Antarctic_Ice_Sheet_cci

Science highlights: Ice sheet mass balance & Ice shelf stability

Summary
The AIS CCI+ project has contributed to 10 scientific publications over the past year including 5 high profile publications in Nature (1), Nature Climate Change (1), Nature Communications (2), and one in Proceedings of the National Academy of Science (1). The project has also provided a direct contribution of ice sheet mass balance data to the upcoming sixth assessment report of the IPCC. The main project highlights cover two topics; ice sheet mass balance and ice shelf stability.

Ice Sheet Mass Balance
A new study led by CCI Antarctica and CCI Greenland researchers and published in Nature Climate Change has shown that ice sheet losses are tracking the IPCC's worst-case climate warming scenario (Slater et al., 2020). The study compared the latest results from satellite surveys from the Ice Sheet Mass Balance Intercomparison Exercise (IMBIE) with calculations from climate models assessed by the IPCC. Greenland and Antarctic ice sheet melting rates are rapidly increasing and have raised the global sea level by 1.8cm since the 1990s. This closely matches the Intergovernmental Panel on Climate Change's high-end (worst-case) climate warming predictions (Figure 1). If these rates continue, the ice sheets are expected to raise sea levels by a further 17cm and expose an additional 16 million people to annual coastal flooding by the end of the century. Melting from Antarctica has pushed global sea levels up by 7.2mm, while Greenland has contributed 10.6mm. The rate at which they are melting has accelerated faster than anticipated, and if they continue to track the worst-case climate warming scenarios we should expect an additional 17cm of sea level rise by 2100 - enough to double the frequency of storm-surge flooding in many of the world's largest coastal cities. The article is in the 99th percentile (ranked 260th) of the 247,333 tracked articles of a similar age in all journals and the 94th percentile (ranked 5th) of the 97 tracked articles of a similar age in Nature Climate Change. It has been accessed 2443 times since publication, has been tweeted about 1448 times, has been reported by 87 individual news outlets, has appeared in 18 blogs and on 5 Wikipedia pages.

In January 2021, the IMBIE dataset was included in a review of Earth's ice imbalance reported in *The Cryosphere* (Slater et al., 2021). The paper used information from ESA's ERS, Envisat and CryoSat satellites as well as the Copernicus Sentinel-1 and Sentinel-2 missions to find that the rate of ice loss Earth has increased markedly within the past three decades, from 0.8 trillion tonnes per year in the 1990s to 1.3 trillion tonnes per year by 2017. Overall, there has been a 65% increase in the rate of ice loss over the 23-year survey. This has been driven mainly by steep rises in losses from the polar ice sheets in Antarctica and Greenland. Ice melt from ice sheets and glaciers raise sea levels, increases the risk of flooding in coastal communities, which has severe consequences for society, the economy and the environment. The study is the first of its kind to examine all the ice that is disappearing on Earth, using satellite observations. The survey covers 215 000 mountain glaciers spread around the planet, the polar ice sheets in Greenland and Antarctica, the ice shelves floating around Antarctica, and sea ice drifting in the Arctic and Southern Oceans. The increase in ice loss has been triggered by warming of the atmosphere and oceans, which have warmed by 0.26°C and 0.12°C per decade since the 1980, respectively. During the survey period, there was a loss of 7.6 trillion tonnes of Arctic sea ice and a loss of 6.5 trillion tonnes from Antarctic ices shelves, both of which float on the polar oceans. Half of all losses were from ice on land – including 6.1 trillion tonnes from mountain glaciers, 3.8 trillion tonnes from the Greenland ice sheet, and 2.5 trillion tonnes from the Antarctic ice sheet. These losses have raised global sea levels by 35 millimetres. Despite storing only 1% of Earth's total ice volume, glaciers have contributed to almost a quarter of the global ice losses over the study period, with all glacier regions around the world losing ice. The study has already been downloaded over 34k times which places it within the all-time top 10 for *The Cryosphere*.

Finally, in March 2021 the IMBIE project completed an updated assessment of Antarctic and Greenland ice sheet mass balance, bringing the previous records in line and updating them to extend through 2020. This update was requested by IPCC, and will feature in the Cryosphere and Sea Level chapters of their upcoming sixth assessment report (AR6). The assessment includes 15 extended estimates of ice sheet mass balance to augment those included in the second IMBIE assessment (The IMBIE Team, 2018; The IMBIE Team, 2019). Among the new estimates are 2 time-series derived from satellite altimetry, 10 time-series derived from satellite gravimetry, and 3 time-series derived from the input output method. The updated gravimetry estimates make

use of measurements acquired by the GRACE Follow-On satellite missions, which was launched in May 2018. The assessment follows the method employed in the second IMBIE assessment. The updated assessment was coordinated by CCI_Antarctica and includes updated estimates from both CCI_Antarctica and CCI_Greenland.

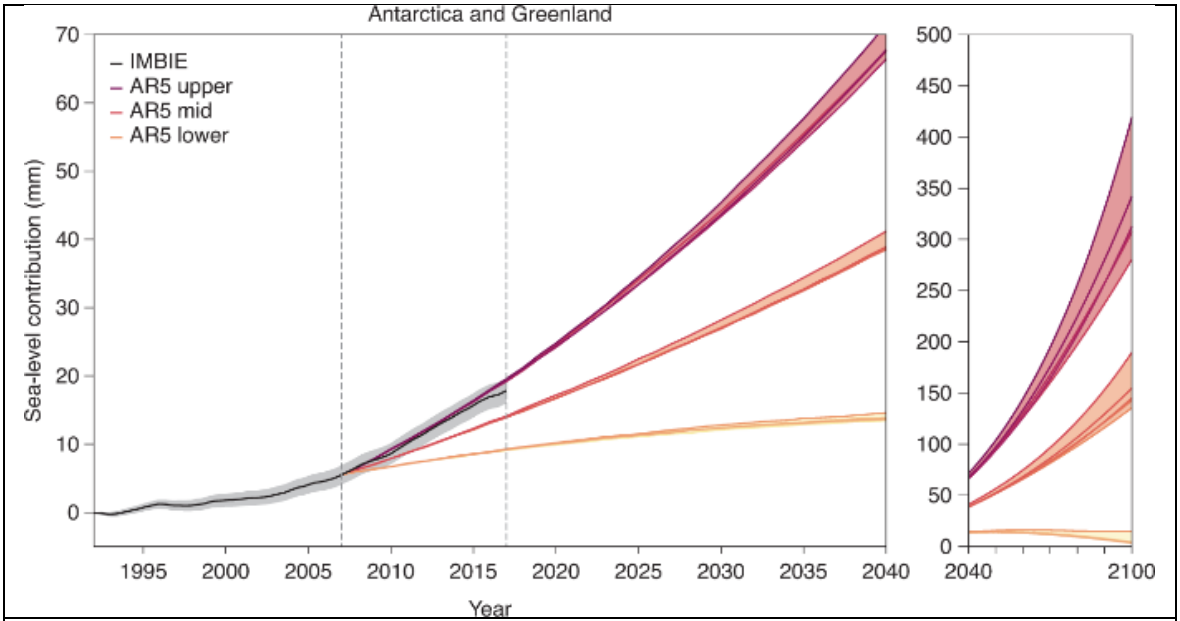
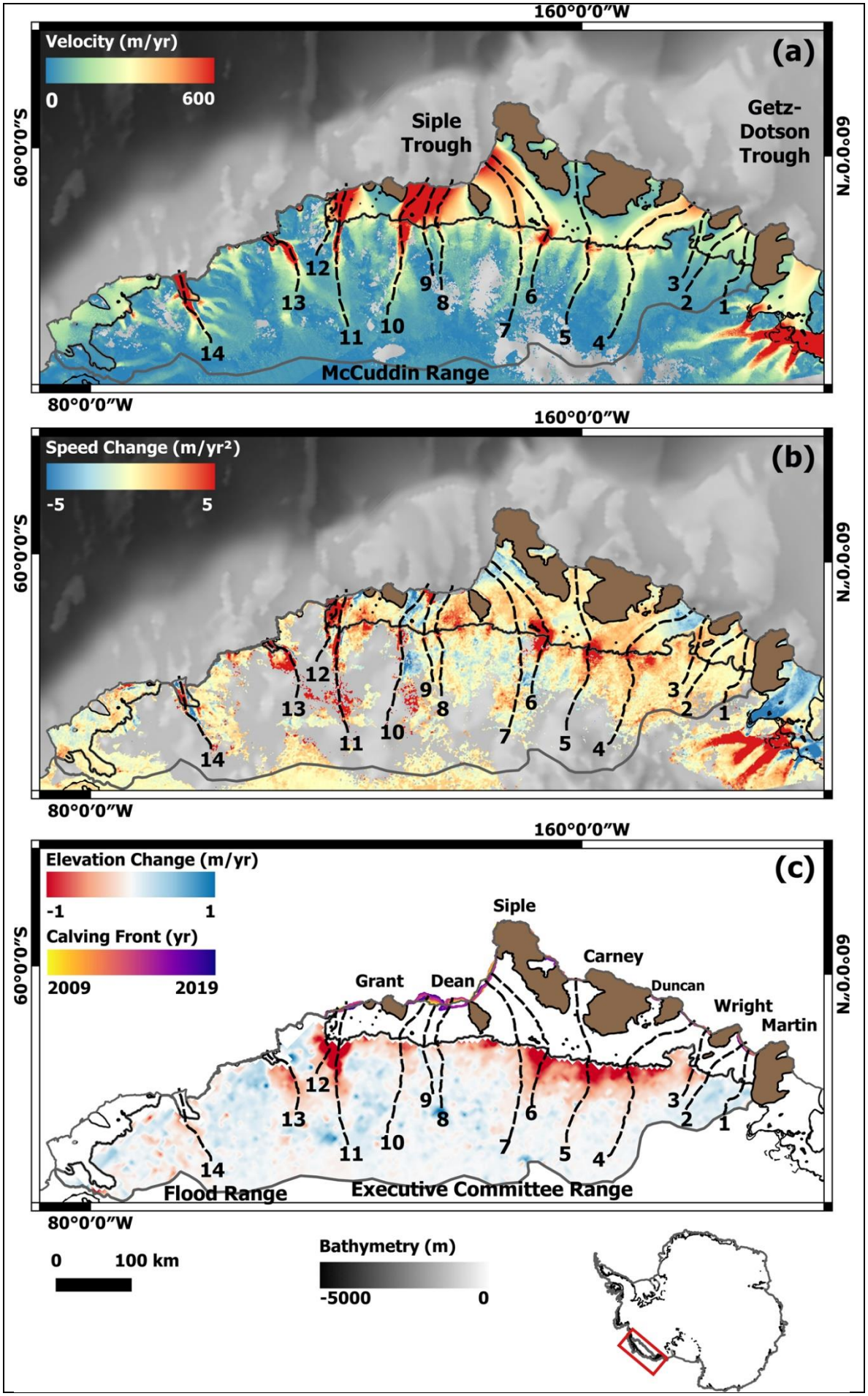


Figure 1. The Antarctic and Greenland ice-sheet contribution to global sea level observed by IMBIE (black) and predicted by IPCC AR5. For each AR5 emission scenario, the upper (maroon), mid (orange) and lower (yellow) estimates are taken from the 95th percentile, median and 5th percentile values of the ensemble range, respectively. AR5 pathways are represented by darker lines in order of increasing emissions: RCP 2.6, RCP 4.5, RCP 6.0, SRES A1B and RCP 8.5.

Ice Shelf Stability

A study on ice shelf fracture (Lhermitte et al., 2020), published in the prestigious journal Proceedings of the National Academy of Science, makes use of Antarctic_Ice_Sheet_cci ice velocity data products to explore the controlling mechanisms involved in iceberg calving from two glaciers draining into the Amundsen Sea Embayment. Pine Island Glacier and Thwaites Glacier are among the fastest changing outlet glaciers in Antarctica. Yet, projecting the future of these glaciers remains a major uncertainty for sea level rise. The study uses satellite imagery to show the development of damage areas with crevasses and open fractures on Pine Island and Thwaites ice shelves. These damage areas are first signs of their structural weakening as they precondition these ice shelves for disintegration. Model results that include the damage mechanism highlight the importance of damage for ice shelf stability, grounding line retreat, and future sea level contributions from Antarctica. Moreover, they underline the need for incorporating damage processes in models to improve sea level rise projections. The publication was additionally reported in an ESA webstory, in 69 individual news articles, 14 blogs, 4 facebook pages, and was referenced in 596 tweets.

A second study on ice shelf stability (Selley et al., 2021) published in Nature Communications makes use of Antarctic_Ice_Sheet_cci ice velocity, grounding line, and surface elevation change data products. A 25-year record of satellite observations was used to show widespread increases in ice speed across the Getz sector for the first time, with some ice accelerating into the ocean by nearly 50%. The study reported that 14 glaciers in the Getz region are thinning and flowing more quickly into the ocean. Between 1994 and 2018, 315 gigatonnes of ice has been lost, adding 0.9 mm to global mean sea level. On average, the speed of all 14 glaciers has increased by almost a quarter with three glaciers' speeding up by more than 44%. This research will help scientists determine whether glaciers in the region may collapse in the next few decades and how this could affect future global sea-level rise. The research reports how the widely reported thinning and acceleration observed in the neighbouring Amundsen Sea glaciers, now extends over 1,000 km along the West Antarctic coastline into Getz. By examining 25 years of ocean measurements, the research team were able to show complex and annual variations in ocean temperatures. These results suggest that the "dynamic imbalance" is mainly caused by longer-term ocean forcing, where increased heat content in the ocean is interacting with the ice and enhancing melt. The research was reported in 22 news outlets including the BBC and ESA, tweeted 371 times, and has been described in 4 blogs.


160°0′0″W
Velocity (m/yr)
0
600
(a)
Siple
Trough
Getz-
Dotson
Trough
60°0′0″S
60°0′0″N
14
13
12
11
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9
8
7
6
5
4
3
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McCuddin Range
80°0′0″W
160°0′0″W
Speed Change (m/yr²)
-5
5
(b)
60°0′0″S
60°0′0″N
14
13
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1
80°0′0″W
160°0′0″W
Elevation Change (m/yr)
-1
1
Calving Front (yr)
2009
2019
(c)
Siple
Carney
Grant
Dean
Duncan
Wright
Martin
60°0′0″S
60°0′0″N
14
13
12
11
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5
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Flood Range
Executive Committee Range
80°0′0″W
0
100 km
Bathymetry (m)
-5000
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Figure 2. (a) Ice speed in the Getz drainage basin of Marie Byrd Land, measured in 2018 using Interferometric Wide (IW) mode synthetic aperture radar (SAR) data acquired by the Sentinel-1a/b satellites. The grounding line location (solid black line), inland limit of the drainage basin (solid grey line) and the location of 14 flow line profiles (dashed black lines) are also shown. Profiles 1 to 9 are located on unnamed glaciers; however, 10 to 14 correspond to DeVicq, Berry, Venzke, Hull and Land Glaciers, respectively. Measurements are superimposed on BEDMAP2 bedrock topography. (b) A map of the observed rate of change in ice speed between 1994 and 2018. (c) Ice sheet elevation change with Firn Densification Model (FDM) correction applied from 1992 to 2017, measured using satellite radar altimetry data. The names of islands and ice rises (brown area) bordering the Getz Ice Shelf are also indicated. The calving front location is shown from 2009 in yellow to 2019 in purple.

Publications

The following 10 publications have emerged from the project over the year:

Title	Journal	Author	Year	IV	GLL	SEC	GMB
Impact of marine processes on flow dynamics of northern Antarctic Peninsula outlet glaciers.	Nature Communications	Rott et al.	2020	*			
Ice-sheet losses track high-end sea-level rise projections.	Nature Climate Change	Slater et al.	2020	*		*	*
Repeat Subglacial Lake Drainage and Filling Beneath Thwaites Glacier	Geophysical Research Letter	Malczyk et al.	2020	*		*	
Damage accelerates ice shelf instability and mass loss in Amundsen Sea Embayment	Proceedings of the National Academy of Science	Lhermitte et al.	2020	*			
Earth's ice imbalance	The Cryosphere	Slater et al.	2021			*	*
Widespread increase in dynamic imbalance in the Getz region of Antarctica from 1994 to 2018	Nature Communications	Selley et al.	2021	*	*	*	
Projected land ice contributions to twenty-first-century sea level rise.	Nature	Edwards et al	2021			*	*
Altimetry for the future: Building on 25 years of progress	Advances in Space Research	International Altimetry Team	2021			*	
Antarctic Ice Mass Change Products from GRACE/GRACE-FO Using Tailored Sensitivity Kernels	Remote Sensing	Andreas Groh	2021				*
The influence of Antarctic ice loss on polar motion: an assessment based on GRACE and multi-mission satellite altimetry	Earth, Planets and Space	Göttl	2021				*

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