Hydrological Unloading of the High Plains Aquifer from Space Geodesy and Ground Networks

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Abstract:

High-precision GPS positioning data can identify patterns in vertical land motion that can illuminate previously unknown crustal processes. In the Great Plains physiographic province of the United States, we use data from 379 GPS stations to construct a regional image of vertical velocity trends. It shows an area 670 km x 280 km with a crustal uplift signal of ~2 mm/year located in the southern Great Plains. This feature is spatially correlated with the southern High Plains aquifer, which lies beneath eight states and is the largest groundwater system in the United States (~450,000 km^2). For the past century, groundwater well data indicate that water levels are declining for the majority of the aquifer, and decline especially fast in the south. Parts of the aquifer located in the Texas Panhandle region measure water table loss >45 m, approximately where the maximum uplift signal is shown by GPS data.

To determine whether the uplift mechanism is related to declining aquifer levels, we investigated changes in the rate, seasonality, and timing of the aquifer response to water content changes using GPS and GRACE data, their relation to climate trends, and anthropogenic activity. Our results indicate that the observed uplift is consistent with seasonal and anthropogenic-driven hydrological unloading further aggravated by climate change. The High Plains aquifer lies at the intersection of 3 uplift timing domains, where peak uplift occurs in spring, summer, or autumn. Our elastic model of water mass removal in the Texas Panhandle region estimates a volume loss of −5.1 km^3/year which is sufficient to drive the crustal uplift signal observed by GPS.

Typically, groundwater depletion in large aquifers is associated with subsidence rather than uplift. However, the sign of vertical land motion driven by aquifer depletion depends strongly on aquifer confinement style, and should considered when interpreting vertical signals.

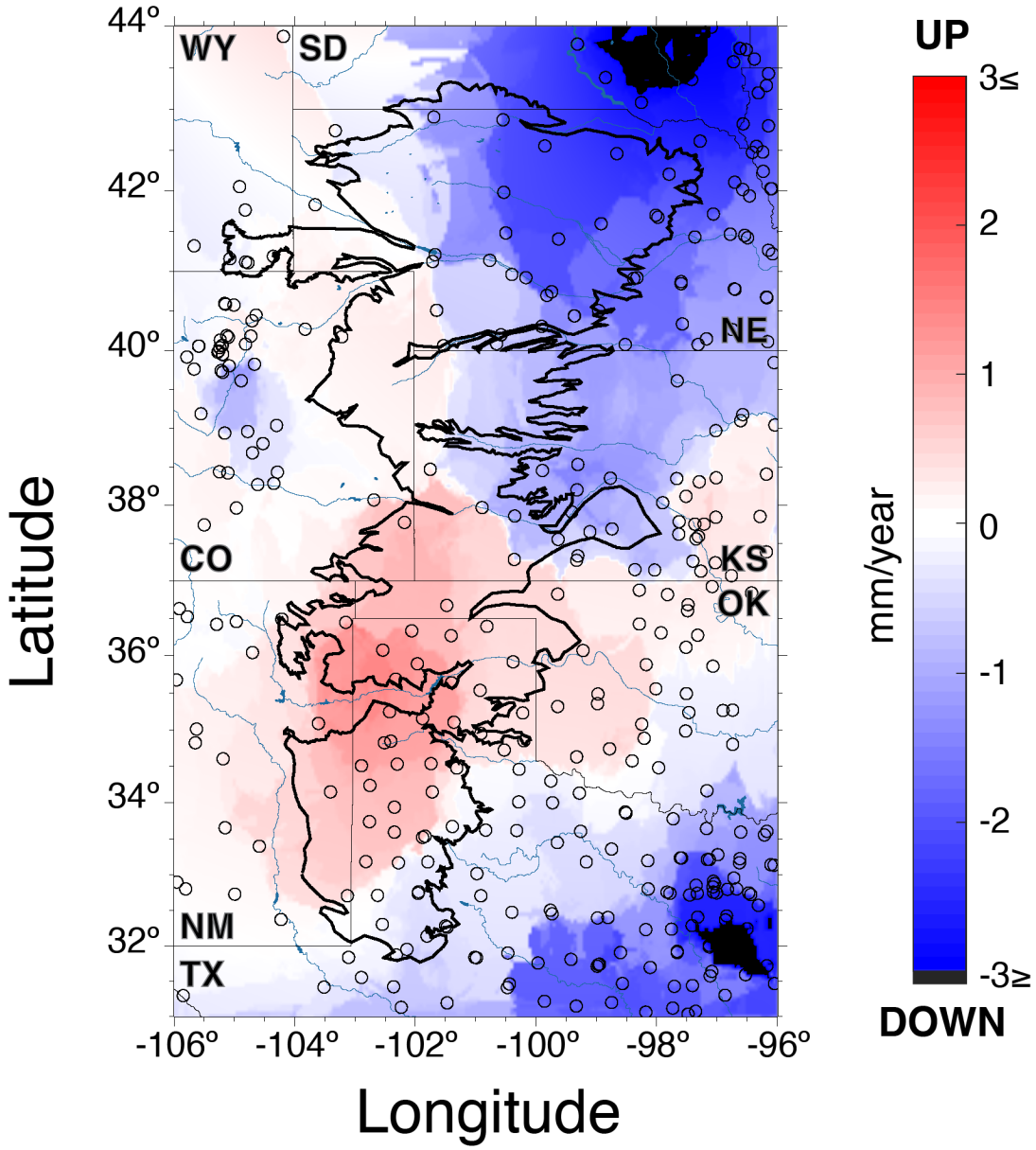

Figure 1. Map view of Great Plains GPS vertical land motion with model for glacial isostatic adjustment removed. Crustal uplift signal (red) of ~2 mm/year is approximately located within the southern part of the High Plains aquifer (outlined in bold black) which is in contrast with surrounding subsidence (blue). GPS stations shown with black circles.