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On the difficulties in estimating water balance components from remote sensing in an anthropogenically modified catchment in southern India

Tejas Kulkarni[1], Mathias Gassmann[1], and Sanaz Vajedian[2]
[1]Universitat Kassel, Institute of water, waste and environment, Department of Hydrology and Substance Balance, Kassel, Germany (tc.kulkarni@gmail.com)
[2]Leibniz Universitat, Hannover, Institute of photogrammetry and geodesy

The Arkavathy river was once a major water supply source to the city of Bangalore, India, till 1970s but has completely dried up post the 1990s. The study re-invigorates on the socio-hydro dynamics in the Upper Arkavathy Catchment (UAC), covering 1432 km^2, through the combination of latest remote sensing products (namely Gravity Recovery and Climate Experiment (GRACE), Global Land Data Assimilation System (GLDAS), Landsat derived NDVI). The parameters of remotely sensed long-term precipitation and temperature from corresponded well with in-situ data. Seasonal trend analysis helped re-instate no evidence of climatic driven drought to explain the decline of flows in the river. To investigate the anthropogenic proximate drivers of change - mainly groundwater exploitation and increase in water intensive cropping in the catchment - a spatio-temporal assimilation of GRACE TWS, GLDAS state variables and LandSAT-NDVI with in-situ well observations is incorporated into the water balance equation. While, studies have shown high correlation in quantifying groundwater storage changes (GWSC) and attempted downscaling with this GRACE-GLDAS-GWL-NDVI assimilation in natural catchments, this did not seem to be very skilful in human-altered fractured rock aquifers of south India for the following reasons. Firstly, the GRACE-TWS (RL-06) for the grid showed a meagre declining trend of -.033mm/year (2002-2018) and did not seem to capture the deeper groundwater extraction as compared to the social narrative in shift of hundreds of metres decline in static water levels. Secondly, the disaggregation through the GLDAS-NOAH soil moisture which corresponded well with rainfall patterns, assigns inclusion of only the shallow storage fluxes in the sub-surficial aquifer showing -5.3mm/year, which explains no overland flows in the river, but neglects the modelling of the GW aquifer and showed a faulty +47.4mm/year (2002-2018). Thirdly, the simple addition of groundwater observation well trends showed a decrease of -106.6mm/year in GWSC (2001-2017) as compared to the -656.6mm/year (1970-2000) of field scale models by Srinivasan et.al (2015). This is attributed to the fact that data used in such studies from the governmental groundwater authority boards are generally of shallower wells (up to 70m below surface) and cannot be representative of the on-ground reality of shift to deeper exploitation of GW (up to 350m) by privatised borewells. Finally, cloud-cover and scan line error corrected NDVI pixels showed an increase of irrigated area in the UAC by 31% (1972-2018). However, we observed long term data gaps (1998-2003) in images and

higher uncertainties during the crucial cropping season due to monsoonal cloud cover (JJASO months) in the images to effectively understand the agricultural dynamics. Hence, it is concluded that this procedure coupled with this period receiving higher rainfall with an average of1000mm/year (2001-2019) as compared to 800mm/year (1901-2000) makes it an unreliable method to disassociate the human interventions in modifying hydro-geologic fluxes or patterns accurately in the UAC.