Soil Moisture Assimilation for Regional NCUM-R Model and its Benefits

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1. Introduction:

Recent past, there have been tremendous advancements in high-resolution numerical weather prediction (NWP) as well as Data Assimilation (DA) systems. It is now well known that soil moisture (SM) is a key driver in the exchanges of water and heat fluxes between the ground and the atmosphere and the land surface-atmosphere interaction depends on the land surface characteristics. Therefore, the SM plays a major role in regulating the surface weather parameters, low cloud and rainfall. Indian monsoon region has been recognized as a 'hot spot' due to the SM-precipitation coupling (Koster et al., 2004) and became an ideal test bed to study the impacts of the land surface on rainfall associated with convective events like monsoon depression (MD). At National Centre for Medium Range Weather Prediction (NCMRWF), many studies have been conducted to understand the impact of land surface on global and regional NWP. The regional version of the "NCMRWF Unified model" (NCUM-R) is used for high resolution NWP. JULES (Joint UK Land Environment Simulator) is the land surface model coupled with both NCUM global and regional versions.

The simplified extended Kalman Filter (sEKF) based Land Surface Data Assimilation (LSDA) system is used to create land surface SM initial conditions for NCUM-R by assimilating ASCAT SM along with 2m humidity and temperature observations (Lodh et al. 2022; Routray et al. 2023). The schematic workflow providing an overview of the regional sEKF based LSDA currently used for assimilation of SM over the Indian region is depicted in Fig. 1a. Results of the numerical experiments carried out to understand the impact of satellite soil moisture observations is presented briefly to demonstrate the significance of soil moisture initialization, especially with the use of satellite observations. Two numerical experiments, namely CTL (incorporating only screen level observations in LSDA) and ASCAT (assimilating both ASCAT SM and screen level observations in LSDA) are carried out. Identical atmospheric initial condition prepared considering the 4DVAR data assimilation technique is used in both experiments. The MD occurred during the period 15-18 August 2018 is considered in this study. The observed track and associated rainfall activities over the region during the life span of the MD are depicted in Fig. 1b.

2. Results

The humidity Jacobians valid at 06 UTC 14 August at all four soil layers (0-10 cm, 10-35cm, 35-100 cm, 100-300 cm) are depicted in Fig-2. It is seen that the humidity Jacobians are positive in all over the regions, suggests the increase SM leads to the increase of the surface level humidity. The high positive Jacobians are noticed in uppermost soil layers and relatively low Jacobians in the deeper layers (de Rosnay et al., 2012). Exceptionally, the high increments are noticed over eastern coast of India in the level 4 soil layer may be the saturation of lower soil layer caused for heavy precipitation during the monsoon season as compared to the other parts of the country. The longitudinally averaged (75–86^{0} E) time-latitude cross-section of rainfall (mm/hr) is depicted in Fig-3. Generally, high precipitation occurred in the south-western quadrant of the MD and the northern part of the MD received light rainfall. The GPM observed rainfall is also showing a similar pattern during our study period. Both simulations well simulated the same features, however, the high magnitude of the rainfall is improved in the ASCAT experiment than the CTL experiment. This high amount of precipitation is missing in the CTL simulation during the period. Overall, this study indicates that the use of ASCAT SM in the preparation of SM initial conditions for the regional NWP system helps to improve the forecast of MD.

References:

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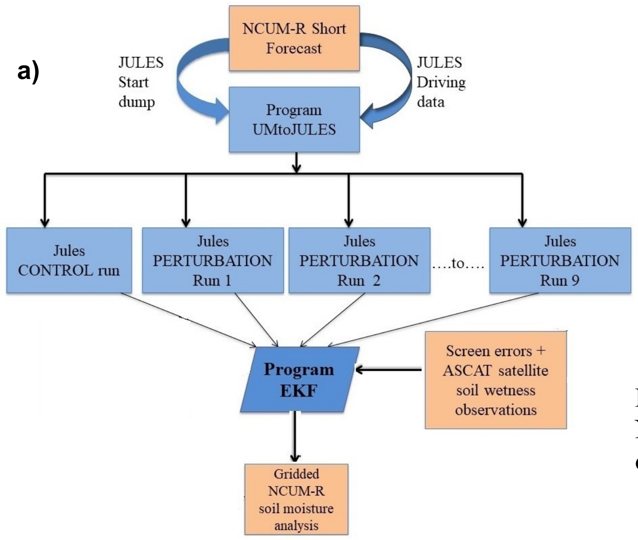

Fig-1a: Schematic of regional sEKF based LSDA

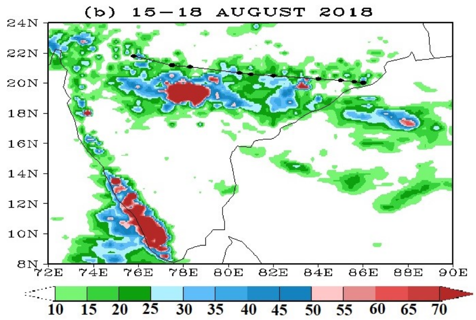

Fig-1b: Time averaged (life span of MD) of IMD-NCMRWF merged rainfall (cm; shaded) and IMD observed track.

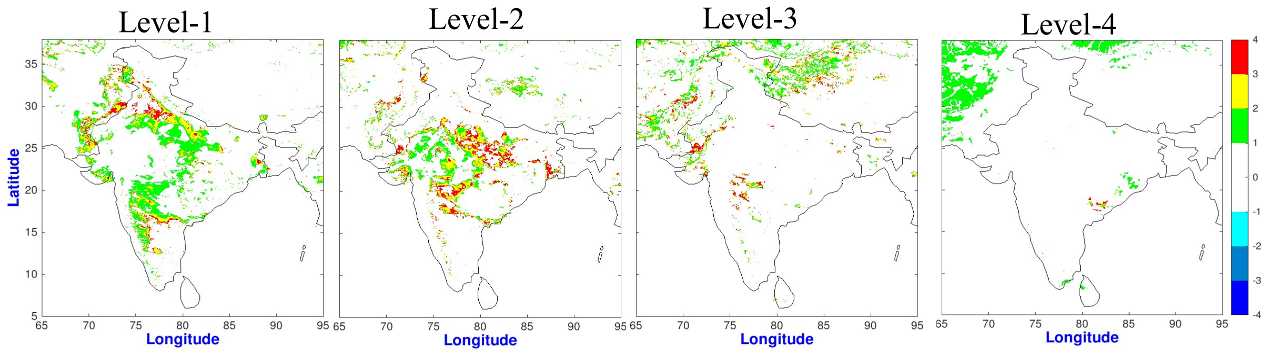

Fig-2: Humidity Jacobians for soil moisture ($\times 10^{-3}$ g/g/m^3/m^3) valid at 06 UTC 14 August 2018.

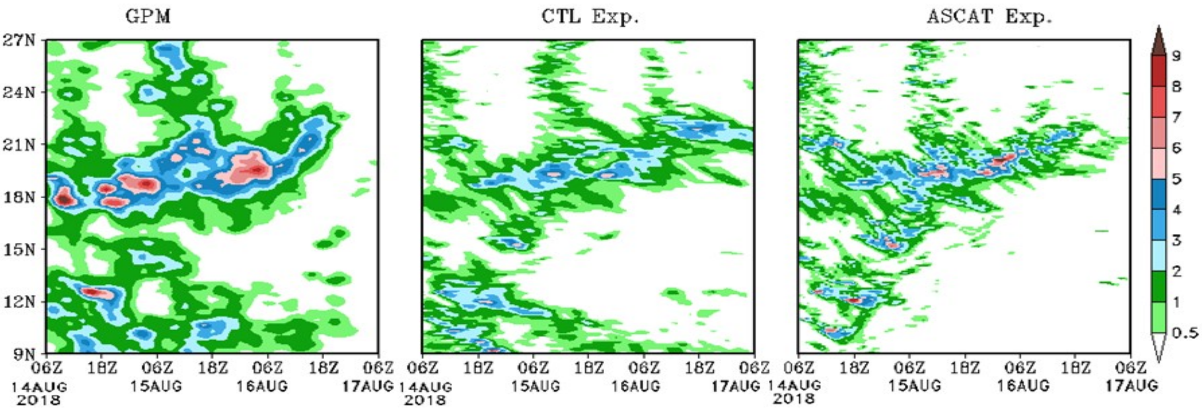

Fig-3: Longitudinally averaged (75-86^0 E) time-latitude cross section of rainfall (mm/hr)