ESA Climate Change Initiative (CCI+)
Essential Climate Variable (ECV)
Antarctic_Ice_Sheet_cci+ (AIS_cci+)
Science Highlights (SH)

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Change Log

Issue	Author	Affected Section	Change	Status
1.0	UL	All	Document Creation	

Acronyms and Abbreviations

Acronyms	Explanation
AIS	Antarctic Ice Sheet
ATBD	Algorithm Theoretical Basis Document
CCI	Climate Change Initiative
CECR	Comprehensive Error Characterisation Report
DEM	Digital Elevation Model
DInSAR	Differential SAR Interferometry
DLR	Deutsche Zentrum für Luft- und Raumfahrt
DTU	Danmarks Tekniske Universitet
ECV	Essential Climate Variables
ENVEO	Environmental Earth Observation
ERS	European remote sensing satellite
IBE	Inverted Barometer Effect
IV	Ice Velocity
IVonIS	Ice Velocity on Ice Shelves
LRM	Low Resolution Mode
OCOG	Offset Centre of Gravity (OCOG) re-tracker
PUG	Product User Guide
RA	Radar Altimetry
RMSE	Root-Mean-Square Error
RR	Round Robin
S3MPC	Sentinel-3 Mission Performance Center
SAR	Synthetic Aperture Radar
SEC	Surface Elevation Chang e
SoW	Statement of Work
TCM	Tidal Correction Module
TFMR	Threshold First Maximum Retracking
TUDr	Technische Universität Dresden
UCL	University College London
UL	University of Leeds
UTC	Coordinated Universal Time

1 Introduction

1.1 Purpose and Scope

This document contains Science Highlights (SH) for the Antarctica_Ice_Sheet_cci (AIS_cci) project for CCI+ Phase 1, in accordance to contract and SoW [AD1 and AD2]. The central aim is to provide science highlights designed for public consumption, including illustrating images and appropriate links for more details.

1.2 Document Structure

This document is structured into a single chapter describing the following scientific highlight: Six-fold increase in polar ice losses since the 1990s.

1.3 Applicable and Reference Documents

Table 1.1: List of Applicable Documents

No	Doc. Id	Doc. Title	Date	Issue/ Revision/ Version
AD1	ESA/Contract No. 4000126813/18/I-NB, and its Appendix 2	CCI+ PHASE 1 - NEW R&D ON CCI ECVS, for Antarctic_Ice Sheet_cci	2019.09.30	
AD2	ESA-CCI-EOPS-PRGM-SOW-18-0118 Appendix 2 to contract.	Climate Change Initiative Extension (CCI+) Phase 1, New R&D on CCI ECVs Statement of Work	2018.05.31	Issue 1 Revision 6

2 Six-fold increase in polar ice losses since the 1990s

2.1 Summary

In March 2020, the IMBIE Team reported their second assessment of ice losses from Antarctica and Greenland. The Antarctic_Ice_Sheet_cci project provides scientific leadership for IMBIE and contributes measurements of the ice sheet mass change based on satellite altimetry, satellite gravimetry, and the mass budget method. The two Nature papers this story is based on have received exceptional attention. The 'Antarctic Ice Sheet' paper ranks number 1 for quality and quantity of online attention of all outputs of a similar age published in Nature and the 'Greenland Ice Sheet' paper ranks number 9. Both papers have attention scores in the top 1% of all research outputs ever tracked by Altimetric. This story has been covered extensively by media outlets and engaged with heavily on Twitter, reaching the top 20 trending topics in the UK on 12th March 2020. Key media sources who reported the 2020 combined assessment include The Guardian, The BBC, The Independent, USA Today, Forbes, and The Japan Times.

Greenland and Antarctica are losing ice faster than in the 1990s and are both tracking the Intergovernmental Panel on Climate Change's worst-case climate warming scenario. The findings, produced by a team of 89 polar scientists from 50 international organisations and published in two companion articles in Nature, constitute the most complete picture of polar ice sheet loss to date. Overall, Greenland and Antarctica lost 6.4 trillion tonnes of ice between 1992 and 2017 – pushing global sea levels up by 17.8 millimetres. The combined rate of ice loss has risen by a factor six in just three decades, up from 81 billion tonnes per year in the 1990s to 475 billion tonnes per year in the 2010s. This means that the polar ice sheets are now responsible for a third of all sea level rise. The assessment, led by Professor Andrew Shepherd at the University of Leeds and Dr Erik Ivins at NASA's Jet Propulsion Laboratory in California, was supported by the European Space Agency (ESA) and the US National Aeronautics and Space Administration (NASA).

2.2 Altimetry

The Antarctica_ice_sheet_cci team contributed estimates of Greenland and Antarctica ice sheet mass balance to the second IMBIE assessment based on satellite altimeter measurements of surface elevation change (McMillan et al., 2016; Shepherd et al., 2019)(e.g. Figure 2-1). Fluctuations in Antarctic Ice Sheet elevation and mass occur over a variety of time scales, owing to changes in snowfall and ice flow. Here we disentangle these signals by combining 25 years of satellite radar altimeter observations and a regional climate model. From these measurements, patterns of change that are strongly associated with glaciological events emerge. While the majority of the ice sheet has remained stable, 24% of West Antarctica is now in a state of dynamical imbalance. Thinning of the Pine Island and Thwaites glacier basins reaches 122 m in places, and their rates of ice loss are now five times greater than at the start of our survey. By partitioning elevation changes into areas of snow and ice variability, we estimate that East and West Antarctica have contributed −1.1 ± 0.4 and +5.7 ± 0.8 mm to global sea level between 1992 and 2017.

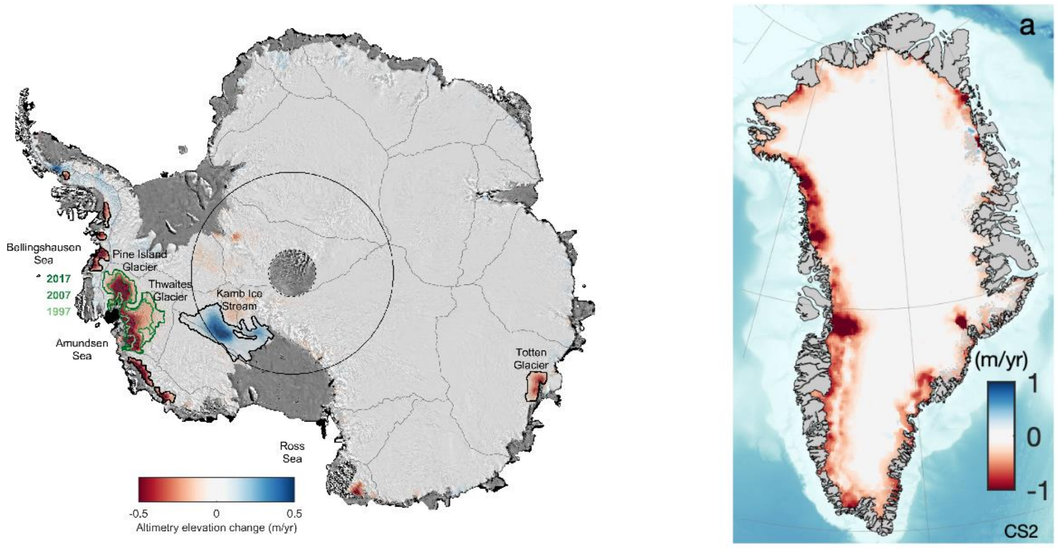

Figure 2-1: Average rate of surface elevation change in Antarctica (left) and Greenland (right) between 1992 and 2017. Black circles at the pole indicate the southern limit of the CryoSat-2 (dashed) and other (solid) satellite orbits. Gray boundaries show glacier drainage basins. Boundaries show areas of dynamical imbalance that do not (black) and do (green) evolve over time.

2.2.1 Gravimetry

The contribution of the Antarctic_Ice_Sheet_cci project to the second IMBIE assessment satellite gravimetry experiment group consists of monthly time series of basin-averaged ice mass changes for different Antarctic drainage basins and aggregations. Based on monthly gravity field solutions acquired by the Gravity Recovery and Climate Experiment (GRACE) satellite mission, processed by TU Graz (ITSG-Grace2016), the time series were derived by TU Dresden using the algorithms developed during the first phase of the AIS_cci project (Figure 2-2). The approach makes use of tailored sensitivity (or integration) kernels, which are designed to minimise the impact of both GRACE errors and signal leakage on the mass change estimates. In addition, TU Dresden submitted results to various experiments performed to quantify the contribution of different parts of the solution spectrum (C20, degree one) and the applied glacial isostatic adjustment model correction. For the period 2003 – 2015, the inferred mass change time series reveal a distinct mass loss of 140.4±19.8 Gt/yr over West Antarctica, whereas at the same time East Antarctica experiences a mass gain of 65.9±32.6 Gt/yr. Together with the mass loss observed over the Antarctic Peninsula (30.9±7.4 Gt/yr), the overall shrinking of the Antarctic Ice Sheet sums up 105.5±35.4 Gt/yr, corresponding to a rise in sea level of 0.29 ±0.10 mm/yr.

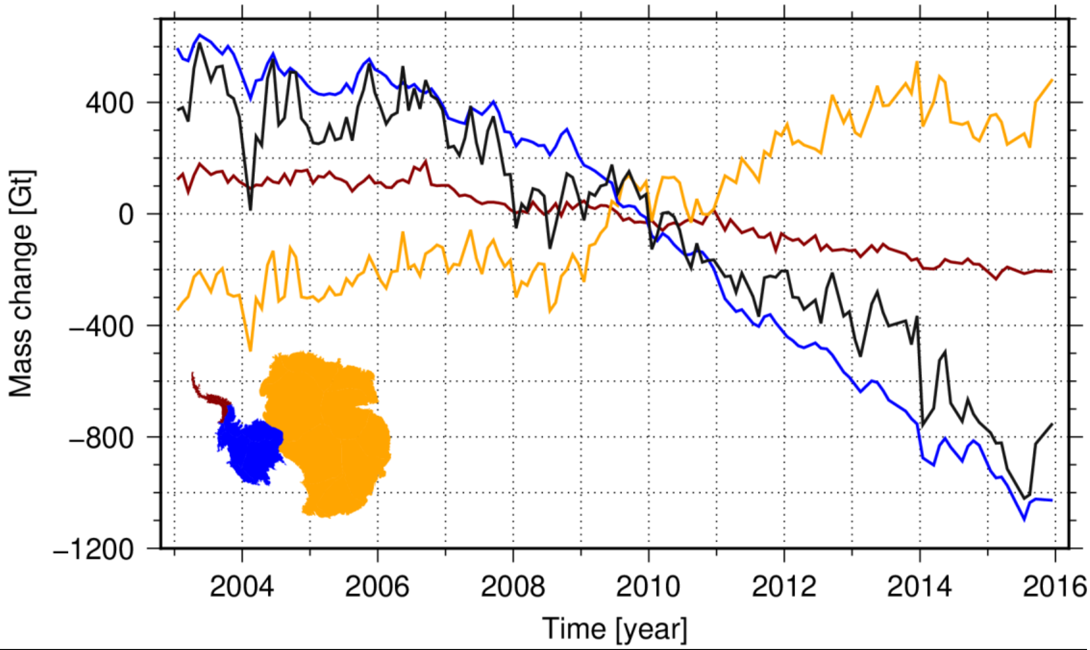

Figure 2-2: Time series of GRACE-derived ice mass changes for the Antarctic Peninsula (red), East Antarctica (orange), West Antarctica (blue) and the entire Antarctic Ice Sheet (black).

2.2.2 Mass Budget

The mass budget approach or input-output method (IOM) for assessment of ice sheet mass balance requires estimates of both total input (e.g. surface mass balance) and total output of ice (e.g. outlet glacier discharge of marine terminating glaciers). The change in ice mass is calculated by the difference between these two. The solid ice discharge at the grounding line is a function of ice thickness and flow velocity. The Greenland_Ice_Sheet_cci and Antarctic_Ice_Sheet_cci project contributed estimates of ice sheet discharge for the second IMBIE assessment. One of the major advancements emerging from these projects are the development and implementation of an automatic system for generation of ice velocity maps from repeat pass Copernicus Sentinel-1 SAR data by project partner ENVEO (Nagler et al., 2015). Based on repeat pass SAR data of the Sentinel-1 mission, but also other high resolution SAR satellites including TerraSAR-X and ALOS PALSAR, ENVEO has generated a dense archive of detailed ice velocity maps covering both polar regions. The ice velocity maps (Figure 2-3), complemented by high resolution DEMs and ice thickness data from radio echo sounding (RES), form the basis for studying ice dynamics and discharge fluctuations and trends at sub-monthly to multi-annual time scales.

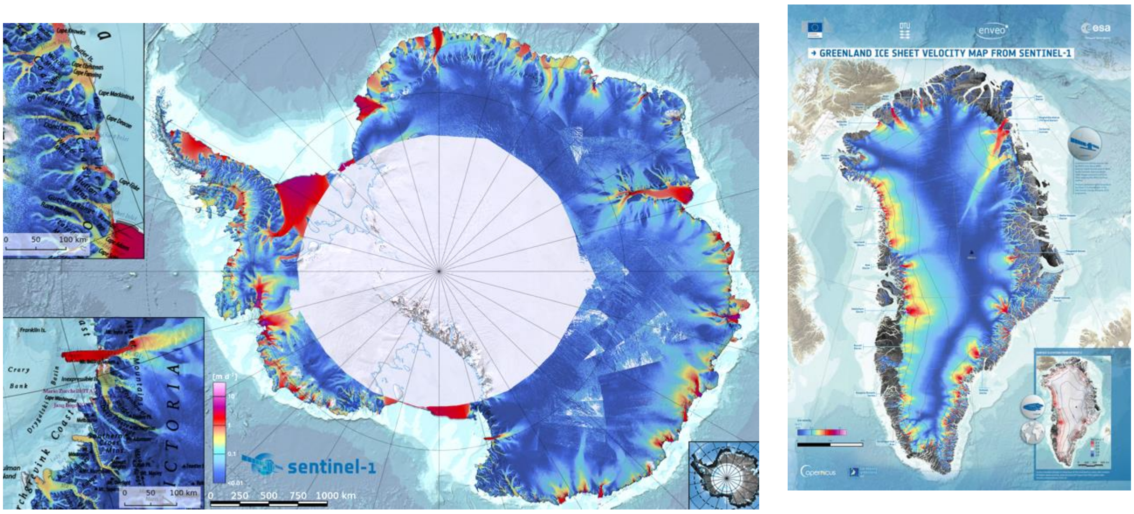

Figure 2-3: Ice sheet velocity for Antarctica (left) and Greenland (right) based on Sentinel-1 SAR.

2.2.3 References

McMillan, M., et al. (2016), A high-resolution record of Greenland mass balance, Geophys. Res. Lett., 43, https://doi:10.1002/2016GL069666

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