European Conference on Severe Storms 2015
14–18 September 2015, Wiener Neustadt, Austria
ECSS2015-95

How does surface drag affect the development of near-surface vertical vorticity in supercell thunderstorms?

Paul Markowski and Yvette Richardson
Department of Meteorology, Pennsylvania State University, University Park, PA, USA (pmarkowski@psu.edu)

It has long been known that surface drag can intensify vortices by preventing cyclostrophic balance and promoting radial inflow, thereby promoting the convergence of angular momentum toward the axis of rotation. However, the vorticity analysis of a recent simulation of a tornadic supercell thunderstorm by Schenkman et al. (2014) suggested that surface drag might have been a crucial *source* of angular momentum for tornadogenesis. Very little is known about the effects of surface drag on the development of near-surface rotation in supercells given the challenges in both observing its effects and including it in numerical simulations. With respect to observing friction's effects, radars seldom can observe the lowest 25 m of a storm or its environment owing to ground clutter and the increase in beam height with range, and even when such low-altitude scans are available, the vertical profile of horizontal winds is not well-resolved, nor is it possible to know how a storm would have evolved in the absence of surface drag. With respect to including friction's effects in numerical simulations, a well-known shortcoming of large-eddy simulation (LES) is the development of excessive vertical wind shear (horizontal vorticity) near the surface, stemming from the fact that the scale of the most important eddies is limited by the distance from the surface; thus, even the largest eddies near the surface are not well-resolved, contrary to LES turbulence closure assumptions. As a result, the subgrid-scale model is overly dissipative, and the vertical wind shear (horizontal vorticity) is too large near the surface. The overprediction of near-surface vertical wind shear is a major problem if one is to credibly assess the effects of surface drag on the vorticity budgets of air parcels entering a near-surface mesocyclone or intense vortex, as well as the effects of surface drag on the parent storm.

We will present and discuss idealized simulations we have been performing in order to investigate the effects of surface friction on the development of near-surface rotation in supercells. The simulations extend the pseudostorm simulation ("toy model") approach of Markowski and Richardson (2014). We will use a highly idealized approach because of the computational expense required to resolve turbulent eddies (surface friction influences the low-level winds by way of eddy momentum transport, after all), maintain a relatively small grid aspect ratio, and resolve near-surface winds so that trajectories computed in subsequent diagnostic studies do not drop below the lowest scalar level as they approach the near-surface mesocyclone. We also have experimented with a modified turbulence model that largely remedies the aforementioned issue of excessive (unrealistic) vertical shear developing near the surface in LES.