River Basin Discharge Estimated From GRACE and a Land-Atmosphere Water Balance

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Abstract :

Monitoring global freshwater discharge is critical to understand a range of climatologic, geomorphologic, hydrologic and ecologic Earth system processes. However, no comprehensive global streamflow observing network for the world's major continental watersheds currently exists. Here we propose a method for estimating monthly basin discharge for large river basins based on the use of new GRACE estimates of terrestrial water storage changes in a coupled land-atmosphere water balance. The method was tested on the Amazon and Mississippi river basins, and could ultimately be applied to the major drainage regions and river basins of the globe. Results for both basins are encouraging. Using GRACE land water storage changes (which include changes in groundwater storage) in the water balance method may result in more holistic estimates of basin discharge that include not only streamflow, but the net of surface, groundwater and tidal inflows and outflows.

Objectives of our research :

(1) Derive monthly estimates of streamflow discharges using observed terrestrial water changes (GRACE) in a combined land atmosphere water balance for two of the world's biggest river basins. (Amazon and Mississippi)

(2) Validate the estimates using in-situ stream gauge data.

(3) Lay the foundation for estimating global terrestrial discharges at monthly time scales using GRACE.

Data Sources :

(1) **GRACE Data :** 22 monthly solutions (Level 2) spanning from Apr '02 till Jul '04 with the exclusion of Dec '02, Jan '03 and Jun '03 were provided by the Center for Space Research at UT Austin.

(2) **Stream Gauge Data:** Daily streamflow data for the Vicksburg gauge in the Mississippi river basin was provided by the United States Army Corps of Engineers (USACE) and for the Obidos gauge in the Amazon river basin by the National Water Agency (ANA) of Brazil.

(3) **Atmospheric Data :** Daily estimates of total column precipitable water (W) and divergence of the atmospheric moisture flux were computed from the European Center for Medium Range Forecast (ECMWF) data. (http://www.ecmwf.int/-research/ifsdocs/CY25r1/index.html; http://www.ecmwf.int/products/-data/operational_system/evolution/index.html)

Data Processing :

(1) The storage change fields were obtained from GRACE solutions truncated at degree 60 and smoothed with a Gaussian averaging kernel of 1000km.

(2) Daily estimates of streamflow, W and $\nabla.\mathbf{Q}$ were aggregated to monthly estimates. This is done in a way that is close to the temporal sampling of GRACE.

(3) All the estimates in the combined water balance equation are averages over the respective basins.

(4) The basin masks needed for the purpose was computed with the location of the respective gauges as the outflow point. Hence only the areas draining through that point of the river is considered.

Methods :

Atmospheric Water Balance :

$$\frac{\partial W}{\partial t} = E - P - \nabla.\mathbf{Q}$$

$$P - E = -\frac{\partial W}{\partial t} - \nabla.\mathbf{Q}$$

W : Total column precipitable water

P : Precipitation

E : Evapotranspiration

$\nabla.\mathbf{Q}$: Horizontal divergence of vertically integrated atmospheric water vapor flux

Terrestrial Water Balance :

$$\frac{\partial S}{\partial t} = P - E - R$$

$$P - E = \frac{\partial S}{\partial t} + R$$

S : Total column terrestrial water storage

P : Precipitation

E : Evapotranspiration

R = Surface and subsurface runoff (including direct ground water discharge.

Combined Land-Atmosphere Water Balance :

$$R = -\frac{\partial W}{\partial t} - \nabla.\mathbf{Q} - \frac{\partial S}{\partial t}$$

Advantages of the methodology :

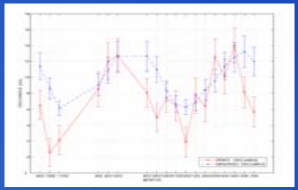
(1) Satellite based estimate of river discharge : Global access.

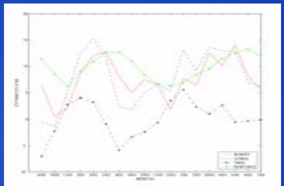
(2) Better than modeled estimates : Incorporation of impacts from changes in surface and subsurface water-bodies (Lakes/Aquifer).

(3) Better than gauge estimates : Especially in braided river channels.

Results :

Amazon River Basin :



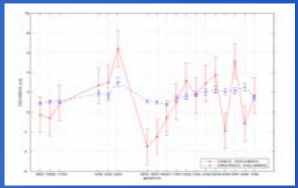


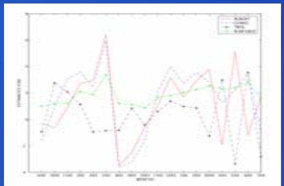
(1) Mean observed streamflow: 9.86 cm; mean estimated streamflow: 7.54 cm; RMSE : 3.85cm.

(2) Good correspondence between the peak values in observed and estimated streamflows whereas low flows are lower than observed.

(3) Estimated flows are almost always dominated by the convergence term.

Mississippi River Basin :





(1) Mean observed streamflow: 1.66 cm; mean estimated streamflow: 1.21 cm; RMSE: 2.33 cm.

(2) Major differences in the magnitude and amplitude of observed and estimated streamflow.

(3) Both the convergence and storage change terms contribute significantly towards the magnitude and variability of estimated streamflow.

References :

Syed, T.H., J.S. Famiglietti, J. Chen, M. Rodell, S.I. Seneviratne, P. Viterbo and C.R. Wilson (2005) : Amazon and Mississippi river basin discharge estimated from GRACE and a land-atmosphere water balance, *Geophys. Res. Lett.* (submitted)

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