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Coupled atmosphere and land-surface assimilation of surface observations with a single column model and ensemble data assimilation

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Numerical weather prediction and data assimilation models are composed of coupled atmosphere and land-surface (LS) components. If possible, the assimilation procedure should be coupled so that observed information in one module is used to correct fields in the coupled module. There have been some attempts in this direction using optimal interpolation, nudging and 2/3DVAR data assimilation techniques. Aside from satellite remote sensed observations, reference height in-situ observations of temperature and moisture have been used in these studies. Among other problems, difficulties in coupled atmosphere and LS assimilation arise as a result of the different time scales characteristic of each component and the unsteady correlation between these components under varying flow conditions. Ensemble data-assimilation techniques rely on flow dependent observations-model covariances. Provided that correlations and covariances between land and atmosphere can be adequately simulated and sampled, ensemble data assimilation should enable appropriate assimilation of observations simultaneously into the atmospheric and LS states.

Our aim is to explore assimilation of reference height in-situ temperature and moisture observations into the coupled atmosphere-LS modules(simultaneously) in NCAR's WRF-ARW model using the NCAR's DART ensemble data-assimilation system. Observing system simulation experiments (OSSEs) are performed using the single column model (SCM) version of WRF. Numerical experiments during a warm season are centered on an atmospheric and soil column in the South Great Plains. Synthetic observations are derived from "truth" WRF-SCM runs for a given date,initialized and forced using North American Regional Reanalyses (NARR). WRF-SCM atmospheric and LS ensembles are created by mixing the atmospheric and soil NARR profile centered on a given date with that from another day (randomly chosen from the same season) with weights drawn from a logit-normal distribution. Three types of one-week long numerical experiments are performed: (a) free ensemble runs; (b) ensemble assimilation that directly impacts the atmospheric-state vector only; (c) ensemble assimilation that directly impacts the coupled atmospheric-LS-state vector. The WRF-SCM is run in two modes: with and without inclusion of externally imposed horizontal advection terms in the atmospheric column (derived from the NARR, too).

Preliminary examination of analyses and 30-min forecasts of reference height temperature and moisture, soil temperature and moisture at four depths (0.05m, 0.25m, 0.7m and 1.5m), fluxes at the surface, and planetary boundary layer (PBL) height shows that:
1. Horizontal advection is important to the realism of PBL heights and fluxes in the "truth", and affects the depth of influence of the assimilation on the soil state; a deeper effect (that could be non-realistic) is more often observed when advection is not included.
2. Inclusion of soil variables in the state vector can be beneficial to estimates of soil temperature and moisture,of moisture- and net latent heat fluxes at the surface, and of atmospheric variables (for the latter especially when no advection is included), However, no benefit is observed on PBL heights.

Further analysis and improvement of the WRF-SCM/DART system (in particular the treatment of advection) is under way.