Analysis of EWT maps from GRACE mission and land hydrology data

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Abstract

Using the Stokes coefficients from the Gravity Recovery and Climate Experiment (GRACE) gravimetric mission we can assess the Equivalent Water Thickness (EWT) maps showing the heterogeneity of the gravitational field. To obtain these maps we used the formula (1). Nevertheless the maps of EWT delivered from unfiltered data, present characteristic stripes (Figure 1a). To cut out the perturbation and to enhance the signal to noise ratio we need to use a filter to the raw data. Then we show the impact of the smoothing of the Stokes coefficients on the resulting EWT map distribution we used the Stokes coefficients made accessible and filtered by the International Centre for Global Earth Models (ICGEM) imported from three research centers GeoForschungsZentrum Potsdam (GFZ), Jet Propulsion Laboratory - NASA (JPL) and Center for Space Research (CSR) with the aid of an anisotropic method of smoothing of the geopotential coefficients from GRACE with three degrees of smoothing DDK3, DDK2 and DDK1 (Kusche 2009). The result of filtering may be seen on Figures 1b, 1c and 1d.

Additionally we made some researches with NOAA Climate Prediction Center (CPC) land hydrosphere geophysical model. We obtained the Stokes coefficients from EWT map from January 2007, computing with formula (2). The resulting coefficients were subjected to filtration in the same way as the GRACE data. Next the EWT maps from the filtered coefficients were computed by formula (1). The result of filtered geophysical EWT maps can be seen in Figures 2b and 2c and compared to the unfiltered map seen in Figure 2a.

Dividing the filtered by the original geophysical maps we got a scaling factor for the DDK filters. In Figures 3a to 3c we can see the scalling factor maps for DDK3, DDK2 and DDK1 filter respectively.

Computational procedure

(1) (D.P. Chambers 2006)

$$\Delta q(\phi,\lambda,t)=\frac{R_E\rho_E}{3\rho_W}\times \sum_{n=0}^{40}\sum_{m=0}^{n}\frac{(2n+1)}{(1+k_n)}P_{nm}(\sin(\phi))[\Delta C_{nm}(t)\cos m\lambda+\Delta S_{nm}(t)\sin m\lambda]$$

(2) (Wahr and Molenaar 1998)

$$\begin{bmatrix}\Delta C_{nm}\\ \Delta S_{nm}\end{bmatrix}=\frac{3\rho_W}{4\pi\rho_E R}\frac{1+k_n}{2n+1}\times \int_0^{2\pi}\int_{-\pi/2}^{\pi/2}\Delta q(\varphi,\lambda,t)P_{nm}(\sin(\varphi))\begin{bmatrix}\cos(m\lambda)\\ \sin(m\lambda)\end{bmatrix}\cos(\varphi)\,d\varphi\, d\lambda$$

$\Delta q(\varphi,\lambda,t)$ – change in water storage in a unit area

$\Delta C_{nm}, \Delta S_{nm}$ – Stokes coefficients

ρ_W – density of fresh water ($1000\ \mathrm{kg/m^3}$)

ρ_E – average density of the Earth ($5517\ \mathrm{kg/m^3}$)

R_E – mean equatorial radius of the Earth (6371 km)

φ – geographic latitude

λ – geographic longitude

$P_{nm}(\sin(\varphi))$ – fully normalized Associated Legendre Polynomials of degree n and order m

k_n – are load Love number of degree n

Figures

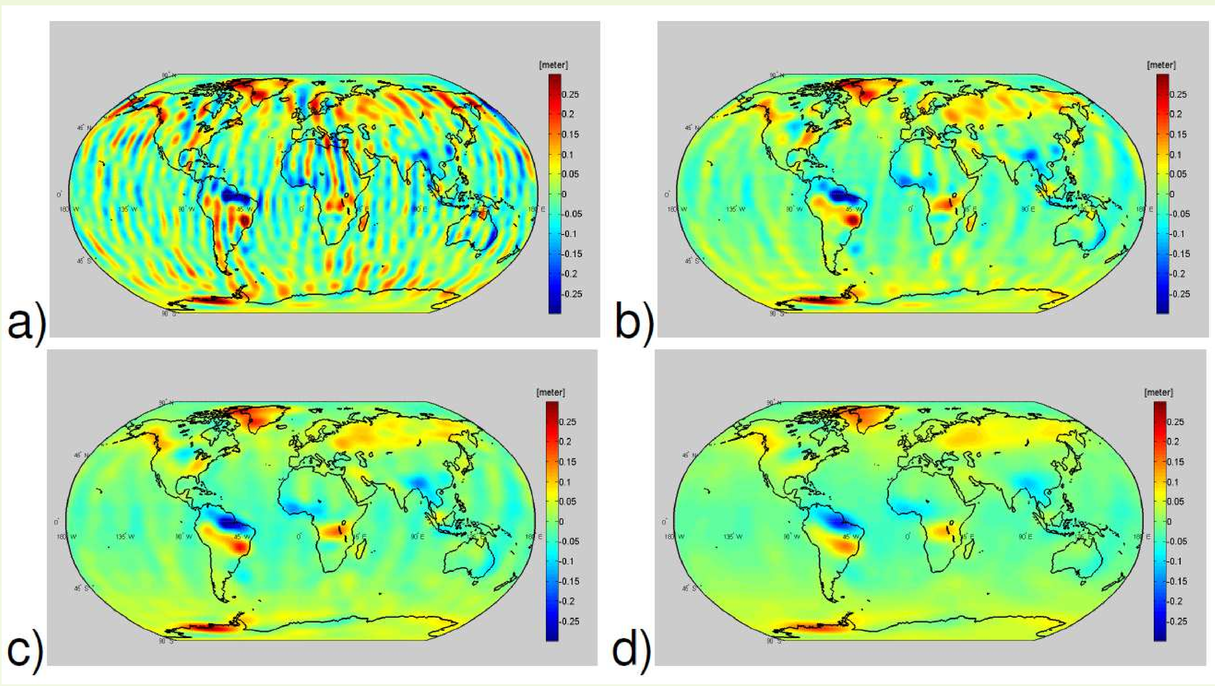

Figure 1: EWT maps computed from Stokes coefficients delivered by CSR center from January 2007 a) without filter b) filterd by DDK3 filter c) filtered by DDK2 filter d) filtered by DDK1 filter

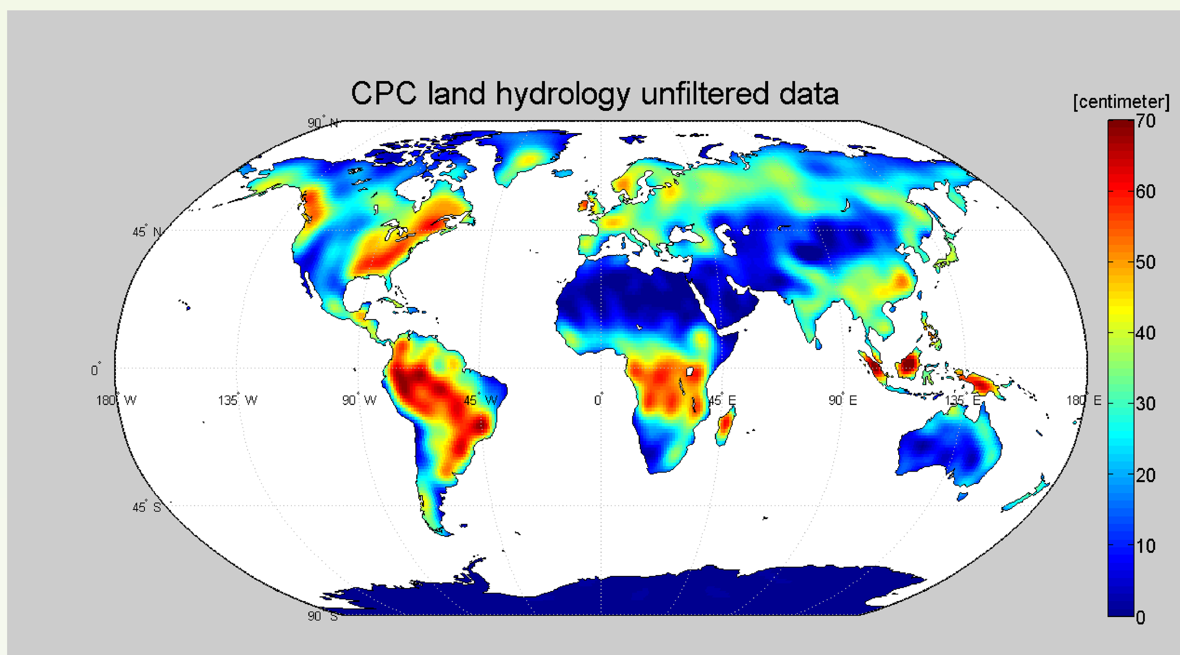

Figure 2a): EWT map from CPC model from January 2007 without any filter

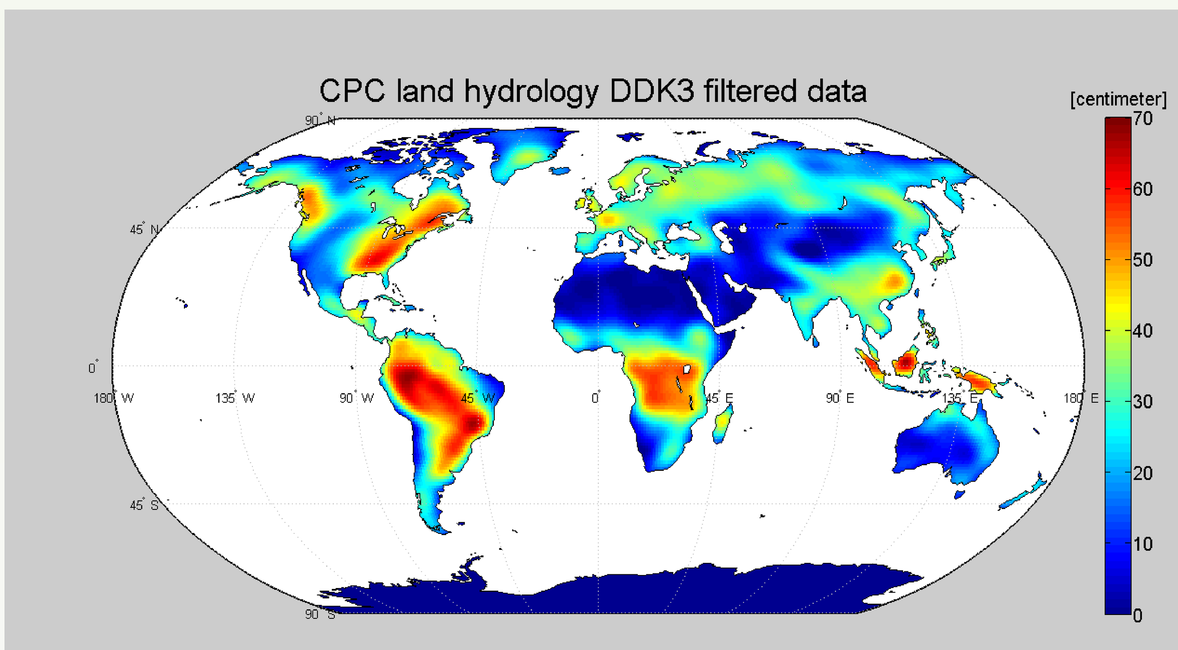

Figure 2b): EWT map from CPC model from January 2007 with usage of DDK3 filter

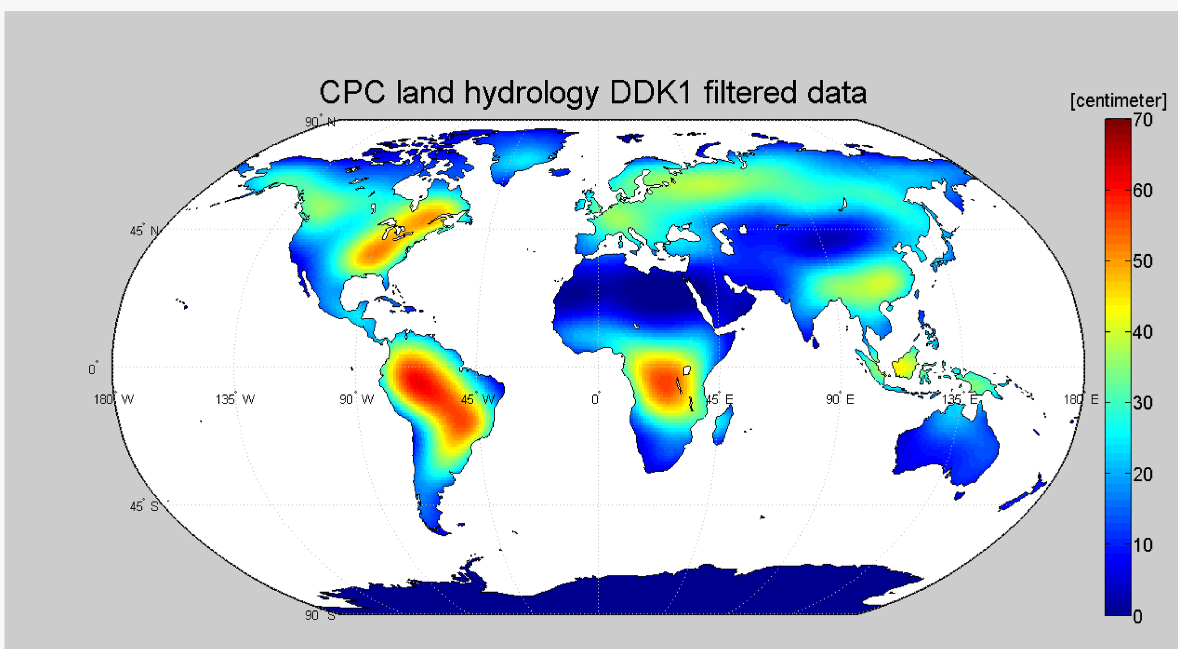

Figure 2c): EWT map from CPC model from January 2007 with usage of DDK1 filter

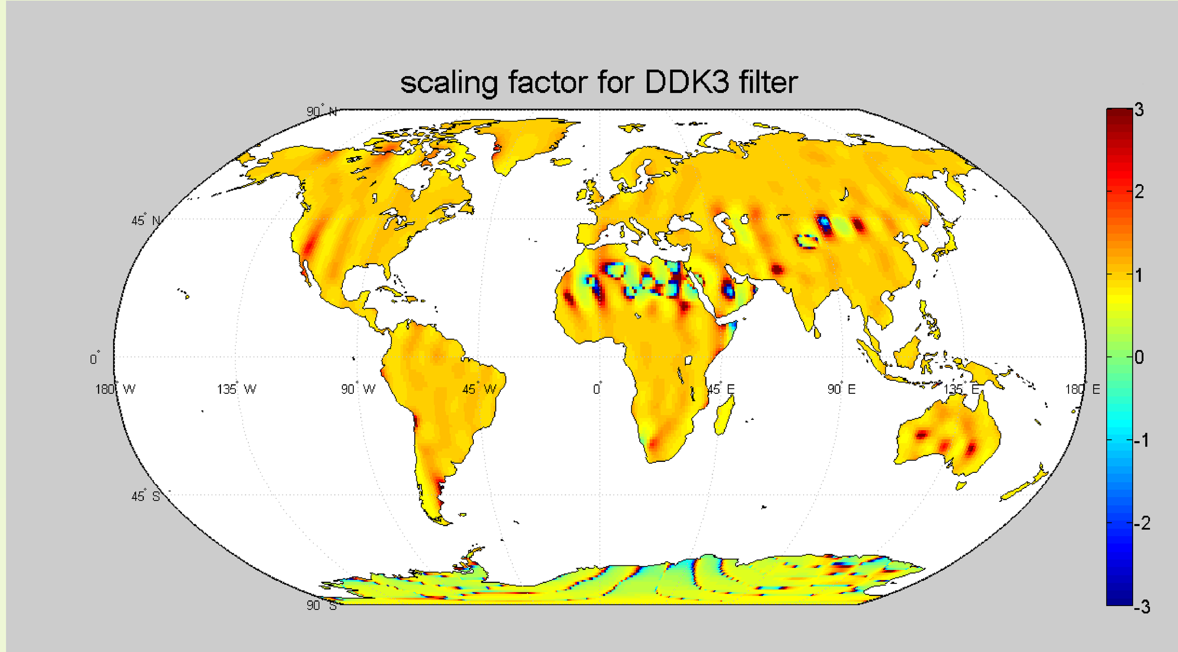

Figure 3a): Map of scaling factor for the DDK3 filter for January 2007

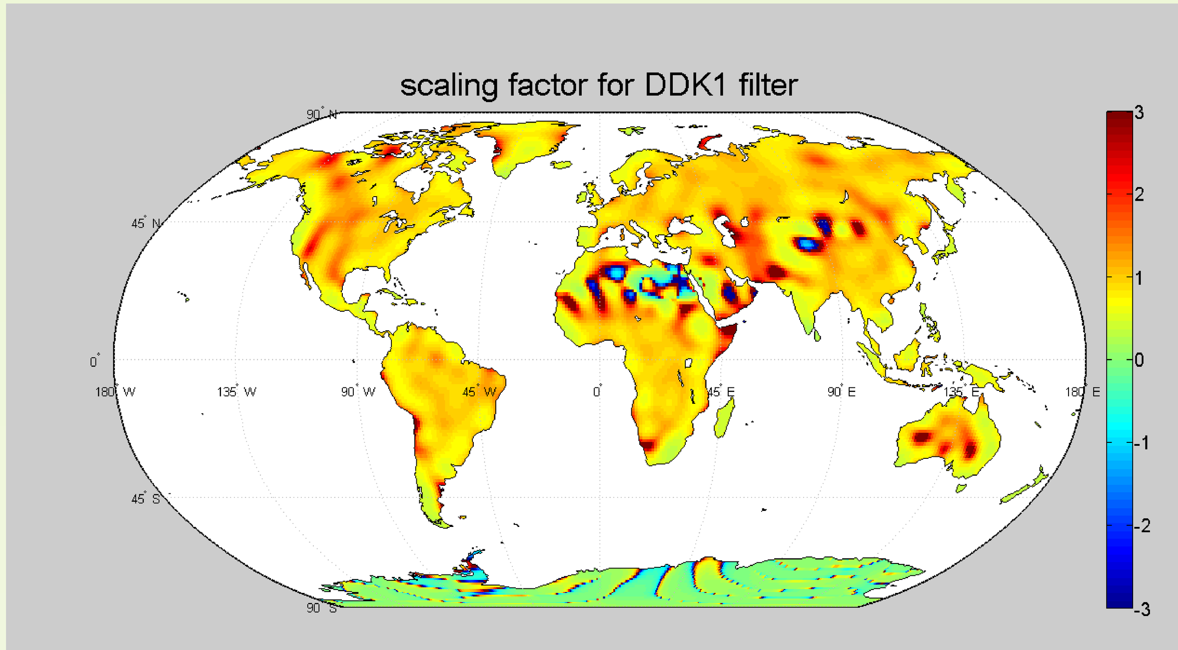

Figure 3b): Map of scaling factor for the DDK1 filter for January 2007

Conclusions

After investigating scaling factor maps we came to some conclusions. Scaling factor reaches values close to unity for DDK3 filter, about 1.3 to 1.7 for DDK2 and up to 3 for DDK1, outside several areas in North Africa, Australia and some parts of Asia, where values exceed significantly value of 3.

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