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Supplement of

A global climatology of sting-jet extratropical cyclones

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S1 Additional composite cyclone maps

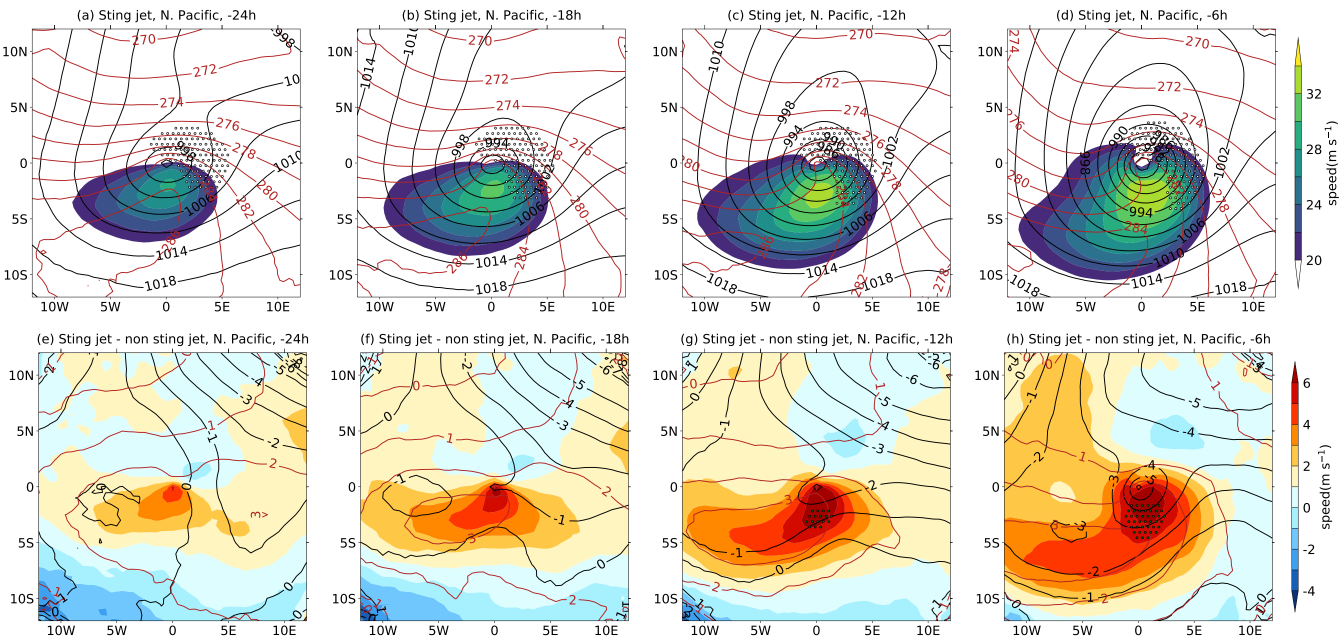

Figure S1. As for Fig. 9 but for the North Pacific.

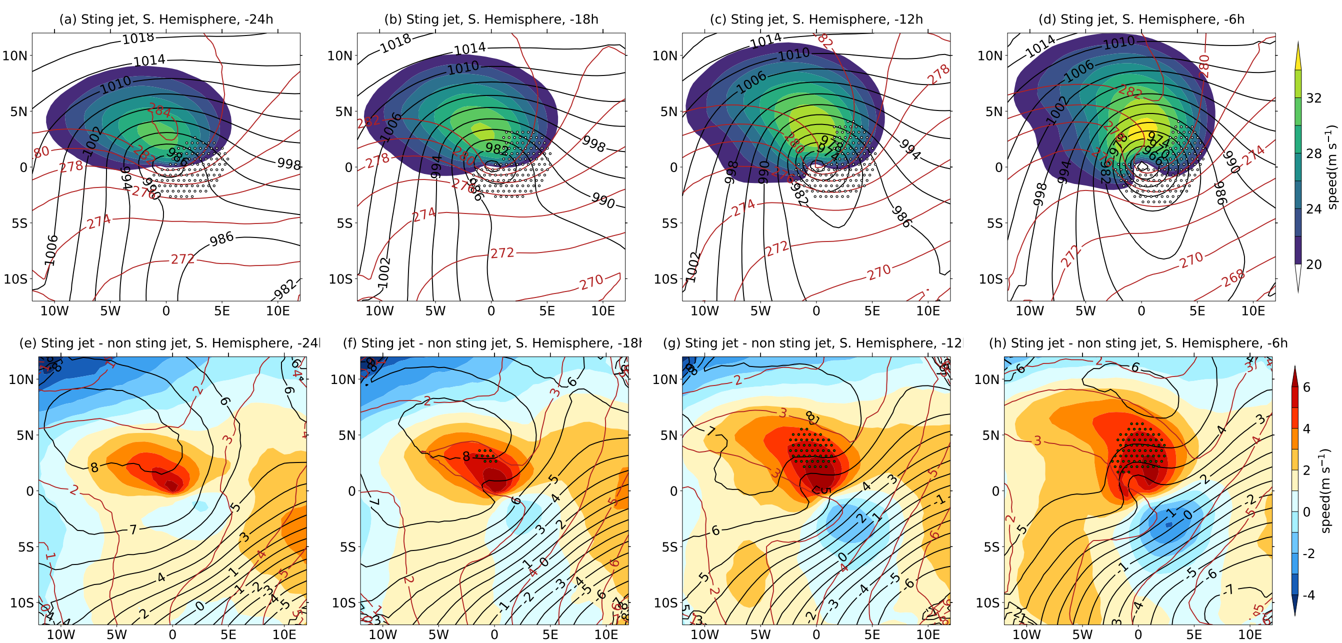

Figure S2. As for Fig. 9 but for the Southern Hemisphere.

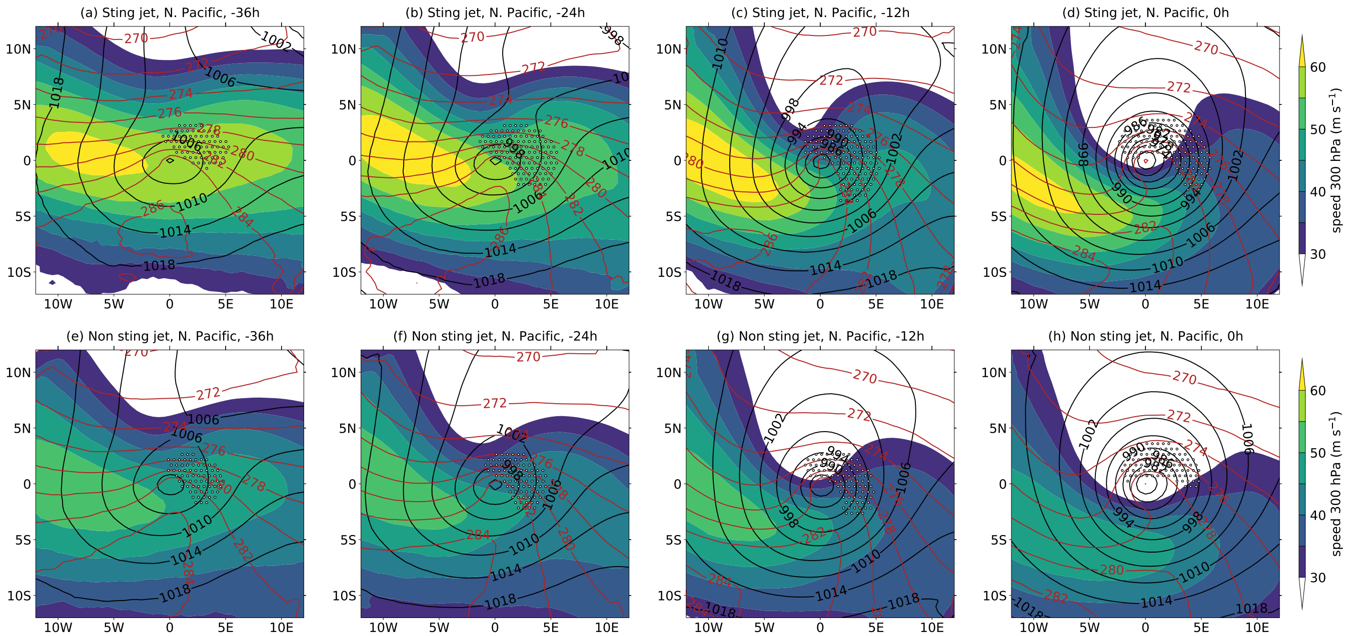

Figure S3. As for Fig. 10 but for the North Pacific.

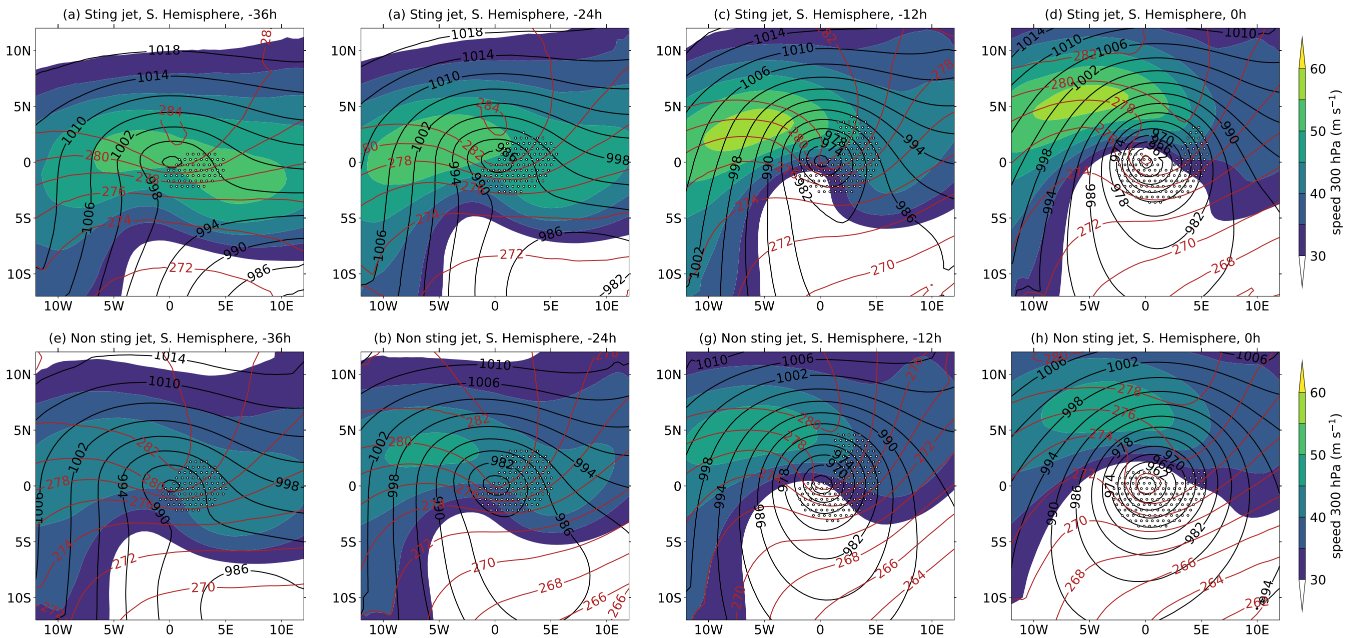

Figure S4. As for Fig. 10 but for the Southern Hemisphere.

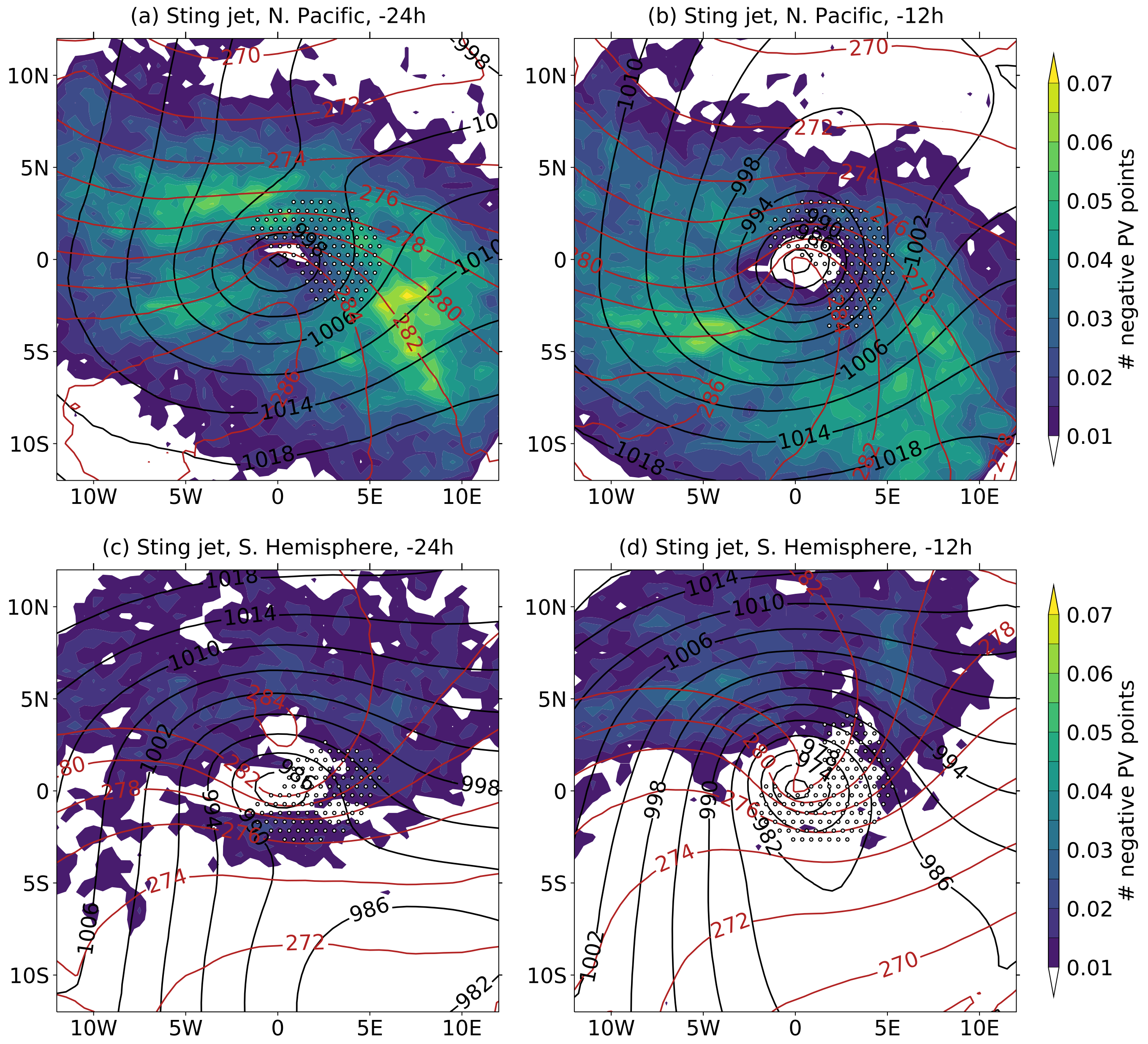

Figure S5. Maps of the composite 700-hPa symmetrically unstable PV structure of the sting-jet cyclones in the North Pacific (top row) and Southern Hemisphere (bottom row) at (a,c) -24 and (b,d) -12 h prior to the time of maximum intensity. Fields as in Fig. 11(a). Note that these PV points are negatively and positively signed for the North Pacific and Southern Hemisphere basins, respectively. Recall that in the Southern Hemisphere composites the cloud head tip is to the southwest of the composite centre and the cold front is ahead of this in a clockwise direction).

S2 Notable storms

As described in the main text, a set of 33 "notable storms" was used to test and refine the algorithm before applying it to the complete cyclone datasets. For each of these storms an "expert judgment" was made as to the likelihood that it contained a sting jet. Where present, satellite imagery and ocean surface wind data (see details in Sect. 2.3 of the main text), together with published results where available, were analysed. Output from the SJP diagnostic (Sect. 3.2) was also examined qualitatively, focusing on the relative locations of cloud head sector and CSI points, the direction of travel of the storms and the number of CSI points present (using map-style plots such as those in Fig. 3 in the main text). All these data were used to form an expert judgement (on a five-point scale: TRUE, LIKELY TRUE, MARGINAL, LIKELY FALSE, FALSE) of the likelihood of sting jet presence (see scores and brief score justifications in Table S2). This manual evaluation of the storm likelihood to contain a sting jet was then compared against the automatic SJP score (TRUE, MARGINAL or FALSE). There was satisfactory agreement between the two sets of scores as they were equivalent or near-to-equivalent (such that the manual and SJP assessments were, respectively, TRUE-TRUE, LIKELY TRUE-TRUE, MARGINAL-MARGINAL, LIKELY FALSE-FALSE, or FALSE-FALSE) in 22 cases out of 33, while 9 of the remaining 11 involved a MARGINAL score in one of the two sets, indicating that either the manually analysed evidence was not clear enough for a conclusive verdict or that the results from the precursor algorithm did not give a clear indication. The only two cases of clear disagreement (storm Martin and the October 2021 Nor'easter storm, both matched as LIKELY FALSE-TRUE) are associated with a lack of clear satellite imagery and a cyclone with a complex track, respectively, and are thus cases where considerable uncertainty applies to either the manual or automatic classifications. Note that the large fraction of TRUE cyclones, 22 according to the SJP diagnostic compared to 6 classified as FALSE and 5 as MARGINAL, does not indicate that the results of the algorithm are skewed towards TRUE, as several of the notable storms are known or hypothesised sting-jet cyclones (with at least seven of them documented as such in the literature). Details of the storms and a comparison between the expert judgement and SJP algorithm determined SJP likelihood scores are given in Tables S1 and S2, respectively.

Table S1: List of notable storms used for the evaluation of the SJP diagnostic, together with their regional location, time of maximum intensity, status of sting jet documentation and availability of observation for our manual expert judgement. In the "Sat. imagery" column, the letters indicate the scatterometer data and the different sources of satellite imagery (C: CCMP3.0; S: SEVIRI; A: AVHRR; I: IR Ring, see Sect. 2.3). Note that storms Daria, Martin, Klaus, Kyrill and Friedhelm were also considered by Hewson and Neu (2015) with the conclusion that the likely cause(s) of the strongest gusts over land did not include a sting jet, but the possibility of sting jets prior to landfall were not considered.

Beginning of Table

Region	Storm name	Max intensity time	Documented SJ	Sat. imagery
N. Atl.–W. Europe	Great Storm	16 Oct 1987 00UTC	Yes: Browning (2004); Browning and Field (2004); Clark et al. (2005); Hewson and Neu (2015)	none
N. Atl.–W. Europe	Daria (Burns' Day)	25 Jan 1990 18UTC	N/A	none
N. Atl.–W. Europe	Braer Storm	08 Jan 1993 06UTC	N/A	C
N. Atl.–W. Europe	Lothar	26 Dec 1999 06UTC	Possible: Hewson and Neu (2015)	C
N. Atl.–W. Europe	Martin	27 Dec 1999 18UTC	N/A	C
N. Atl.–W. Europe	Kyrill	17 Jan 2007 18UTC	N/A	C, H
N. Atl.–W. Europe	Klaus	24 Jan 2009 00UTC	N/A	C, S, A
N. Atl.–W. Europe	Friedhelm	08 Dec 2011 12UTC	Yes: Martínez-Alvarado et al. (2014); Baker et al. (2014)	C, S, A
N. Atl.–W. Europe	Tini	12 Feb 2014 12UTC	Yes: Volonté et al. (2018)	C, S, A
N. Atl.–W. Europe	ex-TC Ophelia	16 Oct 2017 06UTC	N/A	C, S, A
N. Atl.–W. Europe	Arwen	26 Nov 2021 18UTC	N/A	C, S, A, I
N. Atl.–W. Europe	Barra	07 Dec 2021 12UTC	N/A	C, S, A, I
N. Atl.–W. Europe	Corrie	30 Jan 2022 00UTC	N/A	C, S, A, I
N. Atl.–W. Europe	Eunice	18 Feb 2022 06UTC	Yes: Volonté et al. (2023a, b)	C, S, A, I
Med. and Black Seas	Black Sea cyclone	03 Dec 2012 12UTC	Yes: Brâncuş et al. (2019)	C, S, A
N. Atl.–N. USA E. coast	Eastern N. USA cyclone	06 Feb 1988 00UTC	N/A	none
N. Atl.–N. USA E. coast	ERICA cyclone #1	21 Nov 1988 12UTC	N/A	none
N. Atl.–N. USA E. coast	ERICA cyclone #2	13 Dec 1988 06UTC	N/A	none
N. Atl.–N. USA E. coast	N. USA Blizzard #1	09 Feb 2013 06UTC	N/A	C, S, A
N. Atl.–N. USA E. coast	N. USA Blizzard #2	05 Jan 2018 00UTC	N/A	C, S, A
N. Atl.–N. USA E. coast	Nor'easter	27 Oct 2021 06UTC	N/A	C, S, A, I
N. Pac. –N. USA W. coast	Hanukkah Eve Windstorm	15 Dec 2006 00UTC	No: Mass and Dotson (2010)	C
N. Pac. –N. USA W. coast	Great Coastal Gale	02 Dec 2007 06UTC	N/A	C
N. Pac. –N. USA W. coast	N. Pacific cyclone #1	15 Dec 2011 06UTC	Yes: Parker (2013)	C, A
N. Pac. –N. USA W. coast	N. Pacific cyclone #2	12 Jan 2012 12UTC	Yes: Parker (2013)	C, A
N. Pac. –N. USA W. coast	N. Pacific cyclone #3	15 Jan 2013 06 UTC	N/A	C, A
N. Pac. –N. USA W. coast	ex-TC Nuri	08 Nov 2014 00UTC	N/A	C, A
N. Pac. –N. USA W. coast	Alaskan cyclone	08 Dec 2018 00UTC	N/A	C, A
N. Pac. –N. USA W. coast	NE Pacific Bomb	24 Oct 2021 12UTC	N/A	C, A, I
S Hemisphere	Antarctic Bomb	13 Aug 2021 00UTC	N/A	C, S, A, I
S Hemisphere	S. Hemisphere cyclone #1	02 Jun 2021 00UTC	N/A	C, S, A

Continuation of Table				
Region	Storm name	Max intensity time	Documented SJ	Sat. imagery
S Hemisphere	S. Hemisphere cyclone #2	19 Jul 2021 12UTC	N/A	C, S, A, I
S Hemisphere	S. Hemisphere cyclone #3	21 Aug 2021 00UTC	N/A	C, S, A, I

End of Table

Table S2: List of notable storms used for the evaluation of the SJP diagnostic, together with a one-line summary of our manual expert judgement and manual and automatic scores.

Beginning of Table

Storm name	Expert judgement	Expert judgement score	Algorithm score
Great Storm	Precursors consistent with literature.	TRUE	TRUE
Daria (Burns' Day)	CSI points in the right place at plausible time, satellite imagery needed for confirmation.	LIKELY TRUE	TRUE
Braer Storm	No clear scatterometer SJ evidence but there are CSI hints, clear satellite imagery would have helped.	MARGINAL	TRUE
Lothar	Difficult task, lack of clear satellite imagery, uncommon cyclone structure and unclear SJ indications.	MARGINAL	TRUE
Martin	Strong scatterometer winds probably due to CCB rather than SJ, clear satellite imagery would have helped.	LIKELY FALSE	TRUE
Kyrill	Contradicting signals between CSI, scatterometer and satellite imagery (cloud head). Strong winds probably not SJ.	LIKELY FALSE	FALSE
Klaus	Good indications of likely SJ presence from all tools.	LIKELY TRUE	TRUE
Friedhelm	Satellite imagery, scatterometer winds, precursors all pointing towards likely SJ presence, confirmed by literature.	TRUE	TRUE
Tini	Agreement between observations and literature evidence and precursor tool, but short-lived CSI signal.	TRUE	TRUE
ex-TC Ophelia	Contrast between lack of SJ indications in satellite imagery and scatterometer winds, and abundance of cloud-head-tip CSI.	MARGINAL	TRUE
Arwen	Weak evidence in satellite imagery, scatterometer winds and CSI points but (early?) presence of SJ cannot be ruled out.	MARGINAL	MARGINAL
Barra	No clear SJ hint in scatterometer winds but both satellite imagery and CSI points indicate likely cloud-head slantwise motions.	LIKELY TRUE	TRUE
Corrie	Difficult analysis due to storm location and terrain, no clear SJ evidence but it cannot be totally ruled out.	LIKELY FALSE	FALSE
Eunice	Less CSI than expected from literature (documented SJ) and satellite imagery and scatterometer winds, possibly due to compact structure.	TRUE	TRUE
Black Sea cyclone	Satellite imagery, scatterometer winds and precursors are both consistent with the literature in indicating early SJ descent.	TRUE	MARGINAL
Eastern N. USA cyclone	No satellite imagery, but CSI points in right place several times, possibly suggesting unreleased CSI (in ERA5).	LIKELY TRUE	TRUE
ERICA cyclone #1	No satellite imagery, but CSI points are in the right place, mainly in mature stages (unreleased as above?)	MARGINAL	MARGINAL
ERICA cyclone #2	No satellite imagery and no relevant CSI points.	LIKELY FALSE	FALSE
N. USA Blizzard #1	Indications of SJ development from satellite imagery and CSI points, coherent with later wind maximum in frontal fracture.	LIKELY TRUE	MARGINAL

Continuation of Table			
Storm name	Expert judgement	Expert judgement score	Algorithm score
N. USA Blizzard #2	Possible very early SJ development, outside precursor window, and mature stage CSI. Complex track.	MARGINAL	TRUE
Nor'easter	Tricky task due to complex track. Weak SJ signals and cyclone structure not conducive to its development.	LIKELY FALSE	TRUE
Hanukkah Eve Windstorm	Typical SJ cyclone structure. Limited CSI but in the right place. SJ dismissal in published literature seems questionable.	MARGINAL	FALSE
Great Coastal Gale	Strongly positive CSI indication but lack of conclusive satellite imagery.	LIKELY TRUE	TRUE
N. Pacific cyclone #1	Documented SJ case, early banding and cloud-head tip CSI but most CSI is at late stages (unreleased?).	TRUE	TRUE
N. Pacific cyclone #2	Documented SJ case, signals from both satellite imagery and CSI (times not fully consistent), scatterometer winds less clear.	TRUE	TRUE
N. Pacific cyclone #3	Possible very early SJ development, outside precursor window. Widespread late CSI in right areas.	MARGINAL	TRUE
ex-TC Nuri	Sustained CSI in right areas but affected by odd track. SJ hints, weak from scatterometer winds. Frontal fracture not clear.	MARGINAL	MARGINAL
Alaskan cyclone	Weak signals from observations in good agreement with the (again, not strong) CSI signal.	LIKELY TRUE	TRUE
NE Pacific Bomb	Hints of early SJ descent from scatterometer winds and (more clearly) CSI, despite lack of clear satellite imagery evidence.	LIKELY TRUE	TRUE
Antarctic Bomb	Hints of possible SJ presence from satellite imagery and scatterometer winds but absence of CSI in correct region.	MARGINAL	FALSE
S. Hemisphere cyclone #1	All sources point at possible SJ development before maximum intensity.	LIKELY TRUE	TRUE
S. Hemisphere cyclone #2	Absence of any clear evidence of SJ descent.	LIKELY FALSE	FALSE
S. Hemisphere cyclone #3	No prior literature/analysis but multiple evidence of likely SJ presence.	LIKELY TRUE	TRUE
End of Table			

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