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Modelling mass loss and spatial uncertainty of the West Antarctic Ice Sheet: a data assimilation approach

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Quantifying ice mass loss from the Antarctic Ice Sheet remains an important, yet still challenging problem. Although some agreement has been reached as to the order of magnitude of ice loss over the last two decades, in general methods lack statistical rigour in deriving uncertainties and for East Antarctica and the Peninsula significant inconsistencies remain.

Here, we present rigorously-derived, error-bounded mass balance trends for part of the Antarctic ice sheet from a combination of satellite, in situ and regional climate model data sets for 2003-2009.
Estimates for glacial isostatic adjustment (GIA), surface mass balance (SMB) anomaly, and ice mass change are derived from satellite gravimetry (the Gravity Recovery and Climate Experiment, GRACE), laser altimetry (ICESat, the Ice, Cloud and land Elevation Satellite) and GPS bedrock elevation rates. We use a deterministic Bayes approach to simultaneously solve for the unknown parameters and the covariance matrix which provides the uncertainties. The data were distributed onto a finite element grid the resolution of which reflects the gradients in the underlying process: here ice dynamics and surface mass balance. In this proof of concept study we solve for the time averaged, spatial distribution of mass trends over the 7 year time interval. The results illustrate the potential of the approach, especially for the Antarctic Peninsula (AP), where, due to its narrow width and steep orography, data coverage is sparse and error-prone for satellite altimetry.

Results for the ice mass balance estimates are consistent with previous estimates and demonstrate the strength of the approach. Well-known patterns of ice mass change over the WAIS, like the stalled Kamb Ice Stream and the rapid thinning in the Amundsen Sea Embayment, are reproduced in terms of mass trend. Also, without relying on information on ice dynamics, the method correctly places ice loss maxima at the outlets of major glaciers on the AP. Combined ice mass loss trends for the West Antarctic Ice Sheet (WAIS) and the AP are estimated at -101 +- 31 Gt per year for 2003-2009, which compares well with other recent estimates for a similar period. The time-invariant will be extended to time evolving and finally to cover the whole of Antarctica. The approach is not limited to the GRACe epoch alone and will also be extended back in time to 1992, at the beginning of the ERS-1 epoch.