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Land-Atmosphere Interactions in Human-Natural Indian Summer Monsoon System

Subimal Ghosh
Department of Civil Engineering, Indian Institute of Technology Bombay, India (subimal@iitb.ac.in)

The Indian Summer Monsoon Rainfall (ISMR) holds pivotal importance in the predominantly agrarian landscape of India, occurring from June to September. While the influence of large-scale atmospheric circulation on the monsoon has been extensively studied, the role of land surface processes remained largely unexplored until the early 2000s. In order to assess the impact of land surface evapotranspiration on monsoon rainfall in terms of recycled precipitation from June to September, we employed a dynamic recycling model. Our investigation revealed that land evapotranspiration contributes 20-25% of moisture to the late monsoon rainfall in September, specifically in Central and Northeast India. It is important to note that, as the recycling model relied on a reanalysis dataset, it does not account for contributions from land water management practices, such as irrigation.

To comprehensively address the human water management component within the human-natural water cycle in South Asia, we implemented a coupled land-atmosphere regional framework using the Weather Research Forecasting – Community Land Model (WRF-CLM). The primary drawbacks of the state-of-the-art irrigation schemes in land surface models, applied to Indian case studies, included the absence of provisions for considering paddy fields, which typically maintain a submerged cropland. Additionally, they did not consider India-specific irrigation practices, driven not by soil moisture measurements or agricultural necessity but by electricity and water availability, often uncontrolled and characterized by randomness. Moreover, existing irrigation datasets developed and used in the literature for South Asian regions considered the wrong crop season, focusing on pre-monsoon summer rather than the monsoon crop season, leading to misleading findings. By incorporating India-specific scenarios, our study demonstrated that alterations in land irrigation practices induce changes in atmospheric circulation, consequently influencing monsoon rainfall patterns, primarily in September. To substantiate these observations, we constructed a causal network among land-atmosphere variables across different river basins in India. Causal discovery methods revealed connections from land to atmosphere within a basin, atmosphere to atmosphere across basins, and atmosphere to land within a basin. This highlights that two neighboring river basins, traditionally assumed to be hydrologically independent when designing water management practices, are, in fact, interconnected through intricate land-atmosphere-land connections. These findings underscore the necessity for a systematic evaluation of India's proposed large-scale river interlinking project, emphasizing the importance of addressing land-atmospheric feedback to ensure the project's success and sustainability.