National Centre for Atmospheric Science
NATURAL ENVIRONMENT RESEARCH COUNCIL

University of Reading

(Towards...)

A global climatology of sting-jet cyclones

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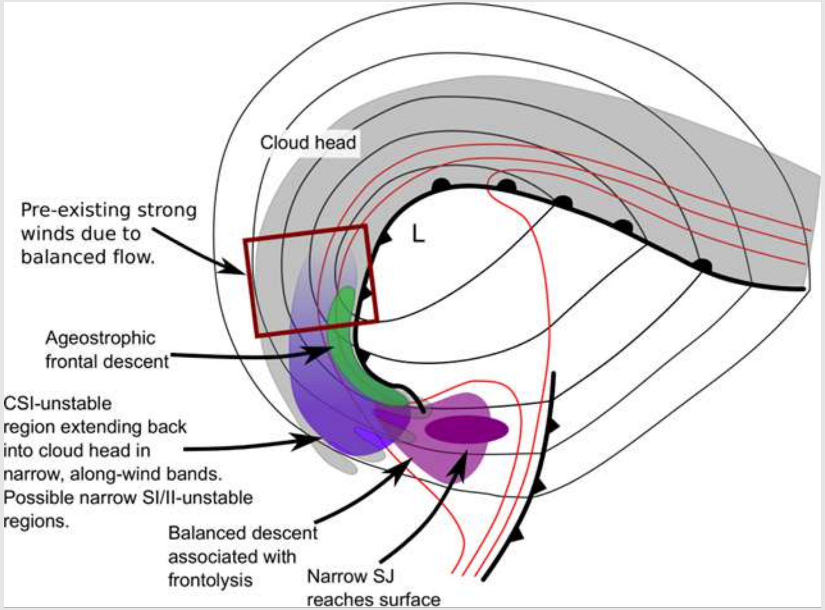
Outline

- The need for a global sting jet climatology
- Our approach for constructing a global climatology
- Two example sting jet cyclones
- Cyclone-relative DSCAPE composites

What is a sting jet?

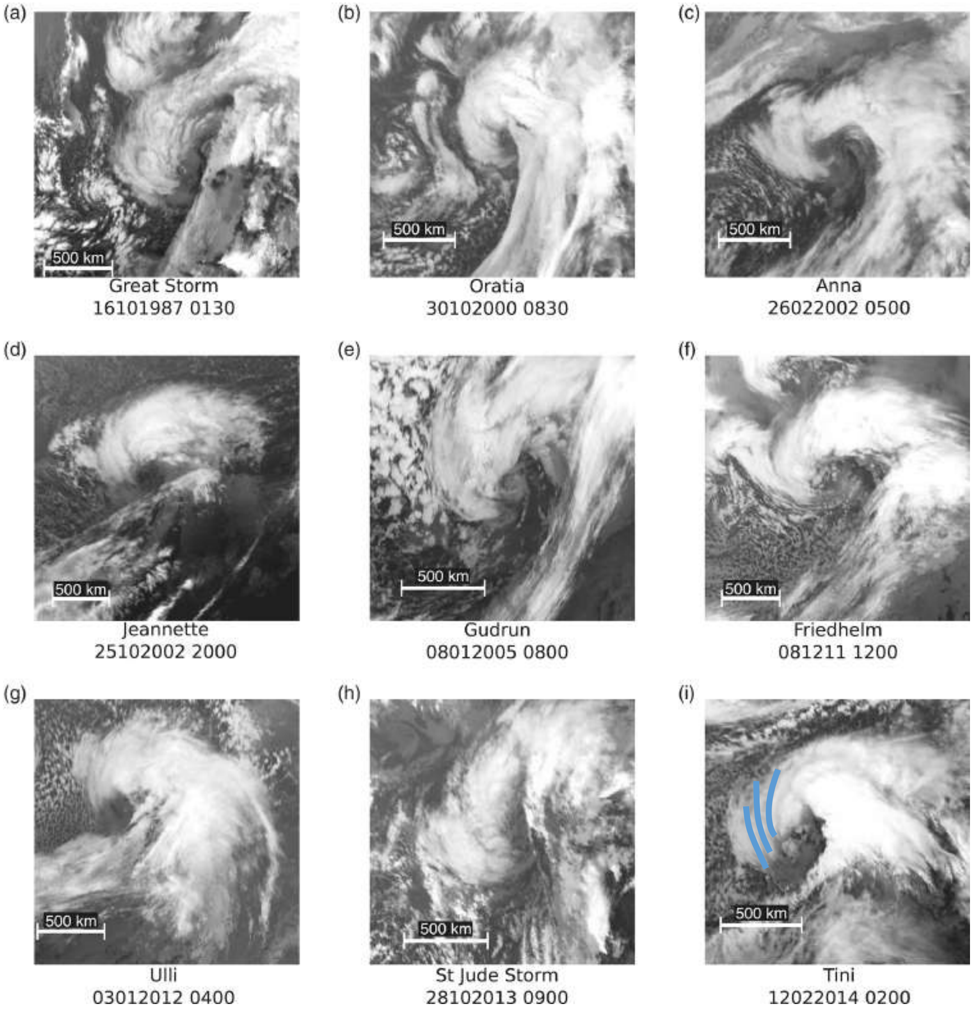
A coherent airflow that **descends from mid-levels inside the cloud head into the frontal-fracture region** of a Shapiro–Keyser cyclone **over a period of a few hours**

- Leads to a region of enhanced near-surface winds, ahead of and distinct from the cold conveyor belt
- A continuum of mechanisms:
  - Balanced frontolytic descent
  - Slantwise convective downdraughts associated with conditional symmetric instability (CSI)



Clark and Gray (2018)

The zoo of sting jet case studies



Our understanding of sting jet dynamics has advanced considerably since their first identification, but mostly through **analysis of case studies** of cyclones crossing the **North Atlantic** to affect northwest Europe

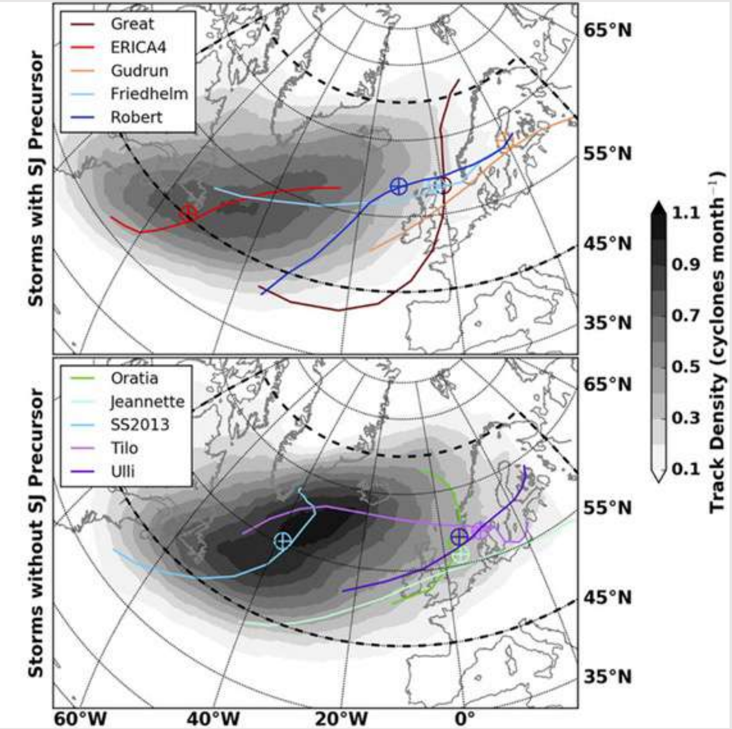
Storm name	Storm date	Impact location	Reference
Great Storm	October 16, 1987	Southern England	Browning (2004); Browning and Field (2004); Clark *et al.* (2005); Gray *et al.* (2011)
Oratia	October 30, 2000	Wales and central England	Browning (2004); Browning (2005)
Anna	February 26, 2002	Central UK	Martínez-Alvarado *et al.* (2010); Gray *et al.* (2011)
Jeanette	October 27, 2002	Wales	Parton *et al.* (2009)
Gudrun/Erwin	January 7/8, 2005	Northern UK	Baker (2009); Gray *et al.* (2011)
Unnamed	December 7/8, 2005	East of Canada	Schultz and Sienkiewicz (2013)
Friedhelm	December 8, 2011	Scotland	Baker *et al.* (2013); Martínez-Alvarado *et al.* (2014a)
Ulli	January 3, 2012	Northern UK	Fox *et al.* (2012); Smart and Browning (2014)
St Jude's Day / *Christian*	October 28, 2013	Southern England	Browning *et al.* (2015)
Tini	February 12, 2014	Ireland, Wales, NW England	Slater *et al.* (2017); Volonté *et al.* (2018)

Clark and Gray (2018)

The need for a global climatology

- Beyond the North Atlantic, a single sting-jet cyclone **originating in the Mediterranean** has been analysed (Brâncuș et al., 2019), but - as far as we're aware - no other published cases exist
- Published climatologies only exist for the North Atlantic region, e.g. Hart et al. (2017) which suggests 1 in 3 cyclones may contain a sting jet
- There is no physical reason why sting jets should not occur in other regions

→ **A global climatology is needed to determine if this is the case, and highlight the associated wind risks**



Hart et al. (2017)

How are sting jets identified?

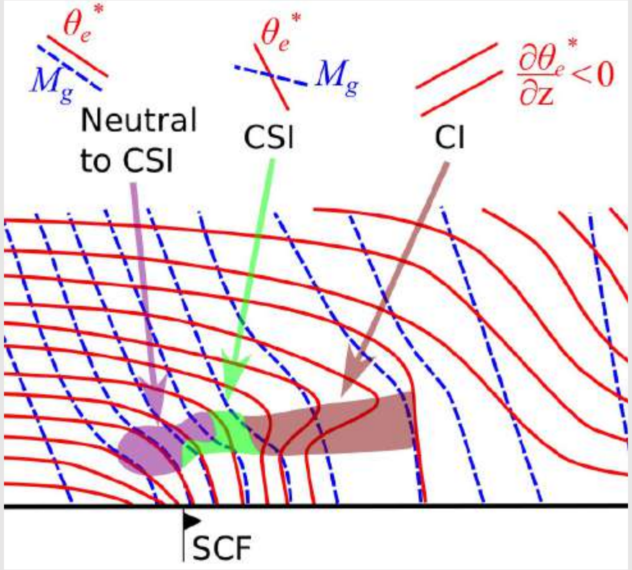
3D Wind Structure	Presence of CSI	Potential for CSI to Develop
• A distinct wind maximum associated with air that has descended from the cloud head → Trajectory analysis (Martinez-Alvarado et al., 2017)	• Banding in the cloud head associated with slantwise circulations generated by CSI → Satellite image analysis (e.g. Browning, 2004) • A reduction of instability	• Substantial amounts of Downdraught Slantwise CAPE in the cloud head region → DSCAPE sting jet precursor diagnostic (Martinez-Alvarado et al., 2013, 2018; Hart et al.,

DSCAPE: A sting jet precursor diagnostic

- Grid spacings of 10-15km (horizontal) and O(200m) (vertical in the mid-troposphere) are required to simulate sting jets
- Do not expect global reanalyses to resolve them (e.g., ERA5 has a nominal resolution of 30km)
- Instead, consider **Downdraught Slantwise CAPE** as an indicator of the **potential for CSI to develop** (Gray et al., 2011):

$$DSCAPE = \int_{M_g} R_d \left(T_{v,e} - T_{v,p}\right) d(\ln p)$$

- Analogous to CAPE, DSCAPE is a measure of potential energy available for release via CSI (units: J/kg) – requires strong vertical wind shear

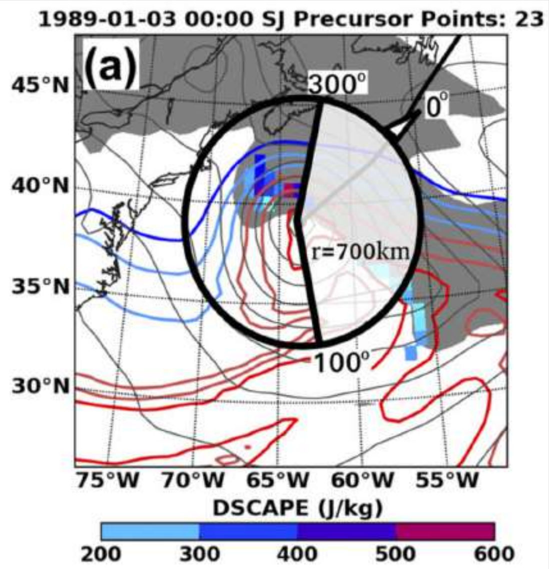


Clark and Gray (2018)

Our approach for constructing a global climatology

Here we extend the methodology of Hart et al. (2017) to global ERA5 data spanning 1979-2022:

1. Track cyclones using 850 hPa relative vorticity (Hodges' TRACK)
2. Subset to those intense ETCs with Shapiro-Keyser structure
3. For each track point, compute DSCAPE over a cut-out around the cyclone centre
4. Classify a cyclone as having a sting-jet precursor if there is substantial DSCAPE (> 200 J/kg) in the cloud head:
    - Moisture constraint: RH > 80%
    - Position constraints: proximity to cyclone, sector, proximity to front
    - Time constraint: 0-12 hours before maximum intensity

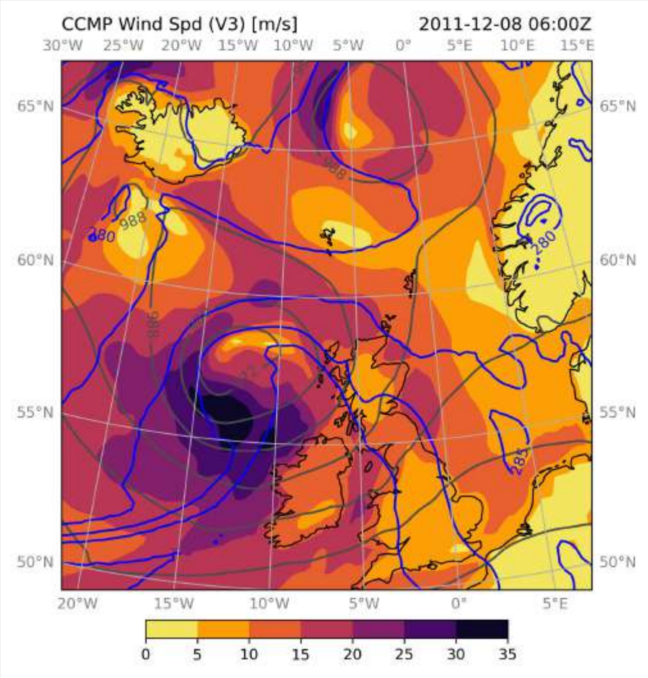


Hart et al. (2017)

Our approach for constructing a global climatology

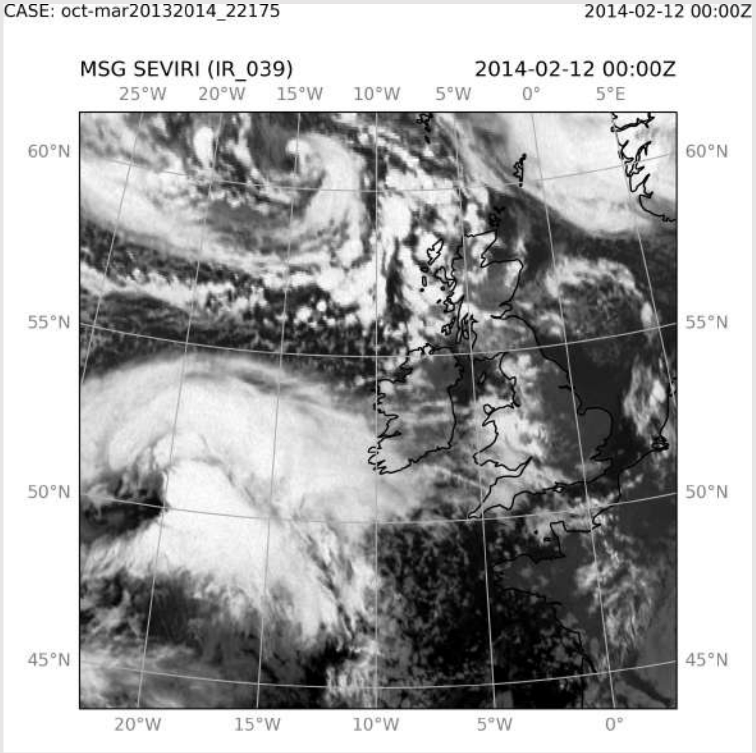
<u>Evaluation</u>

- Use expert judgement to assess the diagnostic against the set of known sting jet storms from the literature together with notable non-sting jet cases
- Include an assessment of new likely sting jet cases from the North Pacific and Southern Ocean storm tracks
    - Satellite imagery
    - Cross-Calibrated Multiplatform (CCMP) ocean surface wind dataset
- Consider revising threshold/parameter settings to ensure the precursor diagnostic is globally applicable

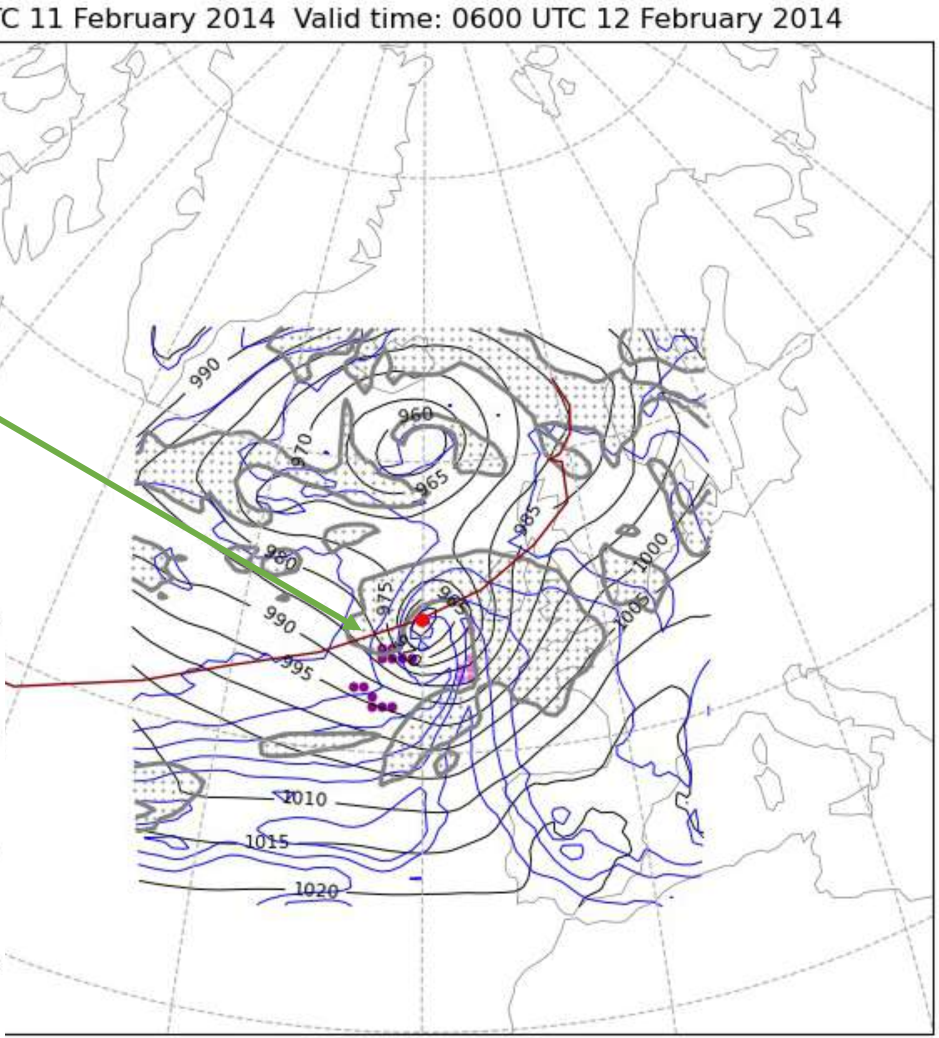


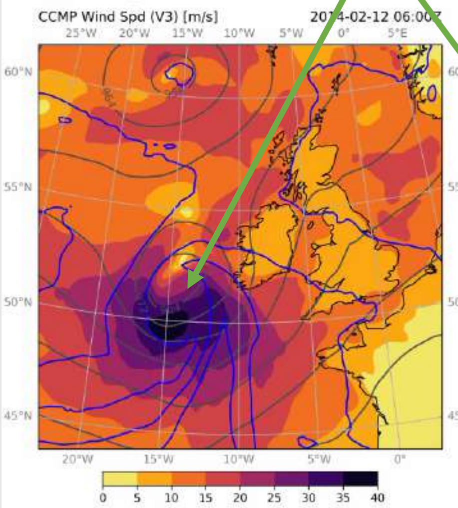
Example 1: Windstorm Tini

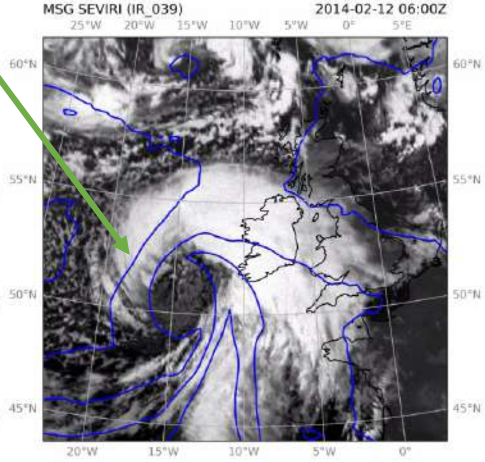
- A confirmed sting jet case analysed by Volonte et al. (2018)
- Max intensity: 12 Feb 2014 12UTC
- Methods of sting jet identification in the literature:
    - Cloud-head banding
    - Wind profiler observations
    - 3D wind structure and trajectory analysis using high resolution simulations



- Cloud-head DSCAPE: localised DSCAPE at cloud-head tip at t-06h, spreading out into frontal-fracture at t+00h
- SJ Precursor status: positive
- Expert judgement: Agreement between obs + literature evidence and the

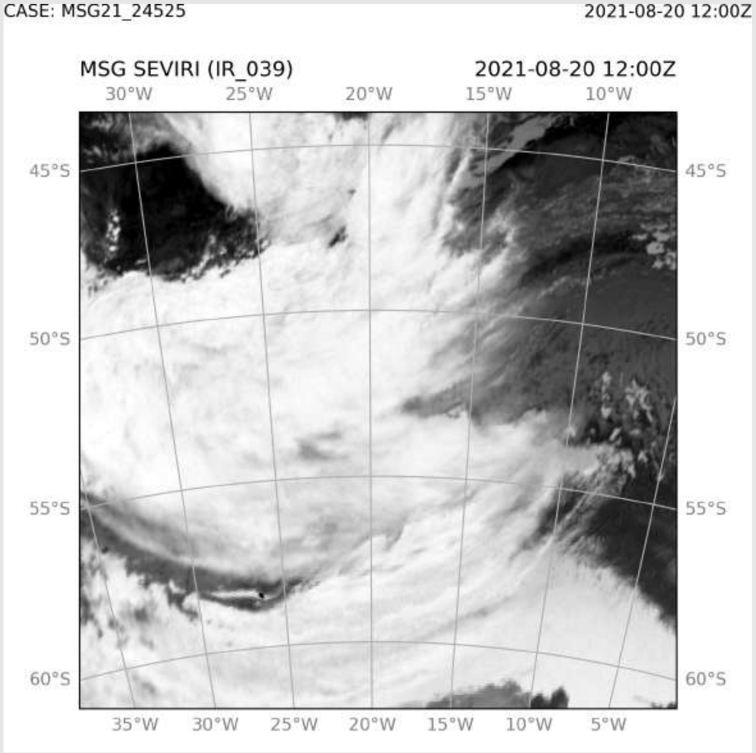




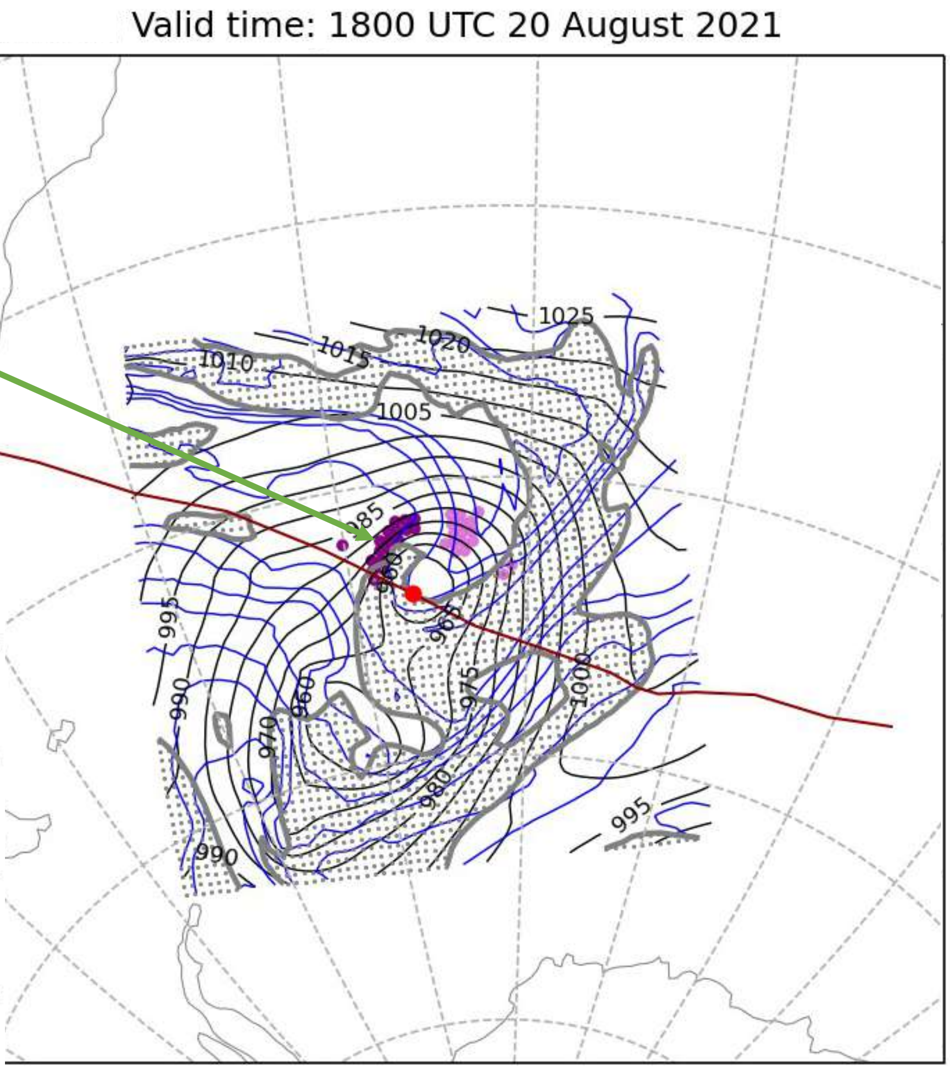


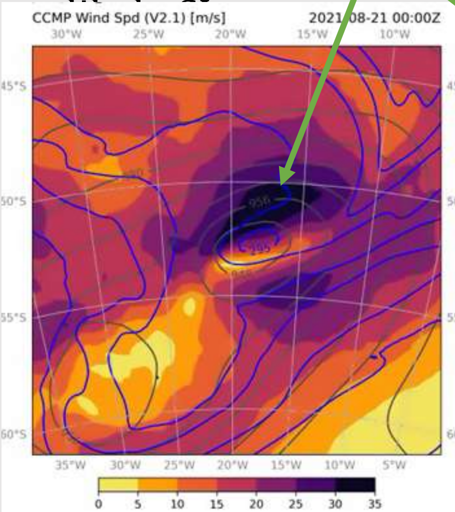
Example 2: South Atlantic 2021 Storm

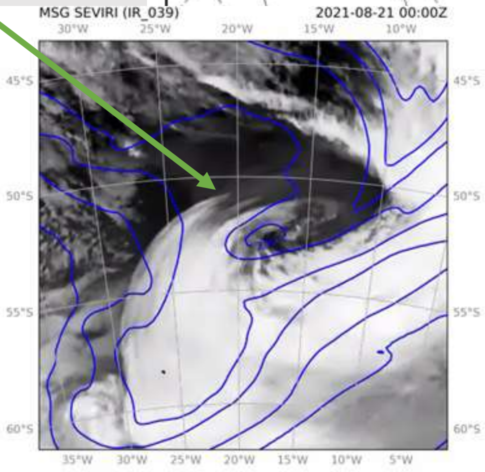
- No prior literature/analysis
- Selected as one of the most intense southern hemisphere storms in 2021
- Max intensity: 21 Aug 2021 00UTC



- Cloud-head DSCAPE: two areas of above threshold DSCAPE at cloud-head tip and in frontal fracture region at t-06h
- SJ Precursor status: positive
- Expert judgement: No prior literature/analysis but multiple evidence of







Cyclone-relative composites

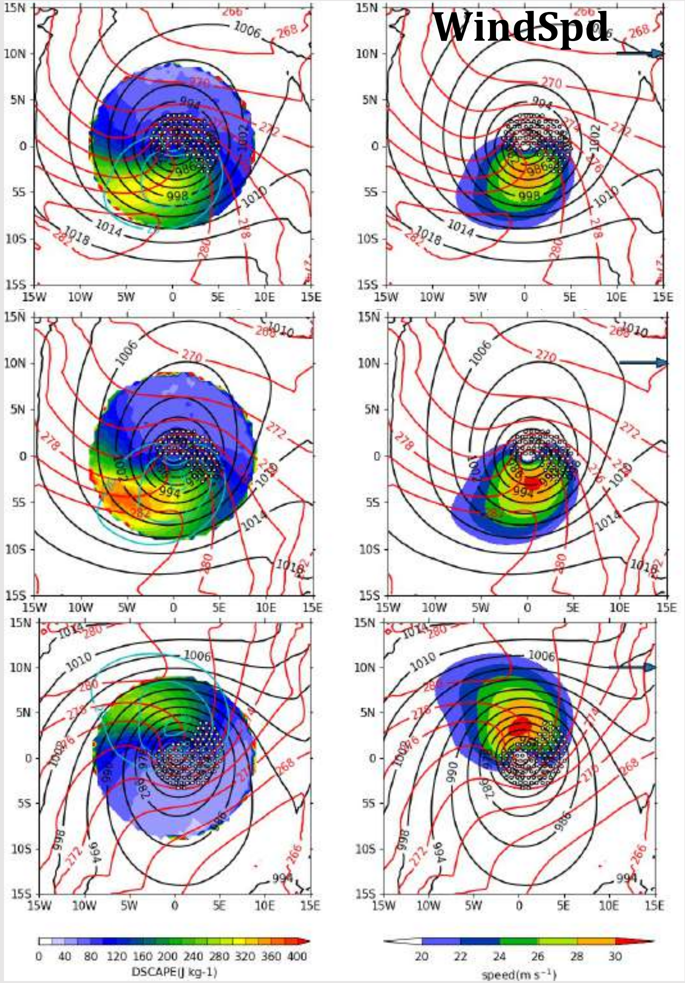
- Rotated composites of intense Shapiro-Keyser cyclones from each storm track
- DSCAPE is highest in N Pac storms, lowest in Southern Ocean storms
- Wind speed strongest in Southern Ocean, weakest in North Atlantic
- Composite mean DSCAPE < 200 J/kg throughout the cloud head
- Provides justification for use of fixed cyclone sectors for cloud head identification

DSCAPE* **850hPa WindSpd**

N Atlantic

N Pacific

Southern Ocean



Summary

- Sting jets have been identified in some of the most damaging mid-latitude cyclones to affect Northwest Europe
- But do they occur in the other storm track regions?
- We present progress towards constructing a global climatology of sting jet cyclones aimed at addressing this gap