Geophysical Research Abstracts
Vol. 16, EGU2014-6201-1, 2014
EGU General Assembly 2014

Spatio-temporal modelling of Antarctic mass balance from multi-satellite observations

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Quantifying ice mass changes, identifying its causes and determining rigorous error estimates, is important for estimating present-day sea-level rise. Yet this remains a challenging task: (i) estimates obtained from altimetry, gravimetry, and mass-budget methods can yield conflicting results with error estimates that do not always overlap, and (ii) the use of different forward models to separate the effects of GIA and surface mass balance (SMB) processes, as is generally done, introduces another source of uncertainty which is hard to quantify. We present a statistical modelling approach that tackles these issues. We combine the observational data together, including radar and laser altimetry, GRACE, GPS and InSAR, and use the different degrees of spatial and temporal smoothness to constrain the underlying geophysical processes. This is achieved via a spatio-temporal Bayesian hierarchical model, employing dimensionality reduction methods to allow the solution to remain tractable in the presence of the large number (> 10ő6) of observations involved. The resulting trend estimates are only dependent on length and smoothness properties obtained from numerical models, but are otherwise data-driven.
We present annual, time-varying trend fields of dynamic ice loss, SMB, firn compaction and GIA; using a combination of GRACE, ICESat, ENVISat, and GPS vertical uplift rates, for 2003-2009. The elastic flexure of the crust is also determined simultaneously. We estimate that, between 2003 and 2009, there has been an acceleration in ice loss, from balance in 2003/2004 to a rate of -200±50Gt/yr by 2009. This was predominantly driven by ice dynamic losses in West Antarctica and the Antarctic Peninsula. However, this has been partially compensated by an overall positive trend in SMB over the whole continent. We conclude that there was no statistically significant net loss or gain in the seven year period. Other data will be included to allow extension back to 1995 and forward to the present day using, for example, CryoSat 2, ice core records and accumulation radar data.