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Lithosphere stress changes due to groundwater unloading in North China Plain

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During the past 50 years, excessive groundwater pumping has led to the continuous decline of groundwater table in North China Plain, which becomes one of the global hotspots of groundwater depletion. Over most of the rural areas of the plain, the shallow aquifer has experienced a water-table decline of more than 15m, with greater declines up to 50m in most urban centres, such as Beijing, Tangshan, Shijiangzhuang and so forth in 1960-2000. The entire groundwater depletion area covers a total area of approximately 56,273 km^2 , more than 40% of the North China Plain. The vast area of enormous groundwater exploitation in North China Plain will definitely unload the lithosphere and create stress perturbations, the problem is if the stresses change large enough to affect tectonic activities. In this essay, we set up a 3 dimensional numerical visco-elastic model to discuss the effect of groundwater over-pumping on the lithosphere deformation and stress state in North China Plain.

Based on the records of total groundwater-table decline during 1960-2010 in North China Plain, we estimate the accumulated deformation and lithosphere stress due to unloading of human-induced groundwater depletion. The area in the model ranges from 34° To 42°N, and 112° To 119°E, including the major groundwater depression cones in North China Plain. According to the simulating result, the maximum surface vertical uplift caused by groundwater unloading is 8cm. Meanwhile cumulative horizontal crustal stress changes near the surface goes up to 100kPa, and up to 40kPa at 15km depth where most earthquakes occurred in this area. The tectonic compressive stress rate is about 0.25kPa per year. Therefore, the stress changes due to groundwater pumping is significant compared with the tectonic driven stress changes. As China developed rapidly since 1978, the groundwater table mainly declined after 1978. Taking the earthquake catalog in the vicinity of groundwater depression zone into consideration, we find that the earthquake events between1978-2014 are obviously less than that during the former 35-year period. There are 11 earthquakes with magnitude greater than M6.0 occurred during 1942-1977 and none in the period of 1978-2014. Although the seismicity may have natural fluctuations, the human effects cannot be excluded, as earthquake events are controlled by regional tectonic stress, which is significantly perturbed by groundwater overpumping in North China Plain. This study also suggests that earth is a complex system, in which each part interacts with others. Human activities on the earth surface may not only affect the atmosphere and the hydrosphere as well known, but also affect the lithosphere.