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Implementation of Land Information System in the NCEP Operational Climate Forecast System CFSv2

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To support NOAA's mission in improving its climate prediction on the seasonal scale, NCEP has launched a new version of the NCEP Climate Forecast System (CFSv2) in 2011. The NASA Land Information System (LIS, Peters-Lidard *et al.*, 2007) is implemented within CFSv2 to execute the Global Land Data Assimilation System (GLDAS) to provide land surface analysis.

Numerical weather and climate prediction and assimilation systems generally use prescribed or simulated soil moisture values to formulate surface layer parameterizations within a land surface model (LSM) to calculate evapotranspiration and latent and sensible heat fluxes, and to solve for the land surface energy and water balance equations. In the first version of the NCEP CFS (CFSv1), the Oregon State University (OSU) LSM (Pan and Mahrt, 1987) was used to calculate the land surface states and fluxes. To outcome the deficiencies in the precipitation forcing from the atmospheric model and to prevent the calculated soil moisture drifting too far from a preferred climatology, an adjustment on the simulated soil moisture was required to compensate the differences between the simulated and observed precipitation. The Noah LSM (Ek *et al.*, 2003) was developed with substantial improvements from the OSU LSM as a collaborative effort between NCEP and numerous partners from the land hydrology community over the last decade. Noah was implemented in the NCEP North American Mesoscale Model (NAM) in 2003 and the NCEP Global Forecast System (GFS) in 2005 for operational regional and global medium-range weather forecasts. In CFSv2, Noah is implemented in both the fully-coupled land-atmosphere-ocean prediction model to make seasonal climate forecast and the semi-coupled GLDAS to perform the land surface analysis.

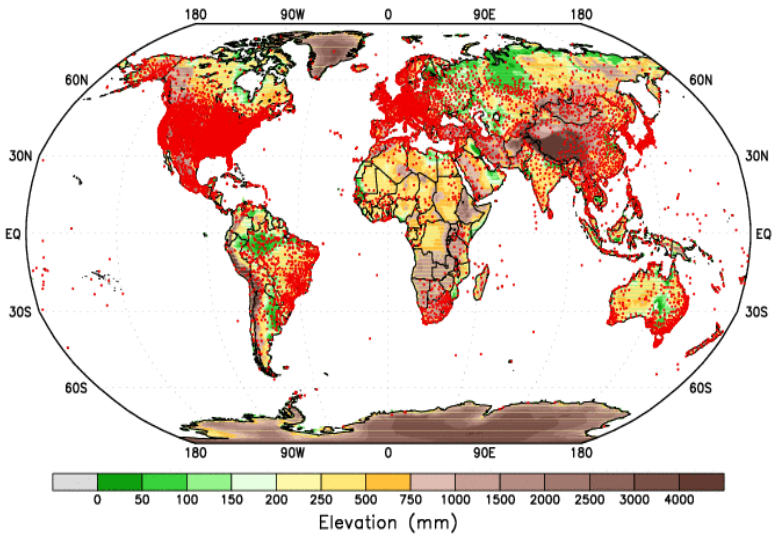

Fig. 1 Example of global gauge distribution used in the CPC unified global daily gauge analysis.

The NASA LIS is employed to execute the CFSv2 land surface analysis. Compared to CFSv1, this CFSv2 LIS uses observed global precipitation analyses as direct forcing to drive the Noah LSM to execute the land surface analysis. The adjustment on soil moisture is based on land surface physics responding to the adjustment on precipitation forcing, rather than the artificial adjustments previously applied in CFSv1. Two sets of observation-based global precipitation analyses are utilized as alternative forcing to drive the CFSv2 LIS. One is the pentad data of CMAP (Xie and Arkin, 1997) that also used in CFSv1; the other is the CPC unified global daily gauge analysis (Xie *et al.*, 2010). After reviewing the global gauges distribution (Figure 1), a merging approach with latitude-dependent weighting masks is designed that favors the gauge-only

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analysis in mid-latitudes, and the satellite-dominated CMAP analysis in tropical latitudes where gauge count is low. In high-latitudes where gauge count is also low and satellite estimate lacks of accuracy, the CFSv2 model predicted precipitation is given the most weights. In addition, the gauge analysis is given the most weight in the regions of high gauge density (*e.g.*, contiguous United States, Europe, and Australia).

In summary, NCEP CFSv2 is for the first time an LDAS strategy is used in a coupled land-atmosphere-ocean global climate prediction system to perform the land surface analysis. Observed precipitation fields are used to constrain the land surface simulation of soil moisture, soil temperature, and snowpack. This product can improve the current understanding of the global land surface energy and water cycles and their roles in the Earth system to further assist the operation and research in hydrology, weather, and climate.

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