CIce2Clouds SCOR Annual Report
July 26, 2024

1. Working group name and number

Working Group #163: CIce2Clouds (Coupling of ocean-ice-atmosphere processes: from sea-Ice biogeochemistry to aerosols and Clouds)

2. Brief summary with the main highlights (200-300 words)

A key goal of CIce2Clouds is to build conceptual models of biological and chemical systems that interact across the ocean - ice - atmosphere interface. A major focus of CIce2Clouds work in 2023 was on a set of synthesis papers that build and present these conceptual models. Work in our three CIce2Clouds subgroups (sulfur cycle, nitrogen cycle, primary aerosols) are developing coupled conceptual models, considering both poles and the seasonal cycle. Manuscripts that describe these conceptual models are in active writing, internal review and revision phases. Work has continued on our tutorial paper, which is in active internal review and revision. The tutorial material targets both early career researchers and senior scientists with expertise in only one of the domains, with a key goal of improving communication and understanding among ocean, sea ice and atmospheric scientists on exchange processes between interfaces and their impacts on polar regions.

3. Activities since the previous report to SCOR (e.g., virtual or in-person meetings, email discussions, special sessions). (Limit 1000 words)

- A successful hybrid meeting was held in September 2023 in Grenoble, France, linked to the CRiceS (Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system; https://www.crices-h2020.eu/) annual meeting. This CIce2Clouds workshop included a large focus on CIce2Clouds conceptual models, particularly for the S-cycle and primary aerosol processes, initiation of a new effort to examine ocean - ice - atmosphere processes in Earth System Models, and a dedicated discussion and writing session focused on our TOR4 deliverables (see below).
- CIce2Clouds sub-working groups on chemical and biological systems ((a) sulfur cycle, (b) nitrogen cycle and (c) primary aerosol), continued to work offline in shared documents and our Slack workspace, and online in sub-group meetings. Sub-working groups met in working sessions during the hybrid meeting in Grenoble, France to further efforts on, and obtain community input on, conceptual models and resulting synthesis papers.
- Continued active writing, internal review and revision of a CIce2Clouds tutorial paper (TOR5, Deliverable #3): “From Sea Ice to Clouds: Fundamental Processes Underpinning Particle and Gas Exchange between the Polar Oceans and Atmospheres” following the original scoping and planning meeting in Cape Town, South Africa in September 2022.
- CIce2Clouds initiated planning and implementation of a CIce2Clouds Special Feature in the journal Elementa: Science of the Anthropocene (https://online.ucpress.edu/elementa/pages/specialfeatures)
- Working group organization activities include communications though a Slack workspace that has expanded in the past year and is open to contributing members of the CIce2Clouds broader community, a Google Team Drive, and a working group website with continued support from the International Global Atmospheric Chemistry (IGAC) initiative (www.cice2clouds.org).

4. Documents published since previous report to SCOR (e.g., peer-reviewed journal articles, reports, Web pages) and should be limited to publications that resulted directly from WG activities and which acknowledge SCOR support

Megan D. Willis, Delphine Lannuzel, Brent Else, Hélène Angot, Karley Campbell, Odile Crabeck, Bruno Delille, Hakase Hayashida, Martine Lizotte, Brice Loose, Klaus M. Meiners, Lisa Miller, Sebastien Moreau, Daiki Nomura, John Prytherch, Julia Schmale, Nadja Steiner, Letizia Tedesco, Jennie Thomas; *Polar oceans and sea ice in a changing climate*. Elementa: Science of the Anthropocene, **2023**; 11 (1): 00056. doi: https://doi.org/10.1525/elementa.2023.00056

5. Progress toward achieving the group's terms of reference. List each term of reference separately and describe progress on each one. (Limit 1000 words)

CIce2Clouds is finalizing three publications that span TORS 1 - 5. These papers and their relevance to each TOR are described further below. Working titles for these publications are as follows:

1. "From Sea Ice to Clouds: Fundamental Processes Underpinning Particle and Gas Exchange between the Polar Oceans and Atmospheres"
2. "Sulfur cycle in coupled ocean-sea ice-atmosphere systems"
3. "Overview of primary aerosol processes at the ocean-sea ice-snow-atmosphere interfaces in polar regions"

Additional papers in development and early writing stages, covering TORs 1 - 5, are:

4. "Nitrogen cycle in polar ocean-sea ice-atmosphere systems"
5. An introductory paper for our CIce2Clouds Special Feature in Elementa: "Coupling of ocean-ice-atmosphere processes: from sea-Ice biogeochemistry to aerosols and Clouds (CIce2Clouds)"
6. "Vision for Interdisciplinary Observations across the Polar Ocean-Ice-Atmosphere Interface"

A CIce2Clouds special feature request has been submitted to the journal Elementa Science of the Anthropocene, and is currently being set up by the editors.

(TOR1) To prioritize key coupled biological and chemical systems that drive atmospheric reactive trace gas, aerosol, and cloud properties in polar ocean environments. Synthesize expertise from ocean, sea-ice, snow, and atmospheric chemistry communities to provide a hierarchy of chemical species that reflect common overlapping science questions (Objective O1).

- Progress toward TOR1:
    - Continued work in sub-working groups on (a) sulfur cycle, (b) nitrogen cycle and (c) primary aerosol, which continue to meet 2 - 3 times/year.
    - Synthesis publications outlining current knowledge, knowledge gaps and observational/modeling recommendations are in various stages of completion, see the papers outlined above.

(TOR2) To identify similarities and differences in controls on exchange processes between the Arctic and Antarctic O-SI-S-A systems. Compare and contrast common sea-ice and snow properties at both poles. Use this polar ocean comparison to describe how sea-ice properties control exchange processes, and constrain projections of future changes (Objective O2).

- Progress toward TOR2:
    - Continued work in sub-working groups, which met online and at our hybrid meeting in Grenoble, France. All CIce2Clouds publications above are being developed in the context of TOR2 Arctic-Antarctic comparison.
    - The working group decided to integrate synthesis on differences between Arctic and Antarctic ocean- ice - atmosphere interactions directly in the conceptual model papers (indicated above) as well as provide some background in the CIce2Clouds introductory paper for the Special Feature in Elementa: Science of the Anthropocene.

(TOR3) To develop a conceptual model of exchange processes in O-SI-S-A systems, focusing on key reactive trace gas and aerosol species prioritized in O1. Conceptual model evolution will be based on existing observational and numerical expertise, and will reflect the impact of heterogeneity in sea-ice environments at present and under future climate change scenarios (Objective O3).

- Progress toward TOR3:
    - Each sub-working group is finalizing bi-polar and seasonal conceptual models on processes relevant to each chemical and biological system.
    - A graphic designer from India (Mrinmayi Dalvi, https://aranyagaatha.wordpress.com/) has been contracted to develop consistent graphics for CIce2Clouds, and to inform on the presentation and communication of our conceptual models. Supplemental funding support was secured from IGAC to pay for partial graphic design fees.
    - Schematics in development with the graphic designer inform the conceptual models of known and constrained processes, and point toward knowledge gaps to inform future research.

(TOR4) To develop interdisciplinary campaign planning recommendations to guide future studies and address model and measurement gaps. Building on the conceptual model (O3), we will identify future needs in observations and model parameterisations, and outline requirements for fully integrated, multidisciplinary and collaborative O-SI-S-A field, laboratory, and modeling research (Objective O4).

- Progress toward TOR4:
    - A major focus of our third hybrid workshop in Grenoble, France was a discussion and working session to scope and create a draft outline for a paper describing a “Vision for Interdisciplinary Observations across the Polar Ocean-Ice-Atmosphere Interface” with community input. This session highlighted the broad range of challenges for interdisciplinary observations across the ocean-ice-atmosphere interface and is informing both IPY32 planning and development of CIce2Clouds deliverables.
    - CIce2Clouds is contributing to the hybrid IPY32 planning workshop: Chemical, biogeochemical, and physical drivers of the coupled polar atmosphere and climate: an International Polar Year 2032-33 planning workshop (17-22 November, 2024)
    - CIce2Clouds led and contributed to a SOLAS Special Issue paper (above; “Polar oceans and sea ice in a changing climate”), which has a substantial focus on new and developing measurements, and how to integrate measurements across the ocean-ice-atmosphere interface. The working group views this, and our contributions to the PICCAASO paper “Untangling the Influence of Antarctic and Southern Ocean Life on Clouds” in 2023, as precursors to the TOR4 visioning paper described above.

(TOR5) To facilitate community and capacity building opportunities for sustainable multidisciplinary science at the O-SI-S-A interface. Engage scientifically emerging countries and early career scientists in both observational and modeling communities (Objective O5).

- Progress toward TOR5:
    - Progress on Deliverable #3 (A tutorial-style review paper linked with a set of recorded introductory training lectures describing fundamental concepts linking sea-ice biogeochemistry and atmospheric science and chemistry for a broad scientific audience, led jointly by representatives from atmospheric and oceanic communities):
        - All tutorial talks remain available at https://www.cice2clouds.org/tutorials
        - Writing of the tutorial-style review paper in Deliverable #3 has progressed to internal review and revision and is planned to be finalized in the coming year.
    - Active planning is still underway for the co-development of a sea-ice field school focusing on ocean-sea-ice atmosphere interactions jointly with BEPSII and CATCH. Planning for this field school was a focus of our third hybrid workshop in September 2023 and will be refined in Goa this November. The school is to be held at Saroma-Ko Lagoon in Japan (host: Daiki Nomura) towards the end of CIce2Clouds lifetime.

- Our third CIce2Clouds workshop will be held in India, in conjunction with the Surface Ocean Lower Atmosphere Study (SOLAS) Open Science Conference.

6. WG activities planned for the coming year. (Limit 500 words)

- Third hybrid CIce2Clouds workshop prior to the SOLAS Open Science Conference in Goa, India, November 8-9, 2024.
  - Workshop Goals & Outcomes: This working meeting will move forward several CIce2Clouds efforts, including synthesis papers from our working groups (TOR1-3, Deliverable #1) on the sulfur cycle, nitrogen cycle and primary aerosol, our tutorial-style review paper (TOR5, Deliverable #3). A major focus will be developing community recommendations for interdisciplinary observations across the polar ocean-ice-atmosphere interface (TOR4, Deliverable #2), which will provide input into the IPY planning workshop in November 2024 (TOR4).
- Completion of the tutorial-style review paper (TOR5, Deliverable #3), which has been in active writing and revision during 2023.
- Continued regular virtual meetings of the full working group, sub-working groups, and finalizing synthesis article(s) (Deliverable #1, covering TORs 1-3)
- A discussion session has been submitted and accepted for the SOLAS OSC titled “The coupling of ocean, sea-ice and atmospheric chemistry & biogeochemistry: A cross-disciplinary research challenge”
- CIce2Clouds is contributing to the hybrid IPY32 planning workshop: Chemical, biogeochemical, and physical drivers of the coupled polar atmosphere and climate: an International Polar Year 2032-33 planning workshop (17-22 November, 2024)
- Following collaborative discussions at the CIce2Clouds meeting in Grenoble, an ECR exchange project on atmosphere-ocean modeling has been set up for October 2024 (Antoine Haddon & Remy Lapere; CIce2Clouds Early Career participants with support from the BEPSII-ECR exchange program fund)
- A joint CATCH (the Cryosphere and ATmospheric CHemistry) and CIce2Clouds session (“Coupling of ocean-ice-atmosphere processes: from sea-ice biogeochemistry to aerosols and clouds”) is proposed for the Fourth International Conference on Arctic Research Planning (ICARP IV) during Arctic Science Summit Week 2025 in Boulder, Colorado (USA). ASSW 2025 will be held from 20-28 March 2025, with the ICARP IV Summit will be held from 25-28 March 2025.

7. Is the group having difficulties expected in achieving terms of reference or meeting the original time schedule? If so, why, and what is being done to address the difficulties (Limit 200 words)

The group is making good progress on our five TORs and associated papers, the cross-disciplinary work has been extremely rewarding, challenging, and productive; however, more time is required to finalize the synthesis papers and conceptual models as well as the field school planning. The synthesis and tutorial papers are a true cross-disciplinary collaboration with multiple rounds of internal co-author reviews to ensure all components can be well understood by and are well linked for ocean, ice and atmosphere specialists. This requires dedicated focus from multiple individuals which takes additional time. Hence, we would like to continue our SCOR-WG for an additional year. This will also allow us to continue our co-development of an interdisciplinary CIce2Clouds field school.

8. Any special comments or requests to SCOR. (Limit 100 words.)

As indicated above, we would like to ask for a 4th year extension. We very much appreciate the support from SCOR for this working group. The cross-disciplinary synthesis work we are currently

developing would not have been possible otherwise, and has been extremely rewarding for all involved and has allowed us to engage a number of early career scientists in leadership roles.

Additional information can be submitted and will be included in the background book for the SCOR meeting at the discretion of the SCOR Executive Committee Reporter for the WG and the SCOR Secretariat.