Hydrol. Earth Syst. Sci. Discuss., 7, C2300–C2305, 2010
www.hydrol-earth-syst-sci-discuss.net/7/C2300/2010/

Hydrology and Earth System Sciences Discussions

Interactive comment on "Interpretation of GRACE data of the Nile Basin using a groundwater recharge model" *by* H. C. Bonsor et al.

H. C. Bonsor et al.

helnso@bgs.ac.uk

Received and published: 14 September 2010

The authors thank the reviewer for their comments. Below we answer the questions raised.

General comments

We disagree with the reviewer's assertion that we have not fulfilled our aim. Our stated aim was to interpret mass changes inferred from GRACE data for the Nile catchment using a groundwater recharge model. The paper does not claim to discuss the efficacy of different hydrological models for the Nile. We believe that our results are a useful addition to Nile hydrology in providing a modelled estimate of groundwater recharge for

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

the basin with validation from the limited data available – river flows and some existing recharge studies. With regard to moisture recycling, since this is (to our knowledge) the first published account of GRACE data for the Nile catchment, it would be remiss not to discuss the large differences between rainfall and mass change across the catchment.

The main reason for choosing a groundwater recharge model was that a) various authors (e.g. Schmidt et al. 2006) have suggested that groundwater recharge is a major component of water storage changes observed by GRACE and often not the focus of existing global models, and b) groundwater recharge models are usually applied at a smaller catchment scale, so we thought it interesting to upscale using this approach, rather than downscale using a global model.

Specific comments

Point 1:

1. We agree that the discussion behind why we used a groundwater recharge model was too condensed in the paper, and appears too dismissive of the global land surface hydrological models.

Within the paper, we state that soil moisture and groundwater in land surface hydrological models are often simply calculated as the remainder. This would be better articulated as groundwater recharge is often calculated as a remainder in these models. This is a fair description of these models as they are designed to represent overland flow processes or soil processes, and not specifically to calculate recharge to the groundwater system.

Work by Schmidt et al. (2006) found the continental water storage changes simulated by these models to be significantly less than that indicated by GRACE data. The WaterGAP Global Hydrology Model (WGHM) uses a soil store, but appears to partition recharge from runoff by various factors (e.g. Doll and Fiedler, 2008). Whilst these factors are comprehensive, including the impact of glaciations, they are qualitative as-

HESSD
7, C2300–C2305, 2010
Interactive Comment

sessments made using expert judgement. This is a valid approach and appropriate for the use of the WGHM on a global basis. However, the aim of this paper was to see if by using a groundwater recharge model, which focuses specifically on calculating groundwater recharge, the groundwater proportion of terrestrial water storage changes indicated by GRACE data could be interpreted.

2. Recharge models, such as ZOODRM, focus on the calculation of recharge that arrives at the water table and are weaker on other processes. ZOODRM is a distributed model that was originally designed to calculate recharge at a catchment scale (∼10 000s km2) and has been modified to operate at a trans-national basin scale (e.g. ∼1 000 000s km2). It still retains the processes that typically operate at the catchment scale. However, the data requirements are still modest which makes it appropriate to use on a large-scale basis. It is this combination of catchment scale processes with modest data requirements that was the attraction for using ZOODRM. See http://www.oomodels.info/

We state clearly the limitations of the model in the paper. We are not trying to say that ZOODRM is the only model that can be used, but it is a model which allows us to examine recharge processes using justifiable quantitative parameters. The value of this work is then to apply this recharge model, to interpret water mass changes indicated by GRACE data specifically with respect to groundwater recharge. To our knowledge recharge models had not been applied to interpret GRACE data in this way before; GRACE data from the Nile basin has not been reported before; and there have been no previous estimates of groundwater recharge for the Nile Basin.

3. Irrigation losses – flow in the River Nile is low relative to the size of the catchment and the precipitation. Although there is a difference between the flow from the Aswan dam and the Nile outflow to the Mediterranean Sea, the difference is small relative to the evaporative losses within the rest of the catchment. Figure 1 can be amended to illustrate this, by including a hydrograph of the Nile river flow immediately downstream of the Aswan dam.

HESSD

7, C2300–C2305, 2010

4. Groundwater discharge – this is an assumed volume, not a modelled volume. Given that the groundwater is not abstracted in large volumes in the parts of the basin where groundwater recharge occurs, it is hydrogeologically reasonable to assume that the groundwater is in quasi equilibrium and that annual discharge is equivalent to annual recharge.

Point 2:

The discussion on moisture recycling relies little on the modelling (only the large volume of evapotranspiration) and mostly on comparison between the GRACE data and observed hydrological data (precipitation and river discharge). We agree that it is not possible to definitively interpret sources of water mass change by interpretation of the GRACE data alone. However, we construct the argument that given the large difference between observed annual precipitation volume (2000 km3) and annual mass changes (150 km3) from GRACE that a plausible explanation is moisture recycling. This is further substantiated by the modelled evapotranspiration (1300 km3) and the small changes in atmospheric moisture (modelled by ECMWF for correcting the GRACE data for atmospheric changes). Yes, the evaporated water could all leave the catchment, and new atmospheric water could replace it to form the precipitation, but a simpler explanation exists in moisture recycling. Fontaine et al. (2002) also inferred a similar importance to moisture recycling in the functioning of West African basins. Given your comments – we would be happy to clarify our discussion in the paper.

Point 3:

We accept these figures are very similar, and this could be addressed in conjunction with point 4 of the reviewer's comments. Figure 6 compares the relative split of the soil moisture and groundwater water mass changes modelled, to the total water mass variation indicated by GRACE data; figure 7 compares the combined total water mass variation of soil moisture and groundwater, to the water mass change indicated by GRACE.

HESSD

7, C2300–C2305, 2010

Point 4:

We agree with this comment, and we can include a table or amend Figure 6 to show a water balance for all the components in the model, including evaporation from wetlands.

Point 5:

We don't claim that we have produced a fully calibrated model, but rather used the application of ZOODRM in comparison with the GRACE data to develop an understanding of how the Nile basin operates, focussing on groundwater recharge. We state clearly that future work would be to improve calibration by moving from comparisons of annual river discharge to seasonal discharge.

The calibration of the model uses parameters that are available in the literature, i.e. root constant and wilting point, and only overland losses are modified within the calibration (the run-off and run-on coefficients). We agree that due to the non-overlapping time periods of the observed discharge data and climate input data calibration is difficult.

However, the calibration, although not a full calibration, is not meaningless. The observed discharge data is only 14% different to modern discharge data at the same gauges where data is available, and, the observed data used is also comparable to the long-term average discharge of the Nile. The recharge rates gained from the model are also similar to those calculated from the few site specific groundwater recharge studies within the catchment.

References

Döll, P and Fiedler, K. Global-scale modelling of groundwater recharge, Hydrol Earth Syst Sci, 2008, 12; 863–885.

Fontaine, B., Roucou, P. and Trzaska, S. Atmospheric water cycle and moisture fluxes in the West African Monsoon: mean annual cycles and relationship using NCEP/NCAR reanalysis, Geophys Res Lett, 2002; 30; 3; 1117-1121.

Schmidt, R, Schwintzer, P., Flechtner, F. Reigber, Ch., Guntner, A., Döll, P., Ramillien, G., Cazenave, A., Petrovic, S., Jochmann, H., Wunsch, J. GRACE observations of changes in continental water storage, Glob Planet Change, 2006; 50; 112-126.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 4501, 2010.