Environmental Research Letters

PERSPECTIVE • **OPEN ACCESS**

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Environmental Research Letters

OPEN ACCESS

RECEIVED
14 February 2018

ACCEPTED FOR PUBLICATION
11 April 2018

PUBLISHED
30 April 2018

PERSPECTIVE

The devil in the detail of storms

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Wintertime windstorms associated with low-pressure systems from the North Atlantic Ocean are the costliest natural hazard for Europe (Ulbrich *et al* 2013). These storms are associated with large pressure gradients and high background winds, but the most destructive gusts are often confined to relatively small areas within the low-pressure systems. Examples include showers and thunderstorms in the area of the cold front (e.g. Ludwig *et al* 2015) and the so-called 'sting jet' as analysed in the recent paper by Martínez-Alvarado *et al* (2018). Sting jets are relatively small and short-lived high-wind zones in the area of the bent-back warm front during the mature stage of a particular type of low-pressure system (see figure 1 for a recent example). The name goes back to a seminal paper by Browning (2004) calling the high winds 'the sting at the end of the tail'. Sting jets typically occur in explosively intensifying storms and are mostly confined to the North Atlantic Ocean and the adjacent British Isles (Hart *et al* 2017). There is an ongoing debate about the details of the physical mechanisms involved in creating sting jets, including aspects such as conditional symmetric instability, frontolysis and cooling through evaporation, melting and sublimation.

Up to now assessments of future risks for winterstorm damages in Europe mostly rely on coarse-resolution global climate models. These show general changes in the number, intensity and track of low-pressure systems, but are not capable of resolving the actual high-wind areas within storms. So the devil in a true account of future wind risk may well lie in the details of how storms change. Generally speaking, three approaches have been applied to address this kind of problem: (1) Nesting a high-resolution regional domain into the global climate model. This is computational expensive and very demanding in terms of data storage, particularly if horizontal and vertical resolutions are high enough to realistically represent convective momentum transport from middle levels (2–5 km) to the surface, which has been shown to be crucial in some storms at least (Ludwig *et al* 2015). (2) Pseudo-global warming experiments, in which representative present-day example cases are simulated in high resolution, artificially modifying temperature, moisture and wind fields to test the dynamical effect of these changes. Such an approach has been used for tornadic storms (e.g. Trapp and Hoogewind 2016), but does not allow a rigorous statistical assessment. Moreover, it is challenging for mid-latitude low-pressure systems, as these travel long distances in short time. (3) Statistical approaches based on dynamical precursors computed from coarse-resolution global climate models that allow diagnosing the potential of hazardous weather on smaller scales without explicitly having to run high-resolution simulations.

The ground-breaking new paper by Martínez-Alvarado *et al* (2018) is the first to apply the dynamical precursor approach for sting jets to a climate change experiment. This has become possible due to the availability of model output suitable to compute all necessary fields. Interestingly, the authors show that while the total number of storms in the model slightly decreases in the future, those with sting jet precursors dramatically increase. In addition, the results by Martínez-Alvarado *et al* (2018) show an expansion of the area affected by explosively deepening sting-jet storms into northern Europe, well beyond the British Isles. A possible physical reason for this behaviour is that in a warmer world the increase in atmospheric moisture content could enhance the moist instabilities involved in creating sting jets. The coarse-resolution model data indicate a general increase in strong wind occurrence, but given the inability of the model to realistically represent sting jets, this may still be a substantial underestimation of the real impact.

This important and alarming result calls for enhanced research efforts focusing on the smaller-scale details of future storm developments. Recent years have already seen the unexpected occurrence of sting jet storms in central Europe (e.g. storm 'Egon' over southern Germany, figure 1). Moreover, in the current climate strong gusts associated with cold-frontal convection are an even more frequent hazard for Europe as a whole. Little has been done to assess

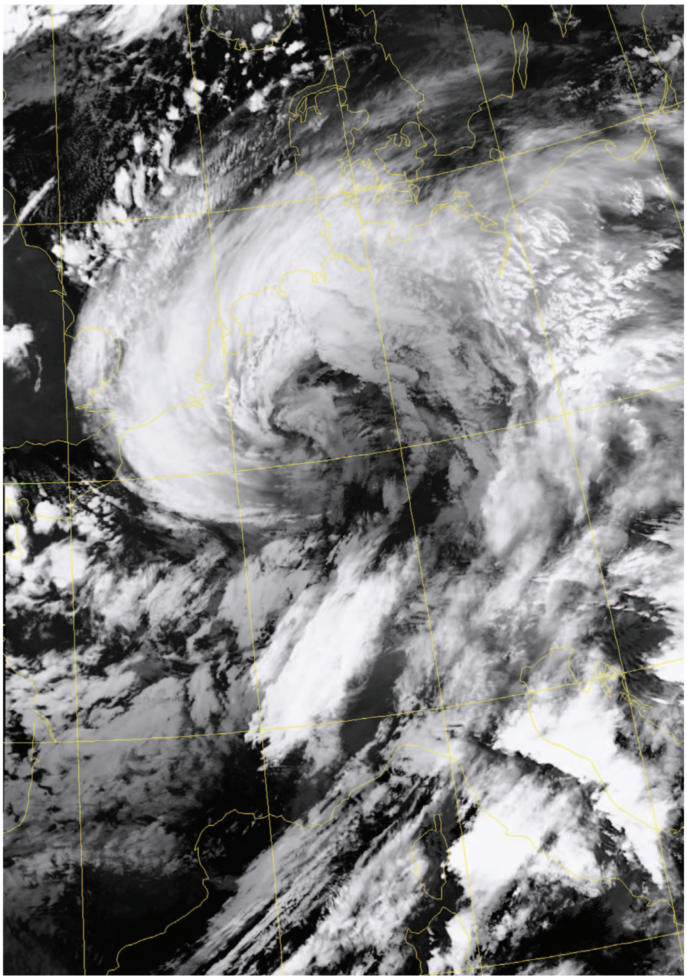

Figure 1. The sting jet of storm 'Egon' affecting southern Germany. 'Fingered' structures at the end of the bent-back cloud head of a mature cyclone are typical indications of a sting jet occurrence. Re-projected image at 0046 UTC on 13 January 2017 (VIIRS, Channel 15, 10263–11263 nm). The image was taken from NERC Satellite Receiving Station, Dundee University, Scotland at http://www.sat.dundee.ac.uk/.

potential changes in their frequency and intensity in the future. Convection-resolving, long-term climate change experiments as those by Leutwyler *et al* (2017) offer new possibilities to analyse storms in much more detail, without the uncertainty coming from any precursor diagnostics. However, such models still struggle to simulate the full lifecycle of low-pressure systems over a sufficiently long time-period. Therefore a careful combination of the approaches listed above remains the most promising way to generate a much more complete picture of the future behaviour of European windstorms and the damaging high-wind areas embedded in them.

Acknowledgments

The research leading to these results has been done within the subproject C5 'Forecast uncertainty for peak surface gusts associated with European cold-season cyclones' of the Transregional Collaborative Research Center SFB/TRR 165 'Waves to Weather' funded by the German Research Foundation (DFG).

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References

Browning K A 2004 The sting at the end of the tail: damaging winds associated with extratropical cyclones *Q. J. R. Meteorolog. Soc.* **130** 375–99

Hart N C, Gray S L and Clark P A 2017 Sting-jet windstorms over the North Atlantic: climatology and contribution to extreme wind risk *J. Clim.* **30** 5455–71

Ludwig P, Pinto J G, Hoepp S A, Fink A H and Gray S L 2015 Secondary cyclogenesis along an occluded front leading to damaging wind gusts: Windstorm Kyrill, January 2007 *Mon. Wea. Rev.* **143** 1417–37

Leutwyler D, Lüthi D, Ban N, Fuhrer O and Schär C 2017 Evaluation of the convection-resolving climate modeling approach on continental scales *J. Geophys. Res. Atmos.* **122** 5237–58

Martínez-Alvarado O, Gray S L, Hart N C G, Clark P A, Hodges K and Roberts M J 2018 Increased wind risk from sting-jet windstorms with climate change *Env. Res. Lett.* **13** 044002

Trapp R J and Hoogewind K A 2016 The realization of extreme tornadic storm events under future anthropogenic climate change *J. Clim.* **29** 5251–65

Ulbrich U, Leckebusch G and Donat M 2013 Windstorms, the most costly natural hazard in Europe *Natural Disasters and Adaptation to Climate Change* ed S Boulter, J Palutikof, D Karoly and D Guitart (Cambridge: Cambridge University Press) pp 109–120