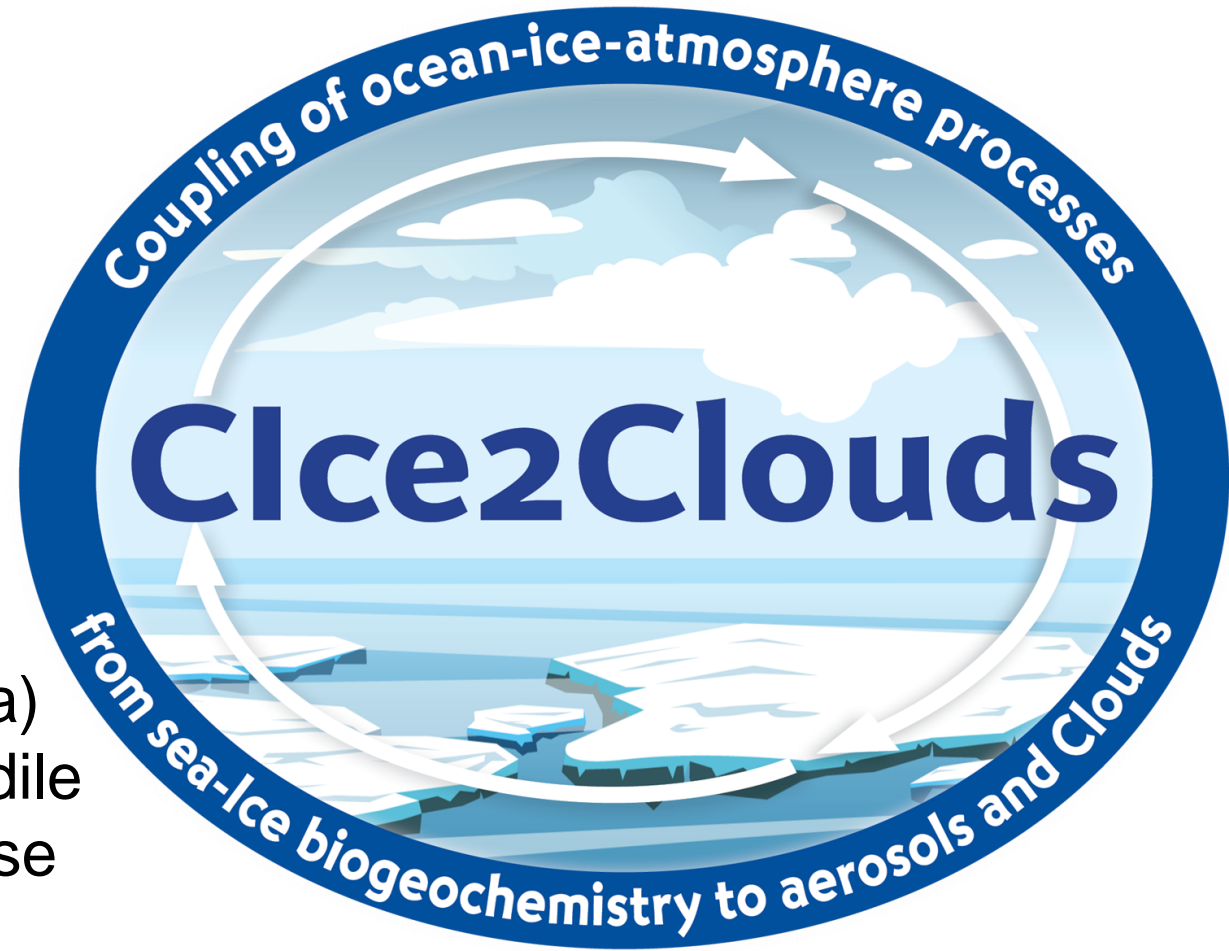


Coupling of ocean-ice-atmosphere processes: from sea-Ice biogeochemistry to aerosols and Clouds (CIce2Clouds)



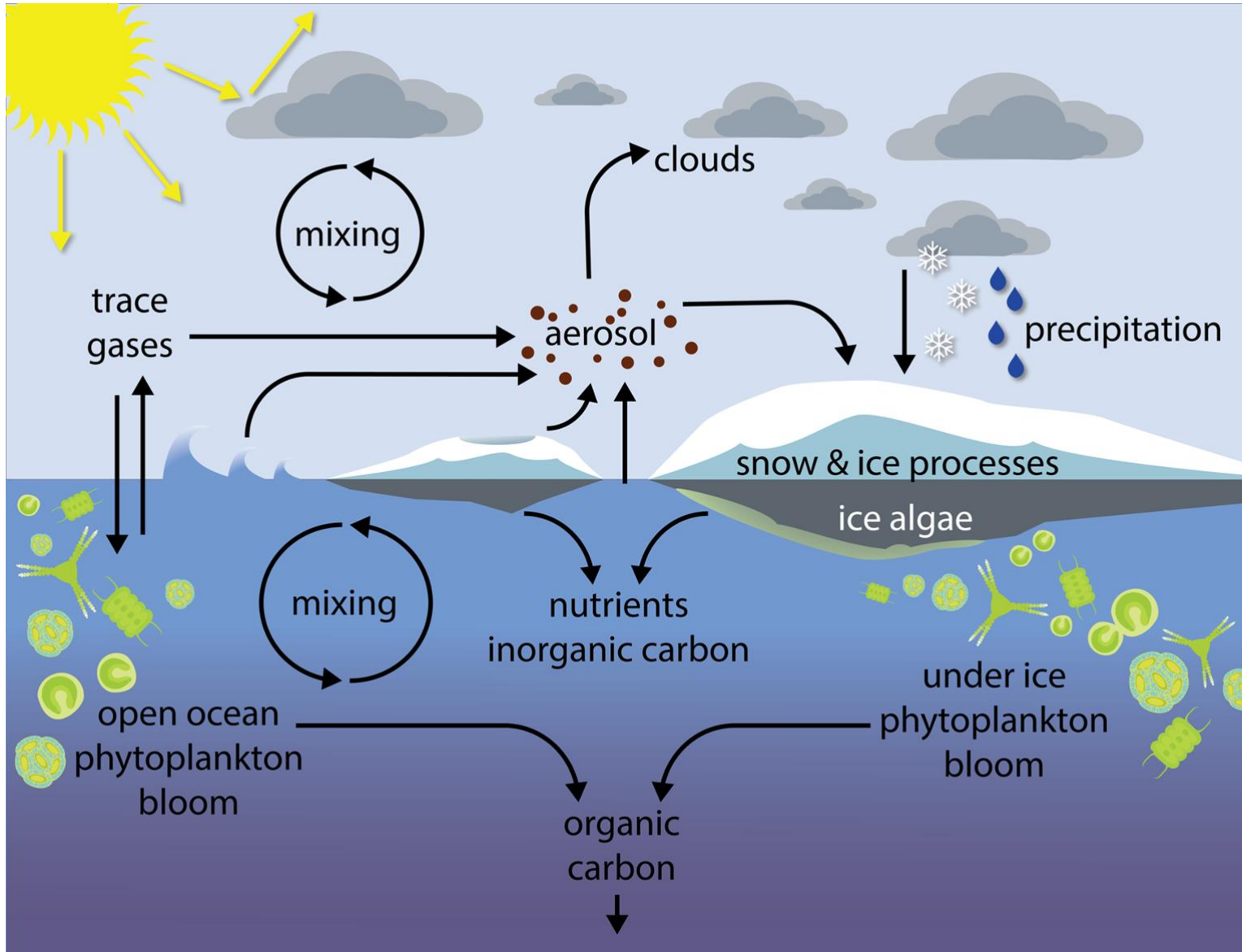
Co-chairs:

Megan Willis (USA) & Nadja Steiner (Canada)

Full Members: Raul Cordero (Argentina), Odile Crabeck (Belgium), Markus Frey (UK), Hakase Hayashida (Japan), Anoop Marajan (India), Daiki Nomura (Japan), Jennie Thomas (France), Liyang Zhan (China) + **Associate Members**

Website: www.cice2clouds.org

Clce2Clouds scientific questions



- What are the **key biological and chemical systems** (i.e., chemical species whose emission and deposition is driven by coupled biological, chemical, and physical processes) in polar ocean environments that control atmospheric chemistry and resulting climate feedbacks?
- How does the **formation, evolution, and melt of sea-ice and snow cover** in the polar oceans impact emission and deposition of climatically and biogeochemically active materials?
- In what ways are these impacts **similar or different between the Arctic and Southern Oceans**?

Clce2Clouds working group objectives



(O1) **Synthesize key *coupled biological and chemical systems* that drive atmospheric reactive trace gas, aerosol, and cloud properties in polar ocean environments.**

(O2) **To identify similarities and differences in controls on exchange processes between the *Arctic and Antarctic ocean-ice-atmosphere (OIA) systems*.**

(O3) **To develop a *conceptual model of exchange processes in OIA systems*, focusing on key reactive trace gas and aerosol species prioritized in O1.**

(O4) **To develop *interdisciplinary campaign planning recommendations* to guide future studies and address model and measurement gaps.**

(O5) **To facilitate *community and capacity building opportunities for sustainable multidisciplinary science at the OIA interface*.**



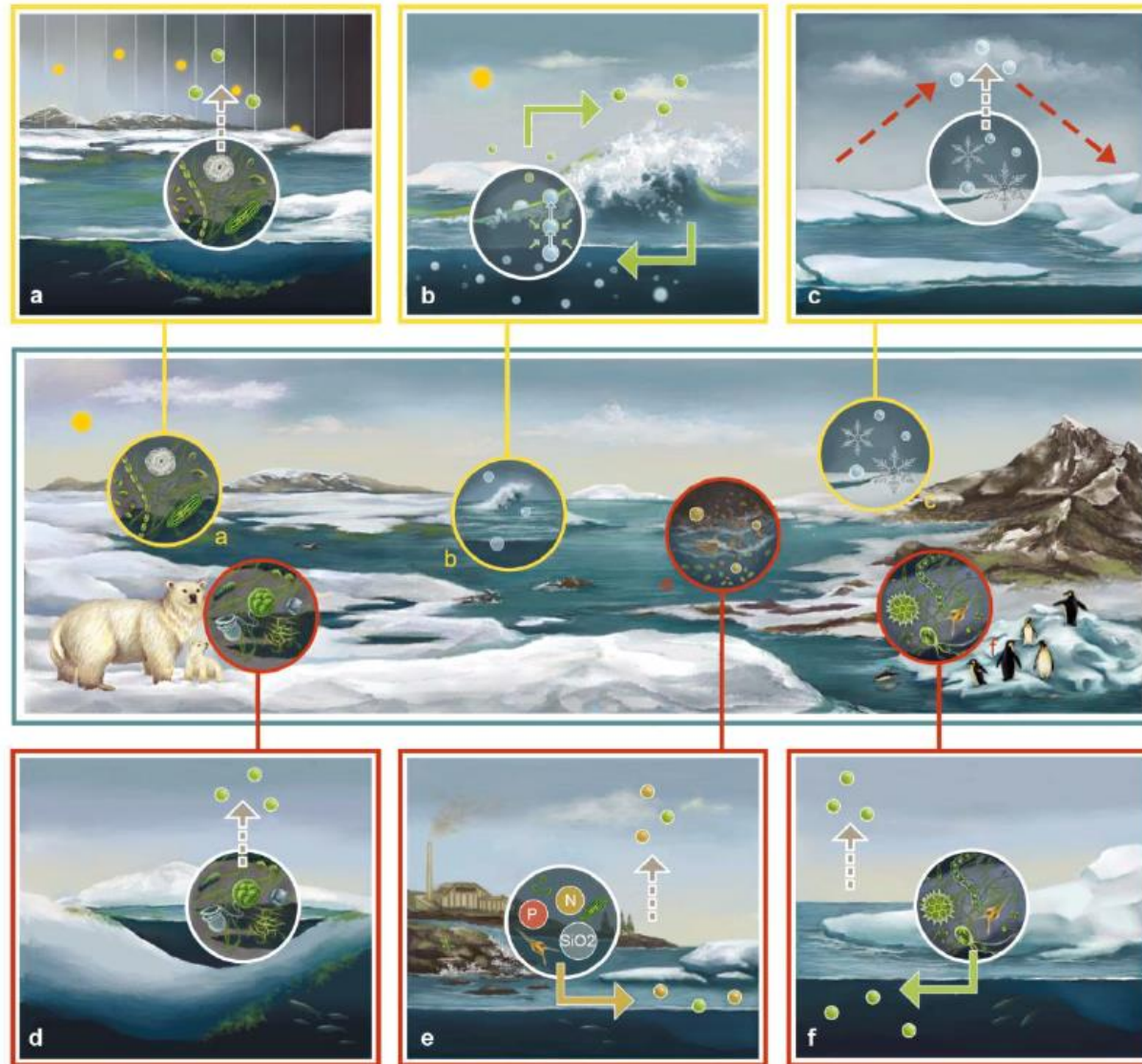
Recent & Upcoming meetings:

- **November 7-9, 2024:** 3rd Cice2Clouds hybrid meeting
 - Ahead of the SOLAS science conference in Goa, India
- **November 17-22, 2024:** IPY32-33 planning workshop
 - Cice2Clouds presentation (focused on TOR4) during orientation to ongoing community IPY planning efforts
- **January 2025 (date TBA):** SOLAS seminar on Cice2Clouds research in India - encouraging collaborations
- **March 10-11, 2026:** Final meeting, Shiretoko, Japan
 - Following the Saroma-Ko Sea Ice School, February 28 - March 9, 2026

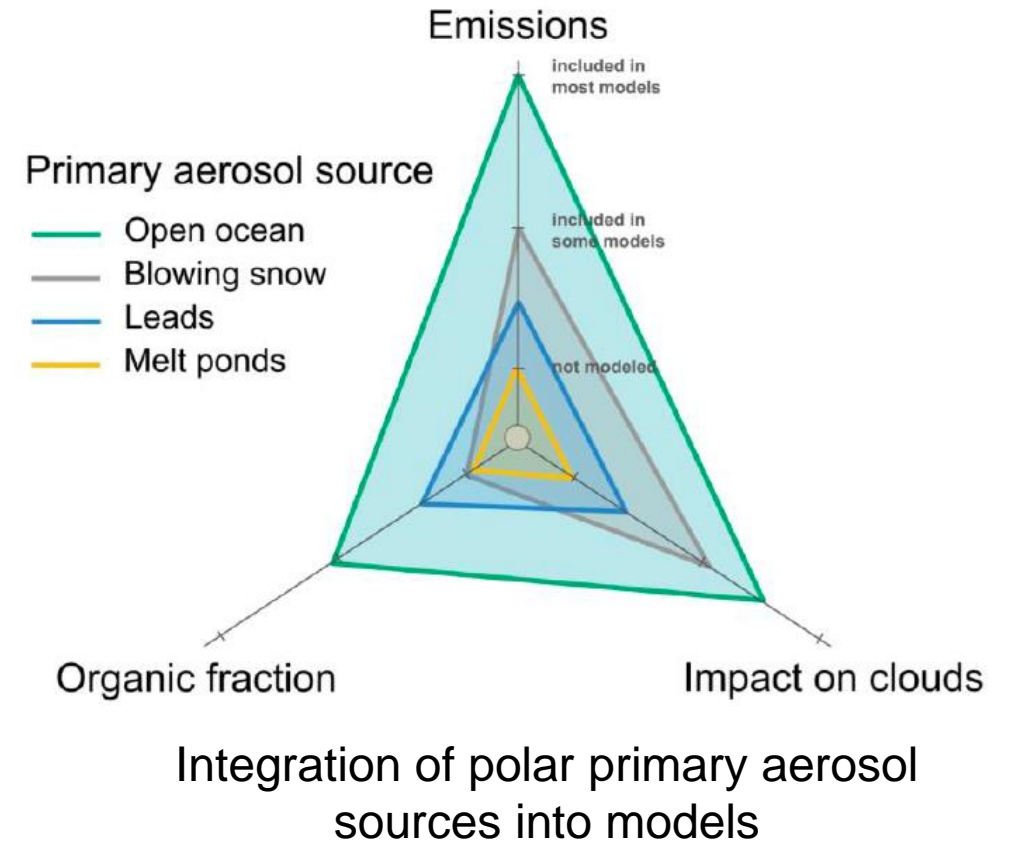
Primary aerosol conceptual model & synthesis



TOR1-3

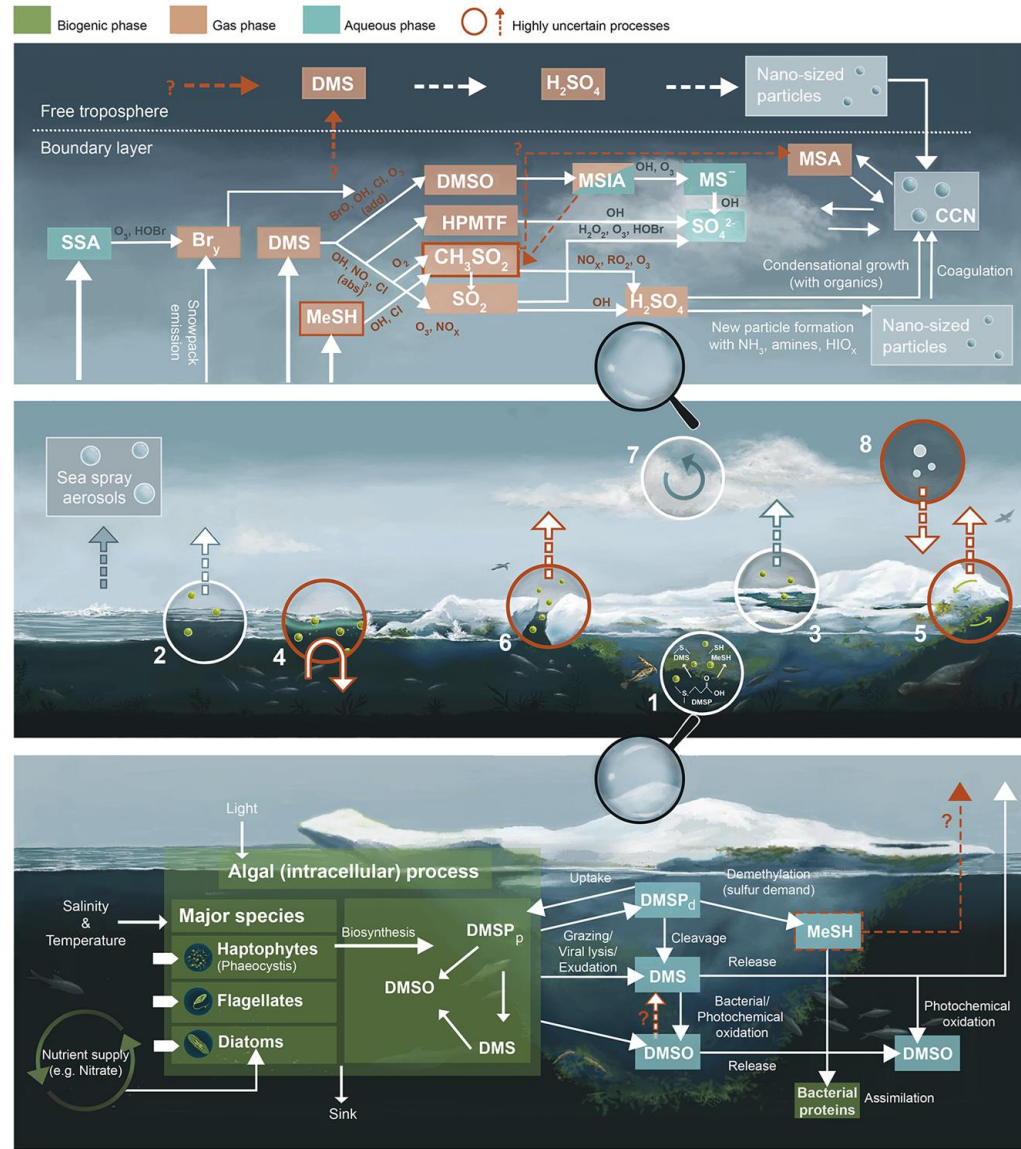


Key biotic and abiotic processes for primary aerosol production and properties

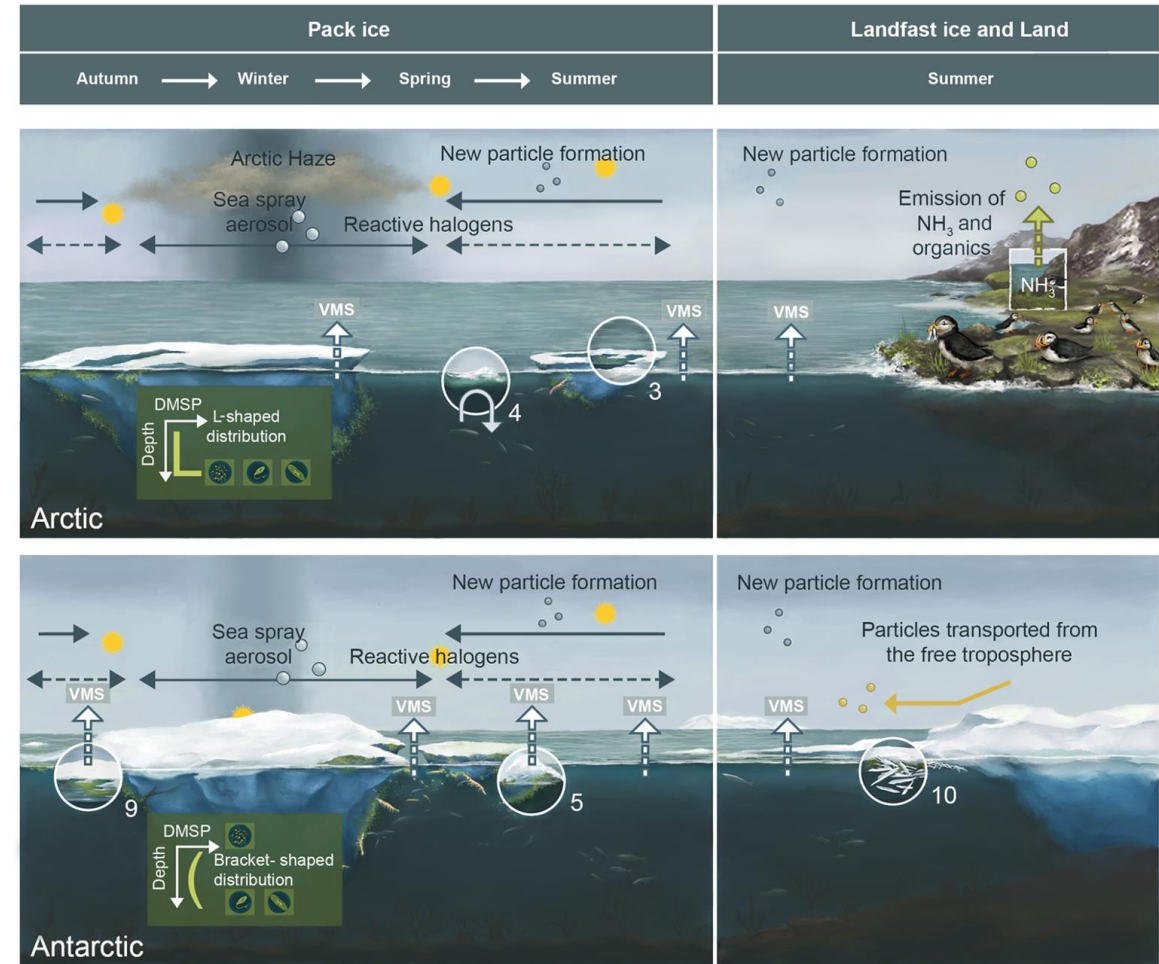


Sulfur cycle conceptual model and synthesis

TOR1-3



Key OIA processes in the biogenic sulfur cycle at both poles



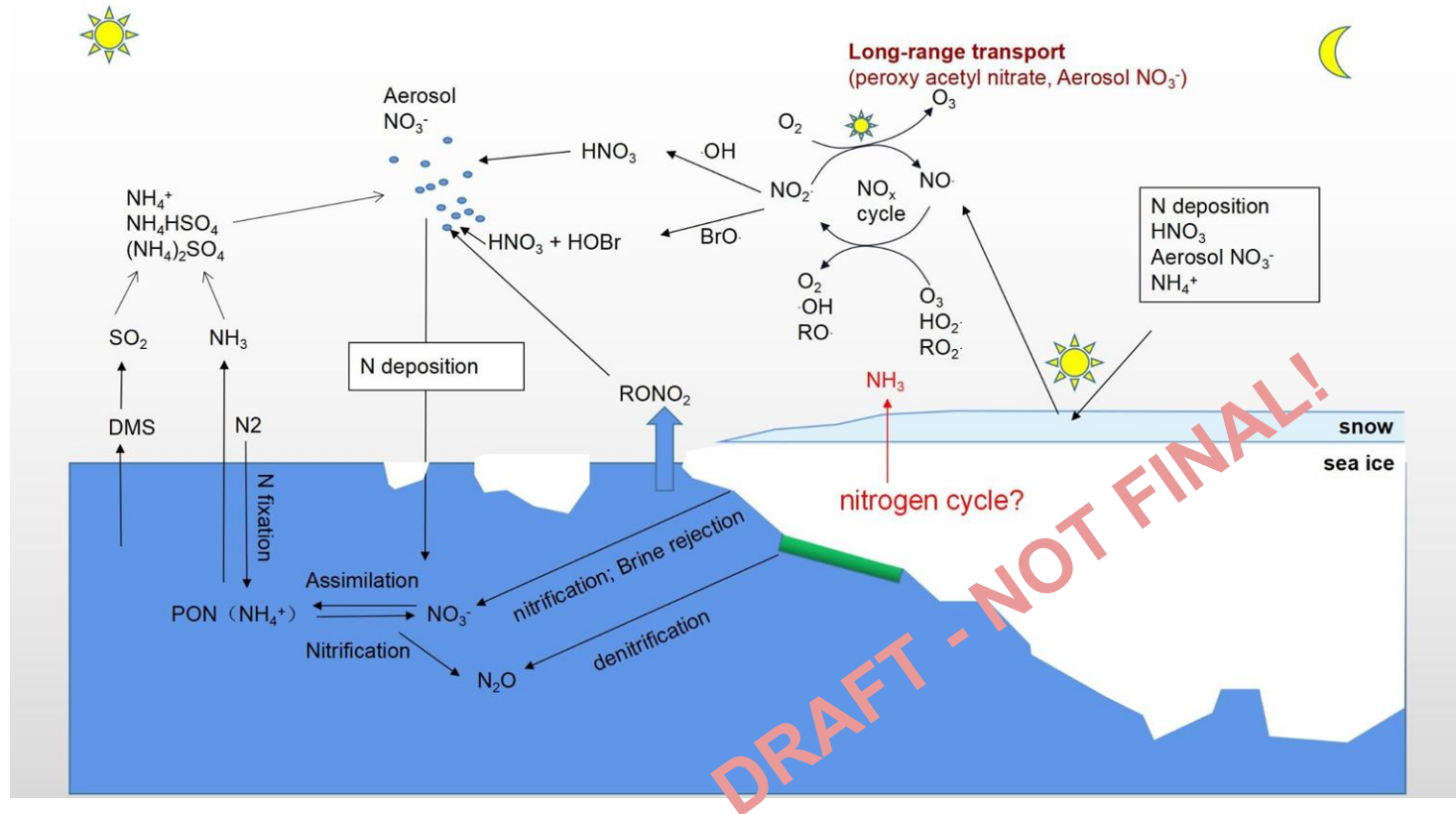
Graphic design: Mrinmayi Dalvi, India
 aranyagaatha.wordpress.com

(S. Ishino et al., revision submitted to Elementa, 2025)

Nitrogen cycle conceptual model & synthesis



TOR1-3



- Discussion sessions have identified major scientific gaps in knowledge of the N-cycle in sea ice, limiting our ability to build a conceptual model

(N-cycle efforts led by *L. Zhan, M. Frey, B. Delille, F. Fripiat*)

- Lack of knowledge in sea ice, and atmosphere, leads to challenges in identifying links to atmospheric oxidising capacity, aerosol and cloud processes
- Rather than a detailed literature review and synthesis, our work on the N-cycle will be reframed as a short commentary highlighting knowledge gaps.

Working Title: A Vision for Interdisciplinary Observations across the Polar Ocean-Ice-Atmosphere (OIA) Interface



TOR4

Goal: Use outcomes from **three open community discussions** to develop a community-driven framework for designing joint oceanic and atmospheric observations that builds on Clce2Clouds conceptual models

Paper Overview:

1. Why bother improving how we observe polar ocean-sea ice-cloud interactions?

- Global relevance of polar OIA research and failings in current models
- 1.1 Major challenges in planning interdisciplinary observations across the OIA interface
 - Disciplinary silos
 - Spatial and temporal mismatch in atmospheric, ocean & sea-ice observations
 - Logistical tensions among disciplines

2. A Way Forward: Interdisciplinary Modeling and Observational Strategy

- 2.1 Breaking down disciplinary boundaries in planning observations: creating an in situ/in silico/in vitro nexus of ocean, atmosphere, and cryosphere science
- 2.2 Addressing the spatial and temporal mismatch in atmospheric, ocean, and sea-ice observations
- 2.3 Resolving logistical tensions among disciplines

3. Examples of interdisciplinary observations at the OIA interface

- 3.1 *Example 1:* The biogenic sulfur cycle in sea-ice regions
- 3.2 *Example 2:* Melt pond systems as sources of primary biological aerosol particles and ice nuclei

4. Conclusions and Recommendations

Status:

- Writing team is currently finalizing a full draft
- IPY workshop presentation in November

Community & capacity building

TOR5



- Overarching focus on Early Career Researcher (ECR) engagement and training in a multidisciplinary context
- **Building a common language and sustainable multidisciplinary science across the OIA interface**
 - *Deliverable being finalized, began at the 2022 Clce2Clouds Workshop:*
 - **Tutorial-style review paper:** focused on fundamental concepts that link sea-ice biogeochemistry with atmospheric science and chemistry
 - “What do we need to know from each other on either side of the OIA interface?”
 - Tutorial talks & lectures available to the community
 - Field school in Saroma-Ko, Japan & Online school to entrain researchers from institutes with emerging polar programs (February 28 - March 9, 2026)
 - SOLAS seminar - collaboration opportunities on Indian research stations
 - Planned for January 2026

From Sea Ice to Clouds: Fundamental Processes Underpinning Particle and Gas Exchange between the Polar Oceans and Atmospheres (L. Miller et al., in prep)



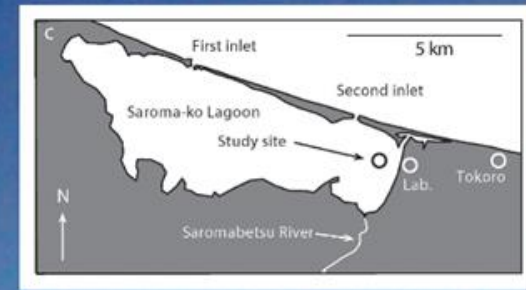
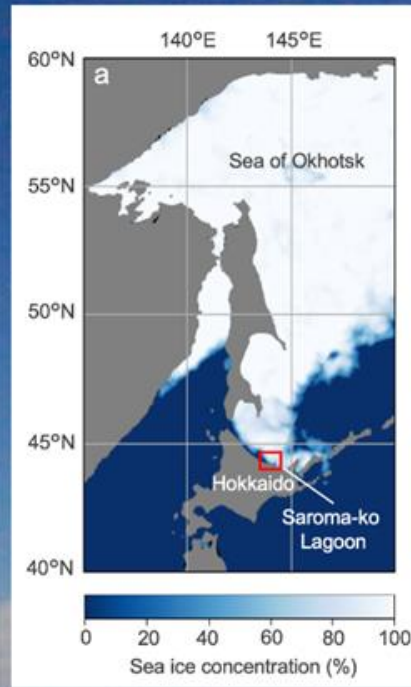
- Tutorial paper covering the basics of atmospheric chemistry, sea-ice biogeochemistry, and oceanography needed for these communities to work together
- Introductory explanations & figures with references to foundational papers and textbooks
- Each section co-written by atmospheric and ocean scientists ⇒ *interdisciplinary interpretation teams*
- ***Interdisciplinary translation and revision is in active progress***

Sea Ice School 2026

Saroma-ko Lagoon, Hokkaido, JAPAN

by BEPSII-CIce2Clouds-CATCH

- Date: 10 days around end of Feb/beginning of Mar 2026
- Target: 30 early career scientist (post doc, Ph.D students etc.)
- Program: Field and Lab work, lecture, workshop
- Deadline for school and funding application: End of 2025
- Further information will be updated in the future (BEPSII site)



Sea ice school 2022 in Canada

Information for research in Saroma-ko Lagoon

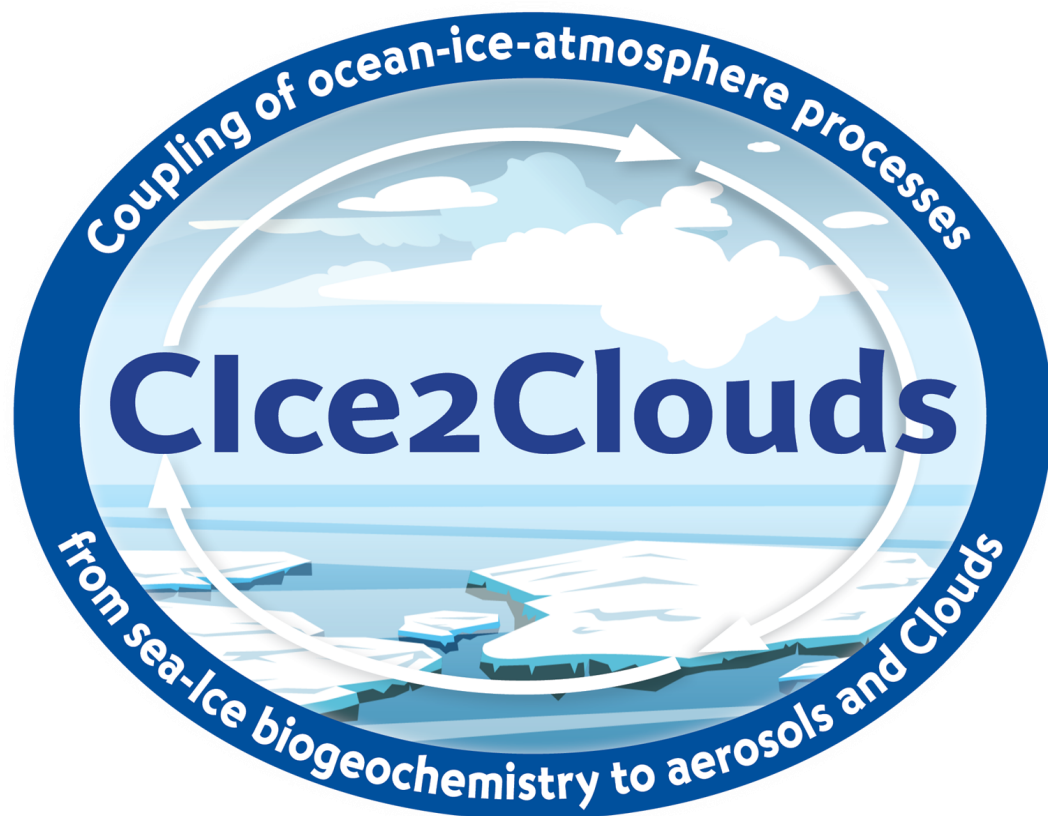
Photo: Daiki Nomura

Elementa Special Feature - Clce2Clouds

Expected articles in preparation:

1. Steiner & Willis, *Coupling of ocean-ice-atmosphere processes: from sea-ice biogeochemistry to aerosols and Clouds (Clce2Clouds)* – Introductory article - [in prep.](#)
2. Ishino et al., *The biogenic sulfur cycle in a coupled ocean-sea ice-atmosphere system* – review/synthesis article - [revision submitted](#)
3. Creamean et al., *Overview of primary aerosol sources and processes at the ocean-sea ice-snow-atmosphere interfaces in polar regions* – review article - [revision submitted](#)
4. Miller et al., *From sea ice to clouds: Fundamental processes underpinning particle and gas exchange between the polar oceans and atmospheres* – tutorial-style review article - [in prep.](#)
5. Zieger, Willis et al., *Vision for Interdisciplinary Observations across the Polar Ocean-Ice-Atmosphere Interface* – synthesis article/white paper - [in prep.](#)
6. Haddon, Steiner et al., *Future Arctic DMS production and emissions from a regional sea ice and ocean biogeochemical model* - [published](#)

Additional article submissions are underway



Upcoming meeting:
Clce2Clouds final meeting March 10-11, 2026
Shiretoko, Japan & Online



3rd Clce2Clouds Hybrid Workshop 2024
Goa, India



www.cice2clouds.org

