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How accurately do we know interannual variations of surface mass balance and firn volume in Antarctica?

Martin Horwath (1), Michiel R. van den Broeke (2), Jan T. M. Lenaerts (2), Stefan R. M. Ligtenberg (2), Benoît Legrésy (3), and Fabien Blarel (3)

(1) Institute of Astronomical and Physical Geodesy, Technische Universität München, München, Germany (martin.horwath@bv.tum.de), (2) Institute for Marine and Atmospheric Research, Utrecht University, Utrecht, The Netherlands, , (3) Laboratoire d'Etudes en Géophysique et Océanographie Spatiales (LEGOS), Toulouse, France

Knowing the interannual variations in the Antarctic ice sheet net snow accumulation, or surface mass balance (SMB), is essential for analyzing and interpreting present-day observations. For example, accumulation events like the one in East Antarctica in 2009 (Shepherd et al. 2012, Science, doi: 10.1126/science.1228102) challenge our ability to interpret observed decadal-scale trends in terms of long-term changes versus natural fluctuations. SMB variations cause changes in the firn density structure, which need to be accounted for when converting volume trends from satellite altimetry into mass trends.

Recent assessments of SMB and firn volume variations mainly rely on atmospheric modeling and firn densification modeling (FDM). The modeling results need observational validation, which has been limited by now. Geodetic observations by satellite altimetry and satellite gravimetry reflect interannual firn volume and mass changes, among other signals like changes in ice flow dynamics. Therefore, these observations provide a means of validating modeling results over the observational period.

We present comprehensive comparisons between interannual volume variations from ENVISAT radar altimetry (RA) and firn densification modeling (FDM), and between interannual mass variations from SMB modeling by the regional atmospheric climate model RACMO2 and GRACE satellite gravimetry. The comparisons are performed based on time series with approximately monthly sampling and with the overlapping period from 2002 to 2010. The RA-FDM comparison spans the spatial scales from 27 km to the continental scale. The mass comparison refers to the regional (drainage basin) and continental scale.

Overall, we find good agreement between the interannual variations described by the models and by the geodetic observations. This agreement proves our ability to track and understand SMB-related ice sheet variations from year to year. The assessment of differences between modeling and observations allows us to quantify upper bounds on the uncertainties of the results from either technique. Moreover, the joint analysis of the four techniques aids in attributing the remaining discrepancies to deficits in individual techniques. These analyses may guide further improvements in observing and modeling SMB-related ice sheet variations.