- **INSTRUCTIONS:**
  - Do not delete content in the Etherpad!
  - *Start comments with your first and last name*
  - Please note questions for the interactive discussion each talk and discussion listed below.
  - You can respond to questions during the interactive discussion and also pose extra questions during the discussion time.
  - This "pad" is a collaborative document that can be edited by anyone who has the URL. ***DO NOT DELETE CONTENT.***

********** 3rd CATCH Open Science Workshop 9-13 May 2022
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Day 5 - 13 May: Coupling of ocean-ice-atmosphere processes: from sea-Ice biogeochemistry to aerosols and Clouds, SCOR WG #163: CIce2Clouds (Megan Willis & Nadja Steiner): Present educational sessions on cross-cutting themes that link the sea-ice/ocean/atmosphere system. Present the plans for CIce2Clouds, and first steps from sub-working groups, to the community and engage community participation.

Please use this etherpad "chat" to leave your comments and specific question to speakers. This way we'll keep a record of your contributions and discussion across all three session of today.

Session 1 - 0600-0800 UTC+2

Intro to CIce2Clouds - Nadja Steiner & Megan Willis
More information about CIce2Clouds is available at:
https://www.cice2clouds.org/

Algal Functional Groups and the Polar Sulfur Cycle - Jacqueline Stefels
Paper relevant to presentation:
https://aslopubs.onlinelibrary.wiley.com/doi/epdf/10.1002/lno.11477

Notes from the discussion:

-Why does phaeocystis produce so much DMSP? Is this a Haptophyte trait in general?

Evolution! Nobody really knows the answer to this yet; haptophytes produce a lot of DMSP, and also dinoflagellates (but maybe not all of them). Some haptophytes convert DMSP to DMS. This is really an evolutionary trait that has developed in the haptophytes (can protect from a variety of environmental stressors, makes them well suited to certain sea-ice environments)

-The correlations between DMSP and haptophyte pigments are striking, and there seems to be well defined zones in the sea-ice that are maintained over months -- is the system really this stable??

The presence of DMSP is really more connected to the presence of certain algal groups than anything else; the ice can change over time, but the algae are stuck essentially. The moment you get melting and brine channels open you get flushing, and up/down migration a little bit. If you have a community present, it gets stuck until some physical forces move it out

-Melt and intrusion event -- does this mean that the algae infiltrates from below? Or from surrounding waters?

From surrounding waters, not from below. Several algal types can then access a low salinity layer at the top of ice where there is a lot of light and they are essentially free of grazers, then they can grow very prolifically.

-If we model phytos in the ice, then we need to use at least two phyto groups in the sea-ice (!), similar to what is done in some models in the open ocean.

-Can you group these with the coccolithophores? (More relevant to the Arctic regions) -- sounds like yes, we can do this reasonably from a modelling perspective

-In the Arctic it seems like we don't see much phaeocystis, maybe in the marginal ice zones ==> from MOSAiC, it seems like they don't produce much of the same pigments, so it is harder to know abundance of haptophytes present and to be able to distinguish them from diatoms

Ilka Peeken: A general problem in the Arctic is that you can not use the usual 19 hex. pigment, which works well in the Antarctic for the Arctic

(see e.g. https://www.jstor.org/stable/24844656), here only chlorophyll c 3 can be used, which makes is more difficult to identify Phaeocystis here.
-Why so much phaeocystis and DMSO in the Antarctic ==> slush layers on top of flooded ice, that are somewhat salty (and high light), this is a perfect environment for phaeocystis
-you don't get this environment so much in the Arctic, maybe in the MIZ, so phaeocystis is more staying in the pelagic blooms (also in Atlantic inflow regions...more and more phaeocystis is coming in)
Overall we have Phaeocystis mainly in in the Atlantic inflow area and from there it is recently spreading north (e.g. https://www.tandfonline.com/doi/full/10.3402/polar.v34.23349 and https://doi.org/10.1098/rsta.2019.0357. You also recently find under ice blooms in fully covered ice areas https://www.nature.com/articles/srep40850. In the Central Arctic DMSP is extremly low see Uhlig et al.
doi: 10.3389/feart.2019.00179
-what is new is under-ice phaeocystis blooms, which may increase in the future

-What is the pH in slush/wet snow layers on sea-ice? Does it become more acidic than the mean ocean pH if the slush layers are less saline than open water? (is phaeocystis more resilient than other algae to pH changes?)
pH maybe high...we don't really know. If there is primary production, then this will consume CO2 and pH should go down
This is kind of connected to how people started thinking about frost flowers as the source of Br explosion, BUT it is really hard to acidify really salty situations, so it can be more possible that snow environments can be acidified more easily

How to model all these ice processes?
-Need to think about modelling the MIZ and broken ice, and these "dirty" areas, this can be quite challenging

@Jacquline - (Jennie here) I was thinking about your talk and I have to say I need even more education about the species/organisms you are talk about. How can we post questions to you about very simpile things we don't understand?

What we know about chemistry of snow that is relevant for snow on sea-ice

- Jennie Thomas

Notes from the discussion:
-Something Bill Simpson is learning more and more ==> the RH just above the snow is make quite constant by snow sublimation, this is like a buffer on the near-surface humidity that makes humidity remain quite constant (this has implications from hydroxymethanesulfonate chemistry in polluted snow/ice conditions)
-This effect should also impact blowing snow, because to get blowing snow you need to get to sublimation conditions
-Within the interstitial air, models assume equilibrium, but often ignore this in the atmosphere, which is probably wrong
-This also means that the surface is very dyanmic and is constantly refreshing

-Do molecules like bromoform interact/react at the snow surface? (has a biological source)
-Observations show that over wintertime large concentrations of bromoform accumulate at the snow/ice surface, and then "goes away" as soon as the light comes back (mechanism seems unclear)
You need quite short wavelengths to directly photolyze bromoform, so we don't think that this is photolyzed directly in the snow
Overall, most Br in the atmosphere is mostly coming from inorganic sources originally -- bromoform is important for the global Br budget (upper troposphere), but doesn't seem important for Br explosion events
This very highly oxidizing (potentially) environment at the top of snow could lead to processes that we haven't really thought about so far.

-Is snow on sea-ice always salty?
For Jennie, snow on sea-ice is always very salty compared to what was shown here, when you have exposure to fresh emission of salt either from deposition or from seawater

-On modelling how NOy gets into the snow in the first place --> how do you initialize the model to get deposited species onto snow?
In Jennie's model, they used the measured concentration to initialize the model, but you could also use HNO3 deposition and assume conversion to NO3- (Becky Alexander's models have done this); the problem here is that there are large uncertainties in the deposition of HNO3 to snow
-key uncertainties in modelling these processes may be more on flooding

and swmaping of the snow on sea-ice, that would overshadow atmospheric inputs

-How do absorbing components in snow (black carbon, or dark algal layers) impact the snow photochemistry? (There are an increasing number of snow algae that are showing up along the coast lines of the Antartic continent and also on Greenland, this must impact the snow by absorbing heat in some way)
It is more likely to change the snow physical structure to affect the chemistry, than to affect the chemistry directly

-Is snow on sea-ice more like a dilute-ish fog chemistry or a concentrated aerosol water chemistry?
It is very saline, so should be more like aerosol chemistry (if you think about fog, snow and aerosol and similar except for different concentrations and pH's). In ice, there might be a smaller range in concentrations than between fog and aerosol.
What about the effects of dilution

-Is the photochemical conversion of DMS to DMSO greater in ice/snow than in the surface ocean? Can this be a way to look into oxidation chemistry in the snow on sea-ice surface?

Bill Simpson: I saw the OH in the snow pack seemed to "run out" in later days of the simulation. Why was that?
Bill - Jennie here - I don't know this. I'm having a look. Seemed like many things "recycled" on subsequent days, but that one (the OH) seemed more to be being consumed (or a precursor). I think the question of if there is a lot of OH in the liquid is a really good one. Thanks!
Thorsten: Agree - thanks for bringing this back to attention. Where there OH scavengers present in the model-snow? @Thorsten - From Jennie: yes, but not the right ones (no DOCs) for example.
@Bill, @Thorsten - I can make an liquid layer OH budget - just need a bit of time. I'll email you if I manage next week.

@Nadja - Jennie here:

- For our 3D work with WRF-Chem also based on the work of Toyota for snow on sea ice, we did not track bromide in snow on sea ice. We consider it always available: https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2020MS002391?af=R

- Also the papers from UW (Alexander group) that I mentioned where they do soemthign more explicit for snow:
  - https://acp.copernicus.org/articles/13/3547/2013/
  - https://acp.copernicus.org/articles/16/2819/2016/

@Megan - better response to your slush question - I think that for very slushy things, it will not be suprising if things change sigifciantly because of the lack of interstitial air. I feel the mix of air/ice in snow is kind of special in terms of getting products to the gas phase that can be ventilated up to the atmopshere.

Session 2 - 1430-1630 UTC+2

Aerosol as Nuclei for Cloud Formation in Polar Environments - Jessie Creamean & Paul Zieger

@all - when you comment in the EtherPad - please start with your first and last name:

Name? @Paul, @Jessie:

From Hyung-Gyu @ Paul: I'm wondering is there any example that Arctic cloud fraction bias is corrected in cases of sea salt or dust simulation included or not
Paul: Good question! Unfortunately I can't answer this. I assume that some of our modellers might have an answer for this.
Thanks Paul: I just found radiative forcing in the Arctic based on sea salt from Fabien Paulot et al 2020 (https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2019GL085601). This paper didn't mention cloud bias correction but low-level cloud feedback can be changed in high latitude in future projection of climate change, quadrupling of CO2 concentrations (abrupt-4×CO2integrated for 300 years), and 1%yr-1CO2increase(1pctCO2) experiment.

From Santiago: Jessie: you mentioned the presence of microbes in the permasfrost. Some of them look like they are deep. Are these ancient/preshistoric microbes? or modern microbes that somehow made it down there? If they are "old" microbes, would you expect them to have

different nucleating potentional when relased to the atmosphere?
-From Jessie: older cores seemed to have less diversity in microbes, but overall more INPs; these permafrost lakes seem quite important for getting thawing lower (older) layer material out into the water and potentialy into the air

Paul Zieger (SU): Is there sufficient bubble bursting inside the lagoons and ponds for INP's to be brought into the atmosphere?
-From Jessie: winds are generally high in these areas, so there is potential for lofting of particles, and/or through a lake spray mechanism

Jennie @ Jessie - are there more uncertanties from local dust as INPs or from the lake sources? Is it known?
-From Jessie: not totally clear yet, working on local soil versus lake samples

-(Question from Markus) Do these surface sources of INPs matter for clouds? In the intro talk Paul talked about dynamics being the major driver. What is the observational evidence that this surface source is coupled and drives cloud properties/local cloud cover?
-From Paul: this is a hard question, when you have warm air intrusions you definitely see these changes clearly. INPs do change the phase of the cloud, which can happen quite fast and have
-From Santiago: cases seen using Calipso, can clearly see that surface sources of dust do meet clouds up to ~1000m (link to paper:https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2016RG000518 see figure 19 , let me know if you need more info about dust in AK)
-From Jennie: remember that weather models are trained to predict cloudiness, even if they don't predict the underlying processes. this model skill doesn't mean that they have the ability to predict cloud impacts in a climate context without getting the underlying aerosol processes
- From Kerri: I can say from personal experience that the weather models are complete crap on the North Slope of Alaska - even one day in advance - sometimes even for the same day. :-)
@Kerri - of course. Yup. I actually think that the fact that they don't work in northern Alaska (where there are few met observations to drive the weather models) supports your point completely. @Kerri - I did say "except for in the Arctic." where weather models are bad :) Indeed.
Jennie: Also I wanted to say they don't have a detailed description of CCN

or IN, as aerosols scientist would think. Maybe that wasn't clear. Of course there are some CCN and sometimes IN, but not based on predicted aerosols.

Joint Campaign Planning Discussion (CIce2Clouds TOR4)

Goals from this session:

-While we can't solve this/create a full science plan in a short discussion, the aim here is to gather as much community input as possible

-Choosing a target region and season will remove significant ambiguity (even if it is not immediately possible because we don't have a ship in hand), then we can come forward with a balanced white-paper on why we are going, and the main open questions that we want to address

-In previous iterations of this discussion (CATCH/BEPSII), we began to settle on SOuthern Ocean, and in the autumn (though we could be more idealistic in a white-paper and describe aims for a seasonal cycle -- "MOSAiC-type" expedition in the SO/Antarctica, maybe with multiple ships)

-Jacqueline: There is some discussion on this type of seasonal expedition, maybe in a 5-year time frame

-Ilka: In a white paper, we should focus on some different seasons and what we would need and what should be done (e.g., climate and biology questions we can answer with laboratory experiments aboard ship)

-Nadja: Linking to conceptual model development -- can we take those conceptual models and indicate what kind of measurements we have available for all the different reservoirs or "arrows". Can we direct our campaign planning using these conceptual models? (i.e., a conceptual model of measurement tools with input from modellers on where sensitivities are -- a kind of cost/benefit analysis)

-Paul: remember that this discussion was always motivated by trying to design the "ideal" experiment, and try to put together a white paper based around the science, and a little bit less constrained by exactly what is available. Markus: also, it is a "camapaign" not only a field experiment, includes lab experiments

-Jennie: to design this, we should go through the exercise of writing down what we learned from past experiments. Discuss really specifically on "what was missing" in past experiments, and what could be done differently

-Jessie: recommend the minimum measurements that could be done on any cruise (ocean or atmosphere focused), so that each different study has a baseline set of measurements to be able to link and coordinate these different sets of experiments (PICCASSO is a great example of this)

-Markus/Nadja: we need to actually take both approaches in this in a

white-paper, start with the basic measurements and then also the broad 'ideal' set of measurements

-Kerri: we also need to have a targeted set of questions that we need both CATCH/BEPSII input and measurements to be able to more effectively make compromises on how measurements are set-up; importance of process level observations

-Jennie: are we going to only pick 1 process and go forward with this only? this can be quite restrictive, how do we plan something like this more broadly? It is hard to know how to order this type of planning process

Marc Mallet: Based on the first Science Question in the Joint Campaign Planning, this paper might be of interest that just came out in Nature Climate Change:

https://www.nature.com/articles/s41558-022-01353-1

I can't say I've read it in detail, but they show quite large changes in the response of the timing of Arctic bloom peaks with climate change.

-on the biological vs chemical processes: what about laboratory studies? e.g., better understanding of when/where small particle do/don't grow, would a dedicated lab study of water uptake or other trace gas uptake help in this area?

We should always keep lab studies in mind, and lab studies we can do on ships!

-for addressing all these questions: we should discuss what kind of triggers are important for different processes (biology timing, chemistry and the presence of light in spring/summer)

-Suggestion on our approach from Nadja: for each of the general science questions -- we should think/discuss in detail what types of experiments are needed to address these (field, lab, model)

-Lab-in-the-field experiments around sources of small particles (chamber experiments in a field setting)

-Discussion on logistics, and measurement needs:

-Is it possible to have an ice-camp and turn the ship into the wind at the same time? This is a challenge, but is possible (e.g., Oden has experience with this)

-Maybe these process-level measurements are the ones that we recommend?

-Importance of vertical profiling and flux measurements
-Distributed sensor measurements?

Next steps and directions:

-Start with lessons learned from past expeditions? Is this being done already, e.g., with MOSAiC? Should we start this within this broader group?

==> a lot of the MOSAiC compromises were made by necessity and related to how different countries decided to supply funding, there will always be compromises and we have to work with this

-What is the best way to have a white-paper to be ready for the opportunities that are coming up in the next 5-10 years? (e.g., we are still in the discussion phase, and not a strong community voice, but there are projects coming up and we aren't quite ready)

-Marc (PICCASSO): there are ~13 voyages upcoming, and they are nearly funded or already funded. It may not be wise to "re-ask" questions, but rather to synthesize them and get them back to the community. It may be more advatageous to focus on how to use and synthesize the observations that ARE coming with models. We know how to feed 'baseline' datasets into models (e.g. CCN, total aerosol), but what about how to make these process studies most useful for our climate models?

-Nadja: could we create a community survey on what went well and what didn't go as well, and compromises, so that we have a consistent way to bring together feedback on lessons learned?

-Markus/Paul: a white-paper needs to demonstrate a strong community driven effort, and what is exactly needed really depends on the countries that are involved.

-Katye: it really helps to have a community open document to back up needs/
plans during a campaign planning process, it is easier to just

@Katye - Jennie - fully agree on this. These docs help demonstrate to funding agencies what we can do together and can influece things.

@all - Jennie here - I think we need to consider not just ships, but also aircraft or other platforms in our planning. People are talking about getting one ship, but I think there has to be other platforms coordianted (i.e. coastal stations)

- Kerri: I really support the idea of pointing to efforts that can be community coordinated at coastal stations and aircraft.

@Manual - Jennie here - I think the BGC people who are interested in working with us know what is INP and CCN. Or we are happy to explian this and discuss together.

@Megan - @Nadja - I have an idea for a venue for the summer school for "adults". Happy to chat later. Sounds good! We also have the offer from Daiki for a winter school in Hokkaido. ok cool - actually we could do this in two phases (two different years, first in Japan) my idea is to apply to get access to the Les Houches Physics School in France if there is interest.

Marc's response to Manuel:
I really think there's two levels to our problem. There's the "DMS, INP, CCN" stuff which lacks input from biologists. Maybe it is a language problem but at the same time there's very real gaps in our knowledge there. The other level is that there are clearly much more complicated processes that link plankton to clouds and climate than we consider/know about. We absolutely need domain knowledge from ocean and sea-ice biologists to figure out processes and fluxes. But the more we go in that direction, I think we become out of touch with where earth system modelling is right now. Even if we knew the abundance and ecosystem processes that lead to the exhange of all these complicated organic materials into the atmosphere, how do we realistically paramaterise that in a coupled earth system model? It's debatable, but as was discussed, it's hard to convince hardcore cloud-folk and meteorologists that aerosols are important, so how do we extend it further to include biology as well? I don't think there's easy answers to any of this but I love the debate.

Leadership:
    -Markus (happy to contribute, will laise with Marc re:PICCASSO)
    -Marc (has already been participating in a PICCASSO white paper)
    -Katye (important that we don't duplicate efforts with PICCASSO)
    -Jennie happy to edit/contribute and wrangle modelers to help, not lead
    -Megan (also happy to edit/contribute, but can't lead right now)
    @ice BGC teams - who is in?: Ilka Peeken happy to contribute
    (Comment from Megan: I hope Jacqeline may also be willing to contribute, and there may be some BEPSII folks currently in the field who has interest and enthusiasm)
Jennie note on this: I think we really should coordinate this closely with

Marc/Ruhi/Soyna to not have the same thing twice.Agree!!
Markus - I see two documents, a. white paper, short term (and the PICAASO paper likely is what's needed now) b. guidance document for campaign planning with more detail on target processes, season/region, method/ experiment, e.g. publication in ELEMENTA
-Paul happy to contribute but leading will be difficult
- Jacq: happy to help. I could immagine that we should have a seperate paper on lessons learnt, seperate from science questions, I mean. Otherwise we might not get the message accross on both issues.

Other Working Group Business:
*we need to discuss the SOLAS meeting, we will meet in GatherTown before the next session to discuss this further!

SOLAS website for the conference:
https://uctcmc.eventsair.com/solas-osc2022/

Session 3 - 1800-2000 UTC+2

Update: Primary aerosol working group

@Paul - Jennie here - lab studies are not all the same in this way. The things Thorsten is doing are a bit different. :)
Markus to Paul/Jennie - UEA sea ice chamber is challenging for air chemistry Let alone biology) because it is hard to control contamination. We are attempting some NOx/HONO/O3 work this summer with Millie. Paul: Cool!
Paul Zieger (SU): Yes, but you can do controlled experiments on ships to look at individual processes. We have brought our sea spray chamber now several times on ships (similar like Karine Selegri's mesocsom experiments) and we could do similar for looking at freezing processes and looking at the emissions (but maybe I am a bit naiv here :-)
Markus: We have been discussing w/ Karine (and earlier Kerri) controlled wind tunnel experiments in the field/lab to look at blowing snow aerosol processes. This will require funding, not part of your standard kit.

Missing from schematic so far (some updates made during meeting):
    -arrows and processes in the ocean/ice (between green and brown components)
    -aerosol and cloud processes

-Discussion on whether to include seconday aerosol processes within this effort
   -this is open, initially we are trying to focus on something tractable, where we have enough information for a conceptual model
   -Secondary aerosol processes (outside sulfur) can be added to this effort, or launched separately (Lucy Carpenter expressed interest in a halogen/iodine effort)

Update: Sulfur cycle working group
- Start builing a schematic from the atmospheric side and then from the ocean and sea ice
- schematic seperated by Antarctic and Arctic. Trying to indetify dominant processes
- try and seperate between gas phase products and aqueous products.
- BrO is a lot more important in the Antarctic than the Arctic.
- Kerri- why is BrO more important in the Antarctic? Reply- Could be what has come out of our current model understanding.
- Kerri- it would be useful, in light of the recent work from Helsinki and NETCARE, to indicate coupling with marine-derived oxidized organics (next to particle growth arrow). There are new questions of these particles as potential INP (see discussion earlier in the workshop) and organics questions about the moleculare composition of the components.

@Megan - Jennie - I am not aware of publicly archived atmopspheric chemistry global model output that includes both a description of polar halogens and DMS chemistry in the atmopshere. Most global models that are public: CAMS, CAM-Chem, do not have halogens in their standard versions that provide public output. For Geos-chem the model is public, but I'm not aware of standard archiving of runs including all of that chemistry you would want.
-discussion on this: maybe useful in our deliverable to write motivations for inclusion of certain processes in models and provide public output to help diagnose issues?

@Hakase: Paul Zieger (SU): Could you post the reference the paper that describes the DMS model here?

-sea-ice BGC model output can be available (Hakase, Nadja) for initializing atmospheric models that don't have coupled sea-ice/ocean processes

-(Hyung-Gyu) How can we get sea-ice timing right, since this seems to important for getting DMS right? Usually models need to nudge sea-ice to get right seasonality, but then you lose some feedbacks.

Update: Nitrogen cycle working group

-Markus: isotopic measurements are a very valuable tool. you can start to contrain N-budgets with comprehensive meansurements in different phases.

-General comment:

-our schematics are all starting to look somehow similar. we could combine these at the end into some kind of interactive graphic that can display any of the different components (primary aerosol, N, S) and provide resources all together