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Surface deformations by ground water depletion over N.W. India: local and global scale observations using InSAR and space geodesy and their geological implications

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The rapid ground water depletion, especially by the anthropogenic activities occasionally causes various environmental disasters such as intensive ground subsidence. An obvious case was founded over Northwest India centered on Punjab and Haryana. The ground water depletion over Northwest India resulted from the overuse of groundwater by the demands of irrigation and industrial purposes. Its presence has been well known by the progressed groundwater level decline as well as the observations by spaceborne geodesy employing Gravity Recovery and Climate Experiment (GRACE) data. Thus, in this study, we conducted comprehensive remote sensing analyses over Northwest Indian areas including Punjab, Haryana and partly Rajasthan, together with spatial and geological interpretations and investigated the consequence of the ground water depletions which may evolve into the ground deformations over the surrounding areas. The Interferometric SAR (InSAR) analysis employing ENVISAT ScanSAR time series combined with a sequence of error regulation methods revealed an extensive ground deformation covering 160,000 square km. By the means of the inter-comparisons with geological context, climate data and GRACE liquid water equivalent thickness, this was clearly inferred as the outcome of the ground water depletion. In addition, we also discovered a strong local ground deformation anomaly around Ambala city located in northern Haryana which showed the most significant ground subsidence with maximum cumulative deformation up to 0.2 meters within 3 years. We incorporated the detailed InSAR time-series investigation employing L-band PALSAR-1, 2 and C band Sentinel-2 and ENVISAT with the geological contexts and the socio-economic factors. Such efforts proved that two ground deformations, the extensive surface deformation centered on Punjab and Haryana and “Ambala anomaly”, were originated by different mechanisms. Conclusively it was identified the extensive ground deformation around the Punjab and Haryana was mainly induced by a seasonal ground water deficiency in the post monsoon seasons, though it has been accumulated in non-negligible ground subsidence in the last decades already. However, “Ambala anomaly” was originated by the damage in poor water aquifer and aquitard consisting independent ground water system around Ambala. Our analyses are currently showing the ground subsidence in “Ambala anomaly” is the most fatal revelations of the permanent damage of the ground water system and should be accounted as a potential source of significant secondary hazard. Based on such context, we are planning further interpretations and analyses to assess the progress on the ground deformation and potential risks utilizing the new space borne sensors and ground survey data.