Co-occurring British flood-wind episodes (1980-2080) and potential large-scale drivers

Hillier, Bloomfield, Manning, Shaffrey, Bates, Kumar, Garry

Preprint

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Journal article

Co-occurring British flood-wind episodes (1980-2080) and potential large-scale drivers

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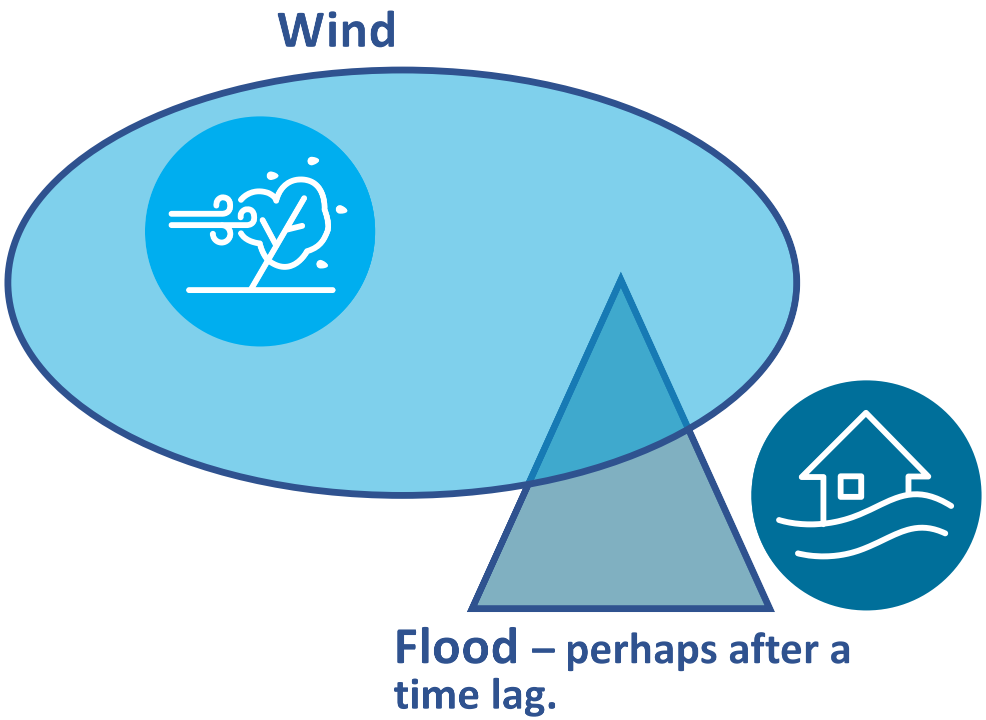

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The work presented here differs

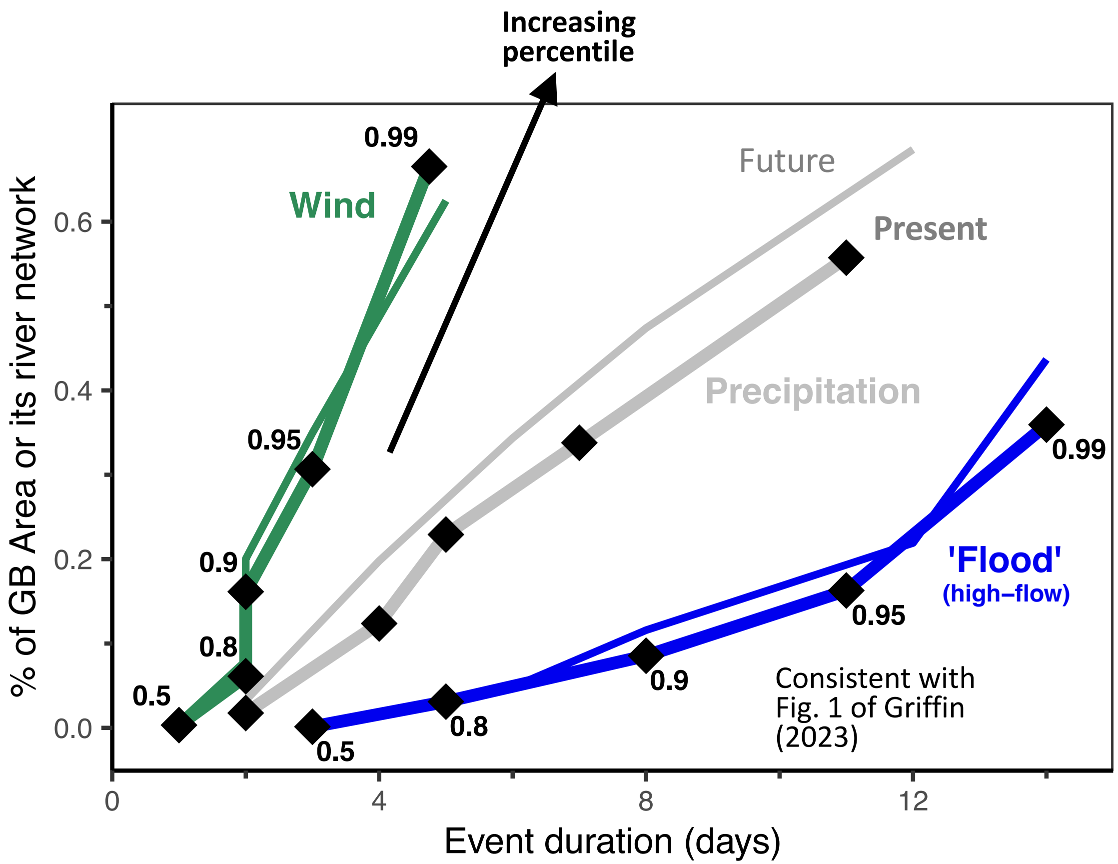
1. In that it defines multi-hazard 'episodes' on a hydro-meteorological basis (i.e. group events into what human might see as a cluster, don't just use back-to-back fixed length windows).
2. This aligns with stakeholder definitions and experience – particular focus on window size of Δt = 3 & 21 days (e.g. DEF sequence).
3. All events derive from the same climate model – UKCP18 (still surprisingly uncommon).
4. Flow, not just precipitation, as a proxy for 'flood' CEH's G2G model by Adam *et al* 2023
5. In terms of processes, it looks more closely at the jet stream as a driver of co-occurrence.

Research questions

Based on total (aggregated) impacts on the UK:

1. Do the most severe extreme winds and river flows tend to co-occur or not?
2. How does strength of co-occurrence vary with the time-window (Δt) used to group events into episodes?
3. Can a simple metric of jet position distinguish jet states characteristic of co-occurrence?
4. How do future changes in the North Atlantic jet stream influence co-occurrence?

Individual events, a sanity check ....



- A wind event set was created to match the existing river-flow one Adam *et al* 2023
- High flows longer duration but less widespread than storms.
- Good to confirm.
- 1981-1999 (thick line)
- 2061-2079 (thin line).
- Little change with time in terms of size and duration of events.

Not a plot of joint distribution.
Axes are independently assessed.

Event co-occurrence in multi-hazard episodes

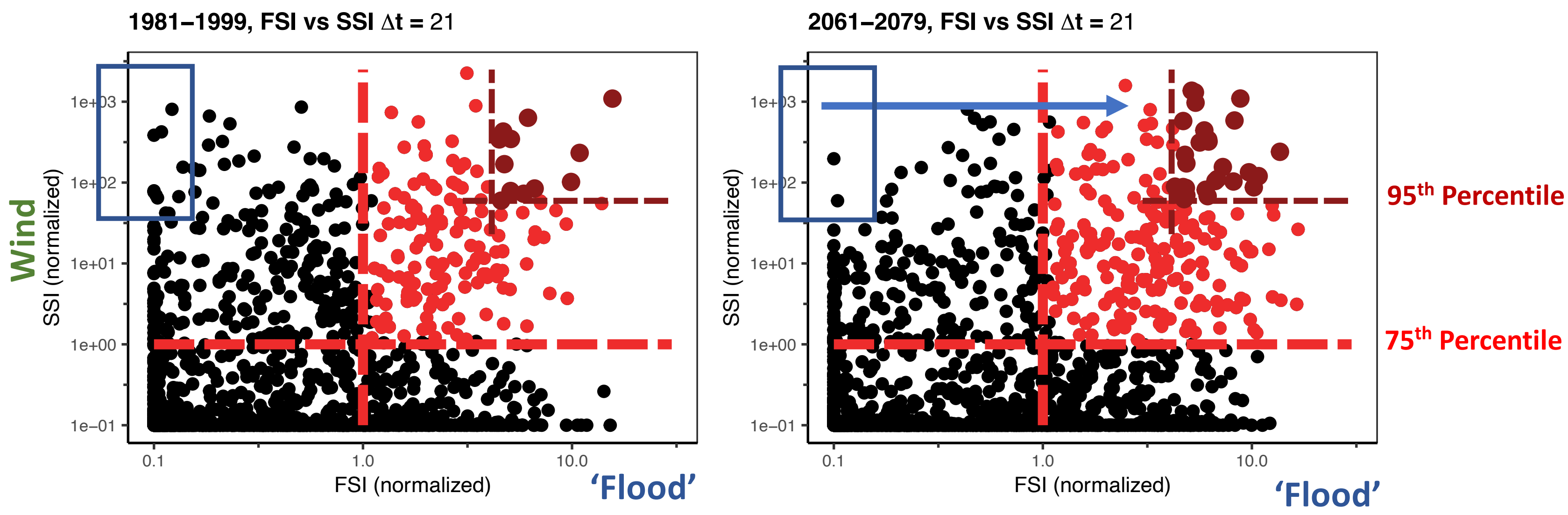
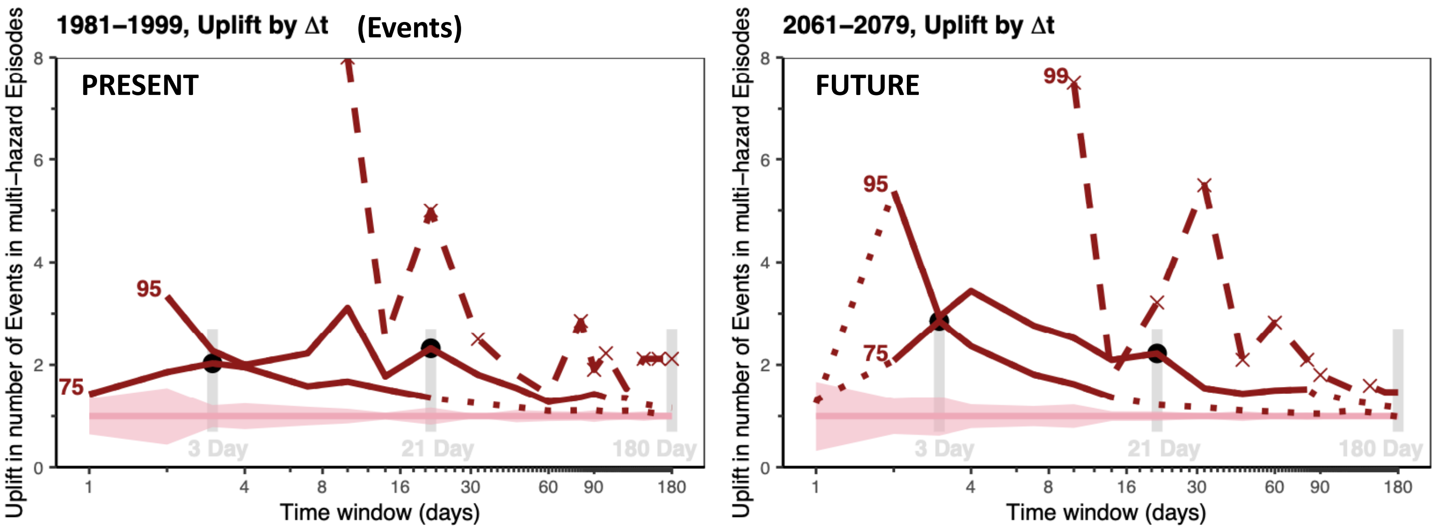


Illustration for windows of up to 21 days (Δt = 21).

Co-occurrence in severe multi-hazard episodes

- Increases in future (i.e. in upper-right corner), roughly doubled.
- Is more common than expected by chance (tested by simulation modelling)

Statistical simulation modelling of uplift in co-occurrence

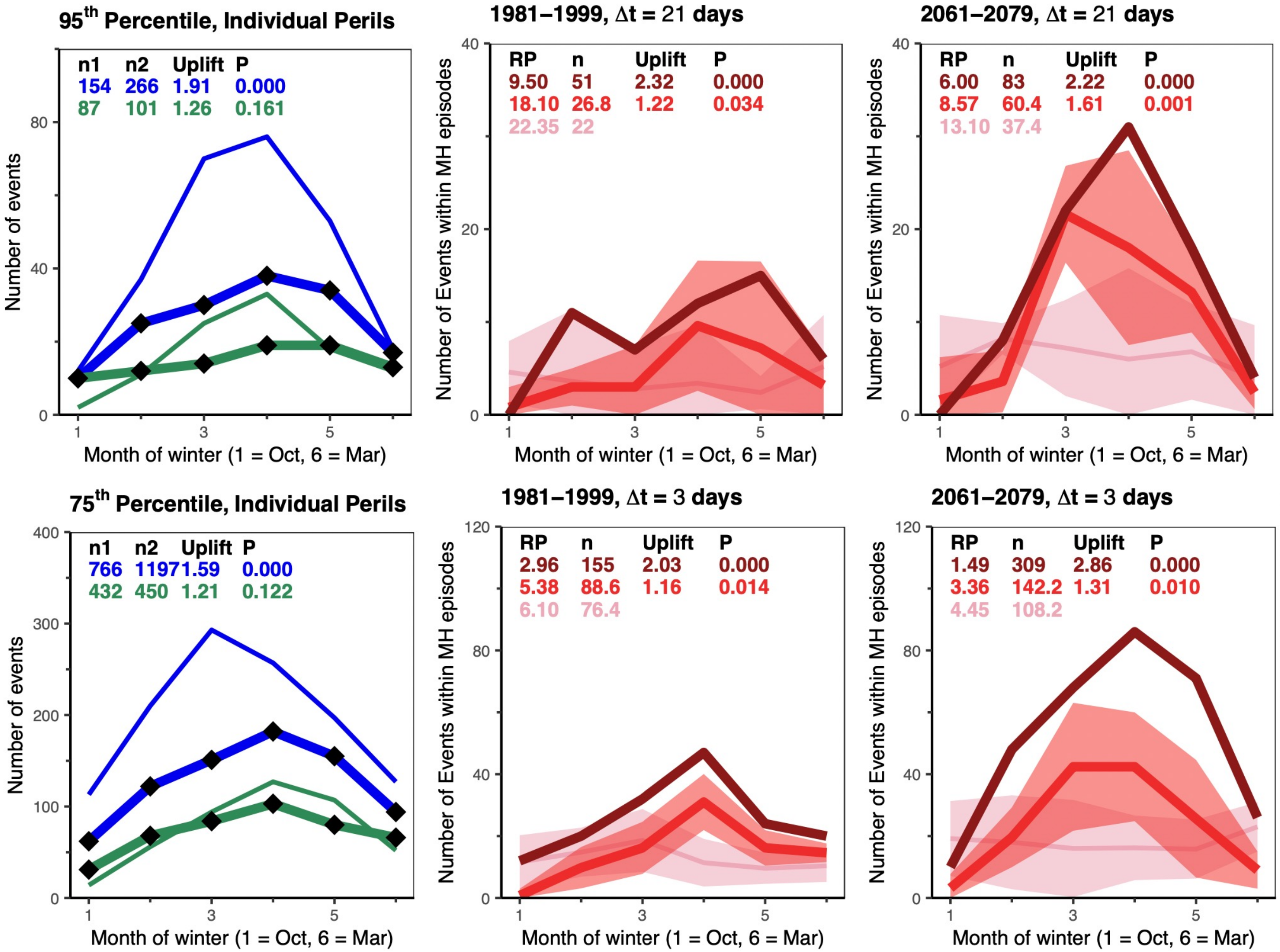


- The **UKCP frequency** of co-occurrence is **x2-4 over expectations for independence** for all Δt and percentiles ($p < 0.05$), present and future.
- **Factor is larger for more extreme, rarer events** (i.e. smaller Δt, higher percentiles).

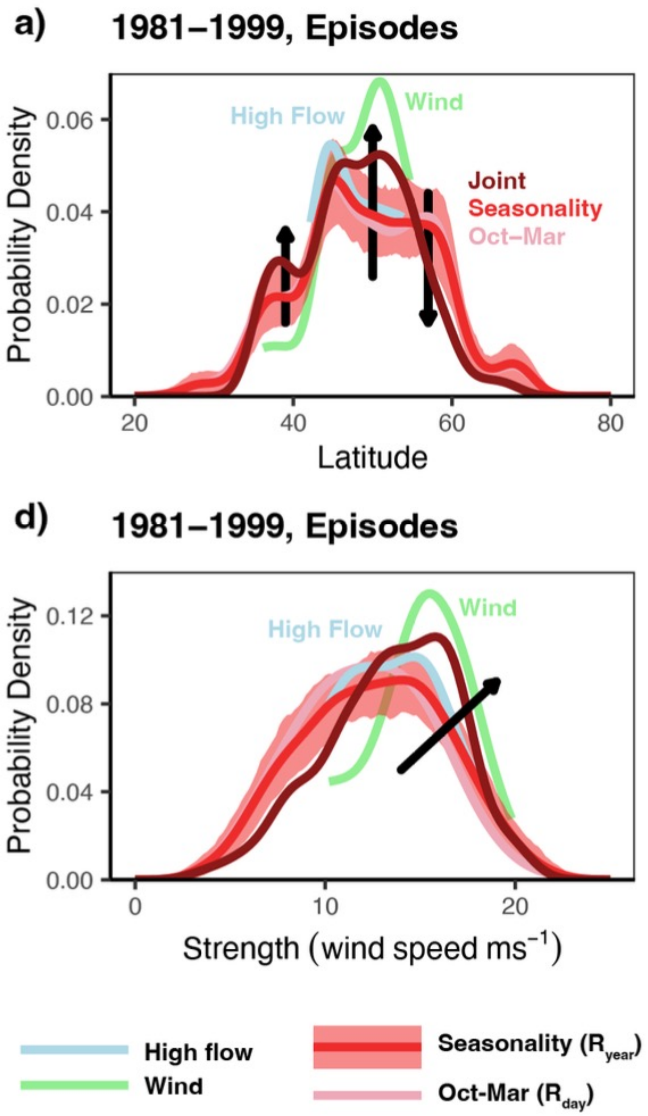
So, we perhaps need to be most concerned about underestimating co-occurrence in the strongest individual or closely consecutive storms

Illustratively, for Δt = 3 in 2061-2079 a 23 year return period event appears to be **a 103 year return period if independence is assumed, substantially underestimating risk.**

Why does the uplift happen? Seasonality of co-occurrence



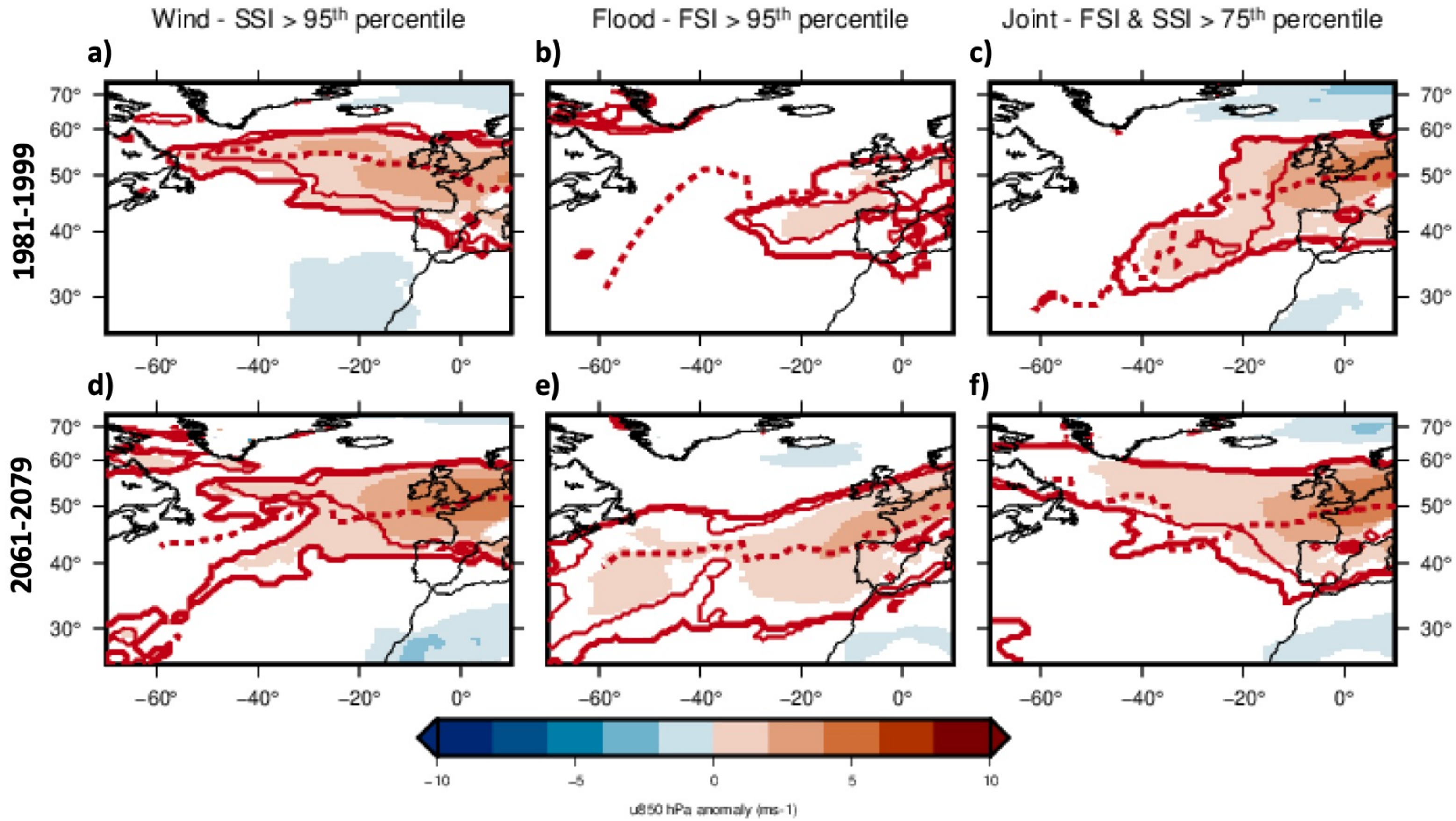
- Individually, flooding (**FL**) and wind (**WS**) events are notably more seasonal in future (thin lines), peaking Dec-Jan.
- **UKCP co-occurrence** is not explained only by **randomly timed events** (i.e. getting wetter isn't the whole answer).
- For Δt = 21, **UKCP co-occurrence** (present & future) is largely explained **if seasonality is modelled** (i.e. events are appropriately squeezed together in time).
- For Δt = 3 another, mechanism is needed.



Is the jet stream a dynamical driver ?

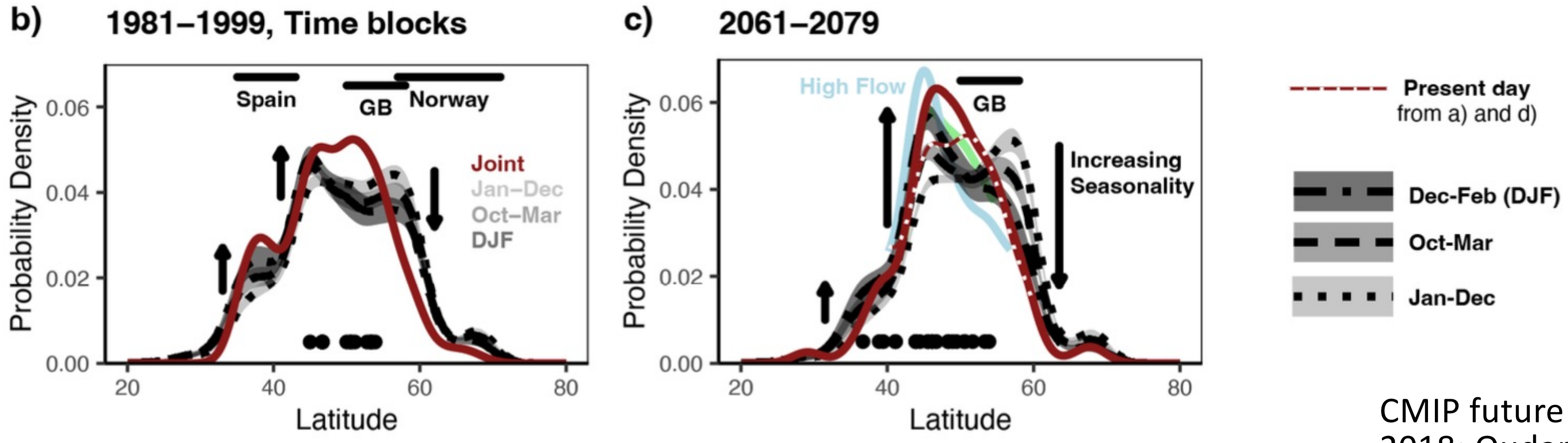
- For **Δt = 3**, 1981-1999 joint episodes have a distinctly strong jet (index of Woolings (2010), pointed at the south of GB.
- Joint event signature is between that of individual flood and wind events.
- Strong suggestion that **jet stream dynamics is involved in grouping high-flows** (and so flooding) **with extreme wind on a short time-scales.**

Zonal wind 850 hPa, for impact dates of Δt = 3

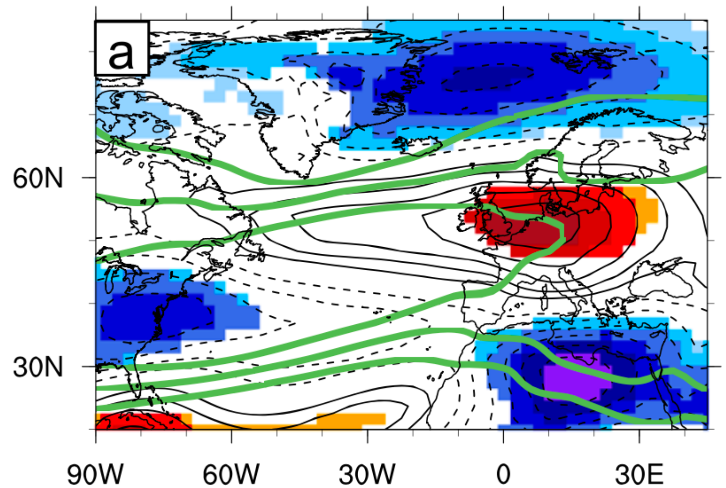


Idea: in future a wet day just needs wind (Bloomfield, 2024). Then, the data are reconciled if a storm tracks south (Manning et al. 2023), with a strong wind-like jet at impact

A squeezed and southward-shifted jet stream



CMIP future change (Peings, 2018; Oudar, 2020)



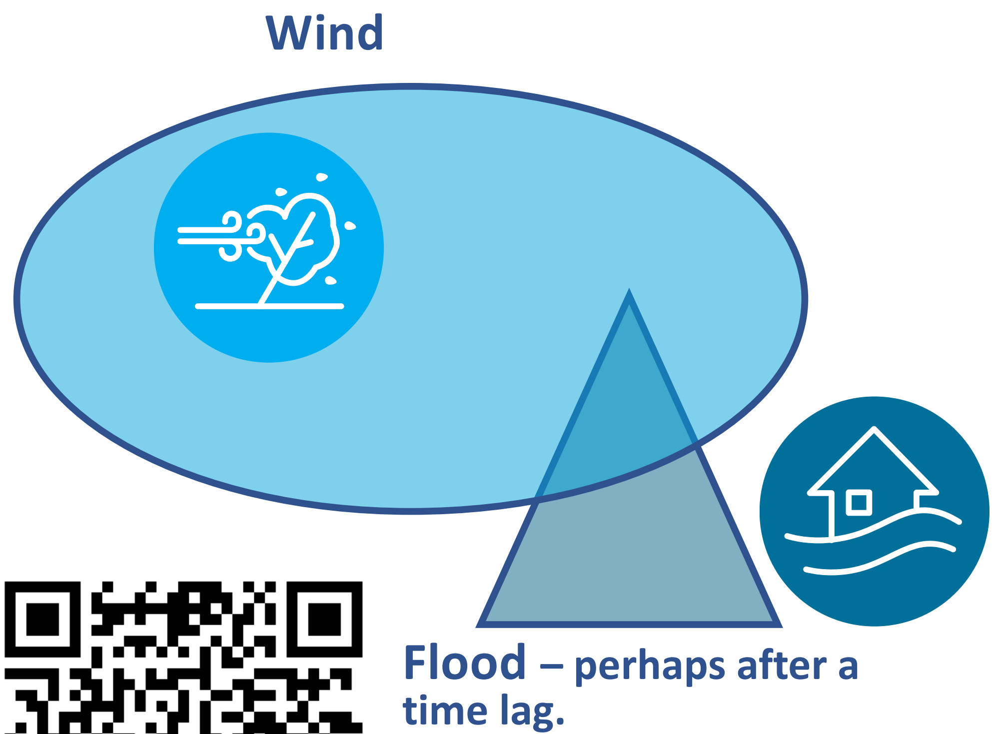
Looking at the future ….

- Latitude is more focussed on the 45°N peak, perhaps explaining events being more concentrated in DJF
- Strength - DFJ becomes more like the pattern for present-day storms with joint flood-wind extremes
- So, there are **also apparently dynamical atmospheric effects** that will also affect longer time-windows ($\Delta t = 21$).

Answers to the Research Questions

1. Do the most severe extreme winds and river flows tend to co-occur or not? Namely, are they asymptotically dependent? **Using 'Uplift' U, risk under-estimation increases with severity** (e.g. from 90th to 99th percentile of events). We need to worry about worst-case flooding and worst-case winds happening together!
2. How does strength of co-occurrence vary with the time-window (Δt) used to group events into episodes? **Using 'Uplift' U, co-occurrence is amplified most in the strongest individual or closely consecutive storms** (e.g. 3-day time window for episodes)
3. Can a simple metric of jet position distinguish jet states characteristic of co-occurrence? **Yes.**
4. How do future changes in the North Atlantic jet stream influence co-occurrence in simulations of the future? In addition to thermodynamics factors (i.e. hotter and wetter, Manning et al 2024), **jet-driven temporal** (to mid-winter) **and latitudinal squeezing (focussed on the UK) increase co-occurrence in future**.

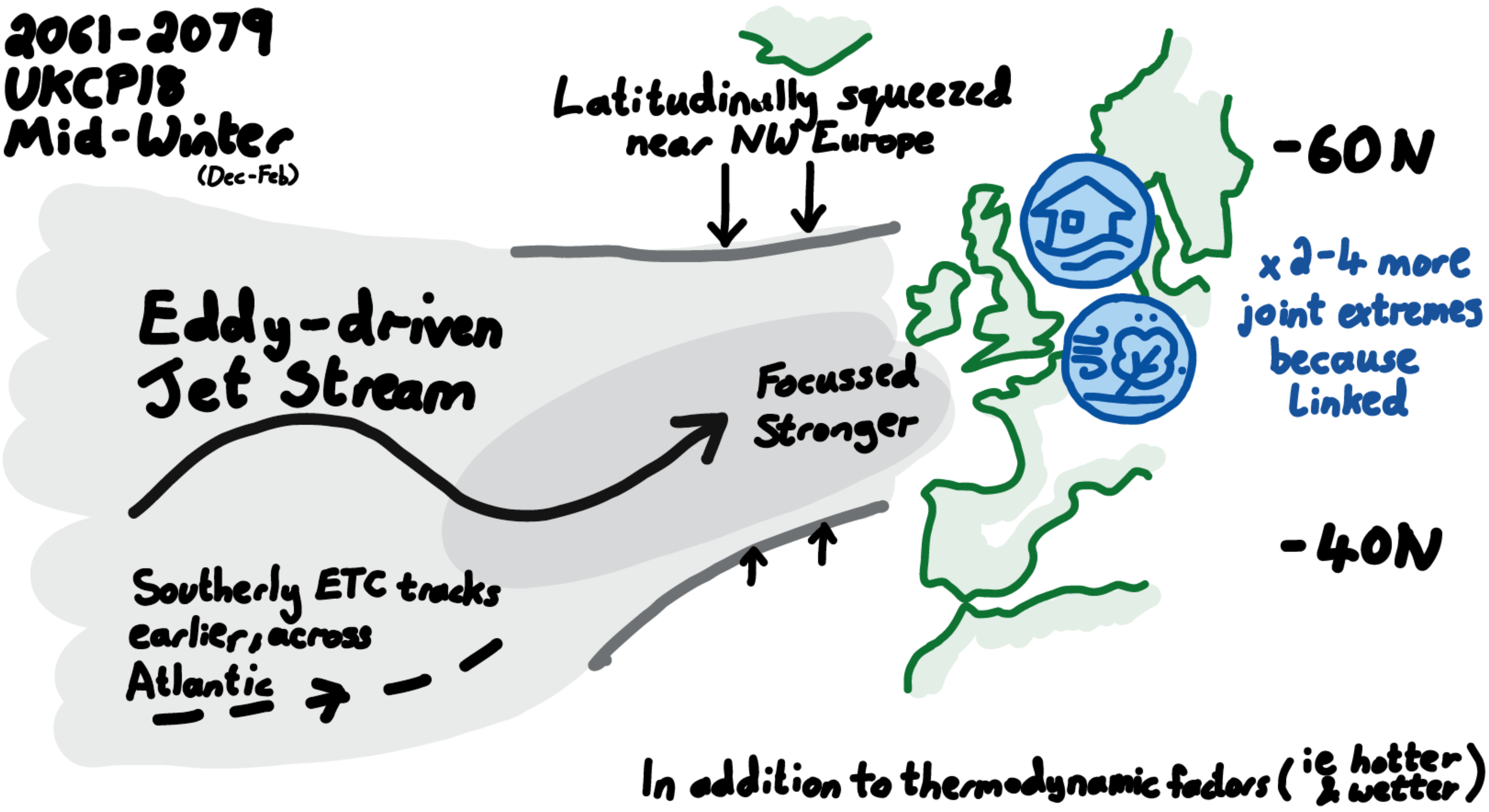
Summary for the future of co-occurring British flood-wind events



Preprint – now accepted

From an analysis of GB scale 'event' footprints combined into multi-hazard episodes, based off the UKCP projections, the following conclusions can be drawn.

1. 'Flooding', but not extreme wind will be more common in the future (2061-2080), likely due to thermodynamics (i.e. wetter)
2. This is a necessary, but insufficient, driver of the increase in co-occurring risks.
3. Jet stream dynamics also appear to alter in a way that will cause more joint UK flood-wind events


2061-2079
UKCP18
Mid-Winter
(Dec-Feb)
Latitudinally squeezed
near NW Europe
-60N
x 2-4 more
joint extremes
because
linked
Eddy-driven
Jet Stream
Focussed
Stronger
-40N
Southerly ETC tracks
earlier, across
Atlantic
In addition to thermodynamic factors (ie hotter & wetter)