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Sting jets in idealised simulations: the role of symmetric instability and the effects of different environmental conditions

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Sting jets (SJ) occur as an additional region of low-level strong, and possibly damaging, winds present in some Shapiro-Keyser extratropical cyclones. It is now widely accepted that those winds are not part of the warm or cold conveyor belts. The precise mechanisms responsible for their occurrence, along with the underlying dynamics and the dependency on environmental conditions, are still being investigated. These key questions are tackled in the present study using idealised simulations.

Idealised simulations of Shapiro-Keyser cyclones show the development of a SJ that descends from the tip of the cloud head and displays a large acceleration while moving into the frontal-fracture region, with a peak wind speed close to 40 m/s at the top of the boundary layer. The dynamics of the SJ is associated with the generation and subsequent release of symmetric instability along the airstream. This is the first idealised study showing that the SJ is associated with a symmetrically unstable environment in its control simulation, which is designed to be the one that most closely represents the real environment. The occurrence of symmetric instability along the jet is related to the generation of regions of negative potential vorticity in the cloud head along a narrow frontal zone, consistent with a vorticity tilting mechanism recently outlined in the study of windstorm Tini.

Sensitivity experiments, exploring more parameters than in previous literature, are performed through variations in model resolution, initial moisture content, initial strength of the jet stream and values of latent heat constants. These experiments show the robustness of the SJ occurrence and its dependency on the different environmental conditions and give an indication of the wind speed and of the descent extent expected in an idealised SJ. The results also confirm that hi-res simulations are necessary to describe the SJ evolution. The SJs produced in the different simulations can be divided into stable and unstable with respect to symmetric instability. The comparison between these two groups of SJs suggests that a larger amount of instability on the airstream is usually associated with a larger peak wind speed and bigger descent.

This idealised study thus shows that the SJ can be considered a robust feature of the evolution of intense Shapiro-Keyser cyclones which can possibly be enhanced by the release, with the mechanism highlighted, of symmetric instability.