Modelling and observational studies of soil moisture over the Indian region

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by

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Abstract

Soil moisture plays a crucial role in land and atmospheric processes, such as the carbon cycle, water cycle, and energy balance. However, the complexity between these processes involving soil moisture makes both the measurement and modelling tasks challenging. The proper understanding of uncertainty in soil moisture measurements, is critical for land surface modelling. Precipitation is an important forcing for land surface models, (LSMs); hence, its uncertainty plays a major role in soil moisture estimates. Data assimilation is a method to combine information from the observations together model estimates, to provide a better evaluation of the state.

The present study investigated the role of precipitation forcing on the uncertainty of soil moisture estimates simulated by LSMs. This study utilized five different forcing precipitation data sets from the following list: Global Data Assimilation System (GDAS), Tropical Rainfall Measurement Mission (TRMM)-Multi-satellite Precipitation Analysis (TMPA), Precipitation Estimation from Remotely Sensed Information using Artificial Neural Networks-Climate Data Record (PERSIANN-CDR), Global Precipitation Mission (GPM), and Indian Meteorological Department (IMD) gridded data, over the Indian domain using the Noah land surface model within the NASA Land Information System (LIS). Results indicate that the LIS-Noah soil moiture estimates, forced with IMD rainfall agreed better among the five simulations with IMD in-situ soil moisture data. In order to overcome the model limitations of Noah LSM, which does not model the irrigation, the present study assimilated the satellite-derived Advanced Scatterometer (ASCAT) soil moisture data, the latter having the irrigation effect, with the Noah LSM soil moisture estimates using Ensemble Kalman filter (EnKF) technique. The results after assimilation show an improvement in the soil moisture estimates, over highly irrigated areas.

Furthermore, the thesis investigated the impact of historical land cover change on atmospheric variables over the Indian region for a 83 year period, the simulations are carried out by the following two methods, first by utilizing the Noah LSM in stand-alone mode, and second, utilizing the coupled land atmospheric model using NASA Unified WRF (NU-WRF). The latter can couple the LIS with WRF. Four simulations have been carried using the stand-alone Noah LSM, including control run and three experimental runs. The control run is undertaken with default MODIS-IGBP land cover data, while the three experimental

runs are performed with three different potential land cover maps for the years 1930, 1975, and 2013. Results indicate that the historical land cover change (1930 to 2013) has reduced the annual mean of latent heat flux and net surface heat flux, while the sensible heat flux and the soil temperature has increased over the domain where the land cover area change is marked. Two simulations have been carried out for the coupled land-atmospheric model using NU-WRF system. The land surface states for both the simulations are initialized by utilizing LIS. The simulations have been initialized using LIS with the potential land cover maps for the years 2013 and 1930, respectively. Results show an decrease in rainfall and latent heat flux for most of the seasons and regions, except during monsoon season due to the land cover change from 1930 to 2013. Furthermore, the land cover change from 1930 to 2013, decreases the planetary boundary layer height, which is attributed to the decrease in sensible heat flux and near surface temperature at 2 m.

Finally, the thesis studied the long-term relationship between extreme soil moisture and extreme precipitation over India using event coincidence analysis (ECA) method. In this study, 21 years (2000-2020) of daily Global Land Evaporation Amsterdam Model (GLEAM) surface soil moisture data and root zone soil moisture data, together with daily India Meteorological Department (IMD) precipitation data are considered.The findings indicate that West central India has a higher long term relationship between soil moisture and precipitation over the surface, as well as root zone, than the rest of the Indian regions. The higher long term relationship between soil moisture and precipitation over West Central India is associated with the transition regions, where the land-atmosphere interaction is more pronounced as compared to either the wet or the dry regions. The results of the ECA method also shows that the number of grid points having higher trigger coincidence rate (TCR) for the highest time lag (30 days), is lower for root zone soil moisture as compared to the surface soil moisture.