HyARC Seminar (HyARC Seminar#166)

Date: February 21 (Friday) 16:00-

Room: The meeting space (#617) of Research Institutes Building.

Speaker: Prof. Gabriel Katul (Duke University)
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Title: Soil moisture feedbacks on convection triggers and the role of soil-plant hydrodynamics

Abstract:
It is now accepted that increases in greenhouse gas emissions lead to increases in air temperature. However, the effects of such increases on the hydrologic cycle are far more difficult to predict, especially precipitation. Nineteenth century equations presented by John Dalton, Rudolf Clausius, and Benoit Paul Emile Clapeyron can provide theoretical constraints on the so-called global hydrologic cycle acceleration following an increase in global air temperature as predicted by state-of-the science general circulation models. However, at finer spatial and temporal scales over land, where the soil-plant system exerts control on the atmospheric boundary-layer (ABL) dynamics and rainfall triggering mechanism, the problem becomes virtually intractable. The reason this problem remains difficult stems from the fact that the coupling between soil moisture and convective rainfall involves a large number of interacting processes occurring within the soil-plant-atmosphere system that vary over a wide range of space and time scales. Belowground and surface processes involve the dynamics of water movement from the soil into the atmosphere (rooting system, plant hydrodynamics, and stomatal regulation dictating water movement from the roots and out of the stomata as water vapor after the phase transition), the canopy aerodynamics (affecting the transport of heat and water vapor from the canopy into the mixed layer), and the partitioning of net radiation into latent, sensible, and soil heat fluxes [thereby influencing skin temperature and directly affecting the dynamics of mean air temperature and water vapor concentration in the ABL. On the other hand, the ABL, with its unique coexistence of mechanically and thermally generated turbulence, acts as an integrator of these surface processes with larger length and slowly evolving synoptic

scale processes affecting entrainment. The dynamics of these land surface fluxes and soil-plant-atmosphere state variables control the simultaneous growth of the convective boundary layer and lifting condensation level (LCL) and thus their crossing—a necessary but not sufficient condition for triggering convection. Even in the most idealized cases, any exploration of the feedback mechanisms between soil moisture and convection triggers must account, at minimum, for all these pathways at the appropriate scales. To progress on this problem, a soil-plant hydrodynamics model was coupled to a simplified atmospheric boundary layer (ABL) budget to explore the feedback of soil moisture on convection triggers. The soil-plant hydraulics formulation accounted mechanistically for features such as root water uptake, root water redistribution, and midday stomatal closure, all known to affect diurnal cycles of surface fluxes and, consequently, ABL growth. The ABL model considered the convective boundary layer as a slab with a discontinuity at the inversion layer. A 30-day dry-down simulation was used to investigate the possible feedback mechanisms between soil moisture and convective rainfall triggers. Previous studies, which made use of surface flux measurements to drive an ABL model, have postulated that a negative feedback was possible, which could award the ecosystem with some degree of self-regulation of its water status. According to model simulation results here, this negative feedback is unlikely. However, drastic changes in external water sources to the ABL are needed for triggering convection when soil moisture is depleted. The apparent negative feedback originated from a decoupling between the water vapor sources needed to produce convection triggers and surface water vapor fluxes.

(given in English)