Autumn and Winter storms over UK and Ireland about 20% wetter due to human-induced Climate Change

Koninklijk Nederlands Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat
World Weather Attribution

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The 2023-2024 storm season

The 2023/24 storm season for the UK and Ireland was exceptionally wet (Fig 1a, b), as well as 'hosting' a notably large number of named storms, some of which led to devastating flooding, with cascading impacts to human health, food production and the cost of living.

Here we present an attribution study for the Oct-Mar season, quantifying the role of human-induced climate change on the frequency and intensity of strong winds and heavy rainfall on storm days as well as total Oct-Mar precipitation. We use probabilistic attribution methods following the World Weather Attribution protocol, synthesising trends in observations with climate models and communicating uncertainties in combination with contextual information on vulnerability and exposure.

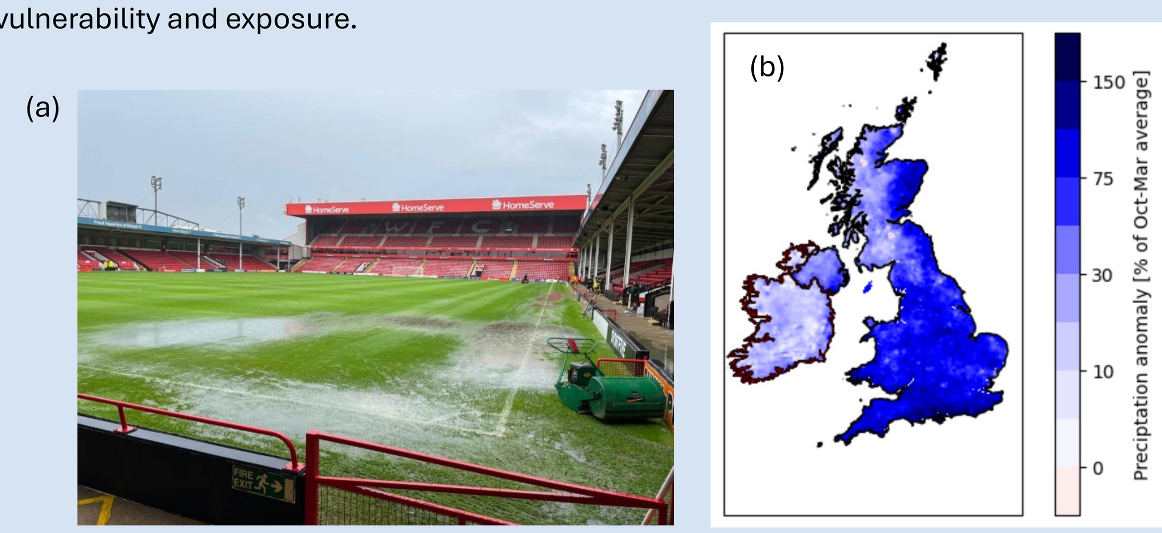

Fig. 1: (a) Flooded football field, (b) Precipitation anomaly [%] relative to the Oct-Mar average over the years 1991/1992 to 2020/2021. Source: Met Office HadUK-Grid and Met Éireann's gridded precipitation datasets.

The Storm Severity Index (SSI)

- Rather than identify individual storms through e.g. MSLP minima (computationally demanding), we use the SSI as a measure of storminess over the study region (Fig. 2a, Fig 2b, 50N-61N, 11W-2E).
- SSI considers both wind strength and the area affected. The max function ensures that only wind speeds above the 98th percentile for that location contribute to the SSI (Eq. 1).
- We use a baseline threshold of SSI – the 90th percentile of SSI (years 1979-2020) to define a stormy day. This approximately captures the number of named storms per season (Fig. 2c, 2d).

$$SSI = \sum_{t=1}^{T}\sum_{k=1}^{K}\left[\left(max(0, \frac{v_{k,t}}{v_k^{98}} - 1)\right)^3 \cdot A_k\right] \quad \text{(Eq. 1)}$$

v - daily mean 10m wind speed at location k and time t
v^{98} - 98th percentile for years 1991-2020 of the daily mean wind speed at location k.
A_k - normalised area weighting to account for the latitudinal dependence of grid box area.

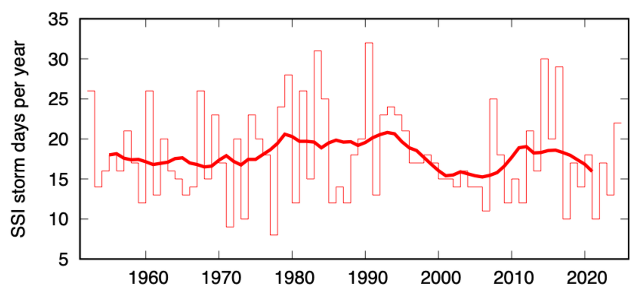

Fig. 2a. SSI stormy day count for study region (thin red) and 10-year running mean (thick red)

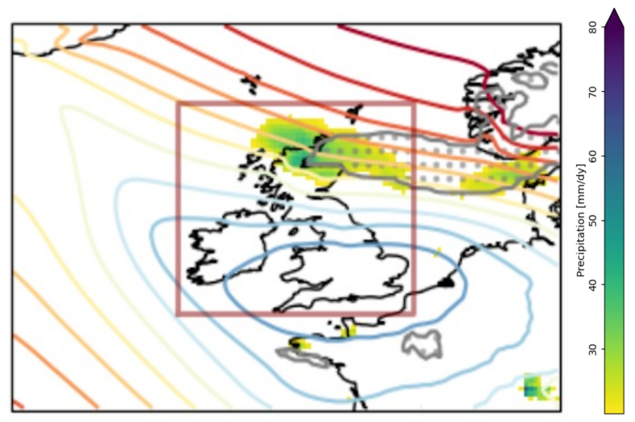

Fig. 2b. Storm Babet, 21 Oct 2023 (contours of MSLP from low (blue) to high (red) pressure), precipitation >20 mm/day (colour shading) and strong winds (contoured in grey, stippling for SSI>0). The study region (50N-61N, 11W-2E) shown as a box surrounding the UK and Ireland. Source: ERA5.

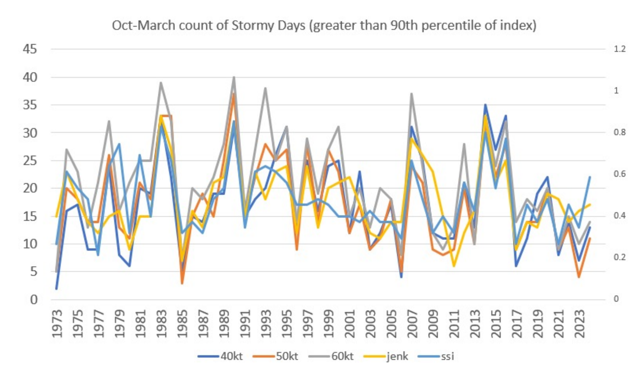

Fig. 2c. Comparison of indices that can be used to describe wind-based storm severity: number of days per year exceeding the 90th percentile of the climatological distribution (1979-2020) of each index, a measure for the number of storm days per year.

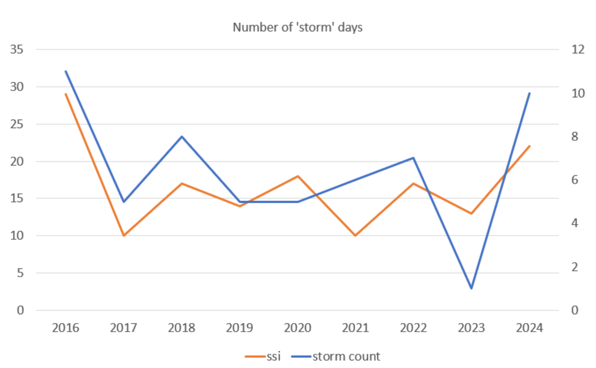

Fig. 2d. Number of storm days based on (orange, lefthand axis) exceeding the 90th percentile of SSI for the study domain and (blue, righthand axis) storms officially named by the storm naming partnership.

Observational analysis

- Analyses of observations are used to determine whether a trend can be observed in the study metrics and to assess how rare the event is.

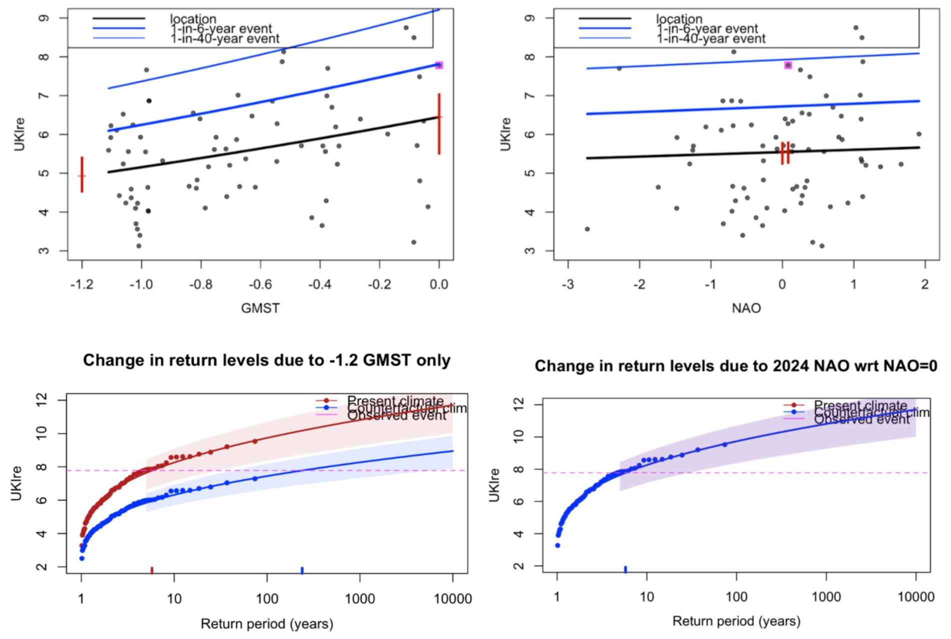

Fig. 3a: Average precipitation on stormy days, showing trends (scale fit) with respect to GMST (upper left) and NAO (upper right) and corresponding return period plots (lower left and right) for the changes in GMST and changes in NAO. The trend plots show the location parameter of the fitted distribution (thick black line), estimated 6- and 40-year return levels (blue lines) and the observed 2023/24 level (magenta box). Vertical lines show a bootstrapped 95% confidence interval for the location parameter at the 2024 GMST and a 1.2°C cooler GMST (trend plots left); the 2023/24 NAO state and a neutral state (trend plots right). The return period figures show 95% confidence intervals (shaded regions), the stormy day precipitation value for the 2023/24 season (dashed pink line), and red and blue ticks on the x axis show best estimate return level of the 2023/24 season in the 2024 climate and 1.2°C cooler climate respectively (left) and the best estimate return level of the 2023/24 season in the 2023/24 NAO state and a neutral NAO state (right).

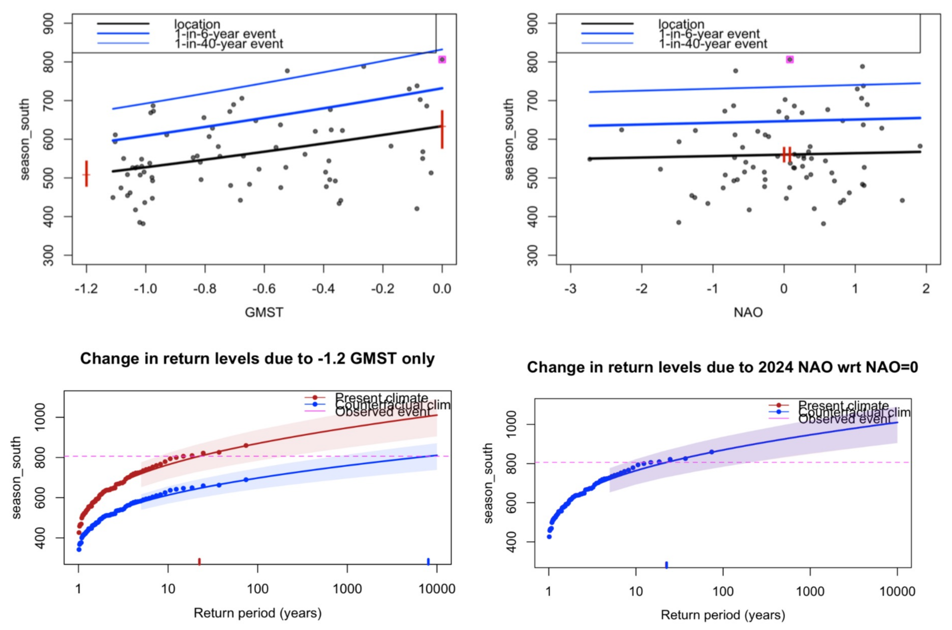

Fig. 3b: Similar to Fig 3a but for Oct-Mar precipitation (in the study domain, south of 54°N) with a scale fit.

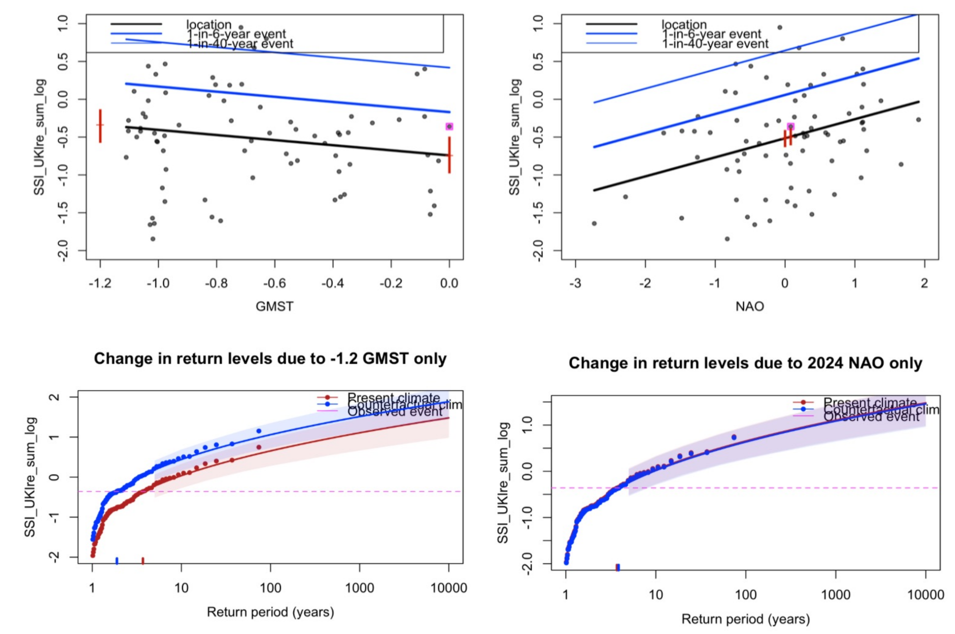

Fig. 3c: Similar to Fig 3a but for SSI in log scale with a shift fit

- In today's climate with 1.2°C of warming, stormy days with precipitation as intense as in the 2023/24 season occur about every 6 years (Fig 3a left). The Oct-Mar seasonal precipitation (Fig 3b left) was more extreme, expected to occur about once every 20 years. The 2023/24 wind associated with stormy days (Fig 3c left) is expected to occur about once every 4 years.
- The North Atlantic Oscillation (NAO) is a key driver of 'storminess' and has been accounted for in this analysis. However, the Oct-Mar 2023/24 averaged NAO was almost neutral and so did not contribute much to the 2023/24 event (Fig 3, right hand panels).

Hazard Synthesis

- To determine the role of climate change in these observed changes, we combine observations with climate models.

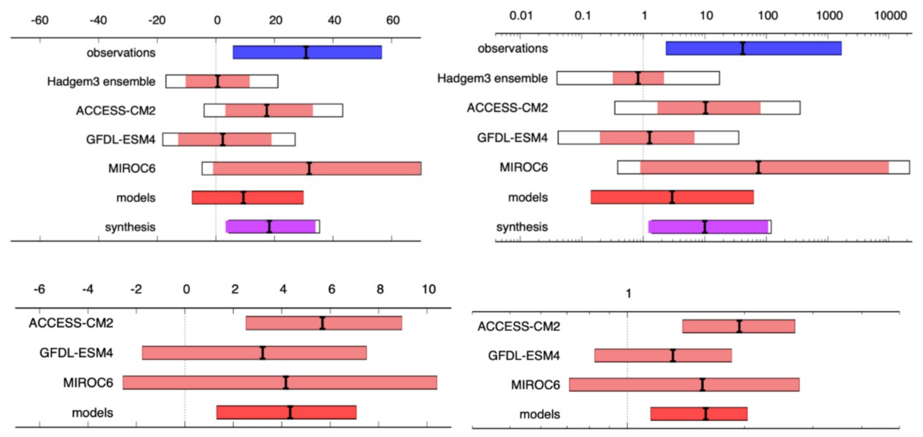

Fig. 4a: Synthesised changes for mean precipitation on stormy days. Changes in intensity (left) and PR (right) are shown for a historical period comparing the past 1.2°C cooler climate with the present (top row) and for a future period, based on model projections only, comparing the present and a 2°C warmed climate (bottom row).

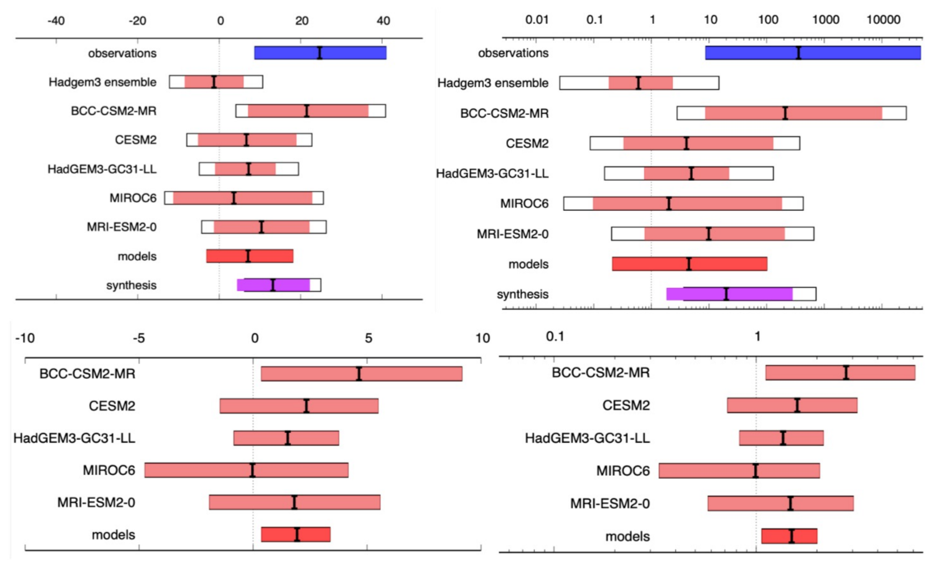

Fig. 4b: Similar to Fig. 4a but for synthesised changes for Oct-Mar precipitation totals for the southern part of the study domain (south of 54°N).

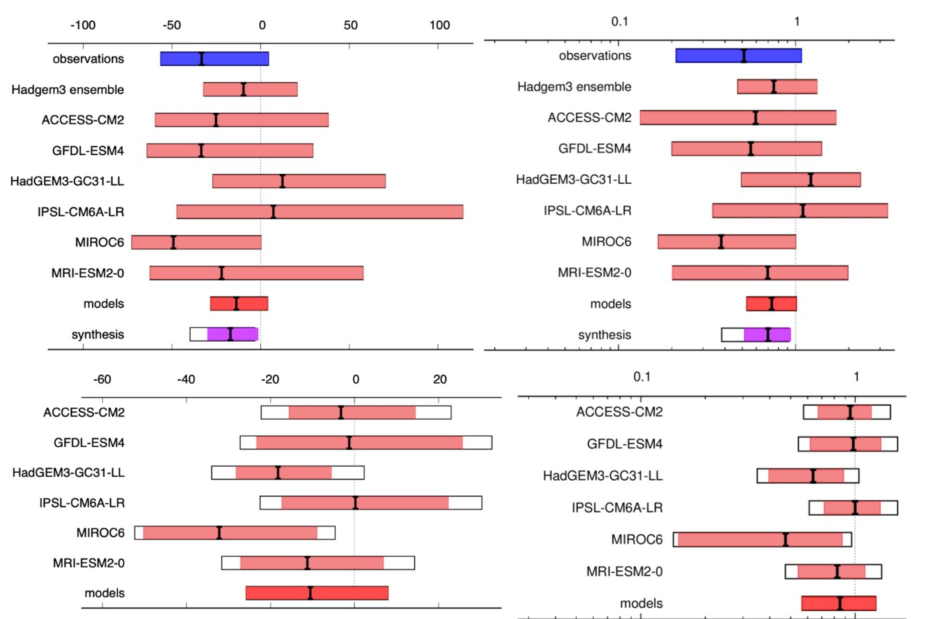

Fig. 4c: Similar to Fig. 4a but for synthesised changes for mean SSI on stormy days.

Vulnerability and Exposure

- Successive floods have compounded impacts on the agriculture and housing sectors, leading to cascading impacts on socioeconomic and psychosocial health
- Coping capacity of low-income groups is being eroded. Combined with the cost-of-living crisis, the successive flood events are another layer of disruption at a time when people's financial resilience is already being tested.
- Comprehensive flood risk management is required in the UK and Ireland that encompasses legislative frameworks, strategic planning, and substantial funding.
- Major UK cities are starting to integrate nature-based solutions into their designs.
- In Ireland, flood relief projects have been integrating nature-based solutions alongside traditional engineering solutions for over 20 years. Both the UK Met Office and Met Éireann are continuously improving their impact-based weather forecasting mechanisms to facilitate the translation of warning into action, in partnership with other government bodies to ensure their people's safety.

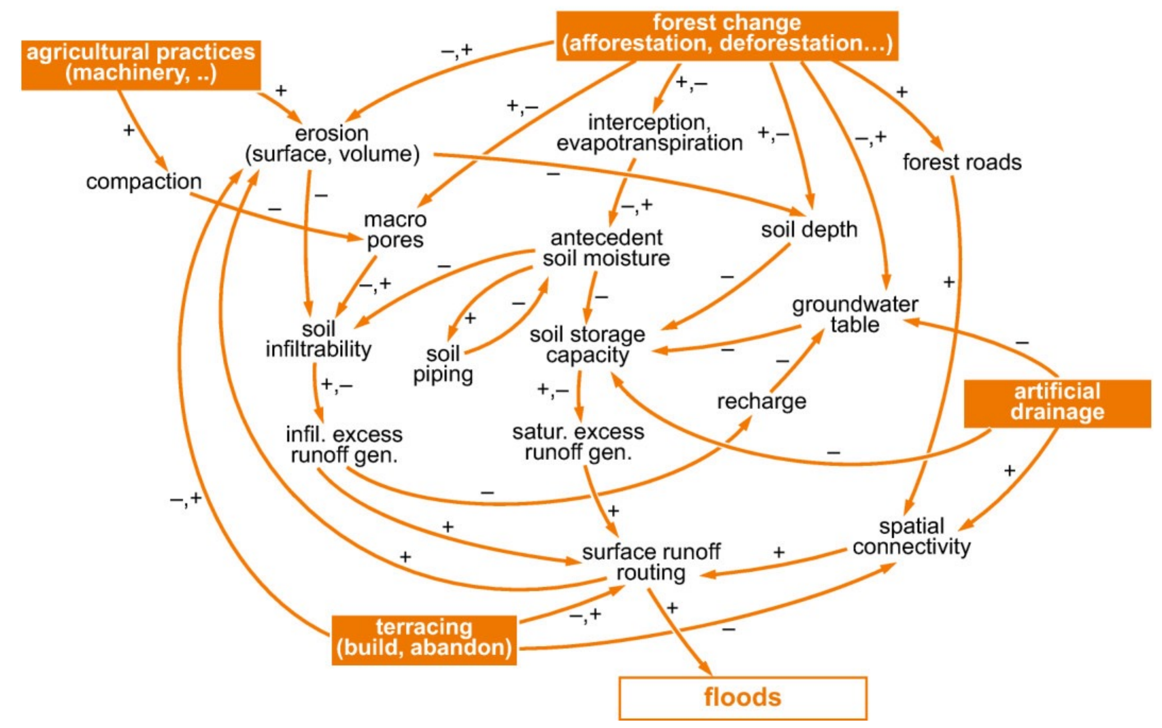

Fig.5: Land use change effects on floods

Main findings

- **Precipitation on stormy days.** Observations: approximately 30% more intense, compared to a 1.2C cooler pre-industrial climate. Models: agree on the direction of change. Synthesis: increased by about 20% due to human induced climate change, or equivalently the 2023/24 level has become about a factor of 10 more likely.
- **Oct-Mar total precipitation.** Observations: strong trend, with a magnitude increase of about 25%. Models: broadly agree on the direction of change. Synthesis: indicates increase in magnitude of 6% to 25%, or equivalently the 2023/24 level has become at least a factor of 4 more likely.
- **Future precipitation trends.** Models: Trends found in the precipitation metrics continue into the future. In a climate that is 0.8C warmer than now, average precipitation on stormy days becomes about another factor of 1.6 times more likely, or 4% more intense, and Oct-Mar total precipitation becomes about a factor of 1.5 more likely or 2% more intense.
- **SSI on stormy days.** Our analysis shows a decreasing trend. Observations: Average SSI indices became about a factor of 2 less likely. Synthesis: a stormy season like 2023/24 is nowadays a factor of about 1.4 less likely due to human induced climate change.
- **Storm indices in other studies.** Some studies using other methods suggest an increase in storminess in a future climate. This highlights the need for ongoing research into how climate change may influence the severity and frequency of windstorms in northern Europe.

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