Geophysical Research Abstracts
Vol. 14, EGU2012-13039-1, 2012
EGU General Assembly 2012

Mass loss over the Greenland ice sheet from GRACE: A reappraisal

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Where has Greenland been losing mass, and when? Has the mass loss been accelerating in the second half of the last decade? We have developed a versatile new method to answer questions like this and others, on a regional and global scale, and use it to reassess the spatial and temporal behavior of Greenland's mass balance using data from the Gravity Recovery and Climate Experiment (GRACE) produced in the last decade. Our method is validated with extensive simulation-based synthetic recovery tests, and requires very few initial assumptions, e.g. there is no a priori subdivision of the continent into geographic units over which the mass loss would commonly be assumed to be going on at a constant rate, nor does it start with an explicit filtering step. Monthly satellite gravity measurements from GRACE, produced since 2002, have led to many estimates of the magnitude, spatial and temporal distribution of mass change of Earth's ice sheets. These estimates often disagree for a variety of known reasons, such as the time span considered, however the reported errors for equivalent mass estimates usually do not encompass estimates from other researchers. We examine Level-2 GRACE data with the goal of determining what portion of the gravity field can be considered signal and which can be considered noise. We perform our analysis in both the spherical harmonic basis and in the spherical Slepian basis, the latter providing spatiospectral localization of both mass change and noise in our regions of interest, Greenland and Antarctica. After fitting and removing secular, annual, and semiannual periodic functions, we use the time series residuals to determine a time averaged noise covariance matrix, which unlike the Level-2 calibrated errors, has strong off-diagonal terms. These terms add contributions important for determining the spatial variance and spatial covariance of the noise. With a more robust estimate of signal to noise in the gravity measurements, we determine what portion of the uncertainty in mass estimation is due to error inherent to the data. We also determine, using Slepian functions, the spatial distribution of mass change (and its variance) and how this change is spatially distributed in time at a much improved resolution over previous methods. In 2003 and 2004, mass loss is concentrated along the eastern coast of Greenland. In 2005 and 2006, mass loss is reduced in the northeast while it is increased in the southeast. Meanwhile, mass loss begins to increase along the northwest coast. From 2007 to 2010, mass loss further increases in northwest Greenland while mass loss diminishes in the southeast coast areas. During the period from 2002 to 2011 we find the overall total integrated mass change rate over Greenland remains constant with very little observed acceleration.