GRACE Secular Trends and Periodic Variations at Global and Regional Scales

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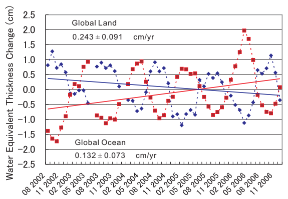
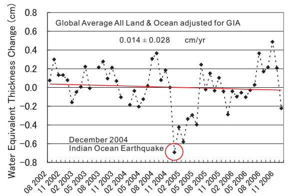
Global Secular Trends and Variations



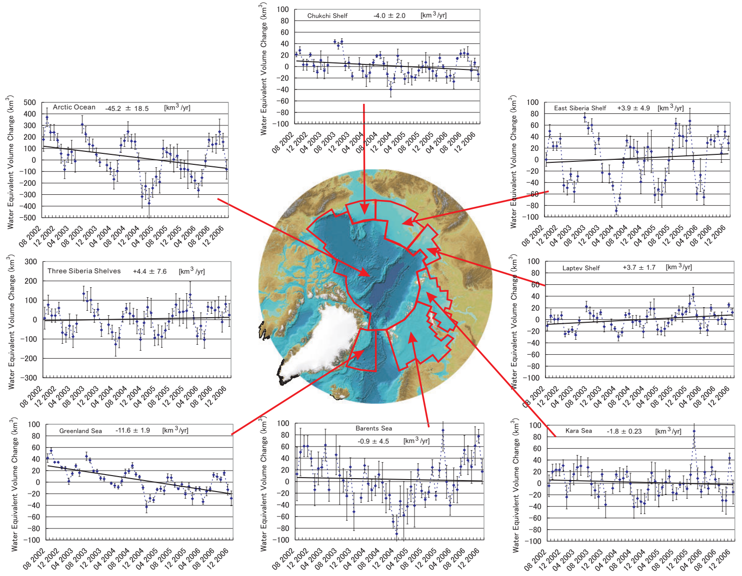


The plots above illustrate the globally-averaged GRACE, Level 3 RL04 monthly time series trends and variations. The top plot show the Land (red) and the Ocean (blue). The near-annular perodicity and near-180 degree phase are evident, suggesting transport of water mass from the oceans, to the land, and back. When all land and ocean data are averaged together, the global time series of water mass change is derived as shown in the bottom plot. Here, we see that the least-squares trend is near zero, suggest a near balance of mass changes from the oceans, to land, and back. However, the series up to December 2004, is remarkably different from the series after that date. The date coincides with the Sumratra-Andaman Earthquake. However, the time series does not assume a value for $\Delta C_{2,0}$ (see Chambers, 2006). Could the Sumratra-Andaman Earthquake have had a fundamental effect on $\Delta C_{2,0}$? The global-averages may be showing a combined tidal alias (Seo et al., 2008; Moore et al., 2008).

Abstract

Datasets of global-distributed monthly water equivalent thickness, i.e. hydrologic mass balance, from the Gravity Recovery and Climate Experiment (GRACE) are investigated. The datasets examined are the Level-3 Release 4, 400 km half-width smoothed, de-striped version from the University of Texas Center for SpaceResearch over the period of August 2002 through December 2006. A glacial isostatic adjustment grid (Paulson et al., 2007; ICE-5G/VM2) is applied to the GRACE monthly grids. Globally, spatially-averaged land and ocean time series are anti-correlated with a near 180-degree phase with maxima (ocean) / minima (land) occurring around September / May. Least squares-derived secular trends indicate increasing monthly water equivalent thickness on land areas and decreasing water equivalent thickness on ocean areas, on average, with spatially non-uniform patterns. These secular trends are in near-balance to within uncertainty, over the period of GRACE observations. However, a reduction of water equivalent thickness occurred from September through December 2004. This reduction, while seen in the regionally-averaged time series in the high-northern latitudes has not yet been identified in other regions. The ΔC_{20} geopotential coefficient is not modeled at this time. Regionally-averaged time series derived on the Arctic Ocean and Khatanga - Lena - Yana River regions are anti-correlated with a near 180-degree phase, and opposing secular trends of water equivalent thickness change. Least-squares regression on the Arctic Ocean region time series indicates a secular trend of water equivalent thickness reduction of 0.072 ± 0.031 cm/month, equivalent to a water volume loss of 91.1 ± 39.2 km^3/yr. Least-squares regression on the region of the Khatanga Lena Yana River region time series indicates a water equivalent thickness gain of 0.098 ± 0.031 cm/month, equivalent to a water volume increase of 74.8 ± 23.7 km^3/yr. Empirical orthogonal function analysis will be needed to resolve periodic and near-periodic components, to better resolve the secular trends in the time series. Comparisons of the regional-averaged GRACE monthly trends and variations with other geophysical time series will be needed to separate source components and assess uncertainty.

Arctic Ocean and Sea's Secular Trends and Variations



The plots above illustrate the GRACE sub-regionly averaged time series trends and variations on the Arctic Ocean and shallow self seas. Overall, the central Arctic Ocean had a volume loss while the Siberian Self Sea had near-zero to volume gain from August 2002 through December 2006. The Greenland Sea sub-region shows a significant volume loss; however, the trend my be comtaminated by the strength of the mass loss from the Greenland icesheet. The area-averaged variation of the Barents Sea, where there is Atlantic Water inflow, shows an interesting multi-year decrease in volume to December 2004, and an increase in volume after that date. Preliminary comparisonsin progress with in-situ derived fresh water change suggests the central Arctic Ocean is becoming saltier while the shallow Siberian Self Seas are becoming fresher. The trends also appear strongly coupled to change in bottom pressure (see Morison et al., 2007).

GRACE Surface Mass Change

The co-orbiting satellites of the Gravity Recovery and Climate Experiment (GRACE) do not measure variations in gravity or mass directly (Chambers, 2006b). Rather, measurements in the variations of the inter-satellite range (range rate and range acceleration) is measured, coupled with accurate GPS location relative to the International Terrestrial Reference Frame 2005, to estimate values of the time change in spherical harmonic geopotential coeficients, ΔC and ΔS, to degree and order 120 (the Level-3 grids are complete to degree and order 40 however). These are then used in the expansion below to estimate movement of water mass:

$$\Delta h(\phi, \lambda, t) = \frac{a_e \rho_e}{3 \rho_w} \sum_{l=0}^{120} \sum_{m=0}^{l} \frac{(2l+1)}{(1+k_l)} W_l P_{lm} \sin\phi [\Delta C_{lm}(t) \cos m\lambda + \Delta S_{lm}(t) \sin m\lambda]$$

[Length unit: cm in water equivalent]

$$W_l = \exp\left[\frac{(lr/a_e)^2}{4 \ln(2)}\right]$$

P_{lm} : Normalized Legendre polynomials
ΔC_{lm}, ΔS_{lm} : Normalized time-varying Stokes spherical harmonic Geopotential coeficients

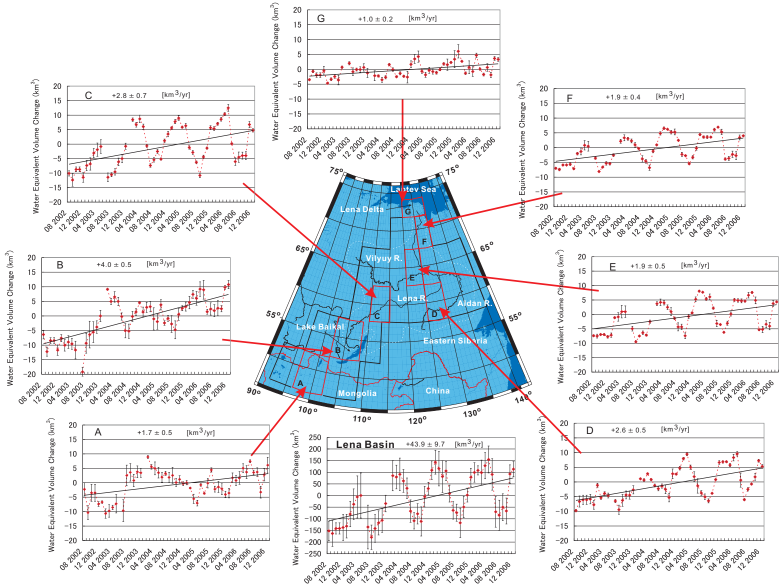
a_e -- Earth mean radius
ρ_e -- Earth mean dinsity
ρ_w -- Density of water
r -- Earth radius
t -- Time
ϕ, λ -- latitude and longitude
k_l -- Love numbers

(From D. Chambers, 2006b)

Method

The GRACE datasets come from the Center for Space Research, University of Texas at Austin. These are the Release 4 Level 3 products, from August 2002 through December 2008, Land and Ocean monthly grids (Chambers, 2006b). The grids were combined to give global land and ocean coverage, then adjusted by a Glacial Isostation Adjustment grid provided by Paulson et al. (2007). Latitude-by-longitude regions were then extracted for each month, and the region sample mean and standard deviation were computed. Least-squares trends were then derived. The region-average time series and trends are shown at the center of the poster.

Lena River Bain Secular Trends and Variations



The above plots illustrate the GRACE sub-regionally averaged time series trends and variations on parts of the Lena River Basin in Siberia from August 2002 through December 2006. Three test-regions, south of Lake Baikal, area-A shown, have poorly resolved seasonal variation. However, on parts of the Lena basin, from area-B through area-F, seasonal variability is well resolved. Overall, the strength and significance of the trends increase from south to north, and from west to east. This feature may be attributed to changes in surface water and groundwater storage. Preliminary investigations are in progress to compare the GRACE trends and variations with in-situ surface water and groundwater storage changes and seasonal variations.

Prospective

This poster summerizes the initial investigation of the GRACE data from the Center for Space Research, Univ. of Texas at Austin, for study of regional water mass changes of the Arctic Ocean and shallow seas and the Lena River Basin in Siberia. The area-average secular trends and near-perodic suggest physical processes, increasing salinity / decreasing salinity of the central Arctic Ocean and Siberian Seas respectively, and ground water storagechanges beneath the Lena River Basin. To evaluate these suggestions, I will be using in-situ oceanographic And groundwater datasets. With regard to land water storage changes in the Arctic, Syed et al. (2007) using the R01 and R02 GRACE datasets, suggest that freshwater discharge (Pan-Arctic) may be accelerating in response to thawing (perhaps ice-rich permafrost and active layer changes).

Acknowledgements

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