Large-scale modelling of groundwater resources: insight from the comparison of models and in-situ observations in Sub-Saharan Africa

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Fundamental challenges remain in the large-scale modelling of groundwater resources using either Global Hydrological Models (GHMs) or Land-Surface Models (LSMs). These challenges include the representation of groundwater recharge processes and geological controls on groundwater occurrence. Current large-scale models, with one notable exception, disregard indirect (*i.e.* focused) recharge that occurs via leakage from surface waters and is often the dominant recharge pathway in semi-arid environments. Further, models do not represent the preferential pathways which can control the timing and magnitude of recharge. Additional challenges include the representation of human withdrawals of groundwater, particularly in areas of intensive irrigation, that are generally disregarded (*e.g.* LSMs) and largely untested. Indeed, because groundwater-level monitoring networks are so limited globally, current assessments of groundwater resources commonly rely upon output from GCMs and LSMs as well as GRACE satellite observations in which groundwater storage changes are resolved using large-scale model data. Such models are furthermore the primary source of information on projected climate change impacts on groundwater resources. There remains a paucity of studies examining the robustness of terrestrial water balances including estimates of groundwater recharge and storage simulated by LSMs and GHMs using in situ observations. On behalf of *The Chronicles Consortium*, I report preliminary analyses comparing groundwater recharge estimated by both LSMs and GHMs to long-term observations of groundwater levels and stable-isotope ratios. Such comparisons require careful consideration as in situ observations may not represent grid-scale averaging. Nevertheless, given the non-linearities in model parameterisations that can occur during the shift to higher grid resolutions (*e.g.* 0.5° to 5 km), it will become increasingly important to reconcile revised model structures with *in situ* observations. Preliminary results derive from the analysis of the relationship between monthly precipitation and subsurface runoff (*i.e.* proxy for groundwater recharge) from 4 LSMs (CLM2.0/CLM4.5, NOAH, MOSAIC, VIC) and 3 GHMs (PCR-GLOBWB, WaterGAP, MATSIRO) at 1°x1° and both multi-decadal records of groundwater levels from 8 countries (Benin, Burkina Faso, Ghana, Niger, South Africa, Tanzania, Uganda, Zimbabwe) and stable-isotope ratios collated from long-term IAEA stations and published sources in 7 countries (Burkina Faso, Chad, Ethiopia, Namibia, South Africa, Tanzania, Zimbabwe). Analyses reveal substantial spatial variability among the GLDAS LSMs in subsurface runoff across Africa. Precipitation and subsurface runoff in LSMs show non-linear (*i.e.* reflecting bias to heavy rainfall), linear, or no bivariate associations in contrast to consistently non-linear relationships noted from the comparison of stable-isotope ratios in rainfall and groundwater. GHMs also demonstrate substantial variability in computed potential recharge though greater consistency is observed in their dependence of groundwater recharge on monthly or seasonal rainfall exceeding a monthly or seasonal threshold, consistent with some piezometric records. A key outcome from the analysis of multi-decadal groundwater-level data is the importance of indirect recharge processes (*e.g.* Niger, South Africa, Tanzania, Zimbabwe) despite their current exclusion from all but one large-scale model. On-going initiatives (*e.g.* GEWEX-GHP/GLASS, *The Chronicles Consortium*) seeking to bring large-scale modelling and GRACE communities together with those analysing *in situ* observations are urgently required to address fundamental and substantial limitations that persist in the modelled representation of groundwater in the terrestrial water balance, particularly in the tropics.

Keywords: groundwater, piezometry, models, stable-isotope ratios

