Quantifying The Sensitivity of North Atlantic Cyclone Development to Atmospheric Precursor Fields

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Introduction

Climatologies of North Atlantic cyclones identify several preferred genesis regions; here we compare cyclones originating in the east and west genesis regions. East Atlantic cyclones have a large impact on the day-to-day weather in Western Europe. They often develop rapidly and are can be small in scale, making them difficult to forecast. Compared to west Atlantic cyclones the factors controlling their development are not well understood. There is also evidence that the number and intensity of east Atlantic cyclones may increase in the future (Bengtsson et al. 2007; Pinto et al. 2008)

AIM: to determine the dynamical mechanisms responsible for the development of North Atlantic cyclones in the west and east from the sensitivity of their maximum intensity to precursor fields.

Method

• Cyclone tracks identified in the ERA-Interim, 6-hourly, reanalysis fields are clustered according to their genesis location (~300east, ~600west cyclones).

• Fields for individual cyclone tracks are extracted from the ERA-Interim reanalysis fields for a 15º circle surrounding their 850hPa vorticity maximum and then rotated in their direction of travel (Catto et al. 2009).

• Precursor fields are selected for specified times prior to that of cyclone maximum intensity.

• Sensitivity is determined by calculating

1. The slope of a linear fit to the max. cyclone track vorticity (ξ_{max}) and the precursor field data, $\partial\xi_{max}/\partial\text{Precursor}$, at each point in the 15º circle surrounding the cyclone centre (Fig. 1).

2. Confidence in the linear relationship, conf, (given a value of 1 or 0) (Fig. 2).

3. The standard deviation, σ, of the precursor (Fig. 3)

4. sensitivity = $\partial\xi_{max}/\partial\text{Precursor}$ x conf x σ of cyclone ξ_{max} to the precursor field (Figs. 4 and 5).

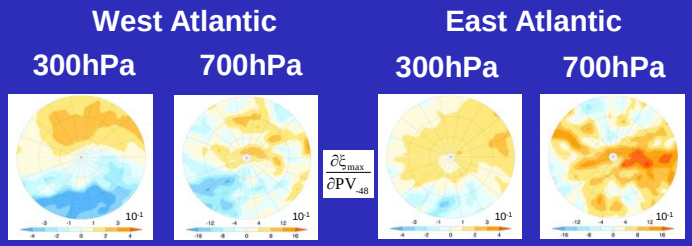

Fig 1. Slope of linear relationship between ξ_{max} and potential vorticity (PV) precursor 48 hours before max. cyclone track vorticity (VU/PVU). West Atlantic cyclones (left) and east Atlantic cyclones (right) at 300hPa and 700hPa. System propagation direction is rightwards.

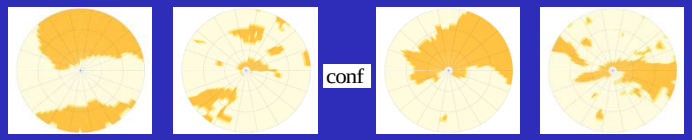

Fig 2. Confidence in the linear relationship between ξ_{max} and PV precursor (shaded for confident relationships).

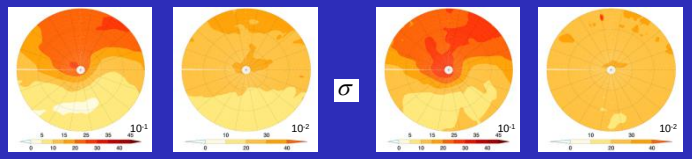

Fig 3. Standard deviation of the mean PV precursor field (PVU).

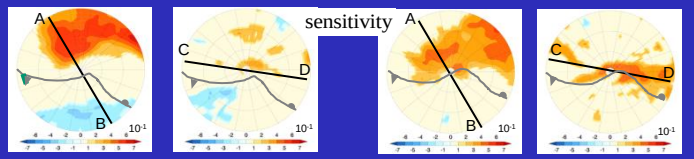

Fig 4. Sensitivity of ξ_{max} to PV precursor field. Overlaid with surface cold and warm fronts (grey)

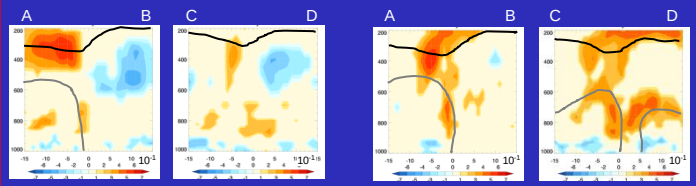

Fig 5. Vertical cross-sections of sensitivity of ξ_{max} to PV precursor along lines shown in Fig 4. Overlaid with tropopause (black) and warm and cold fronts (grey). 0.5 signifies an increase of 0.5VU per 1 standard deviation increase in PV.

Results

• The max. track relative vorticity of both west and east Atlantic cyclones is sensitive to the PV 48 hours earlier.

• Cyclones are sensitive to PV at 2 distinct heights:
  - the tropopause (~ 300hPa)
  - the steering level (~ 700hPa)

• West Atlantic cyclones are more sensitive to PV at the tropopause than that at the steering level (which arises from latent heating along the warm and cold fronts).

• East Atlantic cyclones are equally sensitive to PV at the tropopause and at the steering level.

• More intense cyclones are associated with deeper troughs behind, and stronger ridges ahead of, the precursor tropopause depression, and stronger PV in the precursor frontal zones.

Conclusions

• More intense west and east Atlantic cyclones are associated with stronger precursor tropopause depressions.

• Mid-level latent heating contributes more positively to the development of east Atlantic cyclones than west Atlantic cyclones.

• The identification of sensitivity to PV anomalies at the steering level along the fronts is consistent with the idealised results of Beare et al. (2003).

References

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