Irish Storminess: What Does the Future Hold?

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Summary

Winter storms in recent years have caused major disruption and economic loss in Ireland, but are the storms and their track patterns in the North Atlantic changing or expected to change in the future? This statement examines what role, if any, anthropogenic forcing (i.e. human influence linked to greenhouse gas (GHG) emissions) will have on (a) the frequency, (b) the tracks and (c) the intensity of storms, here primarily assessed on the basis of wind speeds. An assessment of current knowledge, primarily based on climate-model simulations, suggest that projected changes in storminess at the regional scale of Ireland are still subject to considerable uncertainty.

Storm tracks

Storm tracks may be loosely defined as the geographical zones over the seas/oceans where extratropical low-pressure weather systems develop and propagate. Varying spatially and in intensity over the seasons, the Atlantic storm track has a major influence on the Irish climate, particularly in the winter, when it may be linked to extreme winds or extreme precipitation.

The tracks arise from the imbalance in solar heating between the equatorial and polar regions, which is counteracted by the transfer of heat to the poles by the atmosphere and ocean. In the atmosphere this is accomplished by short-lived eddies that develop in the flow, and are recognisable as cyclones and storms. The tracks are geographically relatively narrow and broadly zonal (i.e. the direction of travel is from west to east). However, in the North Atlantic (Figure 1) the storm track has an important southwest–northeast tilt that is linked to the deflection of the mean westerly flow by the Rocky Mountains over North America and the land–sea heat and moisture contrast between the continent and the ocean.

The Atlantic storm track is intimately associated with the Polar Front Jetstream, a ribbon of fast-moving air about 10 km above the surface that plays a symbiotic role with the airflow near the mid-tropospheric steering level (Holton, 2004, 237–8) in shaping and steering the cyclones. It is also influenced by fluctuations in the Gulf Stream and linked to other climate features, such as the North Atlantic Oscillation, the Arctic Oscillation and possibly El-Nino Southern Oscillation.

The complex interplay between these systems makes it difficult to establish causal linkages when changes in the position or intensity of the storm track occur; the complexity is also a major challenge in modelling the future climate.

Changes in storm tracks in the past and current climate

Climatologically, the North Atlantic jet stream, a surrogate for the position and intensity of the storm track, is at its strongest in winter and positioned close to Ireland. In this location it is

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associated with changeable and occasionally stormy weather. In summer it is generally weaker and further north. However, the system is characterised by large variability both at annual and longer timescales. For example, in the early to mid-Holocene (6,000–12,000 years ago) the position of the North Atlantic storm track is likely to have been further south and weaker relative to the current era.

In recent years the frequency and intensity of winter storms affecting Ireland has been exceptional. Using a metric based on the frequency and intensity of storms derived from reanalysis data, Matthews et al. (2014, 2016) found that the 2013/14 winter was the stormiest in records extending back to 1871. The more recent 2015/16 winter was also notable for the number of storms affecting Ireland.[3]

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) (Stocker et al., 2013, 39) commented that:

> It is likely that circulation features have moved poleward since the 1970s, involving a widening of the tropical belt, a poleward shift of storm tracks and jet streams and a contraction of the northern polar vortex … for the years since the 1970s, it is virtually certain that the frequency and intensity of storms in the North Atlantic have increased.

However, the pattern of observed change is complex and, over long time scales, dominated by internal variability. A more recent review of storminess over the North Atlantic by Feser et al. (2015) suggests that most long-term studies show merely decadal variability for the last 100–150 years, and that there is no evidence of a sustained long-term trend.

What is the influence of GHG emissions on storms? There is some evidence (van Oldenborgh et al., 2015; Schaller et al., 2016) that the precipitation intensity associated with some recent storms (e.g. Storm Desmond, 2015) was enhanced by global warming, but the cause of the large-scale changes in storm tracks, storm frequency and wind intensity is more difficult to establish.

Future projections of storm tracks

The enhanced warming of the climate system due to GHG forcing is expected to change the thermal structure of the lower atmosphere: the warming of the poles, particularly in the Arctic, will reduce the equator-to-pole temperature gradient, and this effect is often appealed to as a causal mechanism for a reduction in the number of mid-latitude storms in a warming world. However, in contrast, the tropospheric tropical regions are expected to become warmer while the stratosphere is expected to cool with rising GHG levels, leading to an enhanced upper level equator-to-pole temperature gradient. Both competing effects must be properly described by climate models for predicting future change.

The IPCC Fifth Assessment Report was cautious regarding the robustness of future projections from the then available climate models, either globally or at regional scale:

> There is low confidence in near-term projections of the position and strength of NH storm tracks. Natural variations are larger than the projected impact of GHGs in the near term. (Stocker et al., 2013, 88)

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[3] See https://en.wikipedia.org/wiki/2015%E2%80%9316_UK_and_Ireland_windstorm_season for details of recent (2015/2016) storms.

…

> Poleward shifts in the mid-latitude jets of about 1 to 2 degrees latitude are likely at the end of the 21st century under RCP8.5 in both hemispheres (medium confidence), with weaker shifts in the NH … Substantial uncertainty and thus low confidence remains in projecting changes in NH storm tracks, especially for the North Atlantic basin. (Stocker et al., 2013, 90)

In a later assessment of CMIP5 climate-model simulations, Zappa et al. (2013) performed a detailed investigation of the future (2070–2099) projections based on the hydrological intensity and the frequency and dynamical intensity of winter and summer extratropical cyclones impacting on Europe and the North Atlantic. They found that, while there was an overall reduction in the number of cyclones (track density), particularly in winter, there was a small increase over Ireland/UK in winter and a reduction in summer. The precipitation intensity of cyclones shows a large increase in winter. They also found a slight increase in the number and intensity of winter cyclones with strong wind speeds affecting Ireland/UK. A large number of studies on storminess have since become available, sometimes with contradictory results. Mathews et al. (2016), for example, find no evidence for an increase in storminess in future winters using the same CMIP5 archive, and note that the severity of the 2013/14 storms is a 'highly unlikely' event in the CMIP5 statistics.

A review of the literature on projected changes in storminess (emphasis on wind strength) over the North Atlantic European region by Mölter et al. (2016) suggests an increase in the frequency and intensity of storms affecting Ireland, with a north and eastward shift of the storm track.

Results from a recent (2016) study of storm tracks by the authors, based on a EURO-CORDEX downscaled subset of CMIP5 simulations, are less conclusive. These show a reduction of ~10 per cent in the frequency of less-intense (core-pressure) winter storms affecting Ireland from mid-century, and suggest an eastward extension of the more severe wind storms over Ireland and the UK; these results are also consistent with the regional-model results by Nolan (2015) on future storm tracks and wind speeds over Ireland. Unfortunately, regional downscaling inherits the biases of the global models, and the downscaled data also show relatively poor agreement with observed storm tracks. For these reasons the robustness of the results is questionable.

Conclusions

Model improvements, particularly in the representation of processes in the ocean and stratosphere and an improved resolution of spatial detail, may reduce the uncertainty of the climate projections. The Irish Centre for High-End Computing, supported by funding from the EPA and Met Éireann, is currently involved in the development of a next-generation Earth system model in the EC-Earth consortium. Simulations with this and other enhanced models planned for CMIP6, the follow-up to CMIP5, may shed further light on changes in storm tracks and how they may impact on the Irish climate.

In summary, much uncertainty still remains regarding future changes in the frequency and wind severity of storms affecting Ireland.

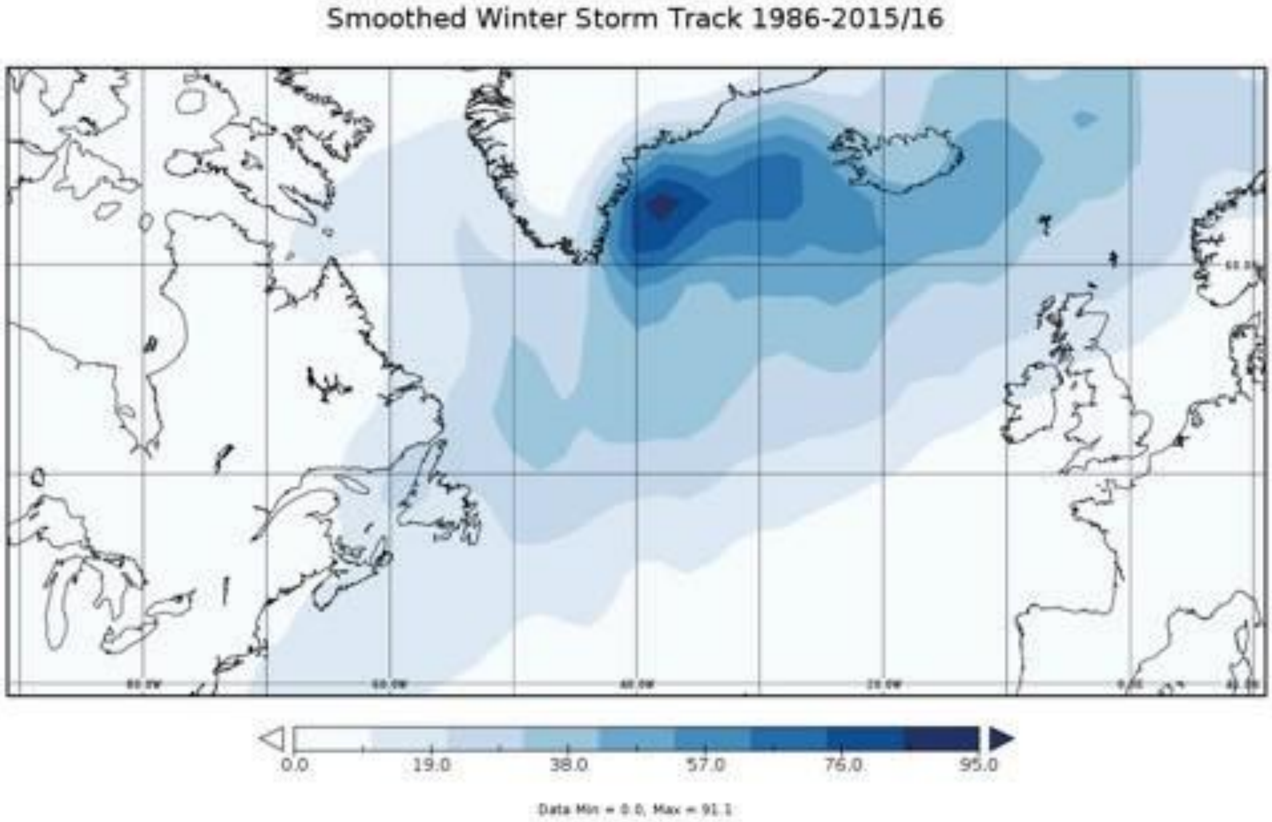

Figure 1: North Atlantic storm-track pattern based on ERA-Interim data (Dee, 2011). Plots show smoothed cyclone density tracks for 1985/86–2015/16 winters. Only cyclones with a lifetime of at least two days and a minimum core pressure of 960 hPa or less at some point along the track are counted. The Icelandic Low, a semi-permanent low-pressure centre, is reflected in the high concentration of tracks between Greenland and Iceland. Note that the impacts of a storm can extend over a wide area beyond the central core.

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