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Continued application and development of a High-Resolution Land Data Assimilation System

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1. Introduction

Using land surface models with MM5 and WRF simulations presents a variety of challenges for initialization. Initializing soil fields (i.e., soil temperature and moisture) with soil fields from other models is routinely done, but mismatches in model physics, resolution, landuse category, and soil category mean that any such initialization is at best a rough approximation to a balanced initialization. The High-Resolution Land Data Assimilation system (HRLDAS) was developed as a means to circumvent these problems when using the Noah Land Surface Model (LSM) in MM5 and WRF.

The HRLDAS system has been described elsewhere (e.g., Chen, et al., 2005) and will be briefly reviewed here. We then present some recent development and applications of HRLDAS.

2. HRLDAS

The Noah Land Surface Model is described by Ek et al. (2003). In HRLDAS, the Noah LSM is run in an offline mode (decoupled from the atmospheric model), and driven by observations-based analyses. The horizontal grid configuration is identical to that of the subsequent atmospheric model, removing the need for horizontal interpolations. Primary forcing fields (and the sources of these fields for current HRLDAS experiments) are precipitation (NCEP Stage IV hourly precipitation estimates), downward short-wave radiation flux (University of Maryland and NESDIS/NOAA analysis), downward long-wave radiation flux (ETA forecast), surface meteorological fields (2-m T, 2-m q_v, surface P, 10-m u and v; all from EDAS). Initial conditions of soil temperature and moisture are from EDAS. HRLDAS should be easily adaptable to use other sources of data as available.

A spin-up period on the order of a year may be optimal for the offline Noah LSM in HRLDAS to reach an approximately balanced state, although realistic heterogeneity in soil moisture and temperature fields begins to develop after just a few days.

3. Applications

HRLDAS has been applied to a variety of cases and experiments in recent studies.

a) IHOP studies

The International H_2O Project (IHOP) provides a useful data set for studying surface moisture fluxes. Several modeling studies of IHOP cases have made use of HRLDAS.

We are currently performing a series of experiments on a 12-day IHOP period during which a variety of precipitating systems passed through the IHOP region.

b) Real-time forecasts

The WRF Development Testbed Center's Wintertime Forecast Experiment (DWFE) ran a 5-km grid over the eastern two-thirds of the Continental United States from January through March 2005. This real-time experiment presented the opportunity to apply HRLDAS on a large scale to winter forecasts.

Similarly the Spring/Summer 2005 forecast experiment at MMM is using HRLDAS to initialize soil fields.

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c) ATEC RTFDDA

The HRLDAS system is also being used to initialize land surface fields in the Real-Time Four-Dimensional Data Assimilation and forecast system (RTFDDA). The RTFDDA system runs operationally at several test ranges of the Army Test and Evaluation Command (ATEC), in support of the range routine test operations. The RTFDDA system runs with multiple nested grids (with grid sizes of 0.5–45 km) and is cycled rapidly (at time intervals of 1–12 hours) to produce real-time 4D analyses and "spun-up" forecasts. HRLDAS provides a good way to refine, maintain, and cycle the fine-scale texture of land use and soil properties through incorporation fine scale accurate RTFDDA surface and upper-air analyses. It produces internally consistent soil moisture and temperature fields to the RTFDDA during the RTFDDA system cycling. More details about the ATEC RTFDDA system and its HRLDAS implementation can be found in Hahmann et al. (2005).

An example of the contrast seen in soil water content with and without HRLDAS fields is given in Figure 1. The HRLDAS initialized fields show structures of finer spatial resolution. In particular for this region, the salt flats (a region of permanent surface water during times of the year) over western Utah are well represented.

4. Future directions

a) Water routing scheme

Currently being incorporated into HRLDAS is a scheme to redistribute surface and subsurface water according to topographical slope information. This redistribution of water becomes important for small grid cells (e.g., O(1 km) or less), for regions of complex topography, and for long LSM simulations (such as the 1-year integrations recommended with HRLDAS).

Treatment of surface ponded water includes the processes of direct evaporation of surface water into the atmosphere, and re-infiltration of surface water into the soil. Subsurface routing follows Wigmosta et al, (1994) and Wigmosta and Lettenmaier (1999), and accounts for the effects of topography, saturated soil depth, and saturated hydraulic conductivity; hydraulic gradients are approximated as the slope of the water table between adjacent grid cells. Overland flow is calculated following Julien et al. (1995) and Ogden (1997) as a fully-unsteady, explicit, finite-difference, 2-dimensional diffusive wave flowing over the land surface.

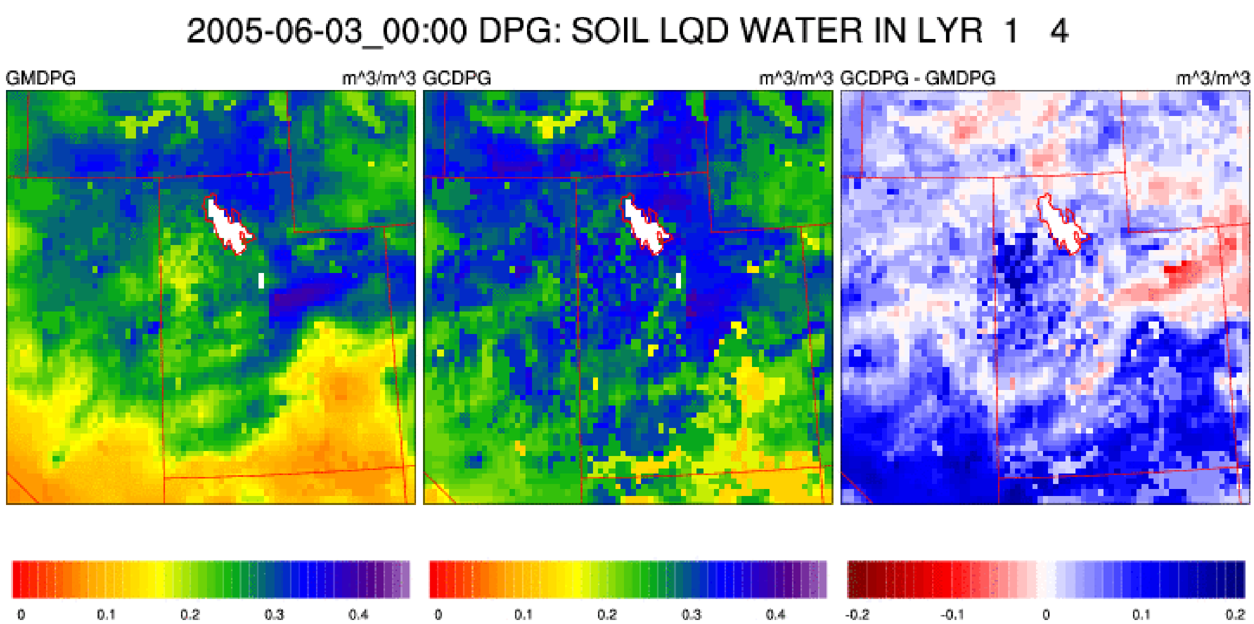

Fig.1 Soil liquid water in the uppermost soil layer as depicted by an MM5 model analysis initialized with ETA-land (left) and HRLDAS-derived (center) land surface fields. The difference between these two fields is shown on the right. Fields are valid at 00:00 UTC 3 June 2005 and correspond to nest 1 (grid spacing of 10 km) of a domain centered over western Utah.

b) Surface emissivity and treatment of urban areas

With the introduction of surface emissivity as a function of landuse category, the surface energy balance equation is modified. Surface emissivity is important for correctly determining the longwave radiation leaving the surface and the surface temperature. For a wide range of surface types, we have used the seasonal maps of emissivity from Wilbur et al. (1999) to specify the emissivities for different regions.

A bulk parameterization for urban landuse has been incorporated in the Noah LSM. It includes:

1) increasing the roughness length from 0.5 m to 0.8 m to represent turbulence generated by roughness elements and drag due to buildings;

2) reducing surface albedo from 0.18 to 0.15 to represent the shortwave radiation trapping in the urban canyons;

3) using a larger volumetric heat capacity of 3.0 J m^{-3} K^{-1} for the urban surface (walls, roofs, and roads) which is usually consisted of concrete or asphalt materials;

4) increasing the value of soil thermal conductivity to 3.24 W m^{-1} K^{-1} to parameterize large heat storage in the urban surface and underlying surfaces;

5) reducing green vegetation fraction over urban city to decrease evaporation.

c) Compatibility with WRF-ARW

The ultimate goal is to have a version of Noah LSM which is plug-compatible between WRF-ARW and HRLDAS. This means that advances to the Noah LSM developed for HRLDAS may be easily ported to WRF-ARW, and vice versa. Work to achieve this plug-compatibility is ongoing.

d) Community support

Our intent is to develop HRLDAS into a tool that experienced users may apply to their own forecast studies or case studies. To that end, a set of scripts is being developed to aid users in acquiring and organizing the extensive amount of data that is required for a long integration of HRLDAS. Because every application of HRLDAS is a little different, and each user has his or her own specific situation, these scripts and programs should be considered more as an example of how to set up HRLDAS than a "black-box" utility that a user can simply turn on and run. Configurations outside of the continental United States, for example, will need to find their own sources of data, as the supported scripts rely on datasets that cover only the CONUS. HRLDAS should be easily adaptable to use other sources of data as available.

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