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The Planetary Boundary Layer and Uncertainty in Lower Boundary Conditions

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This talk is an attempt to provide the basic background, and motivation, for statistical approaches to address some open questions in both (1) parameterization (closure) near the interface between the earth and the atmosphere, and (2) uncertainty in the parameterization. A typical NWP model is formulated by Reynolds-averaging some form of the Navier-Stokes equations. Perturbation quantities are thought of as ``subgrid-scale,'' while mean quantities are handled by direct numerical integration. The canonical closure problem is turbulence, and historically all of the turbulent energy is at subgrid scales such that the inertial subrange is (partially) unresolved by the truncated (filtered) system of equations. Turbulence closure then act like viscosity and an energy sink on the resolved flow. Although turbulence is a 3D process, the horizontal and vertical components are often separated in NWP models. The vertical component is coupled to additional energy source terms entering near the truncation scale through lower-boundary forcing.

Vertical turbulence is often handled in planetary boundary layer (PBL) schemes, because the PBL is defined by such turbulence resulting from large vertical momentum and thermodynamic fluxes. Typical approaches to PBL parameterization rely on a combination of physics and empiricism, and often include parameters defined for convenience or from a handful of field experiments. Sensitivities to these parameters a can be large, and it is often not obvious what values they should take for any given scenario. Parameters that control the lower boundary (the land surface) forcing are particularly important. The problem is compounded because little is known about the multi-scale sensitivity of the atmosphere at short time scales (hours to days) to uncertainty in soil conditions.

A column model is formulated to efficiently explore the first-order behavior in soil, surface-layer, and PBL parameterization schemes. The model contains the quite of soil, surface-layer, and PBL parameterization schemes available in the Weather Research and Forecast (WRF) mesoscale modeling system. It has been implemented within the NCAR Data Assimilation Research Testbed (DART) so that observations can be used to inform parameters in a probabilistic sense. Recent results obtained with the column model and ensemble data assimilation system will be described, including simple parameter estimation experiments. Questions related to uncertainty in PBL parameterization, extension to mesoscale NWP, and the potential role of statistical modeling will be posed.

More information about the model, and some associated publications and manuscripts, can be found at http://www.rap.ucar.edu/staff/hacker/pblda.html