Assessing Sting-Jets in Convection Permitting Climate Simulations

Colin Manning[1,2] (colin.manning@ncl.ac.uk), Lizzie Kendon[2], Hayley Fowler[1], Nigel Roberts[2], Ségolène Berthou[2]

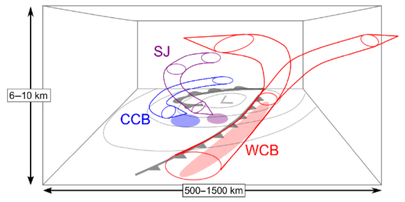
[1] Newcastle University, School of Engineering, Newcastle, UK; [2] Met Office Hadley Centre, Exeter, UK

1. Introduction :

Aim:
- Produce an automated approach to detect sting-jets in CPM simulations
- Assess added value of Convection Permitting Climate Model (CPM) for sting-jets compared to ERA-Interim reanalysis and a 25km GCM

Why?
- Coarse resolution simulations cannot fully resolve sting-jets, especially the small-scale structures, and may therefore underestimate their risk in present and future climates

What is a sting-jet?
- A mesoscale slanted core of strong winds within a Shapiro-Keyser type of cyclone that can lead to extremely damaging surface wind speeds close to southern side of a cyclone's centre



SJ: Sting-jet
CCB: Cold conveyor belt
WCB: Warm conveyor belt

Figure 1: Conceptual model of Shapiro-Keyser Storm, figure has been taken from Clark and Gray (2018)

2. Data & Methods:

CPM Simulations
- Hindcast: 1999 -2009 (driven by ERA-Interim)
- Control: 1997-2007 (driven by 25km GCM)
- Future: 10 years under RCP8.5 (driven by 25km GCM)

Configuration
- Horizontal resolution: 2.2km
- Vertical resolution: approx. 40m, 140m and 300m at heights of 100m, 1km, and 5km.

Data Required
- 6 hourly winds at 850hPa and 700hPa (only 5 levels available in total)
- 6-hourly Wet bulb potential temperature (θ_W) at 850hPa
- 6-hourly MSLP

Added Value Assessment
- Sting-jets storms are only identified in CPM simulations
- 850hPa wind speeds are compared for the identified storms between CPM and GCM/ERAI. We are assessing for differences in wind speed and in future projections

Automated Identification of Sting-Jets in CPM: Storm Erwin Case Study (07/01/2005)

Step 1: Identify warm seclusion of Shapiro-Keyser Cyclone
- Identified when 850hPa θ_W within core of cyclone is 2K greater than θ_W in the surrounding area

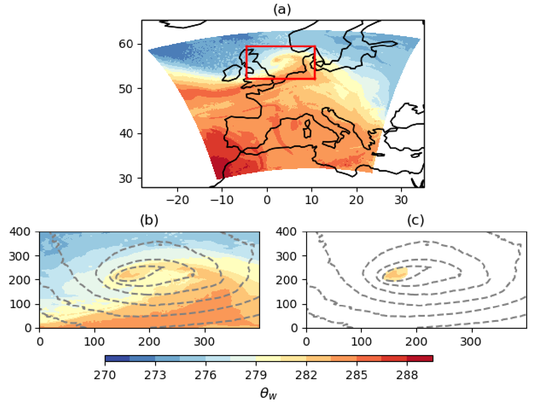


Figure 2: Identification of warm seclusion: (a) θ_W at 850hPa, (b) θ_W extracted from red box in (a) with MSLP contours, (c) the identified warm seclusion within the MSLP core of the cyclone

Step 2. Identify slantwise descent of sting-jet within storm
- Indicated by a reversal in vertical wind gradient between 700hPa and 850hPa along wind trajectories at 850hPa

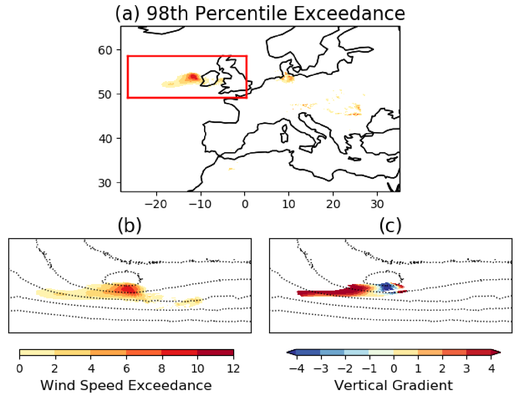


Figure 3: Identification of vertical wind gradient reversal: (a) 98th percentile exceedance at 850hPa, (b) 98th percentile exceedance at 850hPa extracted from red box in (a) with MSLP contours, (c) the extracted sting-jet feature showing a reversal in the gradient between wind speeds at 700hPa and 850hPa along 850hPa wind trajectories.

3. Results :

Frequency of Sting-Jet Storms

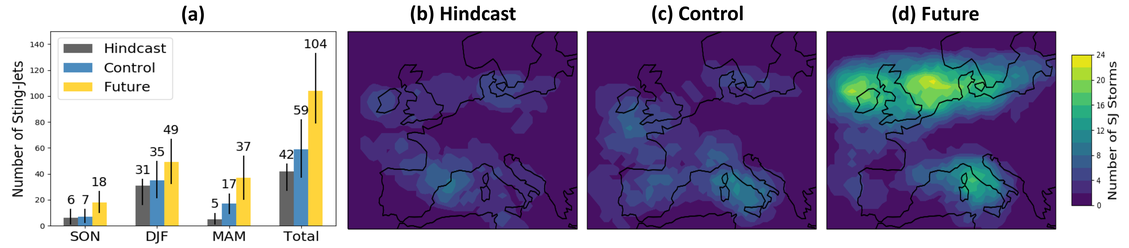


Figure 4: Frequency of sting-jets: (a) Bar plot giving the number of sting-jets in each simulation and season, black line represents 95% uncertainty interval; (b) spatial distribution of sting-jet timesteps in (b) Hindcast, (c) Control and (d) Future

Overall Wind Storm Severity – Hindcast Simulation: CPM vs. ERA Interim (850hPa Winds)

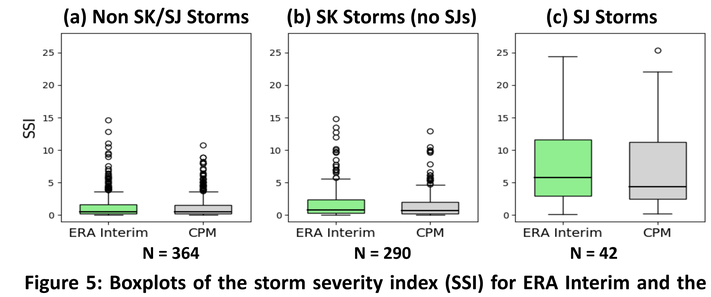


Figure 5: Boxplots of the storm severity index (SSI) for ERA Interim and the CPM for (a) non SK/SJ storms; (b) Shapiro-Keyser storms without SJs and (c) Sting jets storms. Storm types are identified in the CPM only

- **SSI**: based on the cubed wind speed exceedance of the local 98th percentile from all timesteps and grid points affected by a storm
- **SJ storms** are generally **more severe** than other types
- No difference between ERAI and CPM SJ storms for SSI
- **Similar results** are found between CPM and GCM for **control and future simulations**

95th Percentile of Winds within Storms – Climate Simulations: CPM vs. GCM (850hPa Winds)

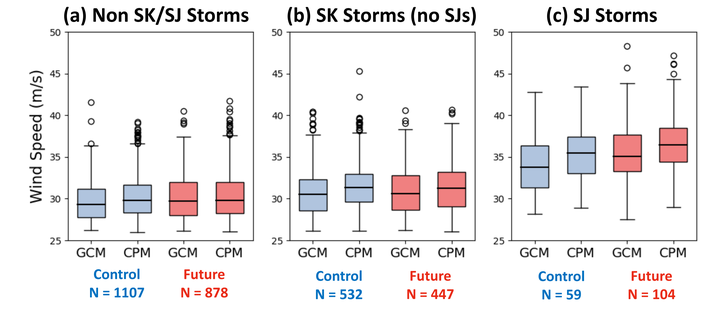


Figure 6: Boxplots of the 95th percentile 850hPa wind speeds within storm footprints from GCM and CPM for (a) All storms; (b) Shapiro-Keyser storms and (c) Sting jets storms.

- **CPM produces higher wind speeds** than GCM in all simulations, with largest differences found for SJ events
- Similar differences are found between CPM and ERAI for hindcast simulation
- **More intense wind speeds in future simulations** for both CPM and GCM
- There is **no difference in the future changes** in wind speeds projected by the CPM and GCM

4. Summary & Conclusions :

- A method has been developed to identify Shapiro-Keyser and sting-jet storms. **The method identifies all known cases from the literature** (not shown here), and further verification will be performed
- **CPM produces higher wind speeds in SJ storms** than seen in the GCM and ERAI, but **no difference has been seen in the future projections**. Further analysis is required to diagnose the source of the differences and future changes in CPM and GCM

Reference:
Clark, P.A. and Gray, S.L., 2018. Sting jets in extratropical cyclones: a review. *Quarterly Journal of the Royal Meteorological Society*, *144*(713), pp.943-969.