h later on 21st November 2016 (b).
- Shows intensity of both hazards (r_a, w_a), single and compound hazards footprints.
- Hazard footprints are in agreement with Met Office observations.



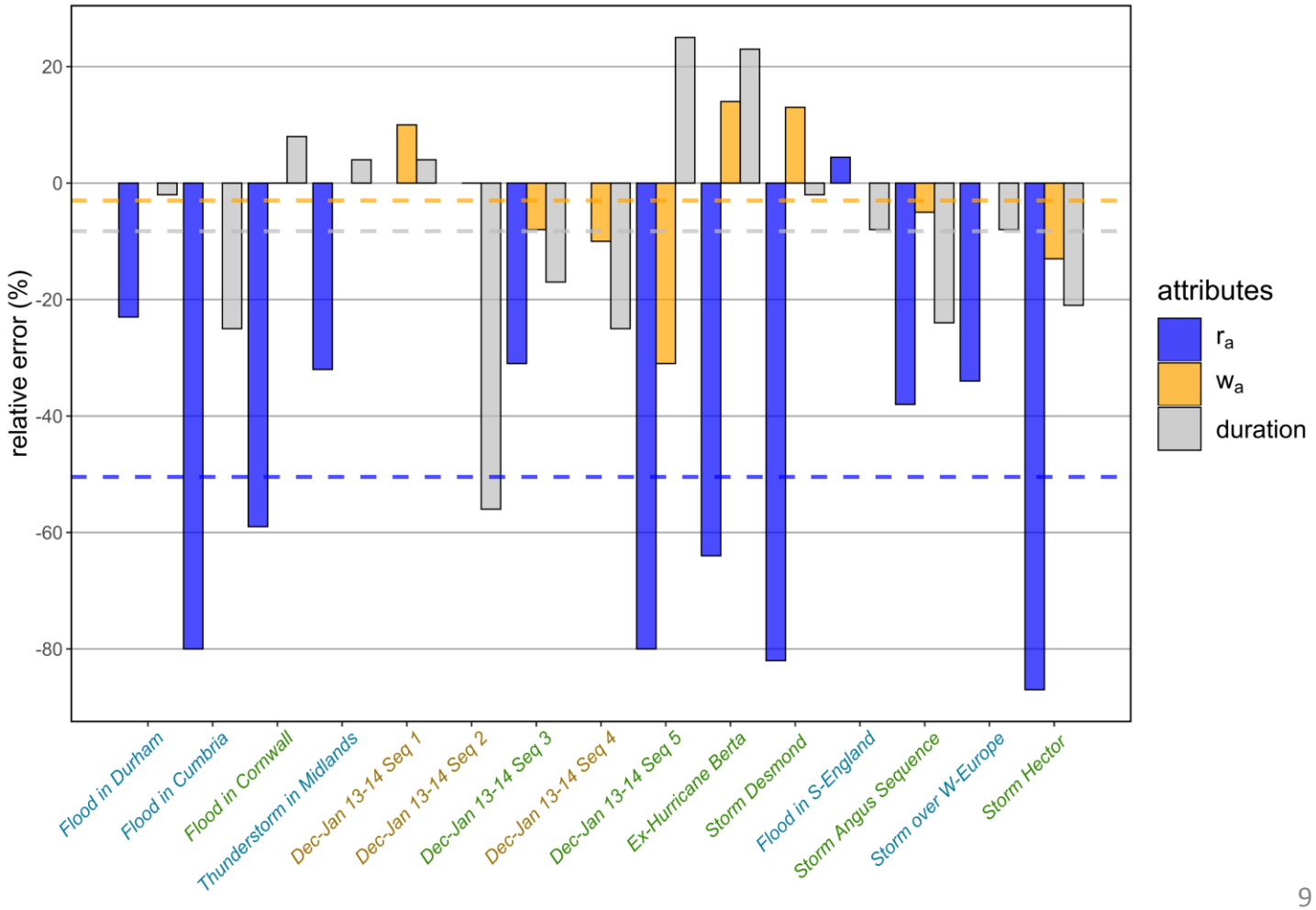
Confrontation with observed past major events

15 past major events from the period 2009-2019 that impacted Great Britain.

- 5 Extreme rainfall events (blue)
- 3 Extreme wind events (brown)
- 7 Compound wind/rain events (green)

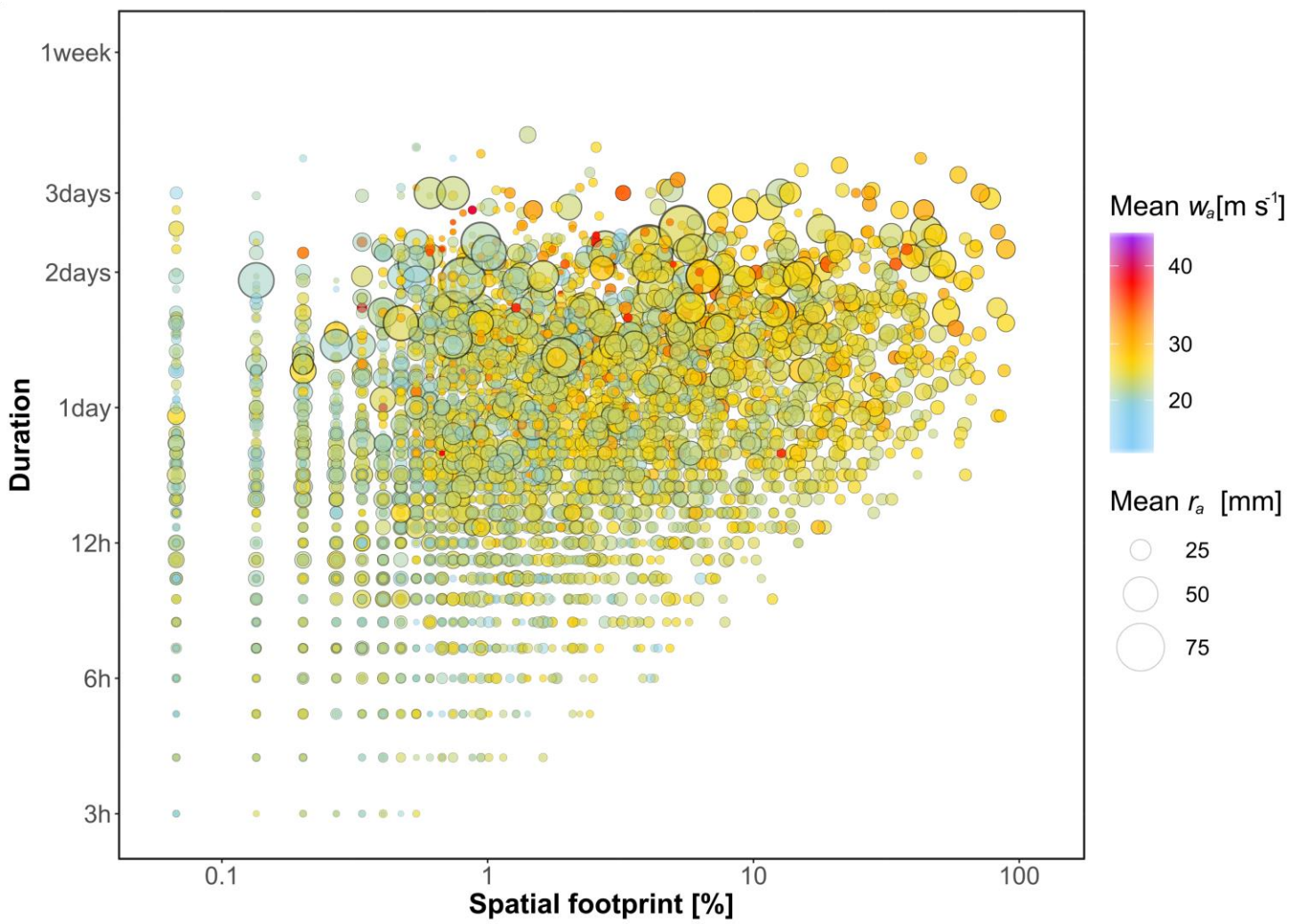
- Comparison cluster attributes (r_a, w_a, duration) against observations.

- Method underestimates r_a but accurately catches w_a and duration



Spatial and temporal properties of compound hazard events

- Compound wind and rain events can last from 3 hours to 4 days and cover up to 90% of the study area.
- Mean w_a ($\overline{wa}$) and mean r_a ($\overline{ra}$) provide information on the average intensity of the two hazards in the events
- Almost no event with high $\overline{wa}$ and $\overline{ra}$
- Potential impact increases with spatial footprint and duration



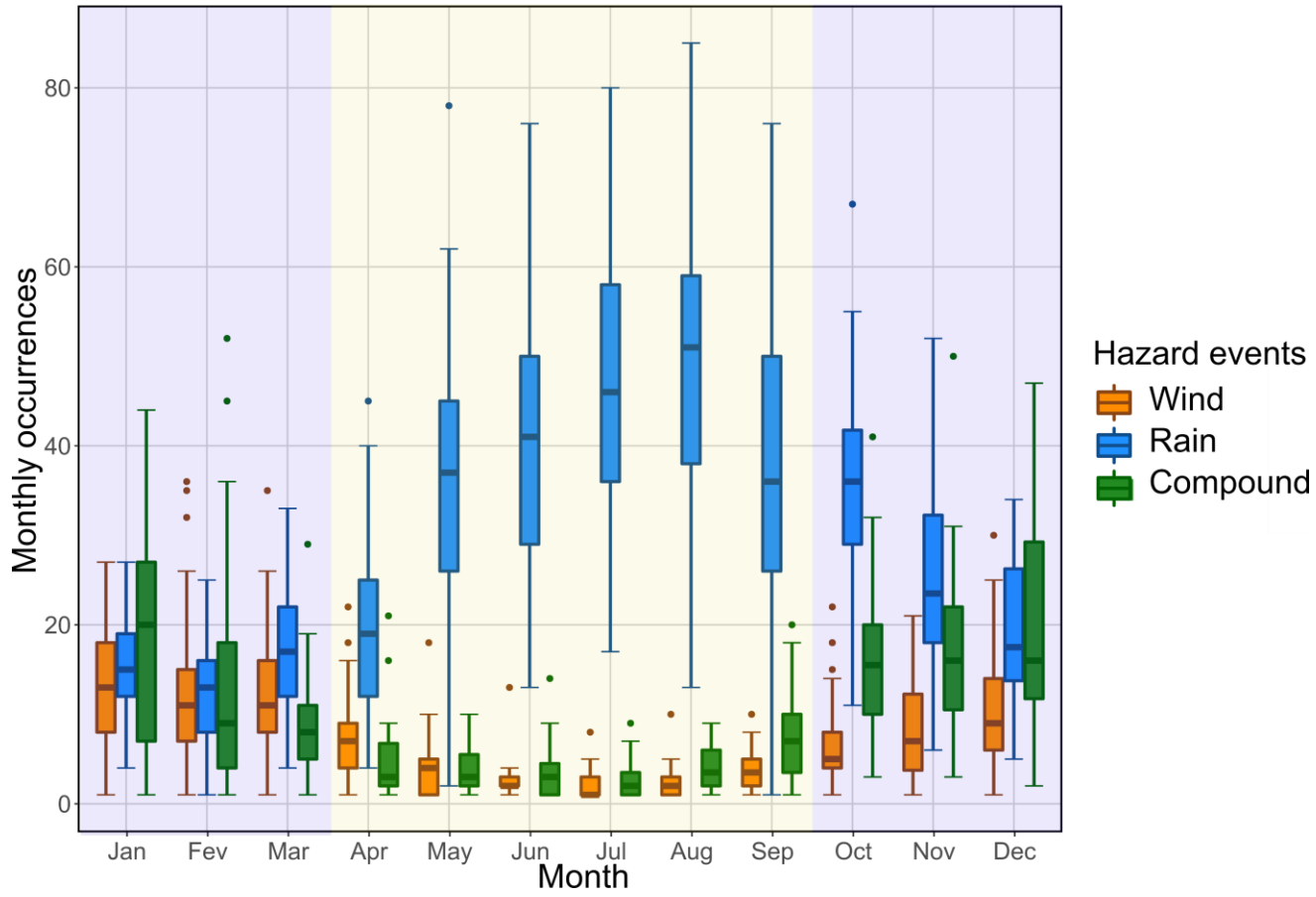
Seasonality of single and compound hazard events

Compound event occurrence is correlated to wind event occurrences in Great Britain.

- "High" Season for compound events is ONDJFM (Winter)
- "Low" Season for compound events is AMJJAS (Summer)

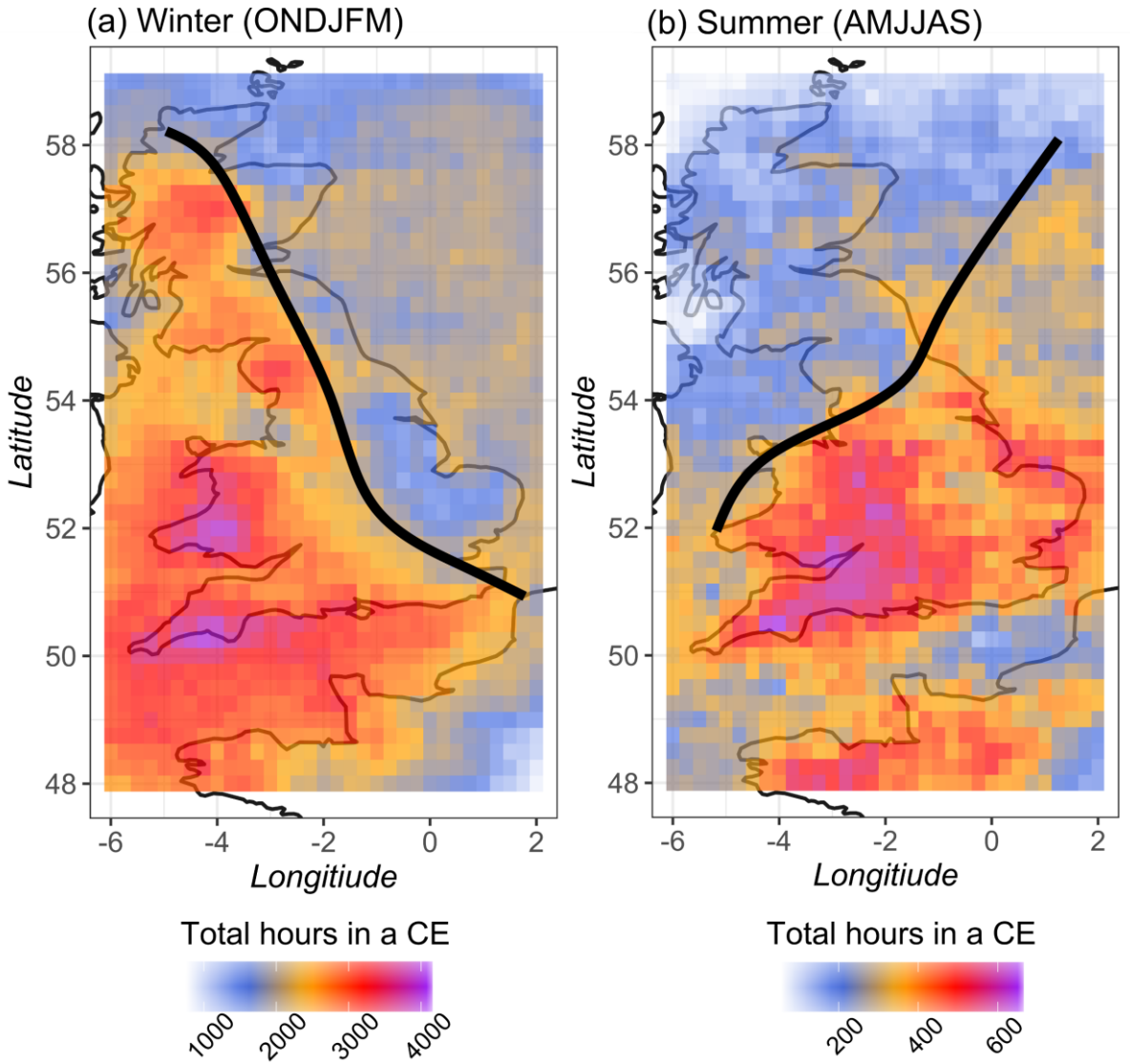
- **82%** of the Compound hazards **events** occur in ONDJFM

- **88%** of **hours** in a compound hazards event occur in ONDJFM



Compound hazards hotspots and patterns

- Compound wind and rain does not affect all parts of Great Britain equally
- **West/East division in Winter**. Most affected areas = South west and mountainous ranges
- **North/South division in Summer**. Most affected areas: South-West and South-East coast.



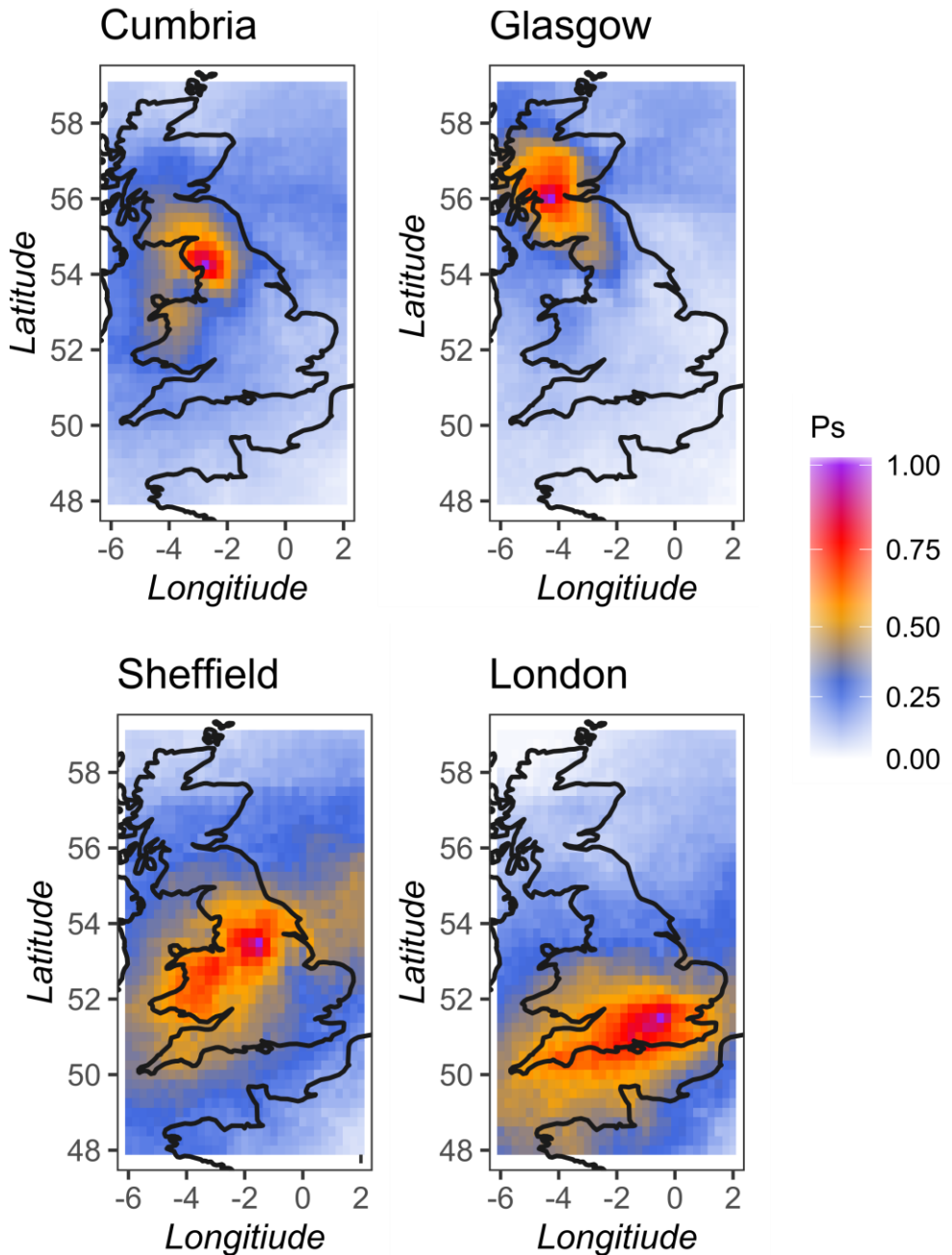
Single sites footprint

- Ps = Probability of each grid box (b) of being in a compound event knowing that one grid box (s) is in a compound hazards event (CE).

$$Ps = P(b \in CE \mid s \in CE)$$

- **Spatial dependence structure varies between sites**

- An event affecting Sheffield area is likely to also affect Wales but unlikely to affect SE England.



Perspectives & Conclusions

Perspectives:

- Estimate return periods of compound hazard events (and their spatial and temporal scales)

Recap and conclusion:

- Extreme events sample from climate reanalysis data
- Creation of a database of **4555 compound wind/rain clusters over Great Britain**
- Visualisation of spatial and temporal scales of compound hazard events
- Identification of spatial and seasonal patterns

- **Open to ideas about other ways to use the database & method**

THANK YOU

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