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The downward transport of strong winds by convective rolls in a Large Eddy Simulation of Mediterranean cyclone Adrian

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Windstorms associated with extratropical cyclones belong to the most destructive natural disasters in the mid-latitudes, potentially causing tens of fatalities and hundreds of millions euros in damages yearly. The impact of windstorms is caused by gusts mainly, which arise from the downward transport of strong winds to the surface. The processes leading to the transport of wind gusts are still poorly understood, because they cannot be studied directly due to their short duration and local extent that are too small scale for both observing networks and numerical weather prediction systems.

The opportunity to address this issue arose when the windstorm Adrian (also known as Vaia) occurred over the north-western Mediterranean on 29 October 2018. Although cyclones are usually less intense over the Mediterranean than over the Atlantic, gusts exceeding 180km/h causing several material damages were recorded in Corsica and make Adrian an ideal case study to analyze the transport of strong winds in numerical simulations.

First, we perform a mesoscale analysis of windstorm Adrian, based on simulations on a 1 km grid with Meso-NH. Even at short range <12h, simulations exhibit high sensitivity to the initial conditions and can delay the cyclone by several hours. In a reference simulation, we show that the strongest surface winds occur below the occluded front, and they are due to the cold conveyor-belt (CCB). From the reference simulation, a Large Eddy Simulation (LES) with a horizontal resolution of 200m is performed over a large domain to capture both the mesoscale dynamics and the fine scale characteristics.

Focusing on the LES, we identify two types of strong wind structures: local cells and elongated structures with surface wind speed > 40m/s and duration < 10min. In the strong wind region, boundary layer convection is organised in rolls oriented along the wind direction, with vertical extension and spacing < 1km. It is found only in the convective and unstable boundary layer characterised by moderate surface sensible heat fluxes and vertical wind shear. This suggests that convective rolls are responsible for transporting strong winds to the surface. To ensure that, passive tracers initiated in the CCB region are computed to illustrate the way strong winds are transferred downward. Subsequently, a detailed study of the turbulent fluxes at the air-sea interface is carried out to evaluate their role in the transport of winds in the atmospheric boundary layer. It shows the influence of the various processes considered in the parameterisations of surface fluxes on the presence and intensification of the convective rolls.

The results show, using the LES, that the downward transport of strong winds in the cold conveyor-belt of Adrian is caused by small-scale convective rolls.