LAND-ATMOSPHERE INTERACTIONS IN SPRING WHEAT CROPLANDS OF INDIA: A NUMERICAL STUDY WITH A COUPLED MODEL

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ABSTRACT

Vegetation is an integral part of the land surface that strongly contributes to the exchange of moisture, heat, and momentum fluxes between the land surface and the atmosphere. Changes in meteorological variables have significant effects on vegetation growth. Vegetation growth modifies surface properties and fluxes that, in turn, also affect the atmosphere. Such two-way interactions lead to feedbacks that can be positive or negative depending on the behaviour of vegetation and atmosphere. This thesis studied the impact of crop dynamics on the near-surface meteorology over spring wheat croplands in northern India.

A coupled model WRF_NOAHMP_SUCROS was developed to study the land-atmosphere interactions over croplands. First, the well-known Simple and Universal Crop growth (SUCROS) model was calibrated and evaluated for spring wheat using observations collected from an experimental site at the Indian Agricultural Research Institute (ICAR-IARI) campus in New Delhi. The coupled model was developed by incorporating the crop growth module of the calibrated SUCROS model into the Noah-MP land module of the Weather Research and Forecasting (WRF) mesoscale model. In WRF_NOAHMP_SUCROS, meteorological drivers like near-surface temperature, humidity and wind speed affect crop growth. The changes in LAI and root depth due to crop growth directly affect the land-atmosphere fluxes and indirectly affect near-surface temperature and humidity. Thus, the coupled WRF_NOAHMP_SUCROS model is capable of simulating the two-way interactions between the cropland and the atmosphere. When compared with observations, WRF_NOAHMP_SUCROS performs much better than the default dynamic vegetation module in WRF in simulating the observed patterns of Leaf Area Index (LAI) at the ICAR-IARI field site.

The newly developed coupled model was used to quantitatively study the effect of dynamic vegetation on near-surface meteorology. Results show that the impact of dynamic vegetation is evident in the patterns of the meteorological parameters that follow the pattern of LAI growth. The latent heat flux varies directly with LAI, and sensible heat flux varies inversely with LAI. As the crop grows due to increased evapotranspiration, the energy transfer takes place more in latent heat flux than sensible heat flux. Hence the growing crops result in near-surface cooling due to decreased Bowen Ratio. The mixing ratio is also increased due to increased latent heat flux. In comparison, the WRF model driven by climatological LAI also shows similar patterns except in the juvenile crop stage where it overestimates the sensible heating and temperature but underestimates latent heat fluxes and mixing ratio.

The thesis also quantitatively investigated the impact of irrigation on crop growth and cropland-atmosphere interactions using the newly developed WRF_NOAHMP_SUCROS coupled model. Irrigation was mimicked by setting the soil moisture at 90%, 60% and 30% field capacity on the irrigation days. Results show that increased irrigation reduces water stress and increase crop growth leading to a cooling and moistening of the near-surface environment.
Overall, this thesis shows that the coupled WRF_NOAHMP_SUCROS model can be a valuable tool to simulate land-atmosphere interactions over agroecosystems and advance our understanding of the Earth System.