Department for Environment Food & Rural Affairs
Department for Energy Security & Net Zero
Department for Science, Innovation, & Technology
Met Office Hadley Centre
Environment Agency

UKCP18 Factsheet: Storms

Headline messages

This document focusses on strong winds and windstorms and briefly includes thunder and lightning; please see separate guidance about rainfall.

Recent observations show no clear trend in wind or windstorms. The variation in wind speed day-to-day and year-to-year is high, which makes any trend due to climate change in past or future wind speeds difficult to detect.

UK Climate Projections show an increase in mean wind speed in winter by the late 21st century, but this is small compared to the natural year-to-year variability. Different climate models show different trends including decreases, so the magnitude of this change is subject to uncertainty.

UK Climate Projections show an increase in windstorm number and intensity over the UK by the late 21st century, but given interannual and inter-model spread careful translation is needed when considering wind impacts.

For thunderstorms, recent UK observations show a slight decrease in the number of days with thunder. In future climate, UK Climate Projections indicate that lightning is projected to increase in spring and summer, decrease in autumn, and shows little change in winter.

Motivation

In 2022, the UK Climate Projections (UKCP)'s Development and Knowledge Sharing (DaKS) Network of users were surveyed to identify gaps in what information had been provided so far. Users requested the need for clearer messaging on trends and observations in storminess. This document aims to provide these overall messages based on what we know already from UKCP, as well as what we know from the wider scientific literature, and offers guidance on where to find more information. It focusses on strong winds and windstorms and briefly includes thunder and lightning; please see separate guidance about rainfall.

Another area where additional information was requested was combined hazards; that is, where more than one weather hazard occurs at the same time (e.g. wind-driven rain) or in quick succession (e.g. a dry period followed by thunderstorms). This is the subject of ongoing research (e.g. Lewis et al., 2019), so this document focuses on single hazards and we plan to monitor this research alongside monitoring user needs for multi-hazard information. Information about storm surges and waves is in other UKCP Guidance (Fung et al., 2018a).

What are storms?

In this document, we focus on the two types of storm that affect the UK (Figure 1): large-scale low pressure systems or windstorms, that bring rain and wind over hundreds of kilometres and can last for a few days; and smaller-scale thunderstorms with hazards possibly including rain, hail, lightning and tornadoes affecting a few kilometres for a few hours. As well as having different spatial and temporal scales, thunderstorms and windstorms are driven by different physical processes. While in reality these hazards can occur at the same time (e.g. Dowdy & Catto, 2017) separating the two types of storms in our climate model analysis allows us to assess the very different physical processes associated with the two types of storm and how they are simulated in the climate model.

Windstorms | **Thunderstorms**

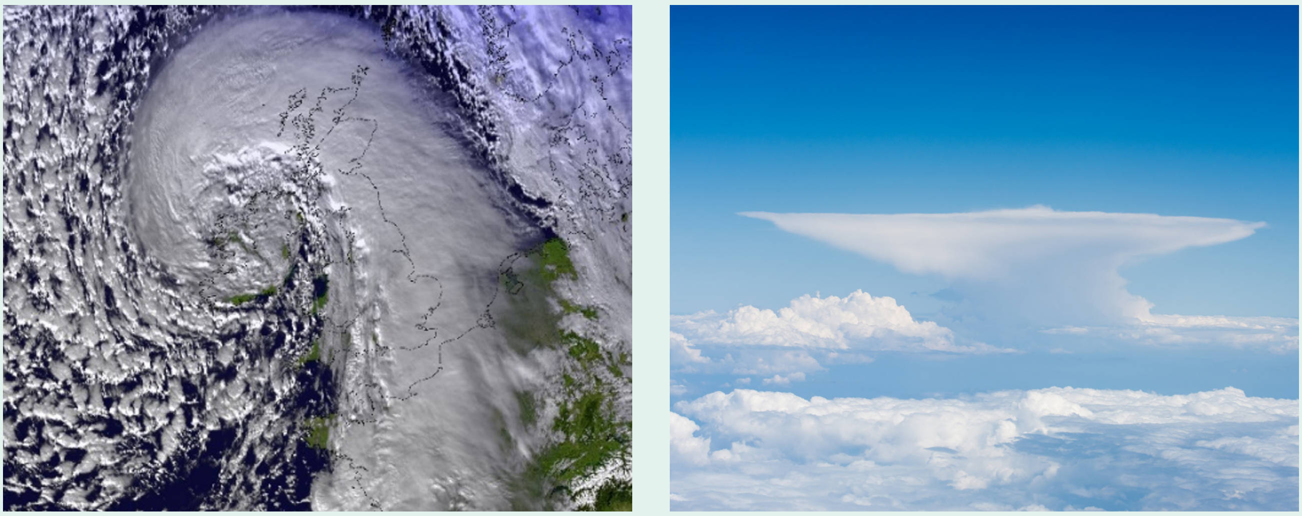

Figure 1 Images of [left] a windstorm and [right] a thunderstorm. [Left] Windstorm Barra from satellite 2022-12-07 1300Z [image: © Crown copyright, Met Office, Satellite data: EUMETSAT, Background data: NASA Earth Observator]. [right] Thunderstorm from plane [image: AdobeStock]

Windstorms can be defined in a variety of ways, depending on the approach taken and subsequent analysis techniques. It is common to analyse trends in the wind speed, or in windstorm events that are automatically identified and tracked. Wind speed can be considered as an average or gust, and/or be compared to the typical wind speeds at each location. For example, the Storm Severity Index (SSI) compares the wind speed at a given point in space and time to the 98th percentile of wind speed (usually daily wind speed) over a long period of the recent climate to give a quantity related to wind power and potential damage. This is further compounded when 'clusters' of storms are considered (Dacre and Pinto, 2020); that is, when multiple storms occur in a particular location within a short time period.

Individual storms' tracks can be accumulated over a long period of time to form the 'storm track density'; that is, a measure for how many storms of a particular intensity move through an area as shown in Figure 2. Being large scale, windstorm trends can also be seen in the patterns of weather across the UK or across the North Atlantic, because some patterns will be related to stormy conditions. For example, a positive phase of the North Atlantic Oscillation (NAO) is associated with westerly winds and stronger, more frequent windstorms; for more details about the NAO see McSweeney and Yamazaki (2020). Furthermore, the factors that make the atmosphere suitable for developing windstorms can also be explored, for example the jet stream – a core of strong winds high in the atmosphere – is a major factor as the storms develop over the North Atlantic (e.g. Pirret et al., 2017).

Note that in this document, we discuss the changes to both wind and windstorms; however, these are different things. Wind is a facet of everyday weather observation (wind speed and direction), but strong winds can have damaging impacts. Strong winds can be associated with storms, but not always for example where there is a local effect from the mountains and/or coast[1]. While windstorms are typically associated with strong winds, the region with the strongest winds will change as a storm moves across the UK and be different for different storm events. Storms can also be compounded by additional weather such as rain, snow or hail. When considering the application of this information, first examine your weather hazard; that is, whether you are likely to see impacts from strong winds, windstorms, or perhaps a compound hazard (e.g. wind-driven rain).

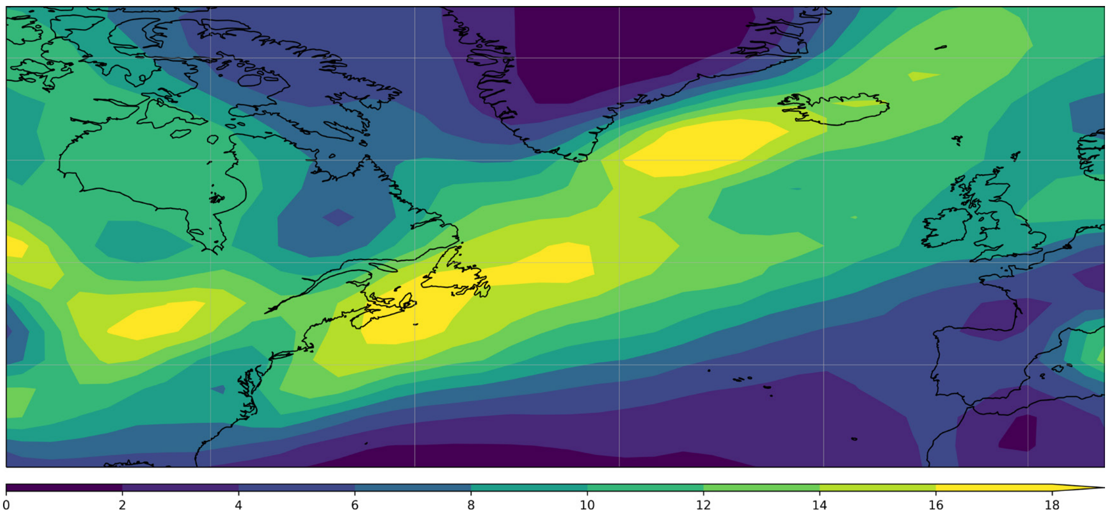

Figure 2 Storm track density in ERA5 for winters (Dec-Jan-Feb) 1979-2014. The storm events are tracked in the vorticity about 1km above the ground (on the 850hPa pressure surface), filtered for events that last for at least 48 hours and travel over 1000km. Units are number of cyclones per month per 5˚ spherical cap (~106km2). Image credit: Duncan Ackerley.

[1] **https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/wind/helm-wind**
https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/wind/wind-names

How have windstorms changed in the recent past?

Multiple datasets show no clear trend in daily mean wind speed over the UK since the mid-20th century (ERA-Interim, Murphy et al., 2018, Figure 5.9; ERA5, Laurila et al., 2021; HadUK-Grid, Kendon et al., 2022). Detecting a change in wind speed is difficult due to large variations, both year-to-year and on longer, decadal timescales.

For windstorms, observations and proxies show no trend over the British Isles, when the period considered is since the mid-20th century or in some cases includes older observational records (e.g. using instrumental records as far back as 1715; Sweeney, 2000). Observations combined with weather forecasting models to give reanalysis data shows a mixed picture with some studies finding an increase, others a decrease and still others no trend, due in part to the dependence of the trend on the time period analysed (Feser et al., 2015).

For the factors that drive windstorms, the NAO has shown a decrease in summer meaning a tendency towards more settled conditions over the UK; in winter, it shows only a slight decrease in the average but an increase in variability (Hanna et al., 2014).

How do the climate model data compare to observations for windstorms?

For wind speed, while the year-to-year variations in wind and gust speed are large, this is similar in the reanalysis (ERA-Interim) and the UKCP Global models, where there are 15 variants of the Met Office model known as the PPE-15 and 13 models from other modelling centres that contributed to the Coupled Modelling Intercomparison Project 5 known as the CMIP5-13. The UKCP models show no clear trend in daily mean wind in recent years (Murphy et al., 2018, Figure 5.9), which is consistent with observations.

The storm track density is examined by Murphy et al (2018) in the UKCP Global data, comprising the PPE-15 and ten of the CMIP5-13 for which the required data were available i.e. a CMIP5-10. Compared to ERA-Interim, the CMIP5-10 ensemble mean overestimates the number of storms coming over the UK and Europe. The PPE-15 ensemble mean verifies well over the UK but underestimates the number of storms to the west of the UK (Murphy et al., 2018, Figure 3.17). These differences should be considered in the context of the magnitude of any future changes.

How are windstorms projected to change in the future?

For daily mean wind speed, in winter a small increase is projected and in summer a small decrease (Murphy et al., 2018, Figure 5.9). However, these changes are small compared to the large interannual variability, meaning that identifying the 'signal' caused by climate change is hard in the 'noise' of the year-to-year variations (Fung et al., 2018b). Furthermore, the winter increase is seen in the PPE-15 and little trend is seen in the CMIP5-13 (Murphy et al., 2018). It is for these reasons the magnitude of the future changes is subject to large uncertainty.

For storm track density, analysis in Murphy et al. (2018) uses the UKCP Global ensemble, again in the PPE-15 and the CMIP5-10. In future, the PPE-15 ensemble mean shows an increase in winter storms over the UK. This increase is also seen in the CMIP5-10 but to a lesser extent (Murphy et al., 2018, Figure 5.10). In the context of the wider area, the changes over the UK are related to a projected extension of the storm track eastwards over the UK and southern Scandinavia giving an increase of windstorms in this area, but a decrease to either side over the Norwegian and Mediterranean Seas (Murphy et al., 2018; Zappa et al., 2013). However, while the direction of these changes is robust across different climate models, the magnitude is different and compounded by differences between the model and observations in recent climate (see previous section) so is subject to uncertainty.

In winter, climate models project an increased frequency of windstorms over the UK in both CMIP5 (Zappa et al., 2013) and the more recent CMIP6[2] (Priestly and Catto, 2022) simulations. Figure 3 (top) shows that this is consistent with findings from UKCP, with the number of storms projected to increase over the UK area by 2061-2080 under a high emissions scenario.

For the numbers of intense windstorms in winter, UKCP shows an increase for most regions including the UK (Figure 3 (bottom)). For windstorm intensity, the CMIP5 and CMIP6 models show an increase in winter leading to more extreme windstorms (Zappa et al., 2013; Priestly and Catto, 2022), and similar results have been found in UKCP including for storms that could contain sting jets (see Manning et al., 2022 and 2023). Furthermore, how storm clustering (multiple storms occurring in a similar area in quick succession) will evolve under climate change is uncertain (Dacre and Pinto, 2020).

While the direction of these trends is robust across different climate models and different analysis approaches, there are differences in the size of the change (Feser et al., 2015) due to variation in how different climate models represent the factors that drive windstorm development (see next section). Also note that projected changes for the British Isles contrast with those over the wider North Atlantic, where Figure 3 shows a decrease in storm numbers but storm intensity shows an increase.

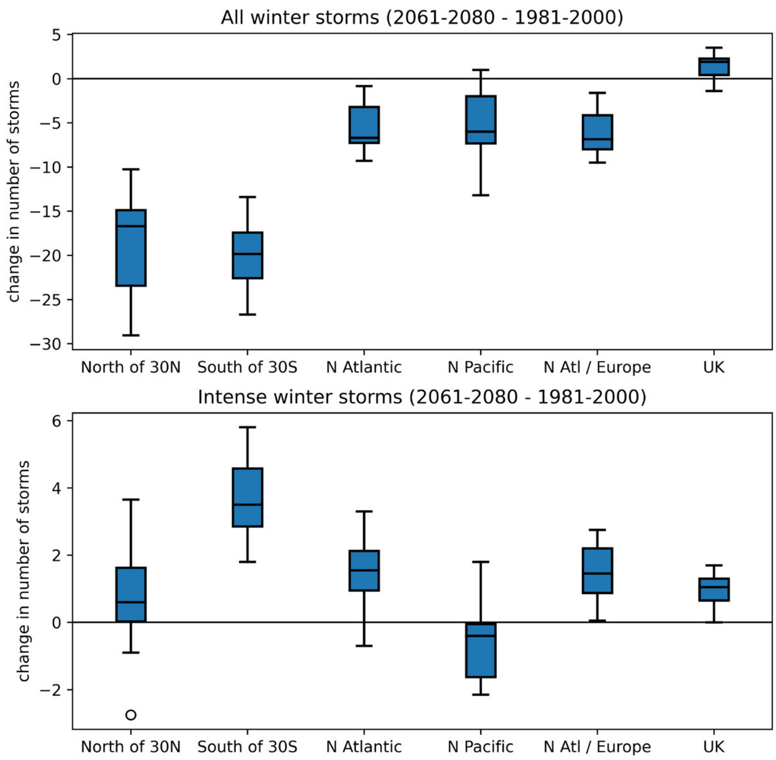

Figure 3 Change in winter (Dec-Jan-Feb) storm counts in UKCP Global PPE-15, comparing recent (1981-2000) and future (2061-2080) climates under RCP8.5. The storm events are tracked in the vorticity about 1km above the ground (on the 850hPa pressure surface). Intense storms are defined as those where the 850hPa vorticity goes over 11x10-6 s-1. The regions are defined as follows: North Pacific: 120 to 240 °E and 30 to 70 °N; North Atlantic: 80° W to 10° W, 30 to 70 °N; North Atlantic / Western Europe: 30° W to 30° E, 35 to 80 °N; and UK: 10 °W to 2 °E and 48 to 62 °N.

[2] CMIP6 is the Coupled Modelling Intercomparison Project 6's dataset is the underpinning data for the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (AR6), published in 2022/2023 and available from: **https://www.ipcc.ch/assessment-report/ar6/**. CMIP5 underpinned the IPCC's Fifth Assessment Report (AR5), published 2013/2014.

What about the large-scale? What about the factors that drive windstorms?

The weather patterns in UKCP Global have been analysed, both as a set of 30 (Pope et al., 2022) and with these 30 grouped together into 8 patterns (McSweeney & Thornton, 2020). Both approaches find that the weather types compare well with recent observations in the recent climate. Both also project a tendency towards more wet and unsettled conditions over the UK in winter under a high emissions scenario, which would imply a trend towards stormier conditions on average. This is also consistent with the projected changes to the North Atlantic Oscillation (NAO) in UKCP Global, which tends towards more positive values (McSweeney & Yamazaki, 2020).

Pope et al. (2022) also find indications that the year-to-year variability in storminess may increase in future climate, but this is the subject of current research. For the jet stream, UKCP Global data show a slight shift towards more northerly positions in autumn and summer, but no clear trend in spring or winter (McSweeney and Bett, 2020). This means in summer and autumn windstorms would tend towards affecting the northern UK with little projected change for the winter and spring; however, note that the jet stream also shows large year-to-year variability in position.

Within UKCP Global, these changes associated with weather patterns, the NAO and jet stream are seen in both the PPE-15 and CMIP-13 parts of the UKCP Global ensemble. However, the changes are less consistent across the CMIP-13 than in the PPE-15. This indicates that there is uncertainty in these aspects of climate change; while there is agreement about the direction of change in the future projections, there is spread between models in their size even in a single emissions scenario (RCP8.5). This difference between climate models for the drivers for windstorm development is also found in the CMIP6 ensemble (Oudar et al., 2020).

A small number of the windstorms that affect the UK are ex-hurricanes (or post-tropical cyclones), that transition from the tropics. There is limited evidence of more frequent post-tropical cyclone events in the North Atlantic (Baker et al., 2022), but the number of tropical and extra-tropical cyclones naturally varies a lot from year-to-year and decade-to-decade, so it is difficult to identify the climate change 'signal' from the natural variability.

How have thunderstorms changed in the recent past?

For thunderstorms, UKCP include data on the daily total lightning flashes and the number of days with thunder. Using the latest observations for the UK, Stone et al., (2022) combine lightning detection with observations of thunder to find a small decrease in the number of days with thunder over 1990 to 2019 of around one day per year. This varies with season and region (north/south or land/sea) with northern parts of the UK seeing a slight increase in summer days of thunder of around 0.5 days per year. Many processes drive thunderstorm development, and how each of these could change with the climate varies by location and season (e.g. Kahraman et al., 2022).

How are thunderstorms projected to change in future climate?

Looking to the future climate, UKCP Local is at a spatial resolution that represents a step forward in how thunderstorms are simulated by climate models (Kendon et al., 2021). For RCP8.5, UKCP Local shows that by 2060-2080 that lightning frequency is projected to increase in summer, increase slightly in spring, decrease in autumn, and shows little change in winter compared to 1980-2000. Note that these changes also vary regionally (see Kendon et al., 2021, Figures 4.5.12 to 4.5.15).

Which data products should I use for storms?

How best to use the projections will depend on the application. It may be important to consider multiple strands of UKCP data (Global 60km, Regional 12km and Local 2.2km), and perhaps also include information from other modelling centres. This can currently be done using the CMIP5 data that is included within UKCP Global, but other data could be used; for example, the upcoming EUROCORDEX-UK dataset. Full details of UKCP data, for example which emissions scenarios are available, can be found in the data availability document (linked from this **webpage**).

See the table below for users in the UK. Outside the UK, users will need to consider the strengths and limitations of the models available for their locale. Note that this table is focussed on wind- and thunderstorms; for rainfall, please refer to 'Using Rainfall Data from UKCP', available from **here**.

Analysis of thunderstorms	Use the UKCP Local data because this model permits the convection that generates thunderstorms. The details of the lightning data ('flashrate') available can be found in the data availability document (linked from this webpage).
Analysis of subdaily data	Use UKCP Local data because this provides hourly wind data (plus hourly rainfall and temperature data).
Analysis at daily and regional scales	The UKCP Regional projections include daily wind data, and can be used where the decision context is regionally-focussed.
Exploring the broader scale in which windstorms are situated	Use the UKCP Global projections that include daily wind data. Examples of use include: • Analysis of the storm track, because UKCP Global covers the North Atlantic where windstorms develop (McSweeney & Bett, 2020). • Analysis of weather patterns (Pope et al., 2022), because the results with the higher resolution models are similar (J. Pope, personal communication, 2022-10-11).
Exploring the broadest range of uncertainty	Use the UKCP Probabilistic Projections. They do not include wind data, but do include rainfall data for mean monthly and seasonal changes.
Exploring the broadest range of uncertainty in extremes	Use the UKCP Probabilistic Extremes. They do not include wind data, but do include extreme daily and 5-daily precipitation. Values represent the return level for extreme events at 20-, 50- and 100-year return periods, for five emissions scenarios. For more information, see the factsheet (available from this **webpage**).

How could UKCP storms information be used?

The UKCP DaKS Network identified that it would be useful to include user's perspectives on how this information could be used. Please find an example of this, below.

Example: Forest Research

UK forests are exposed to stronger winds than those experienced by their counterparts in mainland Europe. This exposure affects all stages of tree development and growth. This is significant, because throughout their lives, trees are known to respond to their wind climate by optimising allocation of the biomass they produce between their three main components, i.e., the canopy, stem, and root system, to resist wind movement and improve stability.

Despite the large daily and yearly variability typical of wind speed records and projections, and the uncertainty associated with the latter, the UKCP shows a small increase in mean wind speed, and a small increase in the frequency of extreme wind speeds associated with windstorms, towards the end of the 21st century. These factors constitute a challenge to the management of UK forests seeking to meet a range of forestry and land use objectives, underpinned by the current rapid increase in forest cover across the UK. These include: growing and maintaining forest carbon stocks; supporting and sustaining timber production; promoting increased biodiversity; increasing species diversity to improve forest resilience; developing a stable forestry sector; and securing the provision of a wide range of ecosystem services such as slope stabilisation, flood mitigation, and tourism and recreation.

As trees are long-lived and slow-growing organisms, both the present and future climate must be considered in the planning and management of forests. The UKCP wind projections provide a scientific narrative that can assist the forestry sector in making decisions to prepare for an uncertain future. Available and accessible wind data and projections inform the application and the development of Forest Research's wind risk and species suitability models (i.e., **ForestGALES** and **ESC**, respectively), and provide a common understanding to allow clear communication with our stakeholders and customers.

Tom Locatelli, Senior Climate Change Scientist, Forest Research

Where can you find more information?

More information about UKCP can be found on the **website**, including:

- About the UKCP project in Lowe et al. (2018)
- Scientific details of the Global (60km) and Regional (12km) projections in Murphy et al. (2018)
- Scientific details of the Local (2.2km) projections in Kendon et al. (2021)
- Closer focus on particular datasets or climate metrics as **factsheets**.

For details of accessing UKCP data, please see the **data webpage** but first read about the **caveats and limitations** and our guide to **Using UKCP data**.

Acknowledgements

The authors would like to thank Duncan Ackerley and Ruth McDonald for the provision of Figures 2 and 3, respectively.

This document can be cited as: Pirret JSR, Fung F, Locatelli T and Manning C, 2023. UK Climate Projections Factsheet: Storms. Met Office, Exeter. Available from **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/factsheets**

References

Baker, A. J., Roberts, M. J., Vidale, P. L., Hodges, K. I., Seddon, J., Vannière, B., Haarsma, R. J., Schiemann, R., Kapetanakis, D., Tourigny, E., Lohmann, K., Roberts, C. D., & Terray, L. (2022). Extratropical Transition of Tropical Cyclones in a Multiresolution Ensemble of Atmosphere-Only and Fully Coupled Global Climate Models, Journal of Climate, 35(16), 5283-5306. **https://doi.org/10.1175/JCLI-D-21-0801.1**

Dacre, H.F., Pinto, J.G. (2020) Serial clustering of extratropical cyclones: a review of where, when and why it occurs. Npj: Climate and Atmospheric Science 3, 48. **https://doi.org/10.1038/s41612-020-00152-9**

Dowdy A., and Catto J., (2017): Extreme weather caused by concurrent cyclone, front and thunderstorm occurrences. Scientific Reports 7, 40359. **https://doi.org/10.1038/srep40359**

Feser, F., Barcikowska, M., Krueger, O., Schenk, F., Weisse, R. and Xia, L. (2015): Storminess over the North Atlantic and northwestern Europe—A review. Quarterly Journal of the Royal Meteorological Society, 141: 350-382. **https://doi.org/10.1002/qj.2364**

Fung F., Palmer M., Howard T., Lowe J., Maisey P. and Mitchell J.F.B. (2018a). UKCP18 Factsheet: Sea Level Rise and Storm Surge, Met Office Hadley Centre, Exeter. Available from **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/factsheets**

Fung F., Bett P., Maisey P., Lowe J.A., McSweeney C., Mitchell J.F.B., Murphy J., Rostron J., Sexton D. and Yamazaki K. (2018b): UKCP18 Factsheet: Wind. Met Office Hadley Centre, Exeter. Available from **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/factsheets**

Hanna, E., Cropper, T.E., Jones, P.D., Scaife, A.A. and Allan, R. (2015), Recent seasonal asymmetric changes in the NAO (a marked summer decline and increased winter variability) and associated changes in the AO and Greenland Blocking Index. Int. J. Climatol, 35: 2540-2554. **https://doi.org/10.1002/joc.4157**

Kahraman A., Kendon E.J., Fowler H.J. and Wilkinson J.M. (2022): Contrasting future lightning stories across Europe. Environmental Research Letters¸17 (11), 114023. **https://doi.org/10.1088/1748-9326/ac9b78**

Kendon E.J., Short C., Pope J., Chan S., Wilkinson J., Tucker S., Bett P., Harris G. and Murphy J. (2021): UKCP Local Projections Update: Technical Note. Available from: **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports**

Kendon, M., McCarthy, M., Jevrejeva, S., Matthews, A., Sparks, T., Garforth, J., and Kennedy, J. (2022): State of the UK Climate 2021. International Journal of Climatology, 42(Suppl. 1)(S1), 1– 80. **https://doi.org/10.1002/joc.7787**

Laurila T.K., Sinclair V.A., and Gregow H., (2021): Climatology, variability, and trends in near-surface wind speeds over the North Atlantic and Europe during 1979–2018 based on ERA5. International Journal of Climatology 41: 2253– 2278. **https://doi.org/10.1002/joc.6957**

Lewis, H. W., et al. (2019): The UKC3 regional coupled environmental prediction system. Geoscientific Model Development 12, 2357-2400, **https://gmd.copernicus.org/articles/12/2357/2019/**

Lowe J.A., et al., (2018): UKCP18 Science Overview report. Met Office. Available from: **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/guidance-science-reports**

Manning, C., Kendon, E.J., Fowler, H.J., Roberts, N.M., Berthou, S., Suri, D., and Roberts, M.J (2022): Extreme windstorms and sting jets in convection-permitting climate simulations over Europe. Climate Dynamics 58, 2387–2404. **https://doi.org/10.1007/s00382-021-06011-4**

Manning C, Kendon E.J., Fowler H.J. and Roberts N. M., (2023): Projected increase in windstorm severity and contribution from sting jets over the UK and Ireland. Weather and Climate Extremes 40, 100562. **https://doi.org/10.1016/j.wace.2023.100562**.

McSweeney C. and Bett P. (2020): UKCP European Circulation Indices: Jet Stream Position and Strength. UKCP Factsheet. Met Office. Available from **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/factsheets**

McSweeney C. and Thornton H. (2020): UKCP European Circulation Indices: Weather Patterns. UKCP Factsheet. Met Office. Available from **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/factsheets**

McSweeney C. and Yamazaki K. (2020): UKCP European Circulation Indices: Winter Atlantic Pressure Gradient (North Atlantic Oscillation – NAO). UKCP Factsheet. Met Office. Available from: **https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/data/factsheets**

Murphy J.M., et al (2018): UKCP18 Land Projections: Science Report. Available from **https://www.metoffice.gov.uk/research/collaboration/ukcp/guidance-science-reports**

Oudar, T., Cattiaux, J., and Douville, H. (2020). Drivers of the northern extratropical eddy-driven jet change in CMIP5 and CMIP6 models. Geophysical Research Letters, 47, e2019GL086695. **https://doi.org/10.1029/2019GL086695**

Pirret J.S.R., Knippertz P. and Trzeciak T.M. (2017): Drivers for the deepening of severe European windstorms and their impacts on forecast quality. Quarterly Journal of the Royal Meteorological Society, 143: 309-320. **https://doi.org/10.1002/qj.2923**

Pope J.O., Brown K., Fung F., Hanlon H.M., Neal R., Palin E.J. and Reid A., (2022): Investigation of future climate change over the British Isles using weather patterns. Climate Dynamics 58, 2405–2419. **https://doi.org/10.1007/s00382-021-06031-0**

Priestley, M. D. K. and Catto, J. L. (2022): Future changes in the extratropical storm tracks and cyclone intensity, wind speed, and structure, Weather and Climate Dynamics, 3, 337–360, **https://doi.org/10.5194/wcd-3-337-2022**

Stone E.K., Horseman A., Odams P. and Marlton G., (2022): A gridded 30-year days of thunder climatology for the United Kingdom. Quarterly Journal of the Royal Meteorological Society, 148 (747), 2784–2795. Available from: **https://doi.org/10.1002/qj.4336**

Sweeney J. 2000. A three-century storm climatology for Dublin 1715–2000. Irish Geography. 33: 1–14, **https://doi.org/10.1080/00750770009478595**

Zappa, G., Shaffrey, L. C., Hodges, K. I., Sansom, P. G. and Stephenson, D. B. (2013): A Multimodel Assessment of Future Projections of North Atlantic and European Extratropical Cyclones in the CMIP5 Climate Models, Journal of Climate, 26(16), 5846-5862. **https://doi.org/10.1175/JCLI-D-12-00573.1**