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Constraining East Antarctic mass trends using a Bayesian inference approach

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East Antarctica is an order of magnitude larger than its western neighbour and the Greenland ice sheet. It has the greatest potential to contribute to sea level rise of any source, including non-glacial contributors. It is, however, the most challenging ice mass to constrain because of a range of factors including the relative paucity of in-situ observations and the poor signal to noise ratio of Earth Observation data such as satellite altimetry and gravimetry. A recent study using satellite radar and laser altimetry (Zwally et al. 2015) concluded that the East Antarctic Ice Sheet (EAIS) had been accumulating mass at a rate of 136±28 Gt/yr for the period 2003-08.

Here, we use a Bayesian hierarchical model, which has been tested on, and applied to, the whole of Antarctica, to investigate the impact of different assumptions regarding the origin of elevation changes of the EAIS. We combined GRACE, satellite laser and radar altimeter data and GPS measurements to solve simultaneously for surface processes (primarily surface mass balance, SMB), ice dynamics and glacio-isostatic adjustment over the period 2003-13. The hierarchical model partitions mass trends between SMB and ice dynamics based on physical principles and measures of statistical likelihood. Without imposing the division between these processes, the model apportions about a third of the mass trend to ice dynamics, +18 Gt/yr, and two thirds, +39 Gt/yr, to SMB. The total mass trend for that period for the EAIS was 57±20 Gt/yr. Over the period 2003-08, we obtain an ice dynamic trend of 12 Gt/yr and a SMB trend of 15 Gt/yr, with a total mass trend of 27 Gt/yr.

We then imposed the condition that the surface mass balance is tightly constrained by the regional climate model $RACMO_2.3$ and allowed height changes due to ice dynamics to occur in areas of low surface velocities (<10 m/yr) , such as those in the interior of East Antarctica (a similar condition as used in Zwally 2015). The model must find a solution that satisfies all the input data, given these constraints. By imposing these conditions, over the period 2003-13 we obtained a mass gain due to ice dynamics of 103±15 Gt/yr but this was offset by a negative trend in SMB of 47 Gt/yr, resulting in an overall positive trend of 56±15 Gt/yr. Over 2003-08, the ice dynamics trend is 96 Gt/yr, offset by a strong negative SMB trend of -81 Gt/yr, with a total mass trend of 15±13Gt/yr. Even after relaxing the ice dynamics constraint over East Antarctica, we are unable to reproduce the large positive trend obtained in Zwally2015. We conclude that this result is inconsistent with the combined observations, irrespective of any assumption made about the density of surface elevation changes.