Ocean Cryosphere Exchanges in Antarctica:

Impacts on Climate and the Earth System

Workshop with ESA CCI and EO on ice shelf mass balance

Milestone MS6

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Contributors	All partners involved.
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The image on the cover sheet	ESA - Thin sea ice https://www.esa.int/ESA_Multimedia/Images/2014/07/Thin_sea_ice

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Means of verification of the achievement of the milestone:

- The workshop has been held and organised by the Danish Meteorological Institute in Copenhagen, from the 23-24 May 2023.
- A report summarising the workshop activities is available (current milestone report).

Work Performed

The OCEAN:ICE EO (**#OCEANICEEO**) workshop was held on the 23rd and 24th May 2023 in Copenhagen as a hybrid event. The workshop was hybrid with the in-person component hosted by Danish Meteorological Institute at the Black Diamond/Royal Library in central Copenhagen. As there were many crossovers and learnings from previous projects, it was decided to jointly host with the H2020-funded project, PROTECT.

There was a dedicated "lessons learned" session from PROTECT which aimed at building collaborations between the projects within the European Polar Cluster. Scientists from projects funded by the ESA CCI, EUMETSAT OSI-SAF and the H2020-funded PolarRES project also presented relevant work. OCEAN:ICE had attendees representing all work packages and the second afternoon session was devoted to developing outcomes from the workshop, including assembling datasets for model evaluation and assimilation. In total, there were 25 talks and two large discussion sessions. All participants also contributed to a document that will be used to produce a scientific publication based on the workshop outcomes.

Goal of the meeting

As the sophistication of atmosphere, ocean and ice sheet models, in general, has grown, so has the availability of remote sensing datasets for evaluation and assimilation. It is often difficult to keep track of what datasets are available. In addition, the combination of these datasets with model outputs allows us to refine estimates of mass budget and better understand ice sheet-ocean–atmosphere interactions.

The workshop aimed to report **together the modelling and EO communities to better integrate satellite and in-situ data with numerical models within OCEAN:ICE**. The focus is on defining freshwater fluxes from Antarctica, in particular, the use of data and models to assess surface mass balance, basal melting and calving fluxes from the continent. We were particularly interested in ice shelves but we also covered the grounded ice sheet and the influence of the ocean.

As the use of machine learning (ML) approaches has grown, both for Earth Observation and climate and ice sheet models, we also held a focused session on these techniques.

Participants

From the earth observation side, there were representatives from ESA, from the climate change initiative and from several related projects including 4D Antarctica, SO-ICE and the ESA fellowship programme (see participant list in Appendix 2). We also invited other Earth observation specialists to attend and present.

Agenda

The workshop took place in Copenhagen on the 23rd and 24th May 2023 as a hybrid event. There were two full days. We ensured that online participants were also able to fully contribute with both online only and fully hybrid discussion sessions. For those in Copenhagen, we organized an optional networking activity in the evening followed by a workshop dinner. All workshop participants were invited to contribute notes for a summary document that will be used to shape a publication

summarising the state of the art in the field at present and giving recommendations for future work that aims to build collaborations between the numerical modelling and earth observation communities working in Antarctica. Time set aside for networking has proved very fruitful with a number of spin-off projects underway as a result of the discussions started at the workshop.

Topics

1. Antarctic surface datasets from in-situ and Earth Observations.
2. Modelling Ice, Atmosphere and Ocean Processes in Antarctica.
3. Insights from modelling, emulation and machine learning applied in Antarctica.
4. Surface Mass Balance from Models: Lessons from PROTECT and PolarRES.
5. Bringing it all together: Freshwater fluxes from Antarctica in OCEAN: ICE.

The full agenda and a list of all talks are provided in Appendix 1.

Conclusions

Three main considerations emerged as recommendations from the workshop:

- A closer collaboration is needed in the research community between those constructing datasets and applying them. Make all your data FAIR and CC-BY compliant: A best practice to share would be the publication of the "raw" data version, with an attribution of a DOI and then publish a second cleaned version, with a second DOI. This would allow complying with FAIR protocol data. See for example the data management plan elaborated by OCEAN: ICE. Use sample scripts to process datasets and publish them, e.g. on Github, and Zenodo.
- Long-term sustainability of data is crucial: Currently, enormous data set amounts are already available but they are not continuous and might stop at some points in time. Solutions need to be worked upon. A potential one is to link the data to marine data integrators (e.g. EMODnet and similar), informing them when new data are available and checking if the data are linked to the data integrators.
- It is clear that machine learning (ML) offers huge benefits for the Antarctic research community, both in improving existing observational datasets and as a tool for enhancing the interpretation of the model output. ML is a powerful tool for reuniting the modelling and observational worlds. Blended model-data-ML approaches, such as the simulation of geometry changes under ice shelves using deep surrogates, are also a new approach that can help to assess the sensitivity of the ice sheet

Further actions to implement

- The conclusions of the workshop are planned to be published in open access on the Bulleting of the American Meteorological Society (BAMS) as a paper within 6 months from now, following the example provided in other projects such as PolarRES[1] for the "Workshop on Polar Fresh Water: Sources, Pathways and Impacts of Freshwater in Northern and Southern Polar Oceans and Seas".
- Most of the speakers have agreed to publish their presentations in open access on Zenodo in the OCEAN: ICE community: https://zenodo.org/communities/oceanice/

[1] https://journals.ametsoc.org/view/journals/bams/104/5/BAMS-D-23-0046.1.xml

Fig.1: Main projects and initiatives represented at the workshop.

Appendix 1: Agenda of the Workshop with ESA CCI and EO on ice shelf mass balance

Day 1: 23 May 2023	
8.30 – 9 am	Coffee and Arrival
9 – 9.30 am	Welcome Ruth Mottram: Icebreaker and framing Andrew Meijers: An introduction to OCEAN:ICE
Session 1 9.30-12pm	Antarctic surface datasets from in-situ and Earth Observations Conveners: Anna Hogg and Ben Davison Coffee break 10.30 – 10.45
Topics: Ice shelves Surface melt Basal melt Calving Fracture and damage Sea ice	Presenters 9.30 Anna Hogg: The SO:ICE Project 9.50 Rebecca Dell: Satellite-derived estimates of slush and ponded water extent across Antarctica's ice shelves, 2013-2021 10.10 Ben Davison: Annual mass budget of Antarctic ice shelves from 1997 to 2021 *Coffee break 10.30 – 10.45* 10.45 Romain Millan/J-B Barre: Ice shelf mass balance observations : toward a spatially and timely resolved dataset for modelling the future evolution of Antarctica 11.05 Keith Nicholls: ApRES data from Antarctic ice shelves 11.25 Noel Gourmelen: Basal melting from satellite observations 11.45 Katie Lowery: Channelised melt evolution from CryoSat Swath Observation: A case study of Pine Island Glacier. 12.05 Magnus Barfod Suhr: Sea ice and Sea surface temperature data at DMI 12.25 - Photo online and offline
12.30 – 13.15	Lunch Break
Session 2 13.15 -15.30	Modelling Ice, Atmosphere and Ocean Processes in Antarctica Convener: Ruth Mottram
Topics: Firn, regional climate, earth system and SMB modelling Coupled models Ocean and ice interactions	13.15 Michiel van den Broeke: Modelling Antarctic firn 13.35 Andrew Orr: From the hemispheric to the local: Atmospheric drivers of melt over Antarctic Ice shelves 13.55 Ben Wallis: Satellite observations of ocean warming driven rapid dynamic activation of a marine-terminating glacier on the west Antarctic Peninsula 14.15 Jan de Rydt: Coupled ice-ocean modelling 14.35 Nico Jourdain: Antarctic freshwater fluxes into ocean models 15.55 Christian Rodehacke: Coupled ice sheets in Earth system models (EC-Earth-PISM)

	15.15 Nicolaj Hansen: Using SMB modelling and ICESat2 to uncover ice sheet mass budget processes
1535 – 15.45	Afternoon coffee break
15.45 – 16.30	Discussion session: Reflections and Suggestions Discussion room(s) for online participants In-person around the islands: Ice shelves, Ocean, Ice Sheet processes, Mass budget and freshwater fluxes
Evening Activities	Harbour tour: 5pm Networking dinner: 8pm
Day 2: 24 May 2023	
8.30 – 9am 9.00 - 9.10	Coffee and Arrival at the Black Diamond Welcome, reflections from day 1, the programme for day 2
Session 3 9.10 – 11 am	Insights from modelling, emulation and machine learning applied in Antarctica Convener: Andrew Meijers
Topics: Deep Learning Emulation Automated processing Data assimilation	9.10 Stef Lhermitte: Title TBC 9. 30 Peter Tuckett, James Lea: Monthly pan-Antarctic surface meltwater area dataset from 2006 - 2021 9.50 Clara Burgard: Emulating present and future simulations of melt rates at the base of Antarctic ice shelves with neural networks 10.10 Sebastian Rosier: Predicting ice-shelf melt with a deep surrogate model 10.30 Amber Leeson: Firn emulation
10.50 – 11.10 am	Morning coffee break
Session 4 11.10 -12.30	Surface Mass Balance from Models: Lessons from PROTECT Convener: Christian Rodehacke
Topics: SMB Model evaluation	11.10 Robin Smith: Coupled Antarctic ice sheet modelling with UKESM 11.30 Charles Amory and Martin Olesen: Insights into ice sheet processes from SMB simulations in PROTECT 11.50 Nicolaj Hansen, Andrew Orr: Using MODIS to evaluate models of the Ross Ice Shelf melt event, January 2016 12.10 Ruth Mottram: New processes in new models: A first look at the next generation regional climate models in Antarctica: Some early results from PolarRES 12.20 Jose Abraham Torres: Developing a new model set-up for Antarctica: Harmonie-Climate
12.40 – 13.30	Lunch
13.30 – 15.30	Project Meeting: So-ICE - discussions
	Project Meeting: WP3 OCEAN:ICE – discussion on data format, delivery and other discussions
15.30 – 15.45	Afternoon coffee break

15.45 – 16.30	Discussion session topics: 1. Learnings from the workshop: high-level recommendations 2. Follow-up activities including publication discussion

Appendix 2: Participants

Online Participants

Amber Leeson
Anastasiia Chyhareva
Andrew Orr
Brad Reed
Christoph Kittel
Clara Burgard
Denis Pishniak
Svein Østerhus
Gael Durand
Ines Otosaka
Jan De Rydt
Keith Nicholls
Livia Jakob
Marcus Engdahl
Marion Devilliers
markus.janout
Michael Meredith
Nico Jourdain
Sebastian Rosier
Stef Lhermitte
Thomas Slater
Verena Haid
Äijälä, Cecilia
Antonio Novellino
Romain Millan
Shenjie Zhou

In-person Participants

Andrew Meijers
Anna Hogg
Benjamin Davidson
Benjamin Wallis
Christian Rodehacke
Jean-Baptiste Barré
Jose Abraham Alavez Torres
Katie Lowery
Magnus Suhr
Martin Graves Rasmussen
Martin Olesen
Michiel van den Broecke
Nicolaj Hansen
Noel Gourmelen
Peter Tucket
Peter Ukkonen
Povl Abrahamsen
Rebecca Dell
Ruth Mottram
Shuting Yang
Leif Denby