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Closing the balance (Louis Agassiz Medal Lecture)

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The 4000 Gt of ice that has been lost since 2003 by the ice sheets of Greenland and West Antarctica accounts for about 1/3 of recent global mean sea level rise. Especially the Greenland ice sheet is far out of balance: each year, 30% more mass leaves the ice sheet than is gained by snowfall at its surface; in Antarctica, this imbalance is currently less than 10%. To make matters worse, the mass loss is accelerating: each year it increases by about 10%, making it likely that the ice sheets will soon become the main source of global mean sea level rise. Given their huge volumes, they could remain so for centuries to come.

Thirty years ago, the concept of rapid melting of the large ice sheets was purely theoretical. But since that time, the evolution of remote sensing techniques (altimetry, gravimetry and interferometry), in situ observations (automatic weather stations, mass balance and ice velocity measurements) and climate models has revealed a surprising diversity of mass loss mechanisms. This ranges from the relatively steady acceleration of large West-Antarctic ice streams to the highly variable (in space and time) flow speed of outlet glaciers in Greenland. Moreover, both ice sheets experience large interannual fluctuations in snowfall and melt, temporarily masking or accentuating the mass loss.

In spite of all the technological developments, there is still room for exciting discoveries. In April 2011, a reservoir of liquid water twice the size of the Netherlands was discovered in the firn in southeast Greenland. In July 2012, an extreme melt event affected the entire Greenland ice sheet, with meltwater runoff destroying infrastructure in west Greenland that had been in place since the 1950's. And in 2014, two separate studies concluded that the mass loss in West Antarctica appears to be irreversible.

When will it be possible to model and robustly predict the fully coupled system of atmosphere, ocean, sea ice and ice sheets? To start answering that question, we explore possibilities and outstanding challenges in the application of Earth System Models to ice sheet mass balance on one hand, and the use of very-high-resolution regional models to individual glacier basins and fjord systems on the other. These models need observations! We show a newly developed suitcase automatic weather station (iWS) for easy deployment in remote, glaciated regions, without compromising measurement accuracy.