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Probabilistic nowcast of PBL profiles with a single column model and ensemble filter assimilation of surface observations

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A long-term goal of this work is to find an efficient system for probabilistic planetary boundary layer (PBL) nowcasting that can be deployed wherever surface observations are present. One approach showing promise is the use of a single column model (SCM) and ensemble filter (EF) data assimilation techniques.

Earlier work showed that surface observations can be an important source of information with an SCM and an EF. Here we extend that work to quantify the deterministic and probabilistic skill of ensemble SCM predictions with added complexity. Although it is appealing to add additional physics and dynamics to the SCM model it is not immediately clear that additional complexity will improve the performance of a PBL nowcasting system based on a simple model. We address this question with regard to treatment of surface assimilation, radiation in the column, and also advection to account for realistic 3D dynamics (a timely WRF prediction). We adopt factor separation analysis to quantify the individual contribution of each model component to the deterministic and probabilistic skill of the system, as well as any beneficial or detrimental interactions between them.

Deterministic skill of the system is evaluated through the mean absolute error, and probabilistic skill through the Brier Skill Score (BSS) and the area under the relative operating characteristic (ROC) curve (AUR). The BSS is further decomposed into both a reliability and resolution term to understand the trade-offs in different components of probabilistic skill.

An alternative system based on climatological covariances and surface observations is used as a reference to assess the real utility of the flow-dependent covariances estimated with the ensemble system. In essence it is a dressing technique, whereby a deterministic 3D mesoscale forecast (e.g. WRF) is corrected with surface forecast errors and covariances computed from a distribution of available historical mesoscale forecasts. The adjusted profile is then dressed with a normal distribution derived from the sample of mesoscale forecasts and surface forecast errors.

Results show that assimilation of surface observations can improve deterministic and probabilistic predictions more significantly than major model improvements under a wide range of flow scenarios. However, under dry convective conditions surface assimilation may enhance the wet bias often observed in parameterized PBL mixing ratio profiles due to inappropriate covariance estimated from the ensemble. In this instance the SCM/EF proves its usefulness as a numerical tool to investigate model error. The SCM/EF mean forecasts clearly show an advantage over the climatological-adjusted profiles whenever the flow is characterized by wide variability from day to day.

We expect that several results will extend to a 3D WRF/EF system assimilating surface observations.