Ocean Cryosphere Exchanges in Antarctica:

Impacts on Climate and the Earth system

OCEAN:ICE WP8 annual storyline meeting 2

Milestone MS24

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1   Means of verification of the achievement of the milestone

The four cross cutting themes (storylines) of OCEAN:ICE are:

- The 'Antarctic Bottom Water' theme, led by Povl Abrahamsen (UKRI-BAS).

- The 'Deep Uncertainty in Freshwater Fluxes (DUFF)' theme, led by Frank Pattyn (ULB) and Jan de Rydt (UNN).

- The 'Role of the Poles' them, led by Robin Smith (UREAD).

- The 'Oxygen isotope' them, led by Casimir de Lavergne (CNRS).

The four meetings of cross cutting themes owere held over October/November 2023. Two of these, the **Deep Uncertainty in Freshwater Fluxes** and the **Antarctic Bottom Water**, were held in person/hybrid during the OCEAN:ICE annual science meeting in Paris (23-26 October 2023), whilst the other two, **Oxygen Isotopes** and **Role of the Poles,** were held virtually in the following weeks. The reason for this spread in meetings was to avoid overlap between people wishing to attend multiple meetings, a likely occurrence for cross cutting themes across work packages. These meetings extend those held virtual in April 2023, and will be followed up with further virtual meetings in May 2024. Each meeting was attended by project members and invited external participants. Meeting notes and the recordings of these meetings are available internally to project partners via the project SharePoint.

A summary of the key discussion points and actions arising is provided in this milestone report.

2   Work performed and main achievements

Each of the four meetings had representatives from each OCEAN:ICE work package attending, as well as the coordination team and various external partners, including from the EPOC project and the SAMBA/SAMOC array. Below are summaries, including lists of identified actions, of the four meetings.

Antarctic Bottom Water and the lower cell of the MOC Storyline

26 October 2023, at the OCEAN:ICE annual meeting, Paris

Moderator: Povl Abrahamsen (UKRI-BAS)

Rapporteur: Andrew Meijers (UKRI-BAS)

Summary

To start off the discussion, we heard four presentations on bottom water and the MOC:

- Alessandro Silvano (University of Southampton) presented on Antarctic Bottom Water Formation (AABW) across the Antarctic, on multiple timescales from interannual to decadal, to centennial, where different processes will influence formation, from internal climate variability to icesheet melt and atmosphere-ocean-icesheet feedbacks.
- Kathryn Gunn (University of Southampton – work presented was done at CSIRO) presented her recent work on an observed reduction in Antarctic Bottom Water in the Australian Antarctic Basin, utilising hydrographic and mooring observations combined with models to fill some of the gaps. This methodology has potential for application elsewhere.
- Christopher Auckland (UKRI-BAS & University of Southampton) gave a talk on his recent work on what controls the flow of AABW from the Weddell Sea to the Atlantic Ocean. Using the time series from the LDEO M2 mooring (in the NW Weddell Sea) and the BAS OP2 mooring (in Orkney Passage), he is trying to determine mechanisms linking high frequency variability in northward transport and observed long term declines in AABW.
- Sabrina Speich (LMD & IPSL, ENS, Paris) gave a talk on recent developments in the SAMBA array. This mooring array aims to measure the variability in overturning across the South Atlantic Ocean at 34.5° S. OCEAN:ICE will deploy 2 Microcats on PIES in each basin, we will be examining these in the context of historical/reanalysis data and deep Argo floats. There may be future French deep Argo float deployments in the east, likely using 4000-m floats. While SAMBA array does well to study Eulerian transport, Argo does well for Lagrangian; this can be important to resolve some variability.
- There was discussion about a possible synthesis of OCEAN:ICE observations together with external analysis at end of project. This could lead to an output around gaps and which observations are key to answering questions posed by models.
- A concern is the general decrease in ship time availability, while there still is a need for more data from hydrographic sections (as seen in Kathy Gunn's work) and as a platform for other critical observations (such as those shown by C. Auckland and S. Speich). It is felt that SOOS needs to be more visible to GOOS, to be placed on map for ship sections, digital twin, Argo, etc. We should aim to raise visibility of moorings, ships, including the importance of deep moorings, rather than "just digital twin + Argo" model of an observing system.
- K. Gunn is recruiting a PhD student for a project on observing system design – with potential links to OCEAN:ICE. When this is advertised, meeting participants were encouraged to share this in their networks.

Actions arising

- Pursue alternative deployment pathway for South Sandwich Trench moorings (Action for UKRI-BAS)
- 'Raise visibility' of lack of available international ship time and importance of 'traditional' observational methods in fora such as SOOS/GOOS/national logistical providers (Action for all).

- Pursue planned deployment plans via partners of SAMBA deep moorings (Action for ENS-LMD).
- Share advertisement of new AABW PhD position (all).

Deep Uncertainties in Freshwater Forcing (DUFF) Storyline

26 October 2023, at the OCEAN:ICE annual meeting, Paris

Moderator: Frank Pattyn (ULB)

Rapporteur: Jan De Rydt (UNN)

Summary

- It was determined that OCEAN:ICE will interact with the *Southern Ocean Freshwater release model experiments InitiAtive* (SOFIA) by contributing to the experiments, and potentially explore ways to provide spatially distributed fluxes.
- There is now a consensus on how WPs **define freshwater fluxes**: all sources that enter the ocean, including fluxes from the ice sheet (e.g., surface and basal runoff, calving, ice-shelf melt), sea-ice melting and precipitation. The remainder of the meeting focussed on freshwater fluxes from the Antarctic Ice Sheet only (henceforth referred to as AFWF). **End-users** for future projections of Antarctic fresh water flux (AFWF) from WP4: predominantly for ocean-only and ESM simulations in WP5 and 6, but also of interest to WP3 who are working on distribution of iceberg melting in the ocean.
- Decisions was made on the **format of products** to be provided by WP4:
    - **Ice Shelf melting**: 3D fields (x,y,z) on native model grid are desirable. Leave it up to individual users to interpolate/extrapolate. Annual (seasonal if possible) frequency is preferred. (Being able to use the 3D fields in an ocean or Earth System model is already a big step compared to SOFIA).
    - **Basal melt from grounded ice**: Much smaller source of AFWF compared to calving fluxes or ice-shelf melt but could play a role in amplifying ice-shelf melt by injecting additional buoyancy at the grounding line. Information on basal run-off from ice-sheet models should be stored but are not considered to be of order 1 importance for WP5, 6.
    - **Calving fluxes**: How to translate these fluxes into iceberg size distributions? NEMO has a simple stochastic scheme based on the size current observed distribution of icebergs. This scheme requires ice thickness and flux as inputs, which ice-sheet models can easily provide. Can this be improved and how? Use some measure of ice damage to say something about iceberg size?
- DUFF set up a *questionnaire* to map out the requirements of the different teams. This is to be filled out by the other work packages. ULB will adjust format of preliminary results for deliverable *D4.1 'Fast-track' sensitivity of freshwater fluxes to climate scenarios,* based on what end-users need. *(April 2024: This deliverable is now available).*
- Decisions made on model scenarios to use, and the definition of uncertainty:
    - Use Coupled Model Intercomparison Project (CMIP) scenarios. WP4 to provide 1 set of fluxes for each scenario + end members.
    - Coordinate between WP4 and WP5 regarding UKESM experiments/forcing
        - Deep uncertainty: what ULB currently includes in the UQ framework: subshelf melting schemes, basal sliding, climate scenarios.
        - What is not currently included: damage, MICI
        - Do we need a robust ensemble design to provide a probability distribution of AFWF for use by ocean models or does WP4 provide outputs from individual (mid-

scenario and end) ensemble members? It was felt that UQ is still needed to assess likelihoods of ensemble members.

Actions arising

- SOFIA: OCEAN:ICE to interact with SOFIA, e.g. by contributing to the experiments, and potentially explore ways to provide spatially distributed fluxes (Action for WP2/CNRS, NPI).
- CMIP: an OCEAN:ICE representative to assist in leading workshop on AFWF (organised by Gavin Schmidt) (Action for UKRI-BAS, ULB). Others to attend/present (Action for all).
- Fill in questionnaire on team modelling output/requirements (Action for: All).
- Assess ensemble design (Action for WP4, ULB, UNN).

Role of the Pole(s) Storyline (RoP)

6 November 2023, online only

Chair and Rapporteur: Robin Smith (UREAD)

Summary

- Jon Robson (UREAD/NCAS) presented the EPOC list of proposed AMOC diagnostics. If our models monthly U,V,T,S everything else AMOC (e.g., AMOC in density space, decomposition, overflows) can be diagnosed, possibly via the common calculation package at https://github.com/NCAR/metric
- Their 6hrly bottom pressure is for a specialised piece of analysis, not relevant to/for/from OCEAN:ICE. EPOC has a MS document at the end of the year for a full diagnostic list.
- It was noted that most of their runs are idealised (4xCO2), on short timescales (30 years) and at high resolution (global 12°). There is likely to be one realistic scenario simulation.
- There was a discussion from the last RoP meeting to create Model User Group action. The DUFF actions were covering technical aspects of what the global models expect in practice and there are enough people who are in both RoP and DUFF to not need another special group at this point. DUFF has set up an internal tracking for the requirements. RoP modellers will integrate the DUFF list of requirements.
- **Status of work was reported on with notable outcomes:**

WP2: Delays in UKESM2 development means (initial?) UKESM runs will be with an older version of NEMO, but any new iceberg code may be fairly simple to backport. UKRI-BAS unlikely to get as far as including subgridscale bathymetry that would be useful for lower resolution models in their development.

WP3: In approx. 6 months they will have estimates for AIS surface flux. GrIS can be provided as well, but there are already lots of products available.

WP4: Two ice sheet models are being run at UNN and ULB. They will produce two products, a fast track for the deliverable D4.1 in Spring 2024 and a slower one. *They need to know which scenarios the other models want to run* (see spreadsheet action above).

WP6 flagged that NEMO-BISICLES development is not where we would want it to be. The deliverable that needs it is planned in M30, so there is still time. WP6 will ensure to align scenarios too and agree ways to extend them beyond 2300, including additional freshwater fluxes from different sources (e.g. add iceberg flux).

- Gavin Schmidt's proposed workshop on multi-lateral efforts to provide a coordinated ice-derived freshwater forcing for climate models. This is one part of what OCEAN:ICE was going to deliver. The workshop is pencilled in for 8-9 January 2025.

Actions arising

- Modelling teams to assess their output and metrics against EPOC documentation (all).
- Follow up collaborations with EPOC, notably modelling, at the next EPOC project meeting (Action for partner UREAD).
- Fill in modelling questionnaire (Action for all).
- Coordinate with DUFF and WP leads to form model users action group (Action for UREAD, UKRI-BAS, ULB).
- Provide speakers and attendees for workshop on freshwater fluxes (Action for all).

Oxygen isotope Storyline

9 November 2023, online only

Chair and Rapporteur: Casimir de Lavergne (CNRS)

Summary

- Overview of tasks resorting to water isotopes in OCEAN:ICE (C. de Lavergne)

- Update on water-isotope field observations part of OCEAN:ICE (R. Grilli)

- Update on water-isotope field observations part of SOS-iClimate (A. Haumann)

- Update on oxygen isotope reconstruction using inverse modelling (X. Davila)

- Update on water-isotope modelling at IPSL (C. de Lavergne)

- Update on water tracer modelling in UKESM (A. McLaren)

- Update on SO-Fresh satellite-based sea surface salinity products (A. Silvano)

- Update on data synthesis following from ORCHESTRA (A. Meijers)

- **Reports on status of work:**

Task 2.4: New instrument to measure water isotopes on site has been developed. Accuracy of deuterium and oxygen-18 measurements was estimated to be between 0.1 and 0.2 per mil. Julien Witwicky (CNRS) is currently in the field and will operate the instrument at two Fimbul Ice Shelf borehole sites, M1 and M2, in December. The sampling strategy has been discussed. Priorities are (1) comparison with water samples to ensure data quality, (2) spatial variability, i.e. measurements in the top 100-200 m of the water column, to sample meltwater, (3) variability over a day (1h or 2h temporal resolution is hoped) to measure over a tidal cycle, and (4) measurement near the seabed to get a deep water signature.

Task 2.5: A water-isotope module has been transferred from NEMO3.6 to NEMO4.2 by M. Ayache, A. Mouchet and J.-C. Dutay (LSCE, France). This module is now being verified in some test simulations. The cryosphere is not yet accounted for. Sea ice will be addressed once a generic tracer module is

available in NEMO. Further development will be done within this task to ensure accurate representation of water isotopes at the ocean-ice sheet interface.

Task 5.2: Work on mapping decorrelation length scales in salinity and oxygen-18 observations has started (NORCE). NORCE (X. Davila) is taking over this work and starting to examine and compile d18O observations in a deliverable *(April 2024: This deliverable is now available).* The Total Matrix Intercomparison (TMI) inverse model of ocean transports ingested the NASA GISS d18O database. These transports are fixed but allow to reconstruct past surface ocean properties using modern interior observations.

Actions arising

- Questions remain regarding initialisation and open boundary fluxes of water-isotope tracers in regional ocean configurations. Assessing global ocean simulations at coarse resolution with a few open cavities will be the first step to verify the developments and possibly to provide boundary conditions for the regional Weddell Sea model (Action for NORCE).
- Report back on success or otherwise of field work utilising new isotopic measurements (Action for CNRS).
- Establish links with UKRI-BAS L. Sime (outside OCEAN:ICE) team working independently on implementation of tracers within NEMO to establish overlaps and opportunities for collaboration (Action for UKRI-BAS, CNRS/IPSL).