Sting jet enhancement through mesoscale instability release in case study and idealised simulations

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Sting jets occur as a mesoscale region of low-level strong, and possibly damaging, transient winds present in some Shapiro-Keyser-type extratropical cyclones. It is now widely accepted that these winds are distinct from the warm or cold conveyor belts. However, different mechanisms have been proposed to be responsible for their occurrence. Here we determine the dependence of sting jet generation and strengthening upon the release of mesoscale instabilities and upon the cyclone evolution in the frontolytic region. We outline a mechanism of generation of instability within the sting jet using two types of simulations run with the Met Office’s MetUM: real-case simulations of extratropical cyclone Tini (2014) and idealised simulations of Shapiro-Keyser extratropical cyclones.

The simulations highlight the evolution of the sting jet as a coherent airstream that descends from the cloud-head tip towards the frontal-fracture region while accelerating (with maximum wind speed close to 60 m/s at the top of the boundary layer in the case study). Lagrangian trajectories, along with vorticity budgets and analysis of frontogenesis field, are used to gain further information on the dynamics of the sting jet. In both simulation types the sting jet is driven by the release of mesoscale instabilities within the airstream. Combined tilting and stretching of vorticity are related to the generation of localised regions of negative potential vorticity along a narrow frontal zone, playing a major role in the local onset of symmetric instability within the sting jet. This mechanism enhances the strong winds already generated by the synoptic-scale cyclone dynamics. Sensitivity runs using both simulation types show the existence of model resolution constraints for the instability to develop within the airstream.

This study highlights a mechanism of generation of mesoscale instability that can take place within the sting jet airstream. Release of this instability leads to an enhancement of the strong winds that the cyclone dynamics would already produce in the frontal-fracture region.