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On the dynamics of the July 2010 Pakistan precipitation events and the central role of land surface – atmosphere interactions

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In July and early August 2010 Russia was afflicted by an unprecedented heat wave and by drought conditions that lead to the death of several thousand people, forest fires, and significant losses in crop harvest. Concomitantly several severe precipitation events and ensuing floods affected Pakistan. At times more than 20% of the country was submerged, causing a humanitarian catastrophe and resulting in significant agricultural and economical losses. The two events did not occur independently and were dynamically closely linked. At upper-levels the flow over western Russia was dominated by the recurrent formation of long-lived anticyclones, so-called blocks during July and early August. Along the downstream flank of these blocks several upper-level troughs formed. These troughs were positive upper-level potential vorticity (PV) anomalies that significantly influenced the low-level wind field over Pakistan. The upper-level anomalies enforced the surface flow component perpendicular to the Himalaya mountains. The ensuing forced lifting of very moist air masses resulted in significant precipitation amounts. Compared to climatology the frequency of upper-level troughs was highly unusual.
Besides the upper-level forcing, evapotranspiration and large-scale advection over land was of fundamental importance for the precipitation events. Detailed analyses of the moisture pathways from the Indian Ocean to northeastern Pakistan using trajectory analyses revealed that a substantial fraction of the moisture that was rained-out over northeastern Pakistan stemmed from the land surface. This is confirmed by model experiments where the moisture flux from the land surface into the atmosphere over Pakistan was turned off 48 hours prior to the onset of a major precipitation event. For this event the area mean precipitation over northeastern Pakistan was reduced by 60% in the experiment compared to a control simulation (this corresponds to a reduction of the area mean 48-hour precipitation by 30mm). Not only the mean but also the precipitation maxima were affected. The maximum (90th percentile) value of the precipitation in northeastern Pakistan was reduced by 50% (46%).