SCOR Working Group Proposal

(max. 6000 words, excluding Appendix)

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

Summary/Abstract *(247 of 250 words)*
The polar oceans, sea-ice, and atmosphere are a tightly coupled system, where interconnected processes are only poorly represented in climate and Earth system models. However, these Earth system components must be studied together if we are to effectively understand and project the changes underway. Coupled biological, physical and chemical processes drive complex interactions between sea-ice, snow on sea-ice, and the overlying atmosphere in the polar regions. Knowledge of these interactions is key to projecting sea-ice impacts on atmospheric gases and aerosols, and cloud cover over polar oceans, which in turn impact sea-ice melt, freeze-up and biogeochemical activity through nutrient exchange and solar radiation scattering. As the climate and sea-ice at both poles are changing, these core polar processes warrant more focused attention from Earth system scientists. Communities that treat individual system components (ocean, sea-ice, snow, atmosphere) are working in parallel, but not necessarily together, in part because of the inherently disparate spatial and temporal scales of most oceanic and atmospheric in-situ observations. These challenges limit our ability to describe and quantify key processes and develop coupled descriptions for climate and Earth system models. By bringing together the ocean and sea-ice oriented BEPSII (Biogeochemical Exchange Processes at Sea-Ice Interfaces) community and the atmospheric chemistry and sea-ice oriented CATCH (Cryosphere and ATmospheric CHemistry) community, this working group will (1) synthesize and refine the conceptual representation of relevant processes and, (2) address key uncertainties in the biological and chemical controls on atmospheric chemistry, aerosol and clouds in polar ocean environments.

Scientific Background and Rationale *(996 of 1250 words)*
The polar regions are experiencing the most rapid climatic changes on Earth (IPCC, 2019). The interconnected physical and chemical ocean - sea-ice - snow - atmosphere (O-SI-S-A) system is now transitioning to an unprecedented and uncertain regime, including increased regional, seasonal and interannual variability, and ice-free conditions during portions of the year (Maksym, 2019). These changes are exemplified by increasing atmosphere and ocean temperatures, high rates of sea-ice loss, increasing cloud cover, changes in precipitation phase and amount, and snowpack physical properties, which directly impact physical and biogeochemical processes and fluxes. Sea-ice and snow are key changing media at the ocean-atmosphere interface. This interface controls chemical, physical and biological drivers of changing atmospheric gases and aerosols, and resulting cloud properties (Schmale et al. 2021, Willis et al., 2018), which in turn have significant impact on the surface energy balance (e.g. Hyder et al., 2018), sea-ice melt and freeze-up processes (e.g. He et al., 2019), and atmospheric deposition to sea-ice environments (Myriokefalitakis et al., 2020). However, the ability of numerical models, including climate and Earth System Models (ESMs), to reproduce observed changes remains limited (Roach et al. 2020, SIMIP 2020, Schmale et al. 2021), in part because our knowledge of exchange and feedback processes across the O-SI-S-A system is incomplete. A key limitation are the inherently disparate spatial and temporal scales of most atmospheric and oceanic measurements, which has led to a lack of fully coupled observations. This challenge hinders our ability to develop conceptual models which adequately describe how the polar and global systems are connected through ocean circulation, atmospheric teleconnections, and climate feedbacks.

Advancing the understanding of coupled physical, biological and chemical processes in the polar ocean regions and their descriptions in models has wide-ranging implications for climate projections even far from the poles. Substantial progress has been made in each specific scientific discipline (e.g. Steiner et al. 2017, Thomas et al. 2019), such as ocean dynamics, sea-ice dynamics, ocean biogeochemistry, sea-ice biogeochemistry (Vancoppenolle et al., 2013, Lannuzel et al., 2020), atmospheric dynamics, and atmospheric chemistry/physics (e.g. Bartels-Rausch et al., 2014, Abbatt et al. 2019). However, to address near-surface exchange processes and feedbacks, we need improved synthesis of knowledge and observations across these research communities (e.g., Abbatt et al. 2019, Thomas et al. 2019). This working group will focus on the physical, biological, and chemical drivers for the exchange of trace gases and aerosols across heterogenous O-SI-S-A interfaces within a changing environment (**Figure 1**).

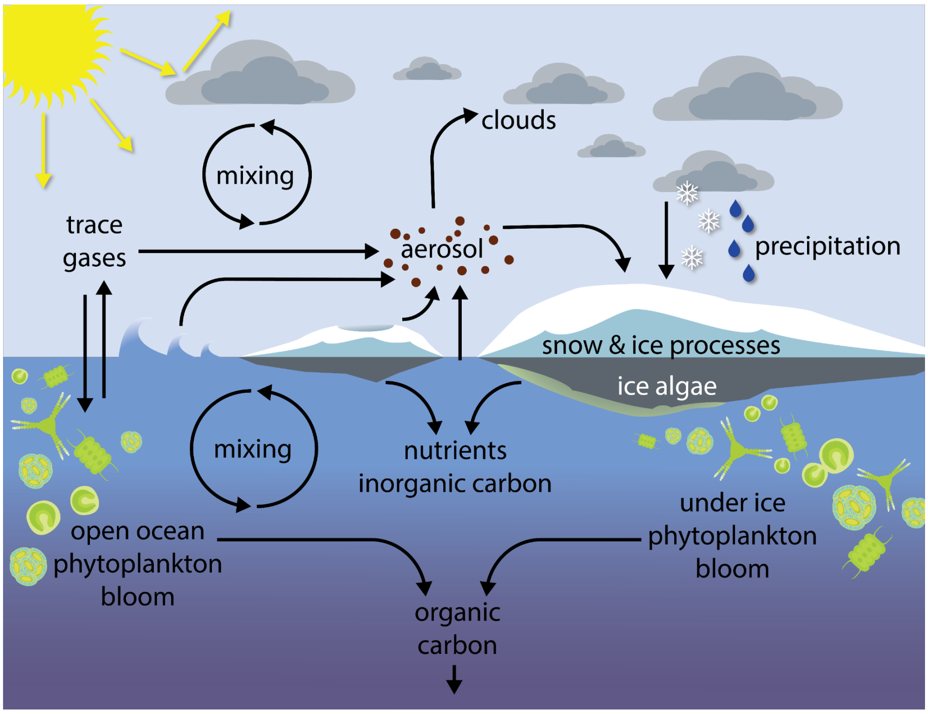

Figure 1: Simplified schematic representing the coupled processes in the O-SI-S-A system that will be addressed in this working group. This schematic representation is not intended to include detailed processes required for a representative conceptual model, but rather emphasizes the need for connection between atmospheric and polar ocean components.

O-SI-S-A trace gas and aerosol exchange in both directions, and changes in resulting cloud properties, are extremely important for determining surface energy budgets and ecosystem functioning. These exchanges control both (1) the natural background trace gas and aerosol budget in polar atmospheres, as well as (2) anthropogenic impacts including nutrient, pollutant, and toxic substance deposition to sea-ice and the polar oceans. In addition, the marine and cryospheric processes that determine atmospheric burdens of aerosols and reactive gases are changing. At present, most atmospheric models do not include basic coupled descriptions of marine and cryospheric exchanges, even if they are known. This deficit has in part led to global models that do not simulate realistic trace gas, aerosol, and cloud properties (e.g. Hyder et al., 2018), and therefore struggle to produce skillful representations of changes in polar climate (Shindell et al. 2008; Sand et al. 2017).

This SCOR working group will focus on addressing the following integrative questions by bringing together the polar atmospheric chemistry and sea-ice biogeochemical communities:

- 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?

Why a SCOR working group?
To resolve open questions about the impacts of the marine cryosphere on atmospheric chemistry and climate in Northern and Southern polar ocean environments, we need to bring the sea-ice and atmospheric communities in both hemispheres together and establish unified research tactics. We need to collaboratively identify what measurements are needed and develop priorities, guidelines, and coupled

observation strategies for experiments that can detect and quantify the key processes at a range of scales. Past field experiments have been hampered by disciplinary silos. Even when atmospheric, sea-ice, and biogeochemical scientists have been in the field together, their measurements are often decoupled, in part because of the inherently disparate spatial and temporal scales of most oceanic and atmospheric in-situ observations. We need science plans that start from an integrative vision and explore new ways of observing this coupled system. Our recommendations will build on lessons learned from past experiments, with respect to science and organisation, planning and logistics (e.g., the MOSAiC expedition) and, reflect regional differences in logistical challenges for observations (e.g., coastal vs. central Arctic, Arctic vs. Antarctic). The communities required to adequately address these challenges include integrative modellers, as well as experts in snow and sea-ice physics, multiphase ice chemistry, sea-ice and ocean biogeochemistry and biology, and atmospheric chemistry/physics. In addition, work in polar regions requires strong international collaboration, because of remote locations, challenging logistics and high costs. This working group will assemble a diverse set of scientists to work jointly towards delivering a set of clear research guidelines that will have wide utility across the polar atmosphere, ocean and climate research communities. The multi-disciplinary and international work we propose would be impossible to support from national or regional funding.

Terms of Reference *(231 of 250 words)*

1. ***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**).

2. ***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**).

3. ***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**).

4. ***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**).

5. ***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**).

Working plan and Timeline *(998 of 1000 words)*

To deliver **O1**, we will use expertise within the working group to review and synthesize knowledge from past observations and modelling. We aim to identify key biological and chemical systems (i.e., chemical species whose emission and deposition is driven by coupled biological, chemical, and physical processes) that shape atmospheric composition, oxidant levels, and aerosol formation. We will prioritize chemical species that must be included in numerical models to advance their ability to represent climate relevant exchange processes in O-SI-S-A systems. Biological and chemical systems of interest include dimethylsulfide and other reduced sulfur compounds, organic and inorganic halogen compounds (e.g. precursors to iodine oxo-acids), volatile organic and nitrogen compounds, and primary aerosol components such as sea salt, organic compounds, and biological components (e.g., microbes, cellular fragments). This process will be facilitated by dialogue, and establishment of common language, between modellers and both field and laboratory observationalists within the working group. Our hierarchy of key systems provides an important first step toward a conceptual model, and will be summarized as a component of **O3** deliverables.

To deliver **O2**, and to provide constraints that build toward our conceptual model (**O3**), we will compare and contrast common Arctic and Antarctic sea-ice physical and chemical properties that are relevant to ocean-atmosphere exchange processes. This effort will consider three main drivers of emission and deposition processes in sea-ice environments. First, how differences in latitude, temperature, and light conditions lead to differing diel and seasonal sea-ice cycles. Second, how precipitation (snow and rain) impacts ocean-atmosphere exchange processes via sea-ice and snow. Third, how conditions during ice formation and melt cause significant differences in sea-ice system structure (e.g., leads, ridges), thickness, consistency (columnar and granular structures, porosity), features (e.g., melt ponds), pH, composition and reactivity (e.g., salinity and other impurities, redox capacity). Comparing and contrasting sea-ice systems at both poles will allow us to describe how chemical and physical sea-ice properties control exchange processes, and how these processes are likely to change as sea-ice environments change in a warming world.

To deliver **O3**, we will focus specifically on the key chemical and biological systems prioritized in **O1.** Building on existing knowledge of the physics, chemistry, and biology dictating exchange of unreactive gases (e.g., greenhouse gases), we will develop a conceptual model of the major processes driving exchange of prioritized reactive trace gases and/or aerosol between ocean, sea-ice, snow, and atmosphere. Conceptual model development will build upon efforts to deliver **O1&2**, and will provide the framework to inform future inclusion of climate relevant ocean-atmosphere exchange processes in process-level and Earth System models. Evolution of this conceptual model will reflect heterogeneity in sea-ice environments at present and under future climate change scenarios, and will consider the overarching impacts of changes in available sunlight and increasing temperatures on the chemistry and biology of O-SI-S-A systems. We will publish the integrated conceptual model in an open access, peer-reviewed synthesis paper.

To deliver **O4**, we will use our conceptual model (**O3**) to evaluate required future observations and model parameterisations. We will leverage experience from past interdisciplinary studies and scientific expertise within the working group to develop recommendations to guide future interdisciplinary studies, focussing on approaches to campaign planning that best facilitate integration of atmospheric and sea-ice biogeochemical observations and modelling. We will host a community workshop that focuses on developing these recommendations, and on developing conceptual approaches for resolving temporal and spatial discontinuities between oceanic and atmospheric observations (e.g., use of distributed ocean sampling networks, measurement of atmospheric fluxes). This workshop, and resulting white paper, will address the practicalities of making such integrative observations, including constraints on making atmospheric observations in remote environments and the types of measurements most needed to integrate atmospheric and sea-ice biogeochemical observations.

Multidisciplinary community and capacity building (**O5**) will be integral to all activities of the working group. An important outcome of this working group will be the opportunity for atmospheric and sea-ice biogeochemistry communities to come together to identify barriers to meaningful collaboration, and to create achievable approaches to address common goals and science questions. To facilitate knowledge transfer between these communities and training of early career scientists (ECS) in interdisciplinary science, we will develop a tutorial-style review paper that describes fundamental concepts in sea-ice biogeochemistry and atmospheric sciences for a broad scientific audience. Our approach to capacity building for early career scientists and scientists from countries with emerging polar programs is described in detail in the capacity building section.

Timeline

Month 1: First online working group meeting, focusing on planning and identification of leadership for deliverables in **O1, O2, O3, O5** and formation of sub-groups from full and associate members.

Months 1-12: Work in sub-groups on **O1, O2, O5**. Sub-groups will meet virtually each month, and communication will be facilitated using an online workspace. The first in-person meeting is tentatively scheduled to occur in conjunction with the SOLAS science conference in South Africa, Sept. 2022 (online if travel remains prohibitive). The meeting will include sub-group meetings on **O1, O2, O5**; planning and organization for conceptual model development and a half-day tutorial workshop for ECS (**O5**).

Months 12-24: Development of the conceptual model (**O3**), continued work on deliverables for **O5**. The third working group meeting will focus on the conceptual model (**O3**) and will include a community workshop focusing on the development of recommendations for future interdisciplinary studies (**O4**). A tutorial workshop for ECS will be associated with the meeting (**O5**) which will be scheduled in conjunction with a major international meeting of broad interest to the group (e.g. IGS, IGAC),

Months 24-36: Summarize recommendations from community workshop in a white paper (**O4**); continued work on the conceptual model and its description for publication (**O3**); continued work on deliverables for **O5**. The final meeting with a focus on community outreach and dissemination of research recommendations (**O3/O4**), will be held as a side-event at a larger meeting (e.g., SCAR/IASC, IGS meeting) to attract wide attendance and participation, and include an ECS workshop (**O5**).

Deliverables *(238 of 250 words)*

1. A synthesis paper (open-access) describing our conceptual model of ocean - atmosphere exchange processes in sea-ice environments. This paper will include a hierarchy of key biological and chemical systems in O-SI-S-A systems, recommendations for systems that should be included in future models (**O1**), and comparison of Arctic and Antarctic sea-ice environments as building blocks of the conceptual model (**O2/3**).

2. A community driven framework, disseminated in a widely accessible opinion paper, for designing joint oceanic and atmospheric observations (field expeditions and laboratory or mesocosm experiments) that effectively incorporate modellers from early planning stages and provide integrated and comparable oceanic and atmospheric measurements. This framework will include forward-looking recommendations for future observations and modelling efforts with a focus on emerging technologies (**O4**).

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 (**O5**).

4. A community of practice including scientists from institutes with both established and emerging polar, or O-SI-S-A, programs to facilitate science collaboration at the O-SI-S-A interface. The list will be shared through the WG website and promoted via supporting organisations (e.g. SOLAS, CLIC, SCAR, IGAC) and include information on capacity (field, ship, laboratory, equipment and model), upcoming campaigns or projects, and potential requirements or needs to encourage fellow researchers to get in touch and open pathways for collaboration (**O5**).

Capacity Building *(1489 of 1500 words)*

Our capacity building efforts will focus on three areas: (1) establishing a strong international research community on O-SI-S-A processes including sea-ice and ocean biogeochemical and atmospheric communities, (2) increasing involvement of scientists from countries with emerging polar ocean scientific programs, and (3) development and training of early career scientists (ECS). We define ECS as graduate students and researchers that are up to 4 years post PhD (not including career breaks). Our approach to each of these areas is outlined below.

1. By establishing an interactive community linking O-SI-S-A processes, we aim to cultivate future integrated research collaborations and develop strong interactions among the well established ocean-sea-ice oriented BEPSII community and the atmospheric chemistry and sea-ice oriented CATCH community. To achieve this, a strong base of established researchers within the O-SI-S-A field and with expertise in community building is essential. Strong ECS involvement is a key element to ensure the longevity of these collaborations, as well as training of ECS in an interdisciplinary context.

2. To increase involvement and engagement of scientists from countries with emerging polar programs, and countries with polar programs but little or no emphasis and expertise in sea-ice associated biogeochemical research (e.g., Chile/South America, South Africa, China), we will focus our efforts in four main areas. First, we specifically target researchers from these countries for participation in working group meetings. Some have already been contacted and entrained in the working group membership, additional institutes have been identified (**Table 1**). Second, we will hold working group meetings outside North America and Europe, particularly in countries represented by our full members, to allow scientists (and ECS) from those regions to attend and participate easily. Third, we will evaluate and recommend specific ways to facilitate exchange of scientists on ongoing field programs. For example, if concurrent campaigns are planned in similar regions during the same period, we will work to facilitate means of arranging an exchange of berths. Such an arrangement would require a significant amount of dialogue and planning, but would lead to increased communication between different countries. Finally, we will provide guidance and connections to facilitate inclusion of researchers from emerging polar biogeochemistry and atmospheric chemistry programs in new project proposals, facilitated through programs such as the SCOR visiting scholar program.

   We have identified a targeted set of established and emerging polar programs that operate observing platforms relevant to the coupled O-SI-S-A system (**Table 1**). As part of the SCOR working group, we will facilitate a community of practice that establishes multilateral engagement and exchange of information between SCOR WG members (including associate members) and the wider research community. These will include coordination and platform sharing as well as coordinating modeling exercise and experiments. Examples are detailed in the table below, additional interested institutes and countries will be added to this list upon expression of interest or identification of common research objectives during the SCOR WG lifecycle.

   Table 1: Examples for community expansion through established and emerging polar/sea-ice science programs. Additional countries with potential interest in the O-SI-S-A system include Portugal, Spain, Poland.

Country	Research institute/Polar Program	Member/associate member/ wider research community target	Goal for engagement with emerging polar programs and ECSs
Germany	The Alfred Wegener	Peeken, Stefels	Keep community informed on planned AWI

	Institute (AWI)	(associate members)	observations including Polarstern cruises, place future SCOR WG observations on the AWI target cruise list for long term planning. Engage ECSs early in future cruise planning.
USA	National Science Foundation (NSF) Polar Programs, National Oceanographic and Atmospheric Administration (NOAA) Arctic program, National Aeronautics and Space Administration (NASA)	Creamean (associate member), Willis (member)	Coordination with major Polar Research programs and infrastructures including programs funded under the NSF Navigating the New Arctic Program and NASA (joint land-based-cruise-flight efforts in Antarctica/SO and in the Arctic (Greenland/Svalbard). Integration of ECSs into internationally coordinated research cruise planning.
Canada	Fisheries and Oceans Canada, The Natural Sciences and Engineering Research Council of Canada (NSERC)	Steiner (member), Miller (associate member)	Coordination with future expeditions in Arctic field camps and on board the CCGS Amundsen, the icebreaker and Arctic research vessel operated by the Canadian Coast Guard. Coordination with Canadian regional climate and global Earth System Modeling including advanced descriptions of polar biogeochemistry.
UK	British Antarctic Survey (BAS), The Natural Environment Research Council (NERC)	Frey (member)	Place SCOR WG objectives on the agenda of NERC science strategy and research cruise planning for the new UK polar research icebreaker *RRS Sir David Attenborough (SDA)*, which is expected to commence polar operations in 2021. Keep the community informed on planned BAS polar observations and projects, including the future SDA schedule and opportunities for cruise participation and research collaboration. Engage ECS team members in polar observations planning.
Japan	National Institute of Polar Research, Arctic Challenge for Sustainability II (ArCSII) and Japanese Antarctic Research Expedition (JARE)	Nomura (member), Ishino (associate member)	Coordination with future expeditions on board *R/V Mirai and Shirase*. Keep the community informed on planned ArCSII and JARE polar observations and projects, opportunities for cruise participation and research collaboration. Engage ECSs in field work and experiment planning.
South Africa	South African National Antarctic	Vichi (associate member)	Integrate regular South African cruises into the view of other research institutes in

	Programme		Europe, Asia, and North America. Foster focus on chemical and biogeochemical interactions in the O-SI-S-A system within the new Polar Research Institute in South Africa.
Sweden	Swedish Polar Secretariat (SPRS)	Zieger (associate member)	Integrating coupled ocean-ice-atmosphere research goals into the thematic calls of SPRS for future research expeditions on the Swedish Polar research vessel the I/B Oden, which regularly operates in the Arctic and occasionally in the Antarctic. Informing the SCOR WG and wider community on opportunities to provide input and plan future research cruises.
France	French Polar Institute (IPEV)	Thomas (member), Marelle (associate member)	Linking the long standing polar observations and modeling efforts in France including work at IPEV supported stations with planned work on the ocean-ice-snow-atmosphere system on ice breaking vessels operated by other countries. Involvement of ECSs in international science planning and cooperation efforts including France and other countries. Coordination with French regional climate and process modeling including advanced descriptions of polar aerosols and atmospheric chemistry.
India	Ministry of Earth Sciences, Government of India	Mahajan (member)	Making the SCOR WG and wider community aware of opportunities to participate in Indian research expeditions in/near the polar regions. Linking ongoing work by MOES in the Southern Ocean/Antarctica/Arctic with O-SI-S-A research by other countries to coordinate and maximize collaboration.
China	Third Institute of Oceanography, Ministry of Natural Resources (TIO)	Zhan (member)	Enhanced two way coordination between planned research activities/cruises in PRIC and the SCOR working group research focus areas.
Switzerland	Paul Scherrer Institute (PSI), Swiss Polar Institute (SPI)	Bartels-Rausch (member), SPI representative to be identified	Enhanced two way coordination between planned research activities funded by SPI/ laboratory work at PSI and the SCOR working group research focus areas.
Korea	Korea Polar Research Institute (KOPRI)	To be identified during the WG operation	Enhanced two way coordination between planned research activities funded by/performed at KOPRI and the SCOR working group research focus areas.
Chile	Instituto Antártico	To be identified	Inform and develop two way communication

	Chileno (INACH)	during the WG operation	between the long standing research program at INACH and our focus on sea ice BGC and atmospheric chemistry to enhance future cooperative research opportunities.
Argentina	Centro Austral de Investigaciones Científicas del Consejo Nacional de Investigaciones Científicas y Técnicas	To be identified during the WG operation	Inform and develop two way communication between the long standing research program in Argentina and our focus on sea ice BGC and atmospheric chemistry to enhance cooperative research opportunities in the future.

3. To facilitate development and training of international early career scientists, we have strong involvement of a diverse group of early career scientists across the WG membership, as co-chair, full, and associate members. Our ECS WG members span a range of career stages, including graduate students, early career research scientists, and early career professors/researchers. We will invite ECS to attend and participate in working group meetings and discussions which will include half-day tutorial workshops. We will involve ECS as active participants in working group meetings through leading, facilitating discussions, and summarizing discussion outcomes to the larger group, with the goal of increasing ECS exposure and building their networks. We will hold working group meetings in conjunction with larger conferences, or CATCH/BEPSII meetings to allow more ECS to attend.

Our main deliverable from **O5** furthers all of the above goals by providing an open-access tutorial style review article focused on linking core concepts in sea-ice and ocean biogeochemistry and atmospheric chemistry. This effort will be linked to a set of recorded tutorial lectures and will facilitate establishing an integrated international community through exchange of knowledge targeted at a general science audience, and will help to facilitate training of diverse ECS in an interdisciplinary context. This material will be made freely available online.

Working Group composition *(411 of 500 words)*

The membership composition has been designed to spread across scientific discipline, geographical location, gender, and career stage as well as to represent established and emerging polar programs. Note that we extended the associate members to 14 to include a larger number of early career scientists (indicated as ECS, 9 in total, including a co-chair). Given there is very little polar research within developing countries, our emphasis is generally on enhancing connections with countries with emerging polar and sea-ice related programs. Some are already included in the member list and additional connections will be explored through objective 5 (deliverable 4) under capacity building (examples are provided in Table 1)

Name	**Gender**	**Place of work**	**Expertise relevant to proposal (ECS/senior)**
Full members			
1. Thorsten Bartels-Rausch	M	Switzerland	Chemistry and micro-physics in ice/snow (senior scientist)

2. Odile Crabeck	F	Belgium	Ocean-ice-atmosphere gas exchange measurements (ECS)
3. Markus Frey	M	UK	Polar atmospheric, snow & ice core chemistry measurements (senior scientist)
4. Hakase Hayashida	M	Australia	Sea-ice/ocean biogeochemical modeling - Arctic/Antarctic (ECS)
5. Anoop S. Mahajan	M	India	Atmospheric chemistry in the polar regions (senior scientist)
6. Daiki Nomura	M	Japan	Atmosphere-sea-ice interaction for gases. (senior scientist)
7. Nadja Steiner (Co-chair)	F	Canada	Sea-ice/ocean biogeochemical modeling- Arctic (senior scientist)
8. Jennie Thomas	F	France	Polar atmospheric chemistry modeling (senior scientist)
9. Megan Willis (Co-chair)	F	USA	Measurements of polar ocean-atmosphere chemical interactions (ECS)
10. Liyang Zhan	M	China	Ocean-ice-atmosphere gas exchange measurements (senior scientist)
Associate members			
1. Jessie Creamean	F	USA	Polar aerosol-cloud interactions, ice nucleation (ECS)
2. Srishti Dasarathy	F	USA	Tropospheric aerosol, sea ice, and surface ocean biogeochemistry modeling & remote sensing (ECS)
3. Bruno Delille	M	Belgium	Ocean-ice-atmosphere gas exchange measurements (senior scientist)
4. Inge Deschepper	F	Canada	Sea-ice ocean biogeochemical modelling (ECS)
5. Francois Fripiat	M	Belgium	Sea-ice and ocean biogeochemistry measurements (senior scientist)
6. Sakiko Ishino	F	Japan	Atmospheric chemistry in polar regions (ECS)
7. Louis Marelle	M	Norway/France	Modeling aerosol-cloud interactions in polar regions (ECS)
8. Klaus Meiners	M	Australia	Coupled sea-ice physical-chemical-biological processes, sea-ice optics (senior scientist)
9. Lisa Miller	F	Canada	Sea-ice chemistry measurements (senior scientist)
10. Ilka Peeken	F	Germany	Sea-ice biogeochemistry (senior scientist)

11. Jacqueline Stefels	F	Netherland/ Germany	Sea-ice & ocean biogeochemistry & DMS fluxes (senior scientist)
12. Marcello Vichi	M	South Africa	Sea-ice physics and biogeochemistry (senior scientist)
13. Esty Willcox	NB	Canada	Sea-ice interface geochemistry measurements (ECS)
14. Paul Zieger	M	Sweden	Aerosol-cloud interactions in polar and pristine regions (senior scientist)

Working Group contributions *(500 of 500 words)*

Thorsten Bartels-Rausch works towards a fundamental understanding of (photo-)chemistry in ice and snow with particular focus on the link between physical processes and chemistry. His team's research involves working at state-of-the-art large scale facilities in Switzerland and he is engaged in community building as CATCH founding member and current co-chair.

Odile Crabeck's (ECS) research focuses on the aqueous-gaseous equilibrium in the brine and bubble inclusions within sea-ice and at the sea-ice-atmosphere interface. She has carried out work in the Arctic, led mesoscale sea-ice experiments and is a ECS representative in the BEPSII Steering Committee

Markus Frey's research focuses on chemical and physical interactions between snow and atmosphere and their impact on atmospheric composition and climate at present, and in the past using ice cores. He has led fieldwork at both Poles, investigating the budgets of reactive nitrogen, halogens and sea salt aerosol, and is a CATCH founding SSC member and co-chair.

Hakase Hayashida (ECS) specialises in numerical modelling of ocean and sea-ice biogeochemistry including DMS. He currently leads the Ice Algae Model Intercomparison Project phase 2 (IAMIP2), which aims to better understand the variability and role of sea-ice algae in the polar biogeochemical cycle and climate.

Anoop Mahajan's research focuses on the emission of oceanic trace gases and their impact on the climate through radiative forcing and oxidation capacity changes. He has worked in both the polar regions and is currently involved in the Indian Southern Ocean and Antarctic programs.

Daiki Nomura's research focuses on the biogeochemical cycle within the atmosphere-sea-ice-ocean system. He has studied sea-ice in the Southern Ocean, the Arctic Ocean, and the Sea of Okhotsk, in addition to conducting laboratory experiments on sea-ice freezing processes.

Nadja Steiner's research focuses on the understanding and modelling of sea-ice biogeochemical processes and integration in Earth system and climate downscaling models. She has significant expertise in community building and stakeholder engagement through her chairmanship of BEPSII and involvement in AMAP.

Jennie Thomas' research focuses on modeling atmospheric chemistry in the polar regions including atmosphere-cryosphere interactions in a changing climate. She worked within large polar research projects and networks including the IPY project GSHOX in Greenland, ICE-ARC (FP7), NETCARE, iCUPE (H2020), CATCH (founding SSC member and co-chair), and is the scientific coordinator of the newly funded H2020 project CRiceS that focuses on the role of polar ocean-ice-snow-atmosphere interactions in polar and global climate.

Megan Willis' (ECS) research focuses on the sources and chemical fate of reactive trace gases in polar and marine environments, and their impact on climate through aerosol formation. She participated in two

NETCARE field campaigns and has experience in community building as a founding member of the CATCH SSC, and a member of the 2018 IGAC early career program organizing committee.

Liyang Zhan's research focuses on the biogeochemical cycles of trace gases in the ocean and their exchange at the ocean-ice-atmosphere interfaces. He is now involved in Chinese National Arctic and Antarctic Research Expedition (CHINARE) projects and has studied trace gases in the Southern Ocean and Arctic Ocean.

Relationship to other international programs and SCOR Working groups ***(****259 of 500 words)*

Based on the recognized need to significantly enhance the connection between ocean-sea-ice and atmospheric/sea-ice/chemical research, this working group is strongly linked to the BEPSII and CATCH communities with members of both communities included in the associate and full membership. In support of the objective to design joint oceanic and atmospheric observations, the WG is also connected to SCOR WG 152, ECVice (Measuring Essential Climate Variables in Sea Ice). The WG membership consists of a healthy combination of past SCOR WG members (BEPSII and ECVice), established researchers new to SCOR, ECSs and researchers of countries with emerging programs. Coordination with BEPSII and CATCH meetings will allow resources sharing and support additional participants, particularly ECSs to attend the meetings.

The WG addresses key science priorities from the Surface Ocean Lower Atmosphere Study (SOLAS), the Climate and Cryosphere Program (CliC), the International Global Atmosphere Chemistry program (IGAC) and the Scientific Committee on Antarctic Research (SCAR). The proposed Cice2Clouds working group has already received written support from SOLAS and IGAC.

The WG is also linked to the newly funded Horizon 2020 projects FORCeS and CRiceS which will allow us to communicate the outcomes of the working group directly into active, funded research projects and the broader international community linked to these projects via advisory boards and international collaborations.

The group is linked to the Arctic Council Arctic Monitoring and Assessment Program through members' participation in writing teams and representation in AMAP's Climate Expert Group. The WG content is particularly relevant for understanding and evaluating regulating ecosystem services in upcoming AMAP reports.

Key References (*420 of 500 words*)

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