Ocean Cryosphere Exchanges in Antarctica:

Impacts on Climate and the Earth system

OCEAN:ICE Annual Project Meeting 1

Milestone MS18

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https://ocean-ice.eu/

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Means of Verification of the Achievement of the Milestone

Delivery of meeting. Partner in charge of delivery of the milestone: UKRI-BAS.

Work Performed

The consortium met at Sorbonne University in Paris on the 25-26 October 2023. This event was also held virtually via Zoom. This meeting was organised in collaboration with the consortium for the H2020 funded project SO-CHIC [1] allowing for overlap to encourage knowledge exchange, collaboration and networking.

The meeting was held in conjunction with the H2020 project SO-CHIC annual meeting (23-24 October 2023) and a jointly organised scientific conference on the 24-25 October 2023. The event brought together several Southern Ocean and cryosphere scientists from OCEAN:ICE, SO-CHIC, but also from other projects funded by the European Union, the European Space Agency, UK Research and Innovation, and related projects from the EU Polar Cluster and beyond. The proceedings of the SO-CHIC and OCEAN:ICE Joint Project Conference are going to be made available in the OCEAN:ICE Zenodo community Ocean-Cryosphere Exchanges in Antarctica: Impacts on Climate and the Earth System in the upcoming weeks.

Goal of the Meeting

The OCEAN:ICE Annual Project Meeting Nr. 1 (year 2023) served as a platform for partners to gain a deeper insight into all project's work packages' progress, results and outline the trajectory for the upcoming 12 months. The meeting created an opportunity to better coordinate the research and agree on the rapid dissemination of findings between the work packages via the cross-cutting theme sessions. Moreover, it was a great chance for the work packages to meet to assess progress and to enhance planning of the upcoming project activities in the next year. The meeting was an undeniable success, reigniting the partnership's enthusiasm for the continuation of OCEAN:ICE work, and it sparked numerous engaging discussions aimed at fine-tuning planned activities as detailed in the description of the action.

Participants

Representatives from all participants and partners were invited to the meeting to participate either in person or virtually. Partners represented were the following: DMI, NORCE, AWI, CNRS, UU, ETT, ULB, ENS-LMD, UGOT, NPI, EPB, PIK, UKRI-BAS, UNN, UoS, UNIVBRIS, UNILIVERPOOL, UREAD.

[1] (GA 821001, http://www.sochic-h2020.eu/)

Agenda

The day 1 of the OCEAN:ICE annual meeting (25 October 2023, in the afternoon) started with an overview of the programme for the day. After that, the presentations by the individual work package leaders and co-leaders followed, revolving around the advancement of the work package activities, the outcomes achieved, and the planning for the next 12 months. To aid the planning of dissemination and outreach activities a **jam board** was utilised. The final presentation of the day aimed at clarifying the project management and reporting activities.

The day 2 of the OCEAN:ICE annual meeting (in the morning of 26 October 2023) began with an overview and key points arising from the day 1, and a discussion outlining the plans for the coming year. After that, the cross-cutting theme parallel sessions on the 'Deep uncertainty in freshwater fluxes' and 'Bottom water and lower cell' were held. Before the annual meeting, the decision has been made to hold the other two cross-cutting theme sessions (e.g., 'Oxygen isotope exploitation' and 'The role of pole(s) in the global climate system') virtually after the annual meeting to maximise the engagement of the project partners.

A poster session took place during the breaks of day 1 and day 2 for in-person participants and the virtual attendees were able to access the posters throughout the entire duration of the meeting. After the cross-cutting themes parallel sessions, the participants came together to listen to the reports from the respective parallel sessions. The OCEAN:ICE annual meeting was concluded with the work package meetings, providing the opportunity to focus on the delivery of scientific and field objectives.

Summary of the Progress in the OCEAN:ICE Work Packages

Up until the OCEAN:ICE Annual Project Meeting 1, all the project's deliverables (D9.3, D7.1, D9.1, D9.2, D9.9, D7.6) and milestones (MS17, MS28, MS23, MS6, MS5, MS26, MS7) were accomplished and reports submitted on time.

WP1 – Subpolar circulation, heat delivery and water mass export

The work is progressing as planned. The delivery of the deliverables and milestones as detailed in the description of the action is on track. WP1 team has grown as intended. Work on SSH and in situ ocean variability is progressing as two teams are working on these using different approaches. In terms of new observations and 23/24 field deployments, international collaboration to deploy and extend the fleet of deployable instrument is paramount and is very encouraging so far. Initial circumpolar sea ice production work has been done in terms of ice production using ERA5 applied at several locations. Ocean modelling test runs are satisfactory. In the future, model results will be compared against the observations. The desire to receive input from the OCEAN:ICE community on required features for the circumpolar ocean model was expressed.

WP2 – Cryosphere-ocean interaction, processes and feedbacks

The work is progressing as planned. The delivery of the deliverables (D2.2, D2.3, D2.1, D2.4) and milestones (MS3 and MS4) as detailed in the description of the action is on track. Work on the deliverable D2.5 hasn't started yet as it is due in October 2026. WP2 team has grown as intended and new PDRA were in attendance in person or virtually. Work has started in terms of improved representation of icebergs in ocean models. Ocean simulations covering the past decades are planned. Fieldwork plan to deploy the Hugins AUV 'Ran' early next year is on track. AUV missions will include launching in a safe, ice-free place, diving down to seabed, swimming into the cavity, swimming up to ice, performing ice survey, then diving down to seabed and swimming northwards for one hour. These are estimated to be 24–28-hour long missions. They will result in the following data sets: high resolution (1 dm) maps of ice base, high resolution (<5 dm) maps of seabed, T, S and O2, CO2, nitrate, Fl, turbidity, water samples (150 ml each), and current velocity. Information will also be collected from the acoustic sensors on board the AUV and UAV operations carried out in region surveyed by AUV. AUV operations will also be carried at the ice shelf front and Bear ridge while through ice measurements will be conducted beneath Fimbul Ice Shelf.

WP3 – Ice sheet mass balance, forcing and dynamics

The work is progressing as planned. The delivery of the deliverables and milestones as detailed in the description of the action is on track. Work on the deliverable D3.4 hasn't started yet as it is due in October 2025. The following milestones MS5, MS6 and MS7 were achieved, and reports submitted on time. WP3 team has grown as intended. Work is ongoing in terms of the D3.2, to set up and run models. Early work has been carried out on SMB and run-off part.

WP4 – Quantification of Antarctic Ice Sheet 'deep uncertainty' and freshwater fluxes under climate forcing

The work is progressing as planned in the work package 4. The delivery of the deliverable D4.1 as detailed in the description of the action is on track. Work on the deliverables D4.2 and D4.3 hasn't started yet as they are due in October 2025 and April 2026 respectively. WP4 team has grown as intended. WP4 is at early stages of setting up circum-Antarctic simulations with the ice sheet model. The aim is to start from an optimised configuration in 2004, allowing 20 years of model validation against observations. Work in the next few months will focus on model initialisation, calibration and validation (2004-2023). Furthermore, Kori-ULB, ice flow model designed for ensemble modelling

(Bayesian calibration), was developed. Improvements on initialisation procedure are planned. Future work in terms of Kori-ULB include extending UQ analysis to include additional processes and their uncertainty, e.g., Calving, subshelf melt, SMB, Basal Sliding, Damage (not all of them in fast track), preparing the report and associated data detailing sensitivity of Antarctic freshwater fluxes to uncertain physical processes and climate scenarios between 2020 and 2300 for fast-track delivery to WP5 and 6 (D4.1). Future work is planned for including model calibration, setting up framework for UQ (starting emulator training, making decisions on parameter choices, prior distributions), obtaining preliminary results on freshwater fluxes for subset of parameters and forcing scenarios. The desire to receive input from the community on required adjustments/additions to the models to serve other work packages was expressed.

WP5 – Ice sheet impacts on global ocean circulation

The work is progressing mostly as planned with a deviation related to the work to be implemented in milestone MS9. So far, there are changes to the delivery time of the D5.5, MS9 and MS10. The WP5 team has grown as intended. Work has started on all planned reports (D5.7, D5.8, D5.9 and D5.5). Detailed plans are in place to work on the D5.6 in terms of the water mass archaeology. Work has started in terms of D5.3 and D5.4 and plans are in place for 2024 to analyse historical and SAMBA observations, as well as re-analyse data to detect changes in salinity and if these changes are correlated with the observed temperature changes in SAMBA-WEST. In terms of D5.2, in the 2022/2023 season, 6 moorings in Orkney Passage have been recovered, 4 moorings redeployed, M2 redeployed, M3 recovered and redeployed. Surplus instrumentation and releases returned to UK for use in South Sandwich Trench. Deployment of moorings in South Sandwich Trench is currently being planned for MS9: Logistical issues have been encountered here with short notice changes to planned deployments due to shipping issues. Work is ongoing to rectify this.

WP6 – Role of Antarctica in the global climate: long-term impacts of short-term decision-making

The work is progressing as planned. The delivery of the deliverables and milestones as detailed in the description of the action is on track. WP6 team has grown as intended. There was a work package leadership change (from R. Winkelmann to T. Albrecht), and the addition of the new project partner is in progress. Work has started on all planned deliverables (D6.1, D6.2 and D6.3). WP6 was busy preparing CMIP surface forcing for ocean and ice, doing test runs with a coupled system under 1pctCO2 scenario, inserting basal melt at depth into the ocean and mass conservation for changes in ice/ocean distribution.

WP7 – Data management

The work is progressing as planned. The delivery of the deliverables and milestones as detailed in the description of the action is on track. The deliverables D7.1 and D7.6 were achieved, and reports submitted on time. As the data management plan will be updated yearly, the desire to receive input from the community was expressed.

WP8 – Science coordination

The work is progressing as planned. The delivery of the deliverables and milestones as detailed in the description of the action is on track. The milestones MS17, MS23 and MS26 were achieved, and reports submitted on time. The storyline meeting coordination is ongoing. Bi-weekly Scientific Steering Committee meetings are taking place. The organisation of the model users' group is in progress. An application was submitted to the Horizon call for the hop-on facility, to include NASC (Ukraine) as an additional partner. The application's acronym is *WISH-OI*. WP8 participated in the Ocean Data Week, SOOS Symposium and numerous other events promoting OCEAN:ICE and external collaboration. It is involved in the organisation of the first policy briefing of the project (planned in January/February 2024 with the European Parliament Intergroup), as well as Southern Ocean Summer School 2024.

WP9 – Project coordination, dissemination and outreach

The work is progressing as planned. The delivery of the deliverables and milestones as detailed in the description of the action is on track. The following deliverables D9.3, D9.1, D9.2, D9.9 and milestone MS28 were achieved, and reports submitted on time. WP9 is organising the first policy briefing and has launched OCEAN:ICE webinars as well as the climate coffee series: https://ocean-ice.eu/climate-coffees/

WP9 actively promotes the project outputs via social media and other outreach material. WP9 reported on the OCEAN:ICE members' participation in more than 50 conferences so far for the first year of work, clustering activities, education and training events, and workshops over the past year. WP9 is continuing to work on ensuring effective both internal and external communication.

Documentation

Direct links to the presentations of the work packages can be found below:

- Janout, M., & Dutrieux, P. (2023, November 6). WP1 Antarctic Shelf Seas. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10074558
- WP2 - Jourdain, N., & Wåhlin, A. (2023, November 3). WP2 Cryosphere-ocean interaction,processes and feedbacks. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10069209
- WP3 - Ruth Mottram. (2022, November 24). OCEAN:ICE Work Package 3 Overview - Antarctic ice-sheet modelling and freshwater fluxes. Zenodo. https://doi.org/10.5281/zenodo.7355763
- WP4 - De Rydt, J., Pattyn, F., Coulon, V., & Qin, Q. (2023, November 3). WP4: Quantification of AIS 'deep uncertainty' and freshwater fluxes. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10069201
- McDonagh, E., & Langebroek, P. (2023, November 6). WP5 - Ice sheet impacts on global ocean circulation. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10074606
- WP6 - Albrecht, T., & Payne, T. (2023, November 3). WP6: Role of Antarctica in the global climate: long term impacts of short term decision making. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10069227
- Novellino, A. (2023, November 6). Data Management (WP7) overview. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10074618
- WP8 - Meijers, A., & Mottram, R. (2023, November 3). OCEAN:ICE WP8 Science Coordination. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10069239
- WP9 - Hayashi, E., & Bearzotti, C. (2023, November 3). WP9 Progress, Results and Next Steps. SO-CHIC and OCEAN:ICE Joint Project Meeting, Sorbonne University, Paris, France. Zenodo. https://doi.org/10.5281/zenodo.10069251

Cross Cutting Themes

There are four cross cutting themes within the project, whose primary purpose is to make sure that work in the individual work packages support each other where appropriate and can be presented together as coherent storylines at the end of the project. Prior to the annual meeting, it was determined that two cross-cutting theme sessions ('Oxygen isotope exploitation' and 'The role of pole(s) in the global climate system') would be conducted virtually in the aftermath of the annual meeting (within two weeks) to enhance participant involvement and avoid participants having to choose 'favourite' themes and thus miss out on opportunities. As such to provide an optimum platform for impactful research, we held two cross-cutting theme meetings ('Deep uncertainty in freshwater fluxes' and 'Bottom water and lower cell') during the annual project meeting. A summary of the discussions in the cross-cutting themes 1 and 2 is reported below. The summary of the discussion for cross-cutting themes 3-4 will be uploaded to Zenodo after their respective meetings.

Theme 1: Deep uncertainty in freshwater fluxes

Lead: Universite Libre de Bruxelles (F. Pattyn), partners: All

The drivers, magnitude and variability of freshwater flux from the polar ice sheets to the ocean is a central theme. To start off the discussion, Frank Pattyn (ULB) delivered a presentation on 'Deep uncertainty in freshwater fluxes' objectives and outcomes.

Summary of discussion points:

- There is a general consensus on how different WPs **define freshwater fluxes**: all sources that enter the ocean, including fluxes from the ice sheet (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 AFWF from WP4: predominantly for ocean-only and ESM simulations in WP5 and WP6, but also of interest to WP3 who are working on distribution of ice-berg melting in the ocean.
- **Format of products** 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 ES model is already a big step compared to SOFIA).
    - Basal melt from grounded ice: much smaller source of FW 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 ice-bergs. 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?
- **Projections and uncertainties**:

    - Use CMIP scenarios. WP4 to provide 1 set of fluxes for each scenario and 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.
- **Synergies** with other efforts outside OCEAN:ICE:
    - SOFIA: OCEAN:ICE to interact with SOFIA, e.g. by contributing to the experiments, and potentially explore ways to provide spatially distributed fluxes.
    - CMIP: an OCEAN:ICE representative to attend a workshop on AFWF (organised by Gavin Smith).

Theme 2: Bottom water and lower cell

Lead: British Antarctic Survey (P. Abrahamsen), partners: WP1, WP2 and WP5

The formation of dense water around Antarctica, its export northward and interaction with similar waters formed in the North Atlantic is explicitly examined across seasonal to millennial timescales in work packages WP1, WP2 and WP5. To start off the discussion, four presentations were delivered on bottom water and the MOC, by Alessandro Silvano (University of Southampton), Kathryn Gunn (University of Southampton – work presented was done at CSIRO), Christopher Auckland (British Antarctic Survey and University of Southampton), and Sabrina Speich (CNRS-LMD and IPSL, École Normale Supérieure, Paris).

Alessandro Silvano started off the session with a presentation on Antarctic Bottom Water Formation 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.

In situ AABW observations dating back to the 1950s in the Ross Sea show clear downward trend in density/salinity, with recent rebound. Observations in Filchner trough since the 1970s show no clear trend. Adélie depression has measurements from the 1980s onwards, showing significant changes since the Mertz calving in 2010. There are few observations in Cape Darnley.

A freshening, contraction, and warming has been observed away from Antarctic, from Purkey & Johnson papers. A closer signal is only clear in Ross, but there is rebound in salinity post 2010, due probably to less sea ice, greater open water/ice production/export, possibly due to reduced blocking sea ice import from upstream in Amundsen Sea via changed wind circulation/El Niño.

What next for AABW: If trend continues, ~2050/60 will have a switch in the sense that AABW will not be produced via HSSW as it is too fresh, based on Ross trend.

Models show freshwater reduces overturning significantly (eg Liu et al, Gunn et al). However, Italian Terra Nova Bay timeseries suggest freshwater trend upwards since 2014, 0.12 recovery very significant offsetting previous 0.17 reduction. So high-frequency variability may be able to offset longer term trends, but whether it will also rapidly decrease in future is unknown. The observed salinity increase is both at the surface (perhaps related to sea ice decrease) and throughout the water column.

Drivers: Ben Davison ice sheet basal melt reconstruction post 90s. Satellite reconstruction largely suggests an increase in Amundsen Sea basal melt post 2016. Consistent with warmer in situ observations, too. Getz Ice Shelf is the largest melt water contributor, 1-2 year advective timescales. Based on models, obs needed.

Sea ice: Something like 50% Antarctic Sea ice production in Ross Sea Polynyas/Terra Nova Bay, ice formation has changed significantly post ~2013-14 based on satellite obs. Sea ice appears key on decadal timescales.

Timescales, do we need to wait another 50 years to understand timescales? Or do we need to rely on models? There may be some help from paleo approaches on very long timescales. Paleo struggles to describe lower cell, cf AMOC. LGM had an expanded lower cell with thicker water, weaker AMOC, prior to 15kyo, then transform to present day with thinner AABW cell, active AMOC. Hard to find analogue for present day in paleo. Alessandro called for more modelling/paleo.

Kathy Gunn 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.

Various hydrographic sections across export gateways to and from the basin. Density generally decreasing, except closest to formation, where rebound is seen. Oxygen shows no significant change. Area/density have a relationship, due to density-based definition of AABW.

Mooring observations were also made at gateways. Speed/density relationship in Ross Sea Bottom Water (denser water flows faster), in addition to seasonal relationship. Moorings don't give areas, so model data are used to define spatial relationships via structure function Models reproduce seasonal features to some extent.

Although there are only three observation points, error analysis based on seasonal to interannual variability on model and observations gives confidence that the signal is real.

Data shows slowdown of Australian Antarctic Basin overturning by ~30% pre 2018. Sum over basin gives overturning estimate. 0.7 Sv/decade decrease over ~20 yrs, but up to 2.5 Sv/decade. Oxygen volume decrease agrees with oxygen concentration decrease. Caused by change in volume, rather than lower oxygen concentration.

Gaps in understanding: What are the physical mechanisms driving AABW change? Decrease in production? Changes in source water properties? A: Both to some extent. is this Natural/anthropogenic? Future work can be expanded to other regions around Antarctica.

Overall shelf water salinity is key driver of speed/area of AABW decrease.

Chris Auckland 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.

Many mechanisms proposed in past literature (from variability of gyre causing lowering of isopycnals along South Scotia Ridge directly affecting outflow, to lowering of isopycnals affecting thermobaric sinking in the "v-shaped front" at the shelf break. Chris is looking at the barotropic response (as previously observed by Meredith et al. 2011, from M2 to the Scotia Sea). Good correlation in temperatures from M2 to OP, with differing lags between cold and warm peaks, suggesting change in boundary current speeds. Wavelet transforms give similar results to simple lag approach. Hard to do in salinity due to instrument issues.

To look at the drivers of this variability, EOF analysis was performed with wind stress curl, zonal and meridional wind components. Strong correlation between wind stress curl anomalies to transport, with transport lagging by ~ 3 months. Seems best related to zonal mode 1. Wind stress curl may be consistent with the SAM signal.

Mechanistically may be due to bottom friction-induced thick bottom boundary layer. Mooring array has potential evidence for this mechanism at play. Timescales make this tricky though, some periods have stronger evidence than others, with some appearing to have multiple mechanisms at play.

There are also links to Pedro Llanillo's work in SO-CHIC, looking at varying lags from AWI moorings along the SR4 section and M2.

Sabrina Speich 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.

SAMBA has evolved. There are PIES/CPIES at the boundary currents, the addition of more instruments/moorings/PIES from 2013 onwards. Tall moorings on slope since 2022. OCEAN:ICE is adding Microcats in the future to look at water mass variability.

Can compute MOC and MHT in, upper and lower cells. But we can only assess variability, rather than total transport. Mean based on models ~14.7 SV, standard dev from obs of 8.3 Sv, with very high variability even on daily scales. Transport can be separated into Ekman, reference, relative, etc., with no clear dominant component in variance. Seasonal cycle in upper cell also has all three terms being important.

Reconstruction of lower cell is ~7.8 Sv, upper 17.3 Sv. AABW layer also shows high variability, but upper/lower cells aren't correlated. 15 Sv std upper, 6 Sv lower. Net heat transport is dominated by change in strength of MOC, weakly anticorrelated with MOC in the abyssal cell.

Some reasonable agreement with XBT upper line. PIES shows wildly stronger variability compared with other methods like Argo. GOSHIP cruises have happened in 2017, showing abyssal MOC of only 2.4 Sv.

Suggested eastern AABW was more modified than west, in contrast to other studies. Believed to take longer to go through east side. Or could be argued that it may go north on west, return east.

Weak correlation between SAMBA and sections at other latitudes, but this is only initial and requires more work. Upper cell Argo-derived properties show freshening in intermediate/mode waters. Increasing in subtropical gyre to 700 m.

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.

Following the four talks, there was discussion about 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. One 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's work) and as a platform for other critical observations (such as those shown by Chris and Sabrina). It is felt that SOOS needs to be more visible to GOOS, so as 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.

Kathy 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.

Annex 1

OCEAN:ICE Annual Meeting Programme

Wednesday 25 October 2023, 13:30-17:30 + Networking Dinner at 19:30	
13:30	**Opening Session**
13:30-13:40	**Overview of the Programme for Day 3** Ruth Mottram (DMI) and Andrew Meijers (UKRI-BAS)
13:40– 15:00	**OCEAN:ICE Work Packages Progress, Results and Plan for the next 12 months** *Moderator: Andrew Meijers (UKRI-BAS)*
13:40-14:00	**WP1 Subpolar circulation, heat delivery and water mass export:** **Talk and Q&A (20 min)** *Presenters: Markus Janout (AWI) and Pierre Dutrieux (UKRI-BAS)*
14:00-14:20	**WP2 Cryosphere-ocean interaction, processes and feedbacks (20 min)** *Presenters: Nicolas Jourdain (CNRS) and Anna Wåhlin (UGOT)*
14:20-14:40	**WP3 Ice sheet mass balance, forcing and dynamics (20 min)** *Presenters: Ruth Mottram (DMI) and Gael Durand (CNRS)*
14:40-15:00	**WP4 Quantification of Antarctic Ice Sheet 'deep uncertainty' and freshwater fluxes under climate forcing (20 min)** *Presenters: Jan De Rydt (UNN) and Frank Pattyn (ULB)*
15:00-15:30	**Health Break and Mingle / Coffee break (30 min)**
15:30-17:10	**OCEAN:ICE Work Packages Progress, Results and Plan for the Next 12 Months** *Moderator: Ruth Mottram (DMI)*
15:30-15:50	**WP5 Ice sheet impacts on global ocean circulation (20 min)** *Presenters: Elaine McDonagh (NORCE) and Petra Langebroek (NORCE)*
15:50-16:10	**WP6 Role of Antarctica in the global climate: long-term impacts of short-term decision-making (20 min)** *Presenters: Ricarda Winkelmann (PIK) and Tony Payne (UNIVBRIS/UNILIVERPOOL)*
16:10-16:30	**WP7 Data Management (20 min)**

	Presenters: Antonio Novellino (ETT)
16:30-16:50	**WP8 Scientific Coordination (20 min)** *Presenters: Andrew Meijers (UKRI-BAS)*
16:50-17:00	**WP9 Dissemination, Outreach, use of Jam Board and EDI Policy (10 min)** *Presenters: Erika Hayashi (DMI)*
17:00-17:10	**WP9 Project Management, Reporting (10 min)** *Presenters: Chiara Bearzotti (DMI)*
17:10-17:30	**Q&A (20 min)**
19:30	**OCEAN:ICE Networking Dinner** *@Restaurant 'Amore Mio', 13 Rue Linné, 75005 Paris*

Thursday 26 October 2023, 09:00-14:10	
09:00 – 09:30	**Opening Session**
09:00 – 09:10	**Overview and key points arising from day one**
09:10 – 09:30	**Plans for Coming Year**
09:30 – 11:10	**Cross-Cutting Themes Parallel Sessions**
09:30 – 11:10	**Deep uncertainty in freshwater fluxes** *Moderator: Frank Pattyn (ULB)* **Bottom water and lower cell** *Moderator: Povl Abrahamsen (UKRI-BAS)*
11:10 – 11:40	**Health Break**
11:40-12:00	**Reports from Cross-Cutting Themes Parallel Sessions**
	Deep uncertainty in freshwater fluxes *Rapporteur: Jan De Rydt (UNN)* **Bottom water and lower cell** *Rapporteur: Povl Abrahamsen (UKRI-BAS)*
12:00 – 13:00	**WP Meetings**

12:00 – 13:00	**WP1-7 Meetings** **WP9 Dissemination:** Jam board for you to contribute during the entire meeting (no specific meeting)
13:10 – 14:10	**Networking lunch**

Annex 2

List of the submitted deliverables and current status

Work Package No	Deliverable Related No	Deliverable Name	Lead Beneficiary	Due Date	Delivery Date	Status
WP1	D1.1	Standardisation of pan-Antarctic mooring and profiles	UKRI-BAS	30 Apr 2024		Pending
WP1	D1.2	Circumpolar EKE/tides from available mooring records	UKRI-BAS	31 Oct 2024		Pending
WP1	D1.3	Comparison and validation of two Antarctic SSH products	CNRS	30 Apr 2025		Pending
WP1	D1.4	Gridded European circumpolar sea ice production fluxes	AWI	31 Jul 2024		Pending
WP1	D1.5	Deployment of profiling floats as pairs	UKRI-BAS	30 Apr 2026		Pending
WP1	D1.6	Deployment of bottom pressure recorders	UKRI-BAS	31 Oct 2025		Pending
WP1	D1.7	Evaluation of Control FESOM hindcast (1979-present)	AWI	31 Oct 2024		Pending
WP1	D1.8	Model-based quantification of fluxes between shelf seas	AWI	30 Apr 2025		Pending
WP1	D1.9	Local and remote processes impacts on high melt regions	UKRI-BAS	31 Oct 2025		Pending
WP1	D1.10	Local and remote processes impacts on dense water formation	AWI	31 Oct 2025		Pending

WP1	D1.11	Observation-based time series of dense shelf water properties	UKRI-BAS	31 Oct 2025		Pending
WP1	D1.12	Record of water mass age and meltwater fractions, Weddell Sea	AWI	30 Jun 2024		Pending
WP2	D2.1	Modelling icebergs, bathymetry and sea ice interactions	CNRS	30 Apr 2025		Pending
WP2	D2.2	AUV observations under the sea-ice around grounded icebergs	UGOT	31 Oct 2024		Pending
WP2	D2.3	Ship and AUV observations near /within a warm ice-shelf cavity	UGOT	31 Oct 2024		Pending
WP2	D2.4	Observations of the ocean beneath Fimbul Ice Shelf	UKRI-BAS	31 Oct 2025		Pending
WP2	D2.5	Water isotope simulations to constrain melting and mixing	CNRS	31 Oct 2026		Pending
WP3	D3.1	Contributions of ice sheet processes to freshwater fluxes	CNRS	30 Apr 2024		Pending
WP3	D3.2	Freshwater fluxes from surface mass budget and sub-shelf melt	DMI	30 Apr 2024		Pending
WP3	D3.3	Estimation of the basal freshwater discharge from the AIS	UNN	30 Apr 2024		Pending
WP3	D3.4	Feasibility study into ice sheet-ocean model initialisation	UKRI-BAS	31 Oct 2025		Pending
WP4	D4.1	'Fast-track' sensitivity of freshwater fluxes to climate scenarios	ULB	30 Apr 2024		Pending

WP4	D4.2	Freshwater fluxes between 2000 and 2300 with robust UQ	ULB	31 Oct 2025		Pending
WP4	D4.3	Comparison of ice-only to coupled ice-ocean simulations	UNN	30 Apr 2026		Pending
WP5	D5.1	Mooring dataset from South Sandwich Trench	UKRI-BAS	31 Oct 2025		Pending
WP5	D5.2	South Sandwich Trench and Orkney Passage comparison	UKRI-BAS	31 Jul 2026		Pending
WP5	D5.3	Dataset of near-bottom sensors on SAMBA array	ENS-LMD	31 Oct 2025		Pending
WP5	D5.4	Deep and bottom water masses from SAMBA observations	ENS-LMD	30 Jun 2026		Pending
WP5	D5.5	Temporal and spatial length scales in δ18O observations	NORCE	30 Apr 2024		Pending
WP5	D5.6	Reconstruction of global surface d180 and salinity	NORCE	30 Apr 2025		Pending
WP5	D5.7	Initialisation and verification of NEMO configuration	CNRS	30 Apr 2025		Pending
WP5	D5.8	Greenland ice sheet freshwater implementation in NorESM	NORCE	30 Apr 2025		Pending
WP5	D5.9	Impact of glacial freshwater forcing on model ocean circulation	NORCE	30 Apr 2026		Pending
WP6	D6.1	Freshwater and iceberg flux impacts with BISICLES-NEMO	UKRI-BAS	30 Apr 2025		Pending

WP6	D6.2	Impacts of ice loss on global climate to 2300 from UK-ESM	UNIVBRIS	31 Jul 2026		Pending
WP6	D6.3	Impacts of ice loss ocean on millennial scales (PISM-MOM)	PIK	31 Jul 2026		Pending
WP7	D7.1	Data management plan v.1.0	ETT	30 Apr 2023	02 May 2023	Submitted
WP7	D7.2	Data management plan v.2.0	ETT	30 Apr 2024		Pending
WP7	D7.3	Data management plan v.3.0	ETT	31 Oct 2025		Pending
WP7	D7.4	Infrastructure design v.1.0	ETT	31 Oct 2024		Pending
WP7	D7.5	Infrastructure design v.2.0	ETT	31 Oct 2025		Pending
WP7	D7.6	Data inventory	ETT	31 Oct 2023	25 Oct 2023	Submitted
WP7	D7.7	Interoperability requirements definition	ETT	31 Oct 2024		Pending
WP7	D7.8	OCEAN ICE data catalogue system	ETT	31 Oct 2025		Pending
WP7	D7.9	Web data portal v.1.0	ETT	31 Oct 2024		Pending
WP7	D7.10	Web data portal v.2.0	ETT	31 Oct 2026		Pending
WP7	D7.11	System performance, monitoring and impact assessment r.1.0	ETT	31 Oct 2024		Pending
WP7	D7.12	System performance, monitoring and impact assessment r.2.0	ETT	31 Oct 2025		Pending
WP7	D7.13	System performance, monitoring and impact assessment r.3.0	ETT	31 Oct 2026		Pending
WP8	D8.1	OCEAN:ICE scientific summary whitepaper	UKRI-BAS	31 Jul 2026		Pending

WP9	D9.1	Dissemination and communication plan	UKRI-BAS	30 Apr 2023	02 May 2023	Submitted
WP9	D9.2	Creation of OCEAN:ICE website and social media presence	UKRI-BAS	30 Apr 2023	19 Apr 2023	Submitted
WP9	D9.3	Design of project visual identity and branding material	UKRI-BAS	31 Jan 2023	26 Jan 2023	Submitted
WP9	D9.4	Final project booklet/report	ETT	31 Oct 2026		Pending
WP9	D9.5	Report on dissemination activities	UKRI-BAS	31 Oct 2026		Pending
WP9	D9.6	Report on first policy briefing	EPB	31 Jan 2024		Pending
WP9	D9.7	Report on second policy briefing	EPB	31 Jul 2026		Pending
WP9	D9.8	Report on webinar series, including webinar recordings	EPB	28 Feb 2026		Pending
WP9	D9.9	OCEAN:ICE Equality, Diversity, and Inclusion Policy	UKRI-BAS	30 Apr 2023	02 May 2023	Submitted

List of the achieved milestones (October 2023)