Hydrology and Earth System Sciences

An Interactive Open Access Journal of the European Geosciences Union

Hydrol. Earth Syst. Sci., 11, 1227-1241, 2007

www.hydrol-earth-syst-sci.net/11/1227/2007/

doi:10.5194/hess-11-1227-2007

The bias in GRACE estimates of continental water storage variations

R. Klees[1], E. A. Zapreeva[1], H. C. Winsemius[2], and H. H. G. Savenije[2]

[1]Delft Institute of Earth Observation and Space Systems (DEOS), Delft University of Technology, The Netherlands

[2]Department of Water Management, Delft University of Technology, The Netherlands

Abstract. The estimation of terrestrial water storage variations at river basin scale is among the best documented applications of the GRACE (Gravity and Climate Experiment) satellite gravity mission. In particular, it is expected that GRACE closes the water balance at river basin scale and allows the verification, improvement and modeling of the related hydrological processes by combining GRACE amplitude estimates with hydrological models' output and in-situ data.

When computing monthly mean storage variations from GRACE gravity field models, spatial filtering is mandatory to reduce GRACE errors, but at the same time yields biased amplitude estimates.

The objective of this paper is three-fold. Firstly, we want to compute and analyze amplitude and time behaviour of the bias in GRACE estimates of monthly mean water storage variations for several target areas in Southern Africa. In particular, we want to know the relation between bias and the choice of the filter correlation length, the size of the target area, and the amplitude of mass variations inside and outside the target area. Secondly, we want to know to what extent the bias can be corrected for using a priori information about mass variations. Thirdly, we want to quantify errors in the estimated bias due to uncertainties in the a priori information about mass variations that are used to compute the bias.

The target areas are located in Southern Africa around the Zambezi river basin. The latest release of monthly GRACE gravity field models have been used for the period from January 2003 until March 2006. An accurate and properly calibrated regional hydrological model has been developed for this area and its surroundings and provides the necessary a priori information about mass variations inside and outside the target areas.

The main conclusion of the study is that spatial smoothing significantly biases GRACE estimates of the amplitude of annual and monthly mean water storage variations and that bias correction using existing hydrological models significantly improves the quality of GRACE estimates. For most of the practical applications, the bias will be positive, which implies that GRACE underestimates the amplitudes. The bias is mainly determined by the filter correlation length; in the case of 1000 km smoothing, which is shown to be an appropriate choice for the target areas, the annual bias attains values up to 50% of the annual storage; the monthly bias is even larger with a maximum value of 75% of the monthly storage. A priori information about mass variations can provide reasonably accurate estimates of the bias, which significantly improves the quality of GRACE water storage amplitudes. For the target areas in Southern Africa, we show that after bias correction, GRACE annual amplitudes differ between 0 and 30 mm from the output of a regional hydrological model, which is between 0% and 25% of the storage. Annual phase shifts are small, not exceeding 0.25 months, i.e. 7.5 deg. It is shown that after bias correction, the fit between GRACE and a hydrological model is overoptimistic, if the same hydrological model is used to estimate the bias and to compare with GRACE. If another hydrological model is used to compute the bias, the fit is less, although the improvement is still very significant compared with uncorrected GRACE estimates of water storage variations. Therefore, the proposed approach for bias correction works for the target areas subject to this study. It may also be an option for other target areas provided that some reasonable a priori information about water storage variations are available.

Final Revised Paper (PDF, 2474 KB) Discussion Paper (HESSD)

Citation: Klees, R., Zapreeva, E. A., Winsemius, H. C., and Savenije, H. H. G.: The bias in GRACE estimates of continental water storage variations, Hydrol. Earth Syst. Sci., 11, 1227-1241, doi:10.5194/hess-11-1227-2007, 2007.