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Weighting climate change from space (Vening Meinesz Medal Lecture)

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The GRACE time-variable gravity satellite mission has provided unprecedented detail about the mass balance of ice sheets and glaciers and ice caps. Over the ice sheets, GRACE has provided precise measurements of change in ice mass since 2002 on a monthly basis. The data show that the mass loss has been increasing with time and spreading around Greenland. We find an excellent agreement between GRACE results and estimates from satellite interferometry, altimetry and regional atmospheric climate models. In Antarctica, the mass loss is more localized but accelerating as well, and we detect large snowfall events in East Antarctica that have been used to evaluate regional atmospheric climate models. The GRACE data remain affected by residual uncertainties in glacial isostatic adjustment, but progress has been made to reduce them, combining GRACE data with altimetry and other data, and this correction does not affect the rate of change in mass loss. We have also been able to survey all glaciers and ice caps from outside Greenland and Antarctica using GRACE data to provide a world-wide, complete mass budget for land ice from satellites. In particular, this approach has made it possible to resolve major uncertainties of past estimates based on the sampling of a few glaciers, and elucidate the partitioning of the water budget between glaciers and rivers in major regions of the world, e.g. High Mountain Asia. We use the GRACE-derived mass fluxes from the ice sheets, glaciers and ice caps and land water mass to calculate their contribution to regional sea level variations (or sea level fingerprints, SLF). For the trend in SLF, the largest contribution is from the ice sheets and glaciers, and this contribution is expected to dominate the pattern of regional sea level on the scale of 40 years and longer. To evaluate the SLF, we compare them with ocean bottom pressure measurements. We detect the SLF signal in the tropics. We also find an excellent agreement with the sea level variation calculated from satellite altimetry minus Argos, which has impacts on the estimation of mass transport between ocean basins. We will end the presentation with a discussion of what will be achievable with the GRACE follow-on mission in the coming decades.