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The contribution of sting-jet windstorms to extreme wind risk in the North Atlantic

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Summary

Wind storms are a major winter weather risk for many countries in Europe. These storms are predominantly associated with explosively-developing extratropical cyclones that track across the region. Recently, interest in the mesoscale variability of the most damaging winds has led to a focus on the role of sting jets in enhancing wind storm severity.

We present a present-era climatology of North Atlantic cyclones that had potential to produce sting jets. Considering only explosively-developing cyclones, those with sting-jet precursors are more likely to have stronger associated low-level wind maxima. Furthermore, the strongest winds for these cyclones are more often in the cool-sector, behind the cold front, when compared with other explosively-developing cyclones which commonly also have strong warm-sector winds. Up to one third of extratropical cyclones within the main storm track have sting-jet precursors, though they are rare over Europe. Thus, the rarity and, until recently, lack of description of sting-jet windstorms is more due to the climatology of storm track location away from highly-populated land masses, than due to an actual rarity of such storms in nature.

Sting jet?

A transient (few hours), mesoscale (~50 km spread) airstream descending from the tip of the banded and hooked cloud head into the frontal fracture region of some extratropical cyclones following the Shapiro-Keyser (1990) evolution.

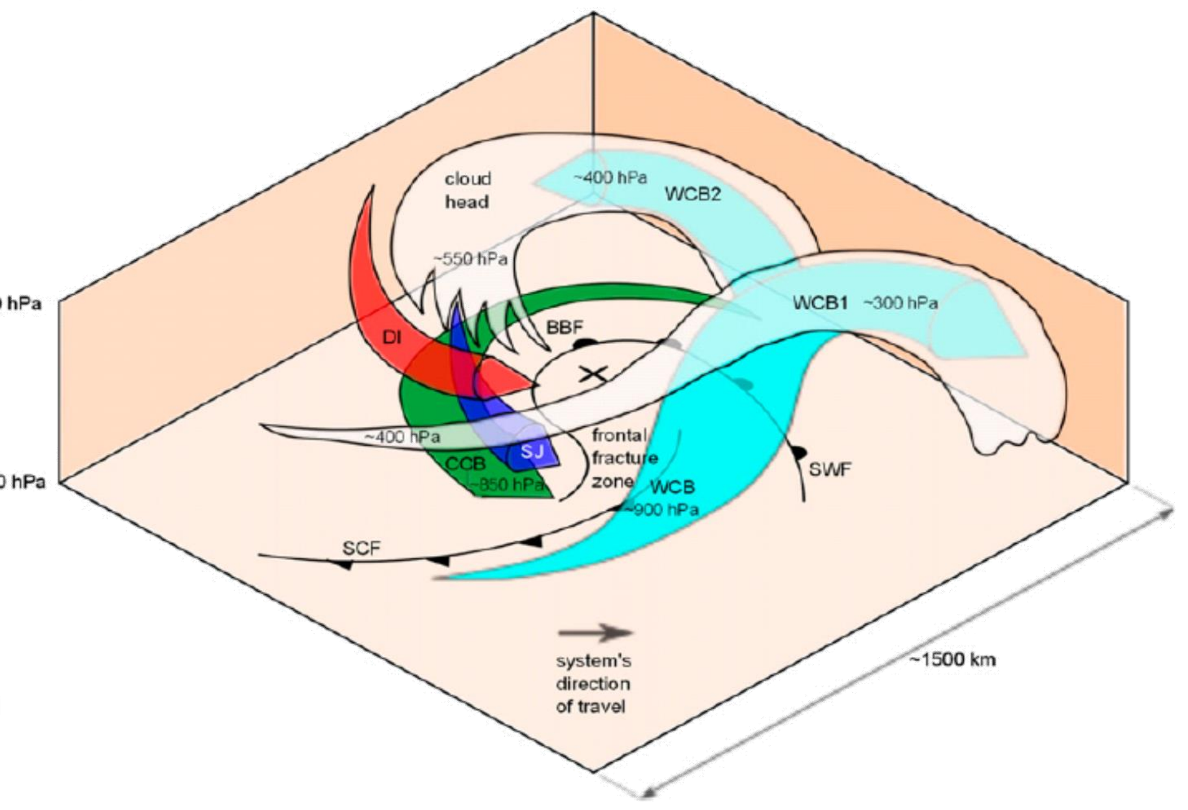

Fig. 1.The structure of a Northern Hemisphere Shapiro–Keyser cyclone in development stage 3: surface cold front (SCF); surface warm front (SWF); bent-back front (BBF); cold conveyor belt (CCB); sting-jet airstream (SJ); dry intrusion (DI); warm conveyor belt (WCB); WCB anticyclonic branch (WCB1); WCB cyclonic branch (WCB2). The large X represents the cyclone centre at the surface and the grey shading represents cloud top. From Martínez-Alvarado et al. (2014).

Identification of sting jet precursors

- ERA-Interim data (1979-2011): 6 hourly, Sept. to May inclusive.
- Extratropical cyclone tracks diagnosed using TRACK algorithm (e.g. Hodges and Hoskins, 2002) using ξ_{850} smoothed to T42 resolution.
- Cyclones reaching their ξ_{max} within a specified North Atlantic domain analysed.
- Sting-jet precursors diagnosed assuming release of atmospheric instability generates or strengthens sting jets (Gray et al., 2011).
- Midtropospheric atmospheric instability to slantwise descent diagnosed using downdraught slantwise CAPE (DSCAPE).
- Sting-jet precursor if sufficiently large contiguous region of DSCAPE exceeding 200 Jkg^{-1} in the cloud head (Fig. 2).
- Previous work (Martínez-Alvarado et al., 2012) has demonstrated skill in identification of cyclones that generated sting jets in weather forecasts.

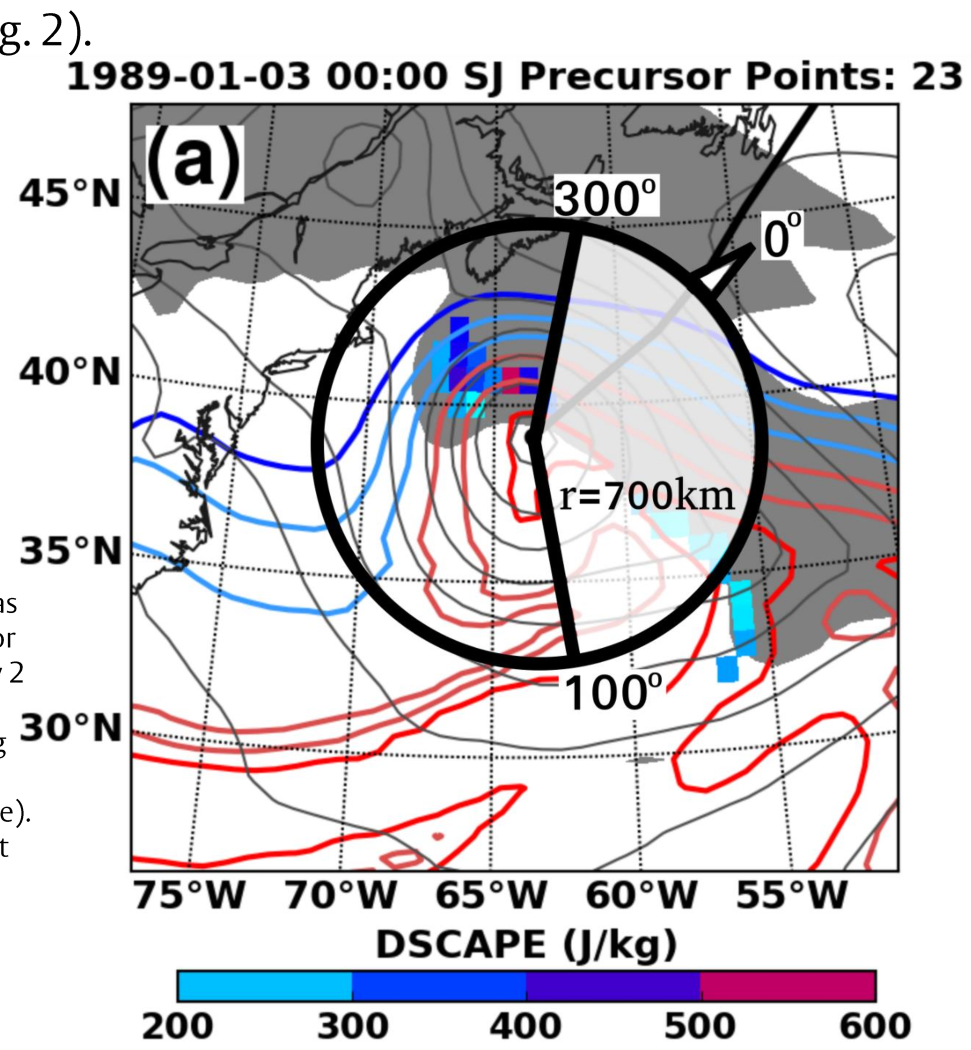

Fig. 2. Methodology example using ERICA IOP4 storm as represented in ERA-Interim. Sting-jet DSCAPE precursor (colour shading), 850 hPa θ_w contours (coloured, every 2 K starting at 277 K in blue) and MSLP (grey contours) with RH>90% in the lower troposphere in grey shading to indicate the cloud head. Northeastward cyclone movement is indicated by system track (thick black line). To satisfy the precursor diagnostic DSCAPE values must be proximate to the cyclone centre (within a circle of radius 700 km) and within the rearward-developing cloud head (clear sector in circle bounded by 100° to 300° when 0° is defined as the direction of cyclone movement).

Cyclone categorisation

Table 1 shows that

- about a third (32%) of all tracked cyclones have a sting jet precursor.
- 22% of cyclones develop explosively,
- Explosively-developing cyclones are more likely to have a sting-jet precursor (42% compared to 29%).

	Non explosive	Explosive (Δp (24h)< -20 hPa)	Totals
No SJ precursor	**3020**	**676**	3696
SJ precursor	**1252**	**499**	1751
Totals	4272	1175	5447

Table 1. Categorisation of tracked cyclones.

Cyclone-related wind risk

Strong low-level winds (here defined as exceeding 30 ms^{-1}) occur most frequently to the south of the storm track, defined as the band of peak cyclone density (Fig. 3).

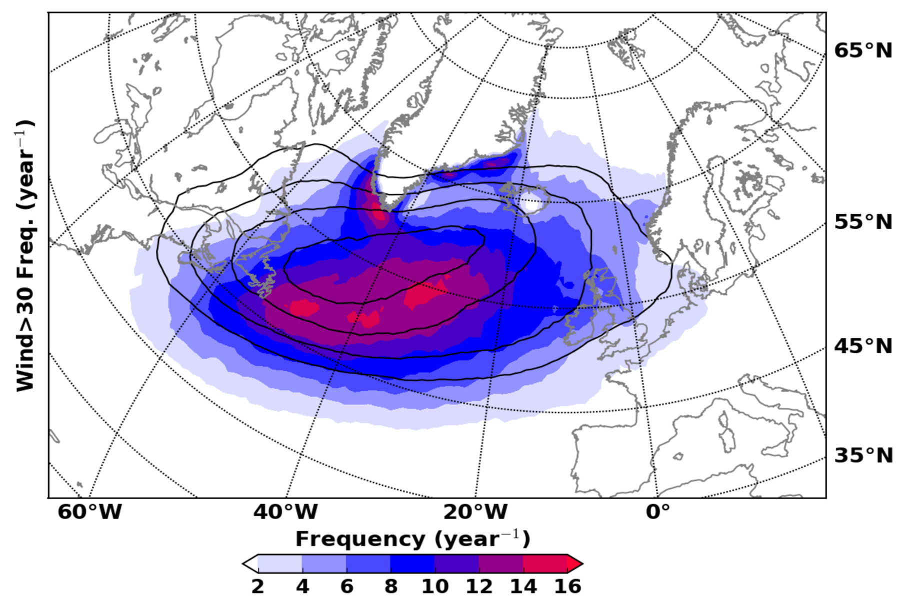

Fig. 3. Annual frequency of 850 hPa wind speeds exceeding 30 ms^{-1} within 1000 km of tracked cyclone centres computed from all storms (colour shading). Contours of cyclone density are overplotted (contours of 3-6, interval 1, per month in an unit area equivalent to a 5° spherical cap (approx. 10^6 km^2)).

Considering explosively-deepening cyclones, those with sting-jet precursors are more likely to be associated with strong low-level winds, particularly in the SW of the North Atlantic (Fig. 4a, b). The cool sector dominates the contribution to strong low-level winds (Fig. 4c, d). Cyclones with SJ precursors contribute more in the SW of the N. Atlantic (Fig. 4c). Cyclones without SJ precursors contribute more in the NE of the N. Atlantic (Fig. 4d). Over the UK, cyclones with SJ precursors dominate for windspeeds > 35 ms^{-1} and become increasingly dominant as speed increases (Fig. 4d insert).

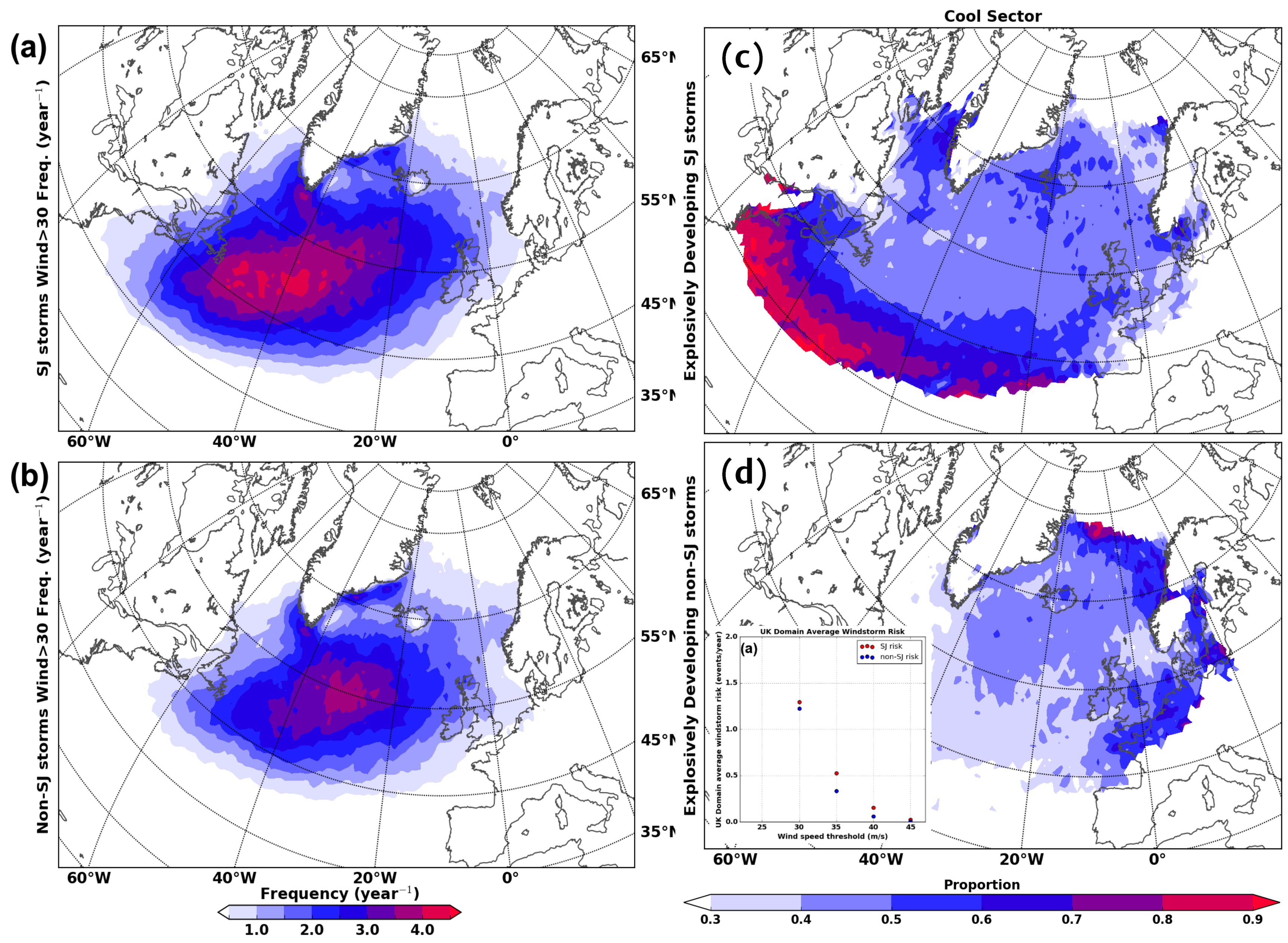

Fig. 4. (a,b) The annual frequency of 850 hPa wind speeds >30 ms^{-1} within 1000 km of tracked cyclone centres computed from explosively-deepening cyclones only and separated into cyclones (a) with and (b) without sting-jet precursors. (c, b) The proportion of the total annual frequency of (sum of (a) and (b)) in the cool sector of the cyclones separated into cyclones (c) with and (d) without sting-jet precursors. Insert in panel d shows the number of explosively-deepening cyclones (with and without sting-jet precursors) averaged over the British Isles as a function of windspeed threshold.

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Acknowledgements - Funded by the AXA research fund.