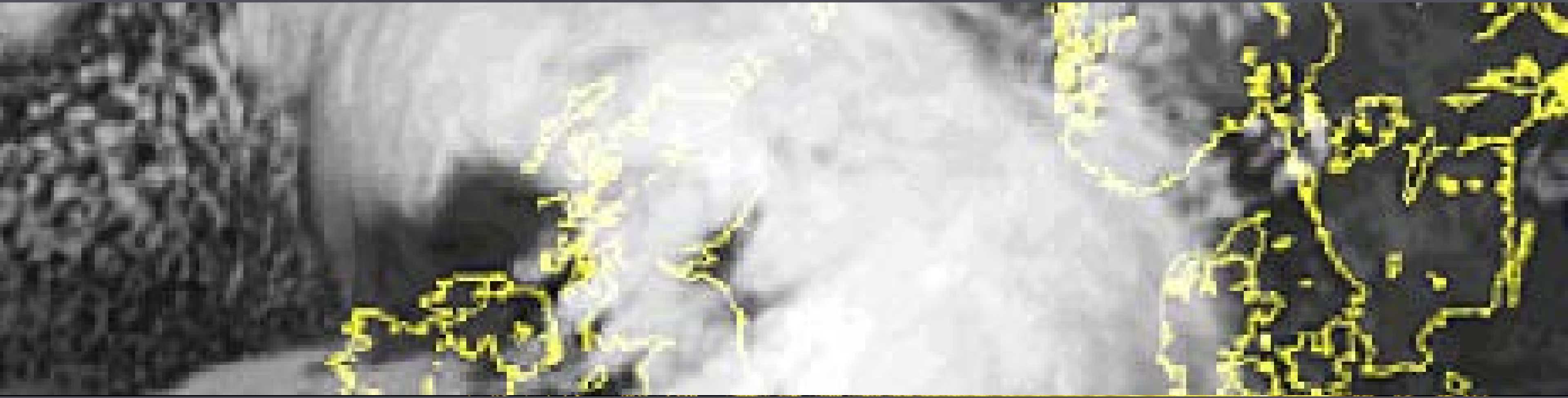
Department of Meteorology

# Sting jet storms in a future warmer climate



Suzanne Gray,

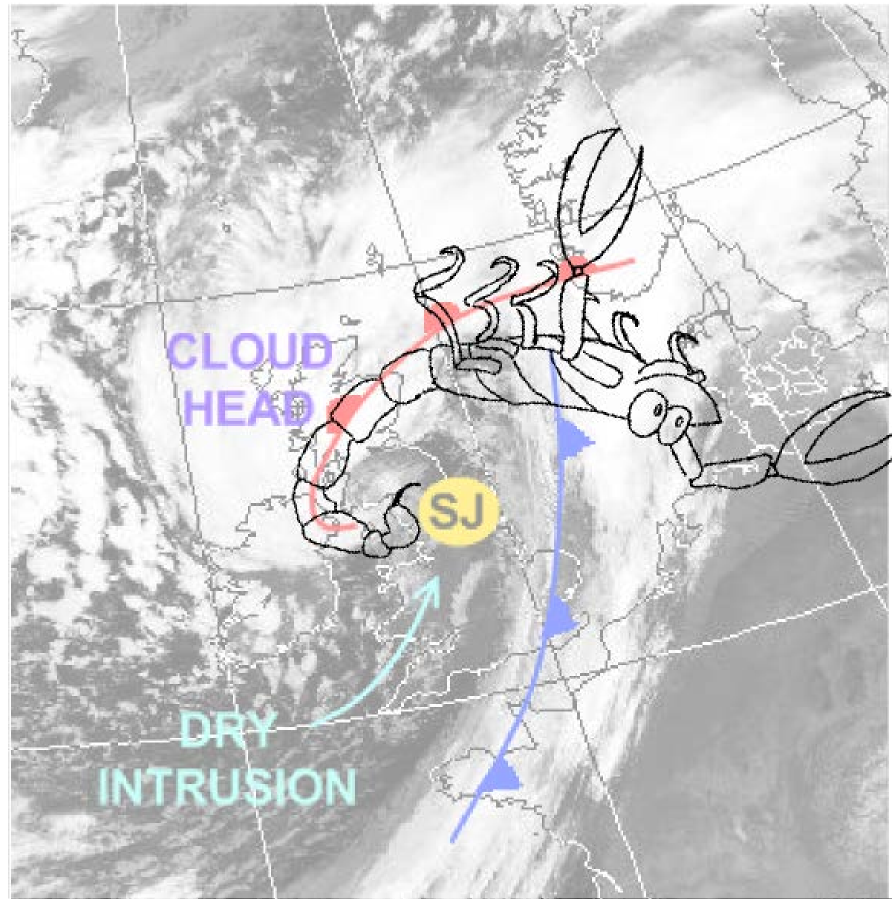
Oscar Martínez-Alvarado, Neil Hart and Peter Clark

with thanks to Kevin Hodges and Malcolm Roberts

# Sting jets

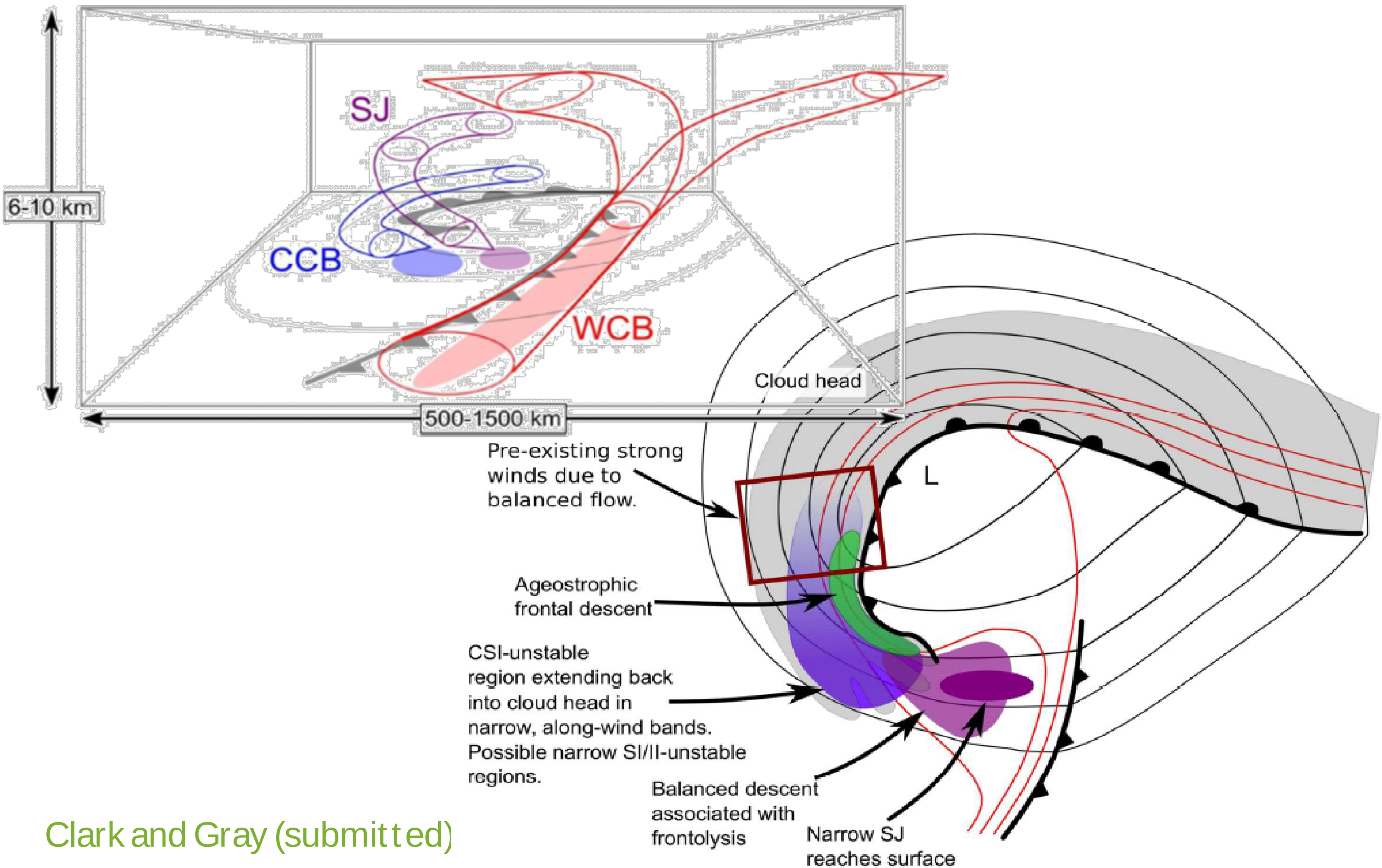
University of Reading

- Transient (few hours), mesoscale (~50km spread) jets of air descending from the tip of the hooked cloud head in the frontal fracture regions of some extratropical storms.
- Can cause damaging winds (and especially gusts).
- Coined 'the sting at the end of the tail by Browning (2004)' in his study of the Great October storm of 1987.
- Since then large body of work performed on modelling, mechanisms and climatologies.
- First research aircraft flight into a sting jet storm led by Reading scientists within DIAMET project: Windstorm Friedhelm in 2011 (Baker et al. 2013, Martínez-Alvarado et al. 2014, Vaughan et al. 2015).
- Term has now entered common usage(?)




Adapted from Laura Baker by Neil Hart.

# Conceptual model




Clark and Gray (submitted)

# Questions

University of Reading

- What is the prevalence of sting-jet cyclones in the N
- Are the characteristics of sting-jet cyclones di ... on sting-jet cyclones:
  - storm track?
  - deepening rate?
  - low-level wind speed?
  - seasonal cycle?
- What is the re ... sting-jet cyclones to strong wind events in Europe o

Answers in
'Sting-jet windstorms over the North Atlantic: Climatology and contribution to extreme wind risk' by Hart, Gray and Clark (*J. Climate*, early online)

- How will all of the above change in a future warmer climate?

# Climate data

University of Reading

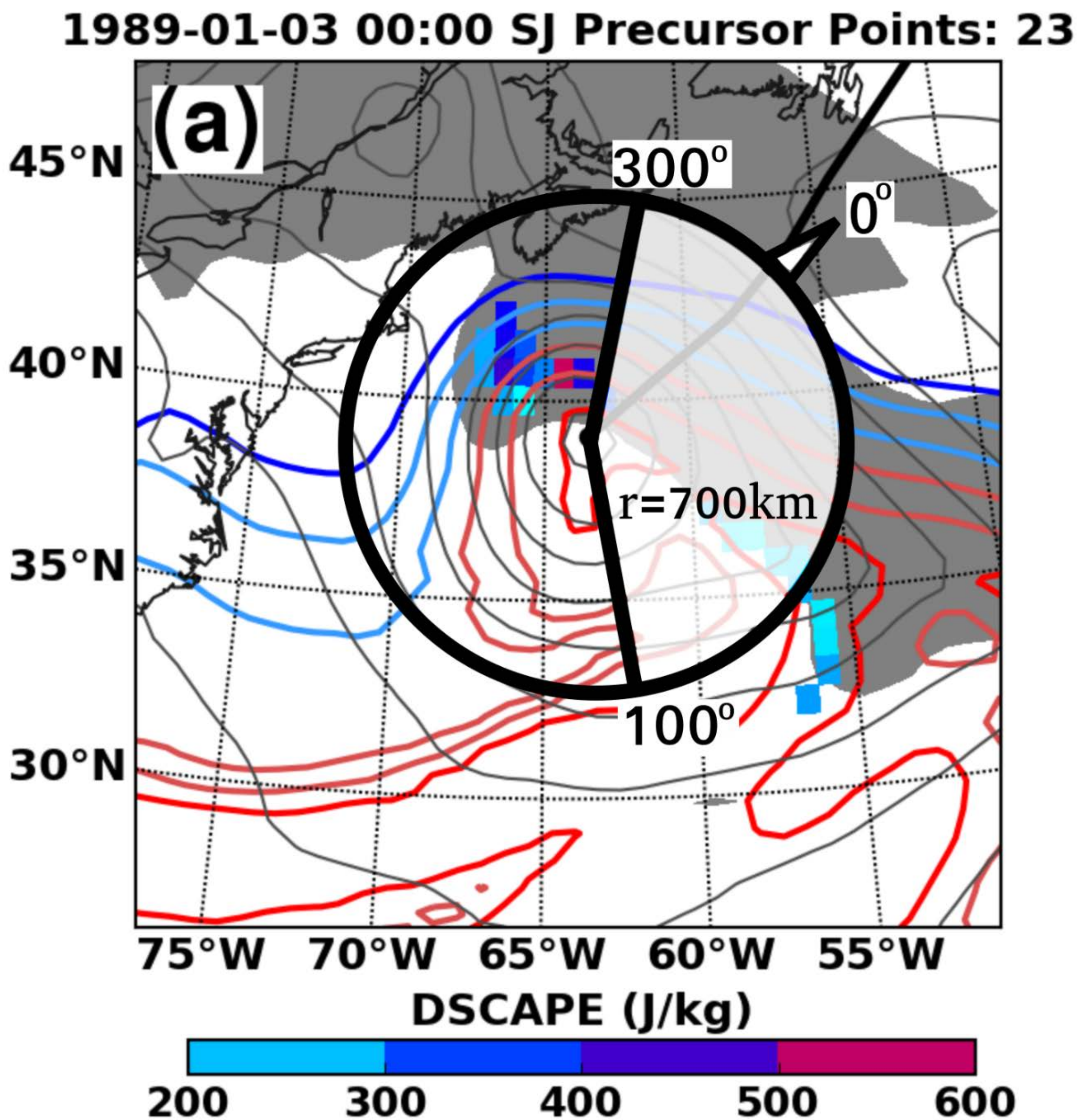
- Extended winter seasons: Sept. to May inclusive.
- North Atlantic region only considered.
- **Current climate reanalysis:** ERA-Interim data (1979-2012): 6-hourly output, T255 (~80 km grid spacing).
- **Current and future climate integrations:**
  - global model, ~60 km grid spacing in the midlatitudes, 6 hourly output, 13-year present-day (1996–2009) and 13-year future (~2100, under the Intergovernmental Panel on Climate Change RCP 8.5 scenario) climates.
  - Same Met Office model integrations as used to drive 12-km and 1.5 km grid-spacing regional climate integrations used in Kendon et al. (2014) to predict heavier summer downpours under climate change.

# Precursor identification method

University of Reading

- Extratropical cyclone tracks diagnosed using TRACK algorithm (e.g. Hodges and Hoskins, 2002) using $\xi_{850}$ smoothed to T42 resolution.
- Cyclones reaching their $\xi_{max}$ 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).
- Cyclones considered to have the potential to produce sting jets have a sufficiently large contiguous region of DSCAPE exceeding 200 J $kg^{-1}$ in their cloud head.
- Identification of cloud head and 'sufficient' DSCAPE is threshold dependant, but previous work (Martínez-Alvarado et al., 2011) has demonstrated skill in identification of cyclones that generated sting jets in weather forecasts.

# Example: ERICA IOP4



# Classification of cyclones: ERA-I

| | Non explosive | Explosive (Δp (24h)< -20 hPa) | Totals |
|---|---|---|---|
| No SJ precursor | **3020 (55%)** | **676 (12%)** | 3696 (68%) |
| SJ precursor | **1252 (23%)** | **499 (9%)** | 1751 (32%) |
| Totals | 4272 (78%) | 1175 (22%) | 5447 |

22% of tracked cyclones are explosive.
32% of tracked cyclones have a SJ precursor.
29% of non-explosive cyclones have a SJ precursor.
42% of explosive cyclones have a SJ precursor.

# Classification of cyclones

| ERA-I | Non explosive | Explosive (Δp (24h)<-20 hPa) |
|---|---|---|
| No SJ precursor | 3020 (55%) | 676 (12%) |
| SJ precursor | 1252 (23%) | 499 (9%) |

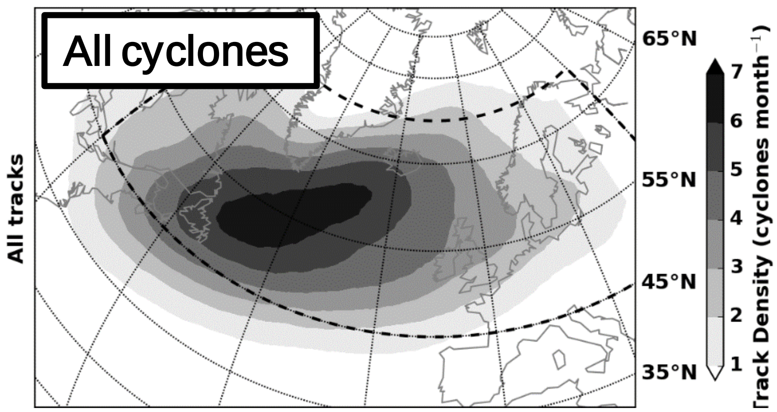
Current 'real' vs. simulated climate

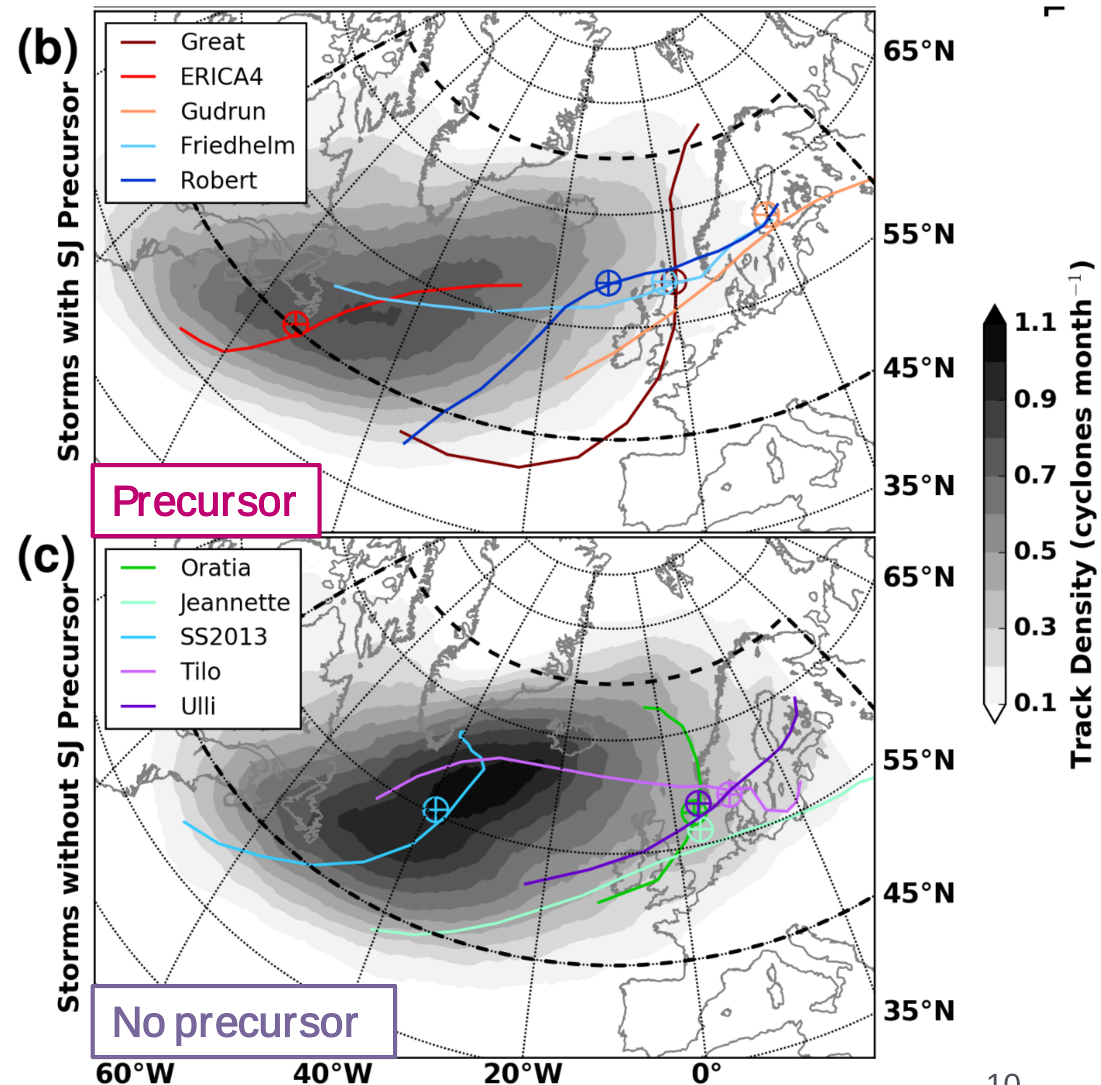
| Current climate integration | Non explosive | Explosive (Δp (24h)<-20 hPa) |
|---|---|---|
| No SJ precursor | 834 (58%) | 130 (9%) |
| SJ precursor | 341 (24%) | 127 (9%) |

| Future climate integration | Non explosive | Explosive (Δp (24h)<-20 hPa) |
|---|---|---|
| No SJ precursor | 639 (49%) | 81 (6%) |
| SJ precursor | 394 (30%) | 185 (14%) |

Simulated current vs. future climate

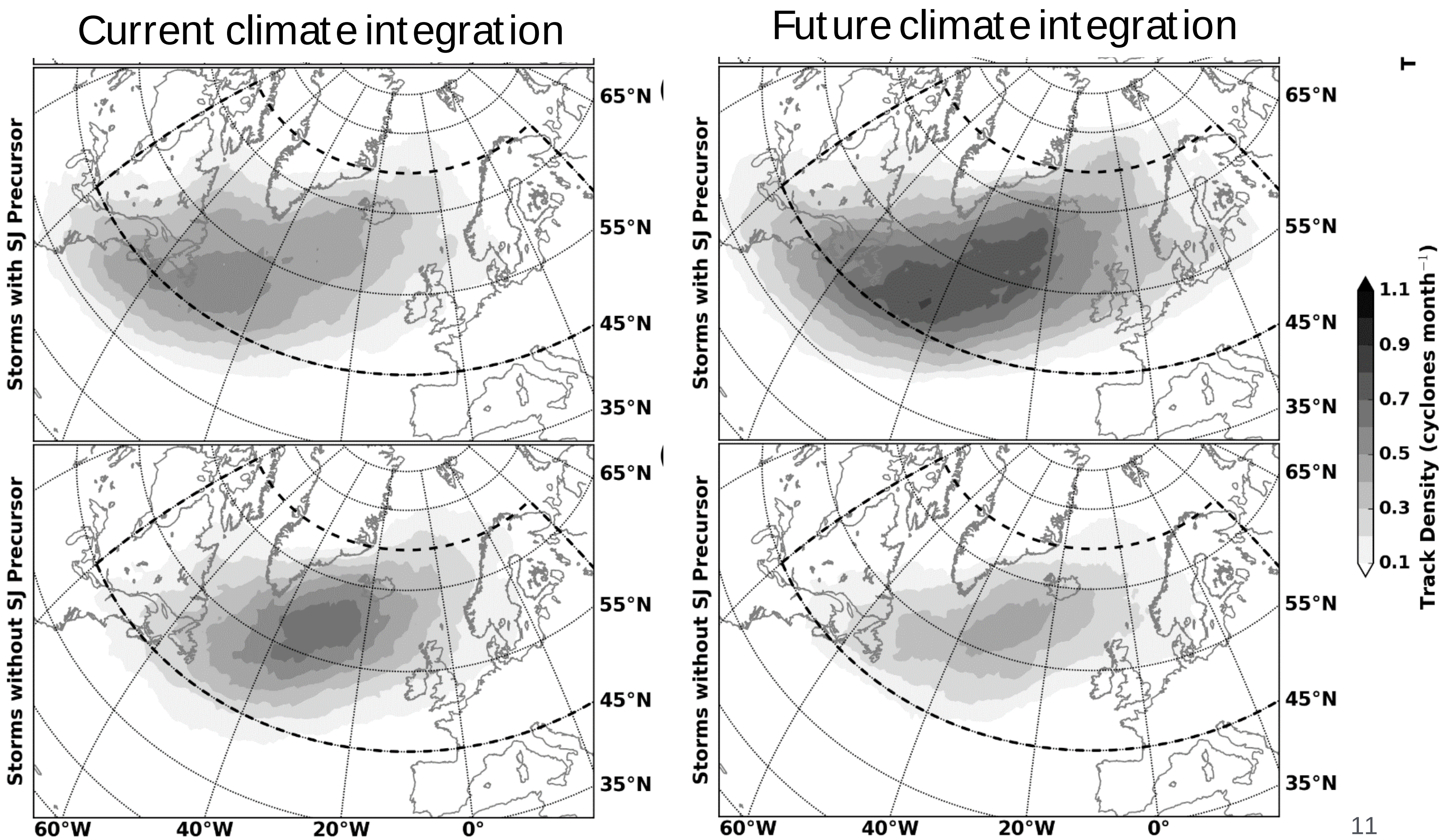
# Track density maps: ERA-I




Cyclones with sting-jet precursors follow a more southerly storm track compared to those without these precursors.

# Track density maps

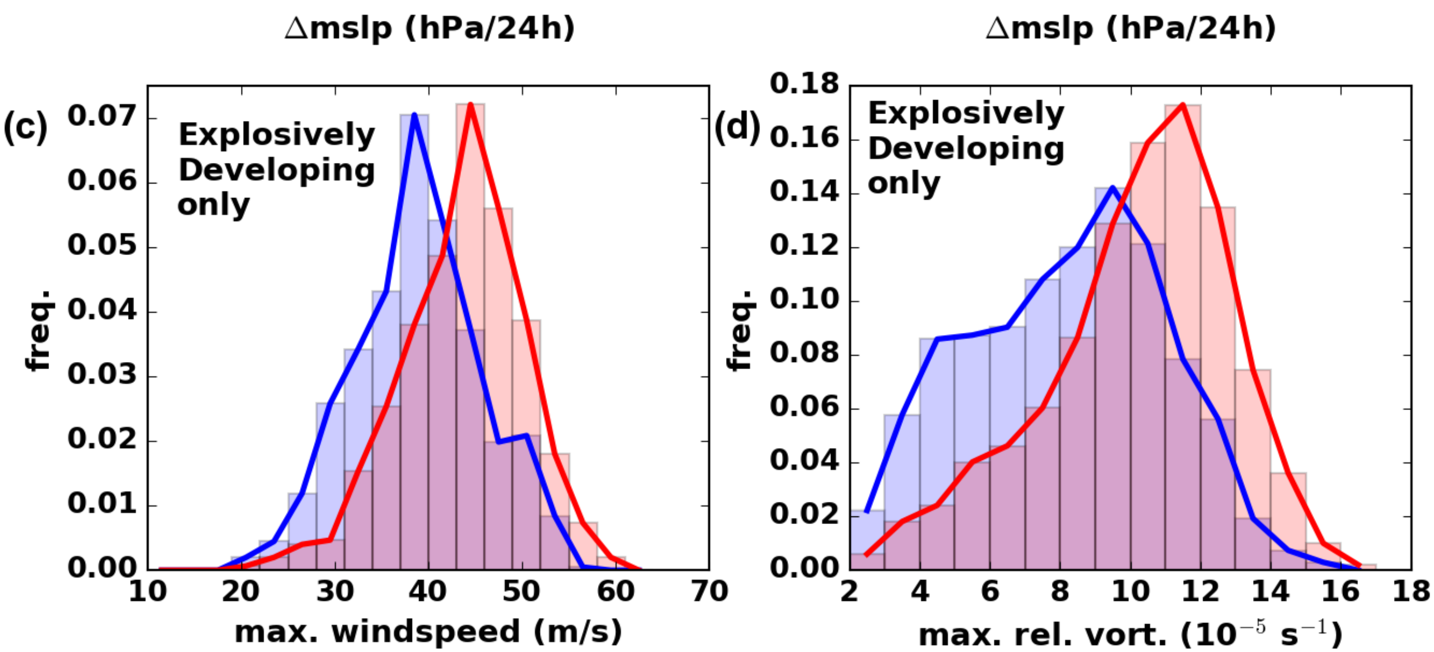


# Cyclone metrics: ERA-I

**But, ERA-Interim is too coarse to resolve SJs.**

Interpretation: precursor identifies those cyclones with atmospheric instability in the cloud head (more substantial cloud head?) that is released by the model dynamics (not necessarily physically) and/or cyclones where potential temperature & momentum surfaces are close to parallel (indicator of a rapidly developing fronts); these factors intensify the cold conveyor belt.

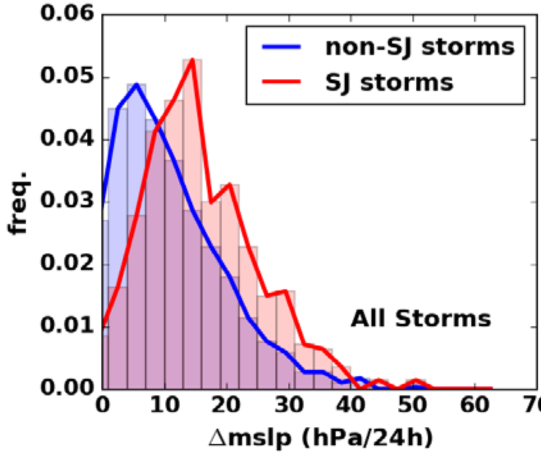
Explosive cyclones with SJ precursor do not significantly deepen faster in MSLP than those without.

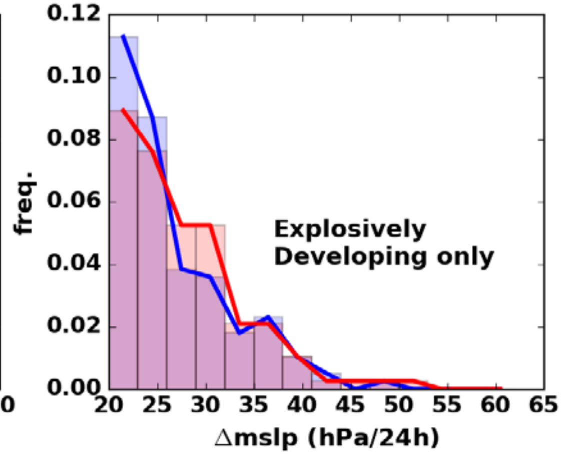


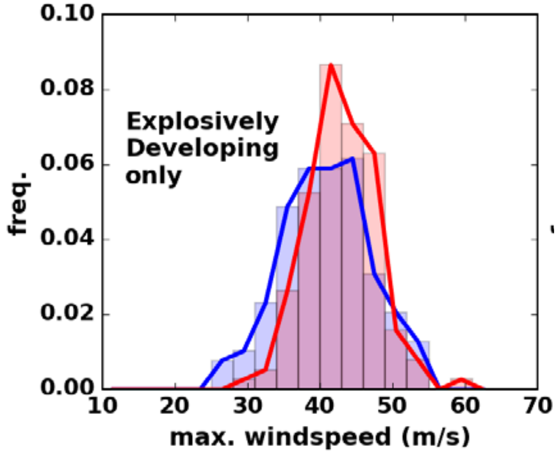

But, cyclones with SJ precursors have faster windspeeds and greater ξ.

# Cyclone metrics

Current and future climate results both similar to ERA-I. Storms with and without SJ precursors have significantly different deepening rates and windspeeds, but current and future climate data is not significantly different.

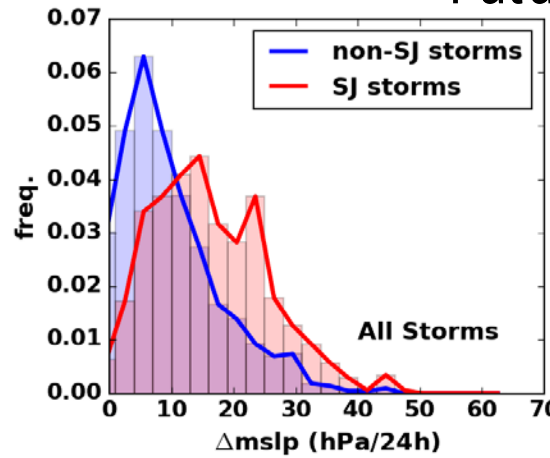


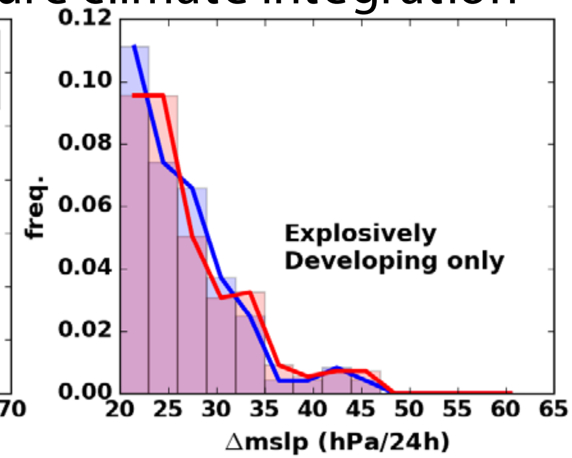



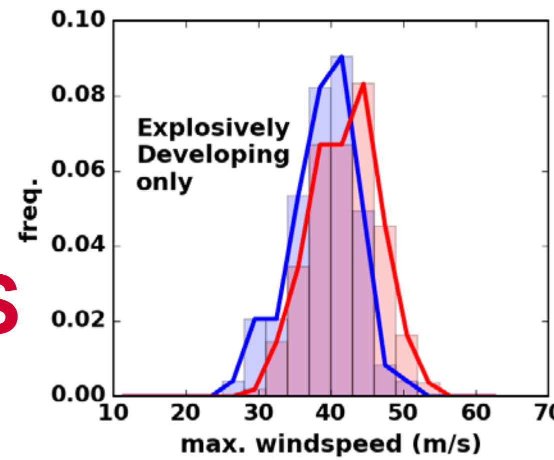



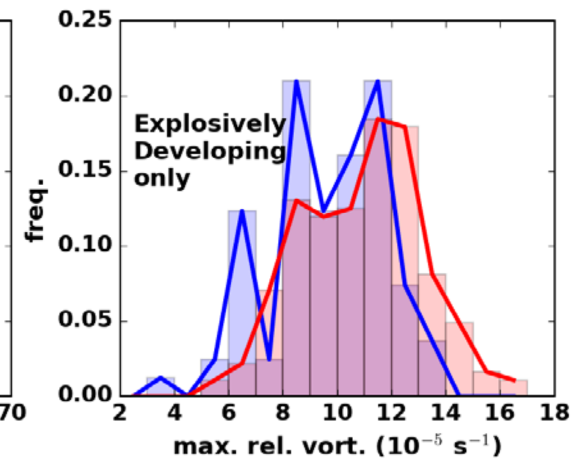

Current climate integration

Future climate integration



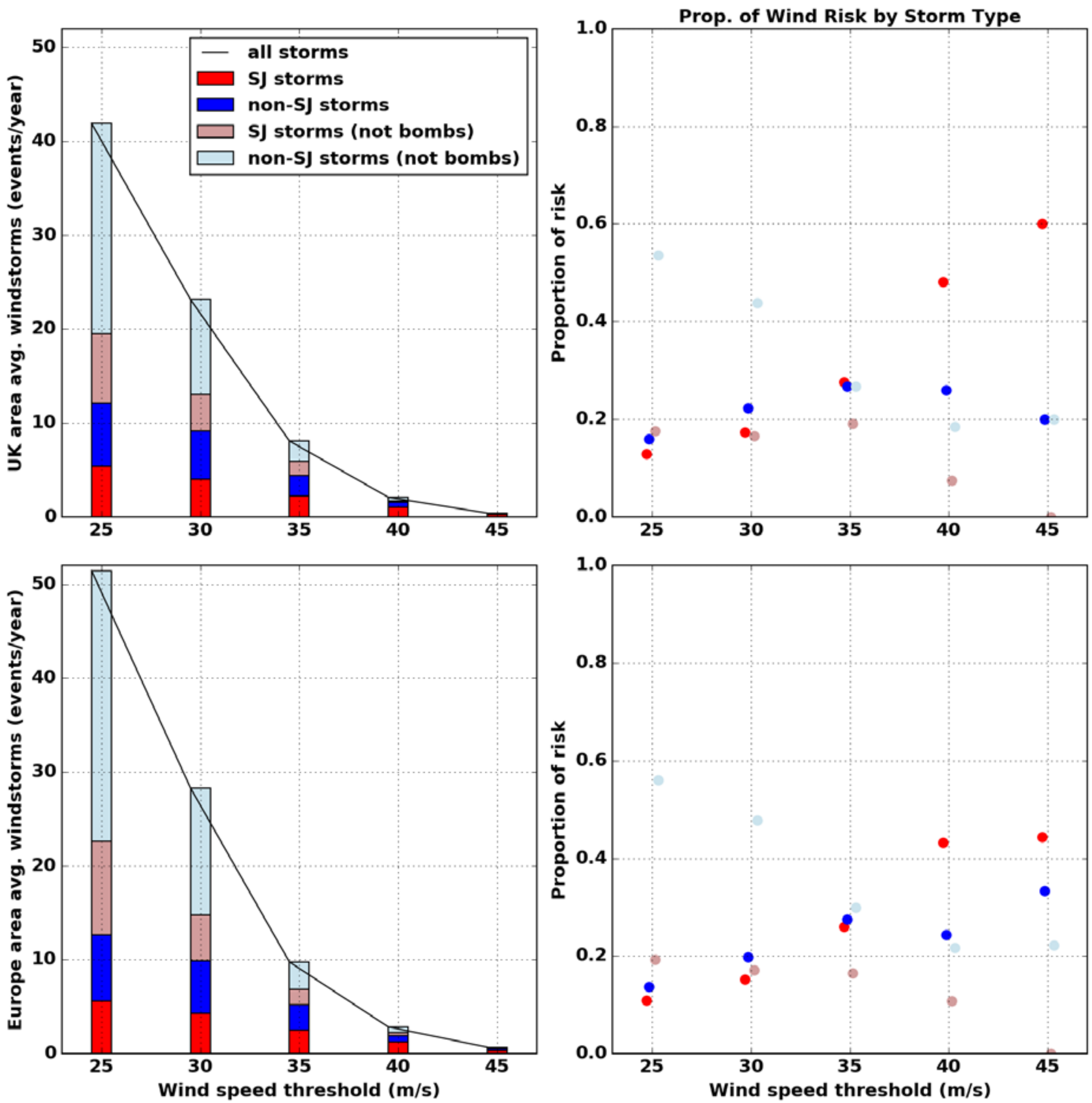



# Wind risk: current climate

British Isles

Europe inc. British Isles



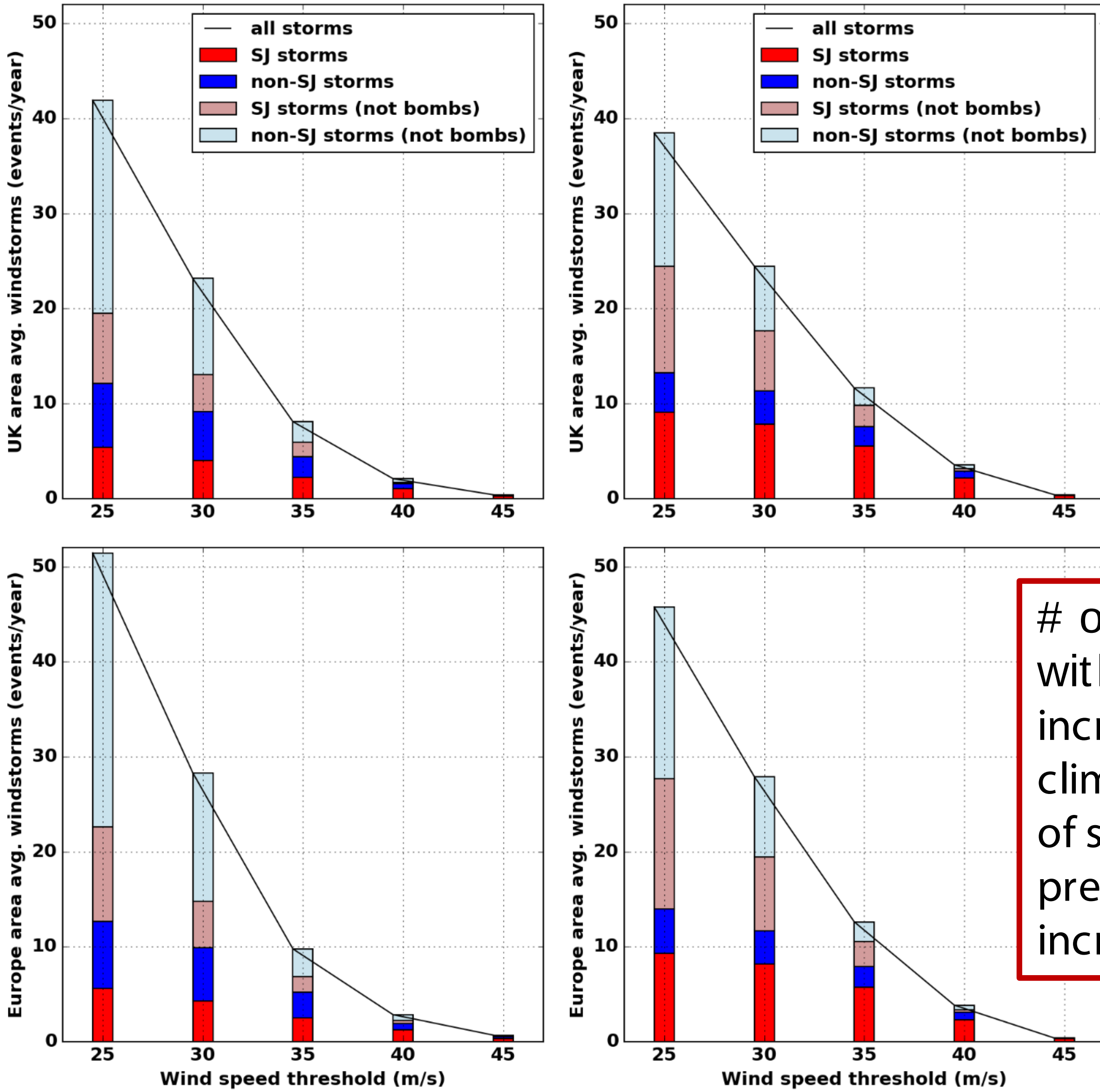
# Wind risk: current vs. future climate

British Isles

Current

Future

Europe inc. British Isles




# of windstorms with winds $\geq 35ms^{-1}$ increases in future climate; proportion of storms with SJ precursors also increases.

# Conclusions

University of Reading

- A diagnostic for sting jet precursors has been applied to tracked North Atlantic cyclones in 13-year current and future climate integrations and compared to published results using the ERA-Interim reanalysis (1979-2011).
- **All 3 datasets:**
  - for explosively developing cyclones, the low-level maximum windspeed and ξ is distributed towards much higher values for those cyclones with SJ precursors.
  - storm track is more southerly and more zonal for explosive cyclones with SJ precursors compared to track for those without precursors.
  - cyclones with SJ precursors become more dominant as the windspeed threshold is increased.
- Proportion of storms with SJ precursors increases from 33% in the current climate (32% for ERA-I) to 45% for the future climate; for explosively developing storms the increase is from 9 to 14%.
- # storms with winds exceeding 30 ms$^{-1}$ increases in the future (compared to current) climate integrations for the British Isles and European regions.
- In real systems (or sting-jet resolving weather forecasts) the sting jet is likely to be an additional cause of strong cold-sector winds, either directly or through enhancement of the cold conveyor belt.