Soil Moisture Feedback over Wet vs. Arid Regions of India

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Rationale

Understanding the spatial and temporal variability of soil moisture is essential for monitoring the water and energy balances in the land-atmosphere interaction. Also, the slowly evolving nature of soil moisture can act as an additional source of predictability for tropical precipitation (Charney Shukla, 1981). The present study aims to analyze how the mean and variability of soil moisture over contrasting regions in India can lead to differences in rainfall variability through an indirect effect affecting regional prediction skills in the monsoon mission (MM) model(Rao et al., 2019)). The study uses soil moisture analysis data (Nayak et al., 2018), which was developed under the MM project.

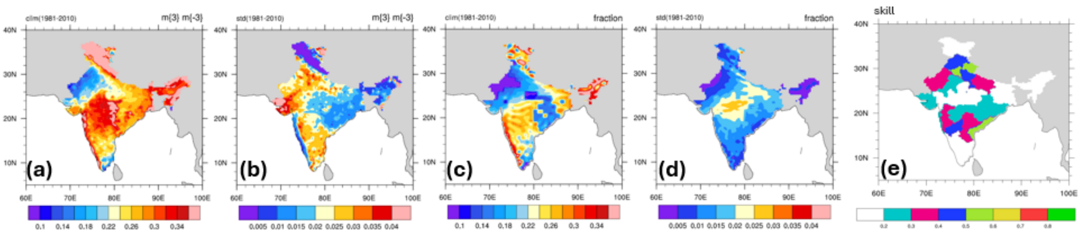

Figure 1: Seasonal mean (June to September) (a) and standard deviation (b) of soil moisture (m^3/m^3) computed using reanalysis. (c) and (d) are the same as (a) and (b) but computed for MM model simulations. (e) Subdivisional map of seasonal Prediction skill of rainfall in MM model.

Results and Discussion

The observed seasonal mean (Fig.1(a)) soil moisture is high over the central, east coast, northeast India, and southern India (except some parts of Tamil Nadu), whereas the mean is comparatively less over northwest India (specifically Rajasthan). The larger (smaller) values of soil moisture over central (northwest) India are associated with the larger (smaller) contribution of monsoon rainfall. On the other hand, the soil moisture variability (Fig.1(b)) over the east and northeast of India is significantly less than that of the northwest and southern India. The model-simulated mean and variability of soil moisture (Fig.1(c, d)) is significantly underestimated throughout the Indian landmass. The underestimation of the mean is more significant over the eastern coast and central India. On the other hand, soil moisture variability is underestimated majorly in north-west India. The underestimation of the mean and variability of soil moisture can result in errors in the feedback processes associated with precipitation or convection and hamper the model's prediction capability. For example, Fig.1(e) shows the seasonal prediction skills at different subdivisions in India. The prediction skill is calculated as the anomaly correlation coefficient between the observed (IMD) and MM model (details in Rao et al., 2019) simulated rainfall. A contrasting skill between dry and wet regions in India can be clearly noted from this figure. The eastern and central parts of India have significantly less skill than the north-western parts, where the skill (0.4) is as high as the prediction skill for all of India's average rainfall (0.5 for this model version). Therefore, we hypothesize that soil moisture and rainfall feedback over these regions play an important role in the differential prediction skill over dry (north-west) and wet (east-central) regions in India.

Eltahir (1998) proposed a mechanism where soil moisture can modulate rainfall variability by changing the boundary layer characteristics and atmospheric stability. Therefore, in Fig. 2, we investigate how these feedback processes differ in observation and model over east-central India and northwest India at an intra-seasonal time scale. An ISO index is defined as the standardized filtered (30–60-day Lanczos bandpass filter) soil moisture anomalies averaged over the regions mentioned above. Active (break) cycles are defined as days when the ISO index is greater (less) than +1(-1). From Fig. 2, during the active phase, the lowered SHF and increased LHF result in a decreased Bowen ratio (ratio of SHF to LHF). Also, due to high moisture, surface albedo decreases, and therefore, the active phase is accompanied by increased net surface radiation and reduced Bowen ratio. Combinedly, they weaken the mixing in the boundary layer. Therefore, the planetary boundary layer (PBL) growth rate is reduced during the active phase of soil moisture. The reduction in the depth of PBL height causes a reduction in entrainment of air with low moist static energy (MSE) from above the PBL. Also, the increase in surface fluxes can cause entrainment of air with high MSE into the PBL from below. Both processes result in an increased MSE in the PBL. An increase in MSE in the