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Antarctic surface mass balance variations reflected by regional atmospheric modeling, satellite altimetry, and GRACE

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Interannual variations of the Antarctic ice sheet due to surface mass balance (SMB) fluctuations are important for estimates and interpretations of ice sheet mass balance. Recent assessments mainly rely on atmospheric modeling, but SMB variations on an ice-sheet scale are also reflected in satellite altimetry and GRACE satellite gravimetry data.

All three approaches have their limitations. On the one hand, modeled interannual SMB variations need observational validation, which has been limited by now. On the other hand, the space-geodetic data do not exclusively reflect SMB phenomena, but also ice dynamics, glacial isostatic adjustment, and errors. Moreover, quantifying ice mass changes from altimetry requires assumptions on firn density and compaction. Finally, the spatial sensitivity of GRACE is limited to a few hundred kilometers. Nonetheless, previous work has shown promising qualitative agreement between interannual change patterns in ENVISAT radar altimetry (RA) and GRACE and between regional-scale interannual signals from GRACE and atmospheric modeling.

Here we present comprehensive comparisons between all three techniques for the Antarctic ice sheet. We use the RACMO2/ANT high-resolution regional atmospheric model, ENVISAT RA estimates from an advanced along-track repeat analysis, and GRACE estimates from regional analyses based on different series of time-variable gravity field solutions. The overlapping period of the three techniques is August 2002 to October 2010.

The high-resolution (27 km) spatial representations of interannual phenomena in ENVISAT RA and RACMO2/ANT match well for many regions, and show good agreement with the larger-scale patterns of mass varations determined with GRACE. We quantify this agreement by statistical parameters. Next, we combine all three techniques to characterize and quantify selected temporal SMB anomalies, such as an excess accumulation in West Antarctica and Wilkes Land in September/October 2005. The presented overall agreement indicates that, to a large extent, interannual signals in ENVISAT and GRACE are well understood as temporal SMB variations represented by RACMO2/ANT. Remaining differences between the three techniques help us to assess their limitations, and may guide further improvement in observing and modeling SMB-related ice sheet variations.