Geophysical Research Abstracts,
Vol. 11, EGU2009-7148, 2009
EGU General Assembly 2009

Assessing mass change trends in GRACE models

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The DEOS Mass Transport model, release 1 (DMT-1), has been recently presented to the scientific community. The model is based on GRACE data and consists of sets of spherical harmonic coefficients to degree 120, which are estimated once per month. Currently, the DMT-1 model covers the time span from Feb. 2003 to Dec. 2006. The high spatial resolution of the model could be achieved by applying a statistically optimal Wiener-type filter, which is superior to standard filtering techniques. The optimal Wiener-type filter is a regularization-type filter which makes full use of the variance/covariance matrices of the sets of spherical harmonic coefficients. It can be shown that applying this filter is equivalent to introducing an additional set of observations: Each set of spherical harmonic coefficients is assumed to be zero. The variance/covariance matrix of this information is chosen according to the signal contained within the sets of spherical harmonic coefficients, expressed in terms of equivalent water layer thickness in the spatial domain, with respect to its variations in time.

It will be demonstrated that DMT-1 provides a much better localization and more realistic amplitudes than alternative filtered models. In particular, we will consider a lower maximum degree of the spherical harmonic expansion (e.g. 70), as well as standard filters like an isotropic Gaussian filter. For the sake of a fair comparison, we will use the same GRACE observations as well as the same method for the inversion of the observations to obtain the alternative filtered models. For the inversion method, we will choose the three-point range combination approach. Thus, we will compare four different models:
(1) GRACE solution with maximum degree 120, filtered by optimal Wiener-type filter (the DMT-1 model)
(2) GRACE solution with maximum degree 120, filtered by standard filter
(3) GRACE solution with maximum degree 70, filtered by optimal Wiener-type filter
(4) GRACE solution with maximum degree 70, filtered by standard filter

Within the comparison, we will focus on the amplitude of long-term mass change signals with respect to spatial resolution. The challenge for the recovery of such signals from GRACE based solutions results from the fact that the solutions must be filtered and that filtering of always smoothes not only noise, but also to some extend signal. Since the observation density is much higher near the poles than at the equator, which is due to the orbits of the GRACE satellites, we expect that the magnitude of estimated mass change signals in polar areas is less underestimated than in equatorial areas. For this reason will investigate trends at locations in equatorial areas as well as trends at locations in polar areas. In particular, we will investigate Lake Victoria, Lake Malawi and Lake Tanganyika, which are all located in Eastern Africa, near to the equator. Furthermore, we will show trends of two locations at the South-East coast of Greenland, Abbot Ice-Shelf and Marie-Byrd-Land in Antarctica

For validation, we use water level variations in Lake Victoria (69000 km2), Lake Malawi (29000 km2) and Lake Tanganyika (33000 km2) as ground truth. The water level, which is measured by satellite radar altimetry, decreases at a rate of approximately 47 cm in Lake Victoria, 42 cm in Lake Malawi and 30 cm in Lake Tanganyika over the period from Feb. 2003 to Dec. 2006. Because all three lakes are located in tropical and subtropical clime, the mass change signal will consist of large seasonal variations in addition to the trend component we are interested in. However, also the amplitude of estimated seasonal variations can be used as an indicator of the quality of the models within the comparison. Since the lakesáreas are at the edge of the spatial resolution GRACE data can provide, they are a good example of the advantages of high-resolution mass change models like DMT-1.