The downward transport of momentum to the surface in idealized sting-jet cyclones

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Damaging surface winds may occur in connection with the presence of sting jets within extratropical cyclones. The sting jet is a mesoscale jet above the bent-back warm front associated with air masses descending from the mid-tropospheric cloud head to the top of the boundary layer. Existing studies emphasized the fact that sting jets are likely to be responsible for the formation of multiple bands of strong surface winds in the frontal-fracture region ahead of the bent-back warm front. However, boundary-layer processes responsible for the downward transfer of high momentum from the sting jet to the surface and circumstances under which such a transfer occurs are not well known. Our study aims at better identifying such processes by analyzing idealized simulations of a sting-jet cyclone performed with a high-resolution numerical model. Different experiments are conducted by changing the horizontal resolution and the surface roughness and by turning off the evaporative cooling processes. It is shown that the strongest surface winds of the idealized extratropical cyclone occur in the frontal-fracture region below the sting jet when the resolution is high enough (about 1-km grid spacing) and the surface roughness is strong enough. For coarser resolution and/or weaker roughness, the maximum surface wind gusts occur below the cold-conveyor-belt jet. Only the 1-km resolution simulations with strong surface roughness are shown to rather adequately reproduce the multiple bands of strong surface wind speed reported in the literature for sting-jet cyclones. The role of evaporative cooling in the intensification of the boundary-layer convective rolls is also quantified and shown to be important in the downward transfer of momentum at the frontal-fracture region. Finally, the distinct roles of subgrid-scale and resolved boundary-layer circulations in bringing high momentum to the surface are also analyzed.