Charting Ice Sheet Contributions to Global Sea Level Rise

An international team produced an integrated assessment of polar ice mass losses in 2012. Now efforts to provide an up-to-date assessment are under way, with an open invitation for participation.

A large iceberg floating in Disko Bay near the town of Ilulissat in West Greenland is one of many stranded in this shallow region where the fjord meets the ocean. Much of Greenland's contribution to global sea level rise occurs through calving of icebergs such as this. Credit: Ian Joughin, University of Washington

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The Greenland and Antarctic ice sheets hold enough water to potentially raise the global sea level by 65 meters in total [*Bamber et al.,* 2013; *Fretwell et al.,* 2013]. Mitigating the consequences of sea level rise effectively requires accurate monitoring and prediction of the contribution from the polar ice sheets.

In 2012, the first community assessment of ice mass losses from Antarctica and Greenland demonstrated confidence in our estimates, showing that measurements based on data from different classes of satellite sensors agreed with one another and that the combined rate of loss had tripled over the previous 2 decades. Now, we've begun a second phase of this assessment, with an open call for participation and an ambitious schedule to deliver annual updates.

The IMBIE project, for the first time, brought together experts in satellite geodetic techniques and experts in modeling ancillary data sets to provide a single consensus assessment.
In the past, there has been apparent disagreement among different satellite-based assessments of mass loss from the ice sheets, and even the most advanced global climate models struggle to resolve the detailed pattern of ice sheet imbalance. Consequently, future changes in sea level remain among the most uncertain of all climate projections. To make progress, we require a better understanding of the processes and mechanisms controlling ice sheet mass imbalance. This, in turn, relies on detailed and accurate observations.

Today, there are well over 150 individual assessments of ice sheet mass balance based on measurements acquired by at least 15 different satellite missions. Perhaps unsurprisingly, it has proven difficult to collectively interpret this observational record, not just because of differences in processing methods but also because of differences in the geographical and temporal extent of each survey.

The Ice sheet Mass Balance Inter-comparison Exercise (IMBIE (http://imbie.org/)) was established in 2011 with the dual aim of understanding the apparent differences in the results of ice sheet mass balance studies and providing a single consensus assessment. Supported by the European Space Agency (ESA) and NASA, the IMBIE project, for the first time, brought together experts in the different satellite geodetic techniques for measuring ice sheet mass balance and also experts in modeling of the ancillary data sets in order to collectively tackle this problem.

Satellites Measure Ice Mass Loss

The team found that there was, in fact, excellent agreement between estimates of ice sheet mass balance determined using entirely different approaches.
Scientists assess the contribution of Earth's polar ice sheets to global sea level rise by determining changes in their mass—their mass balance. Because of the vast size and inaccessibility of the ice sheets in

Greenland and Antarctica, these mass balance assessments are best made with measurements collected from satellite platforms.

There are three main ways in which data from satellites are used to measure ice sheet mass balance: by directly measuring the changes in mass using gravimetry, by measuring the changes in volume using altimetry, and by measuring the changes in the mass inputs and outputs using satellite measurements of the ice flow speed and modeled estimates of the surface mass balance (the mass budget method).

The First Ice Sheet Mass Balance Intercomparison Exercise

In the first exercise, the IMBIE team designed and carried out intercomparison experiments using common time periods and common definitions of ice sheet extent to understand the differences in the mass balance measurements. By adopting this consistent approach, the team found that there was, in fact, excellent agreement between estimates of ice sheet mass balance determined using entirely different approaches.

This consensus paved the way for the production of a single reconciled estimate of ice sheet mass balance [*Shepherd et al.,* 2012], which was a timely contribution to the *Intergovernmental Panel on Climate Change* [2013] assessment report. The IMBIE results showed that the Antarctic and Greenland Ice Sheets contributed 3.7 and 7.4 millimeters to global sea levels, respectively, between 1992 and 2011, and —alarmingly—the combined contribution rose from about 10% to 30% of the global sea level trend over the same period [*Beckley et al.,* 2010].

Progress Since 2012

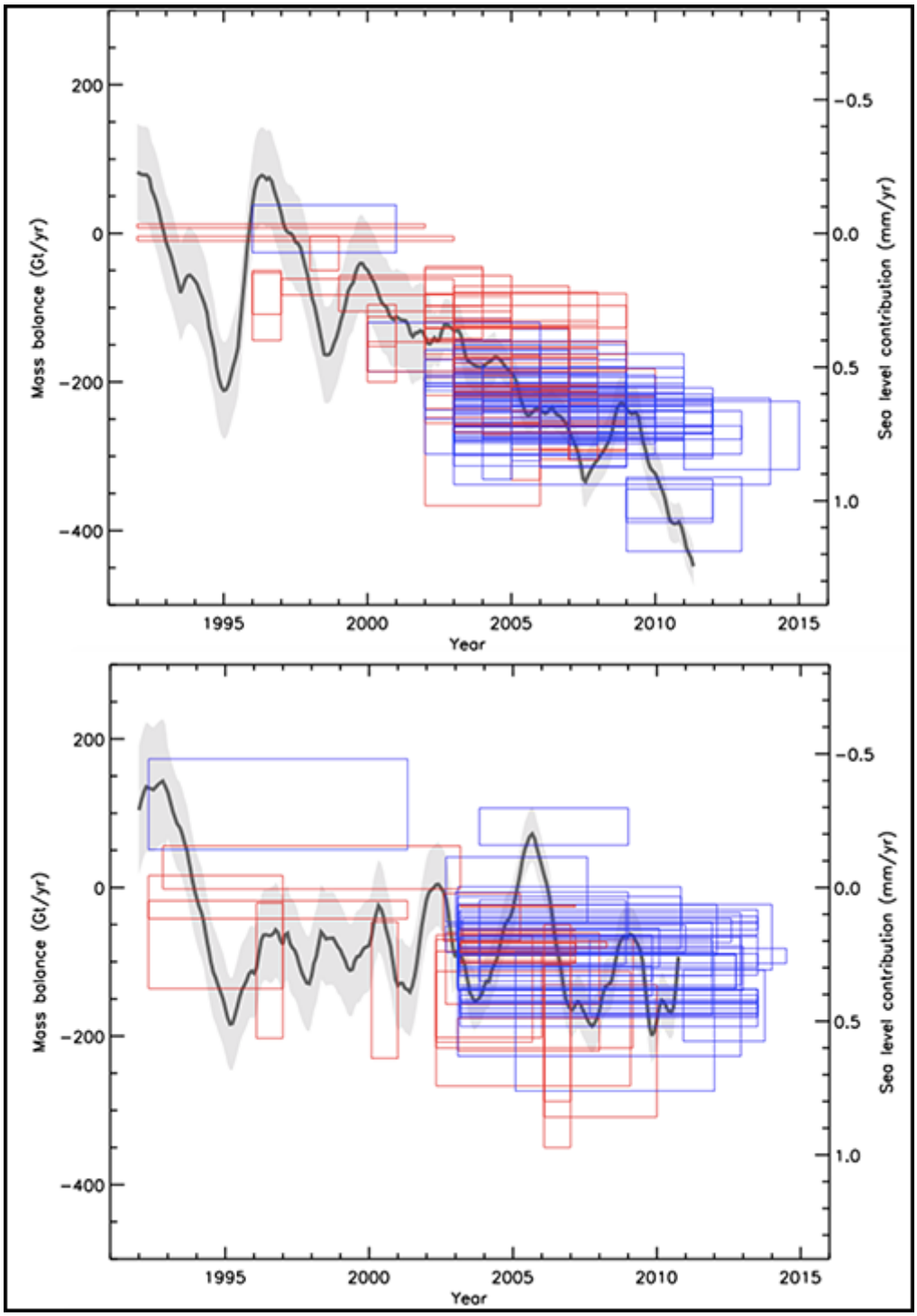

Fig. 1. Estimates of (top) Greenland and (bottom) Antarctic ice sheet mass balance published before (red) and after (blue) the first Ice sheet Mass Balance Inter-comparison Exercise (IMBIE) assessment (gray). There are more than 150 estimates of ice sheet mass balance, more than half of which have been published since 2012.

In the years since the first IMBIE assessment, the launch of new satellites, the development of new techniques and geophysical corrections, and the emergence of new teams have led to a growing body of mass balance assessments. In total there have been an additional 52 published mass balance estimates

for Greenland and 34 for Antarctica, which point to continuing mass losses from both ice sheets since 2011 (Figure 1). (A full list of references for the estimates included in the figure may be found here (http://imbie.org/imbie-2012/reference-list/).)

In Greenland, where substantial interannual variability in mass balance has been common throughout the satellite record, a swing between extreme melting and accumulation events from 2012 to 2013–2014 [*Tedesco et al.,* 2015] is consistent with large recorded mass loss followed by a temporary abatement. In Antarctica, the latest measurements from the European Space Agency satellite, CryoSat-2 (http://www.esa.int/Our_Activities/Observing_the_Earth/The_Living_Planet_Programme/Earth_Explorers/CryoSat-2) [*McMillan et al.*, 2014], point to further increases in ice losses. In light of all of these developments, it is now time for an updated community assessment of ice sheet mass balance.

The Next Assessment

Now that a framework for IMBIE has been established, we are conducting a second assessment this year, with rolling annual updates planned for thereafter. As in the first exercise, the general approach is to integrate, interpret, and report satellite estimates of ice sheet mass balance, with the overall aim of producing a community assessment of Greenland's and Antarctica's ongoing contributions to global sea level rise. IMBIE will also conduct additional experiments to improve our understanding of any differences that may emerge and of the processes that are driving ice sheet imbalance.

As in the first assessment, the exercise will be structured around five main experimental teams based on the techniques of gravimetry, altimetry, the mass budget method, and surface mass balance and glacial isostatic adjustment modeling. The exercise continues to be supported by ESA and NASA.

This year's deadline for registration is 31 July, and the submission of data sets will close at the end of September 2016.
A key objective of this next phase of IMBIE is to broaden participation across the scientific community. We invite any team able to contribute a unique data set to one of our five experimental groups to join in our future assessments.

We will analyze unique data sets submitted to the assessment using technique-specific experiments before comparing and combining them with measurements from the other techniques. Our aim is to present the initial analysis at a community discussion meeting in late 2016, which all participants are invited to attend. In addition to discussing the experimental outcomes, this meeting will plan future assessments. The results of the assessment will then be reported in the peer-reviewed literature and released as a single record of ice sheet mass balance.

At this time, we invite members of the scientific community to register their interest in participating in our next assessment via the IMBIE project website (http://imbie.org/imbie-2016/), where further details on each experimental group can be found. This year's deadline for registration is 31 July, and the submission of data sets will close at the end of September 2016. If you wish to participate in the exercise but cannot make this year's deadline, however, we have designed IMBIE so that you can join in future years—gaining the involvement and support of the entire community is crucial for the project's success.

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