Tracking groundwater depletion

As water demand rises rapidly, some regions are withdrawing groundwater faster than it can recharge. Now scientists can couple new space-based observations with models and data to quantify global and regional groundwater changes, reports **Ninad Bondre.**

While conducting fieldwork in the villages of western India, my colleagues and I were often trailed by a group of curious onlookers. When we informed them that we were geologists, observing rocks and collecting samples, someone invariably asked: "Could you give me some tips about water?" It was groundwater that they were interested in, wanting to know the best locations to dig productive wells or how long they would continue to get an assured supply from their existing wells. It is no surprise that for these subsistence farmers and small landholders at the mercy of the Southwest Monsoon, a prognosis about local groundwater was critical.

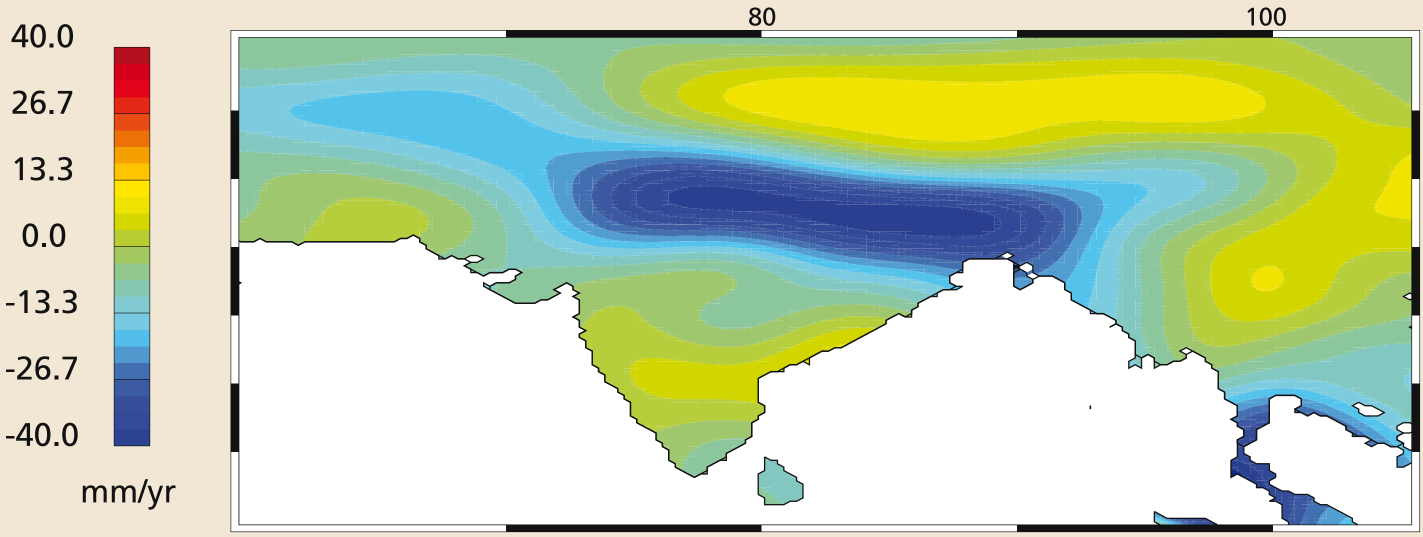
Globally, groundwater is about a quarter of the total water consumed (Döll 2009). Irrigated agriculture accounts for almost 80 percent of freshwater use, and in India, almost half of the water used for irrigation comes from aquifers. Groundwater can be relied upon during times of low surface-water availability, particularly in regions dominated by strongly seasonal precipitation. And it is an assured source of relatively clean water in regions where surface water sources are highly polluted (Döll 2009). But increases in population, industrialisation and the areas of land brought under irrigation are putting unprecedented pressure on groundwater resources.

Natural recharge is no longer replenishing the aquifers adequately.

A case in point is the northern Indian subcontinent. We knew from well data that groundwater withdrawals here were exceeding recharge, leading to a lowering of water tables. But the scale and seriousness of the problem became apparent in 2009, after two independent groups published their findings. Using observations made by NASA's Gravity Recovery and Climate Experiment (GRACE) satellites, these studies showed a dramatic depletion of groundwater in this region from 2002-2008 (Rodell *et al*. 2009; Tiwari *et al*. 2009). Consistently high rates of withdrawal lowered water tables by up to 4 cm/year (see figure). Natural recharge is no longer replenishing the aquifers adequately.

GRACE data have also provided insights into the scale of groundwater withdrawal in other regions. In California's agriculturally productive Central Valley, for example, the water tables have been lowering at the rate of 2 cm/year during the past six years or so (Famiglietti *et al.* 2011). Interestingly, the GRACE mission – a pair of satellites in polar orbit constantly measuring the distance between each other – had nothing to do with monitoring groundwater. It was designed to measure changes in the Earth's gravitational field, which could then be used to infer regional variations in mass. But as Felicity Barringer writes in the *New York Times* (30 May), the creative use of GRACE by hydrologists has provided a powerful new way to monitor regional and global changes in groundwater, which until recently relied heavily on compilation of data gathered from thousands of individual wells.

The concerns raised by GRACE-based studies are confirmed by other approaches. A global analysis published last year used a hydrological model to quantify recharge and a variety of records to estimate withdrawal (Wada *et*



Changes in groundwater storage in the Indian subcontinent (mm/year) estimated using GRACE data. Note the zone of marked depletion extending from the northwest to the northeast. Figure courtesy Sean Swenson, University Corporation for Atmospheric Research.

al. 2010). The results show that globally, the difference between withdrawal and recharge has more than doubled compared to what it was in 1960.

This is not to say that groundwater is depleting uniformly around the world. Recharge is sufficient to balance withdrawal in many regions, for example in the northeastern United States and much of Europe. But what is worrying about recent results is that groundwater use is unsustainable in precisely those regions that will continue to rely on it the most for irrigation and domestic consumption – highly populated regions like northern India and arid or semi-arid regions like the southwestern United States.

Climate change adds a new twist to the tale. There is some potentially good news for regions like northern India in that models indicate no substantial change in groundwater recharge by 2050, and even a slight increase (Döll 2009). This is because of an expected increase in precipitation in this region as the Earth warms (although the projections of different models regarding precipitation vary widely). But Tiwari *et al.* (2010) point out that a warmer world will entail greater evapotranspiration, which might balance out the gains in this region due to increased precipitation and recharge. And future demand for groundwater in the region could be different from current demand.

Studies that rely on GRACE data and global hydrological models provide a broad overview of groundwater depletion. This is also the case with simulations of changes in groundwater recharge due to future climate change. Such studies could be invaluable in informing policy decisions at the state or national level. However, they cannot be relied on solely by those entrusted with managing smaller administrative units.

The challenge is to distil the relevance of global findings to local settings – such as those farmers in western India – accounting for a host of variables including changes in population, socio-economic conditions, demand and future availability of surface water. We need to act now to find solutions to ensure that these underground stores of water remain wellsprings for the future.

Climate change adds a new twist to the tale.

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