surface ocean solas lower atmosphere study

Report for the year 2015 and future activities

SOLAS CANADA ***compiled by: Maurice Levasseur***

PART 1 - Activities from January 2015 to December 2015

1. Scientific highlights

1. Ammonia in the summertime Arctic marine boundary layer: sources, sinks and implications

Continuous hourly measurements of gas-phase ammonia ($NH_{3(g)}$) were taken from 13 July to 7 August 2014 on a research cruise throughout Baffin Bay and the eastern Canadian Arctic Archipelago. Concentrations ranged from 30 to 650 ng m^{-3} (40–870 pptv) with the highest values recorded in Lancaster Sound. Simultaneous measurements of total ammonium ([NH_x]), pH and temperature in the ocean and in melt ponds were used to compute the compensation point (χ), which is the ambient $NH_{3(g)}$ concentration at which surface–air fluxes change direction. Ambient $NH_{3(g)}$ was usually several orders of magnitude larger than both χ_{ocean} and χ_{MP} indicating these surface pools are net sinks of NH_3. The GEOS-Chem chemical transport model was employed to examine the impact of $NH_{3(g)}$ emissions from seabird guano on boundary-layer composition and nss-SO_4^{2-} neutralization. A GEOS-Chem simulation without seabird emissions underestimated boundary layer $NH_{3(g)}$ by several orders of magnitude and yielded highly acidic aerosol. A simulation that included seabird NH_3 emissions was in better agreement with observations for both $NH_{3(g)}$ concentrations and nss-SO_4^{2-} neutralization. This is strong evidence that seabird colonies are significant sources of NH_3 in the summertime Arctic, and are ubiquitous enough to impact atmospheric composition across the entire Baffin Bay region.

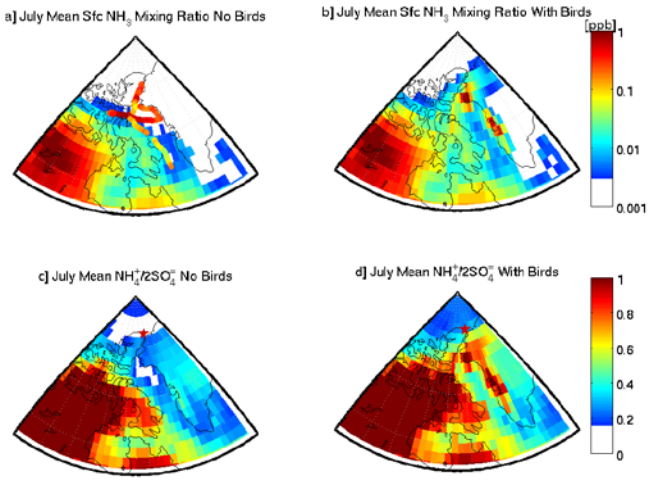

Figure 1. GEOS-Chem simulation of NH_3 mixing ratio (ppb) of the July monthly mean surface layer for (a) no seabird emissions and (b) with seabird emissions. Circles in (a) represent the ship track coloured by NH_3 measurements. Panels (c) and (d) show GEOS-Chem simulations for the

ammonium to non-sea salt sulphate ratio during the same period for (c) no seabird emissions and (d) with seabird emissions. The star indicates the average ratio observed at Alert during July.

Wentworth, G. R. J. G. Murphy, B. Croft, R. V. Martin, J. R. Pierce, J.-S. Côté, I. Courchesne, J.-É. Tremblay, J. Gagnon, J. L. Thomas, S. Sharma, D. Toom-Sauntry, A. Chivulescu, M. Levasseur, and J. P. D. Abbatt, "Ammonia in the summertime Arctic marine boundary layer: sources, sinks and implications", Atmos. Chem. Phys., 16, 1937-1953, 2016. doi:10.5194/acp-16-1937-2016 http://www.atmos-chem-phys.net/16/1937/2016/

2. Dimethyl Sulfide oxidation contributes to summertime Arctic SO_2 and fine aerosol sulfate

DMS and its oxidation products SO_2, as well as size segregated aerosol sulfate were measured aboard the Canadian Coast Guard ship the Amundsen in the Arctic during July 2014. DMS contributions to SO_2 and fine aerosol sulfate (<0.49 microns: >70%) were considerable. Gas to particle conversion was determined to be the most likely source of a majority of the fine aerosol sulfate during most sampling periods. Evidence for this was a strong correspondence between the isotope composition of SO_2 and fine aerosol sulfate (Figure). Potential aerosol growth was also inferred for particular sampling periods. Similarity between δ^{34}S values for aerosols in the fine and accumulation mode and SO_2 suggests either the SO_2 and aerosols were transported together from their source region, or that aerosol growth took place. These results emphasize the importance of marine organisms to the formation, and possibly growth, of fine particles in the marine boundary layer above the Arctic Ocean in summer.

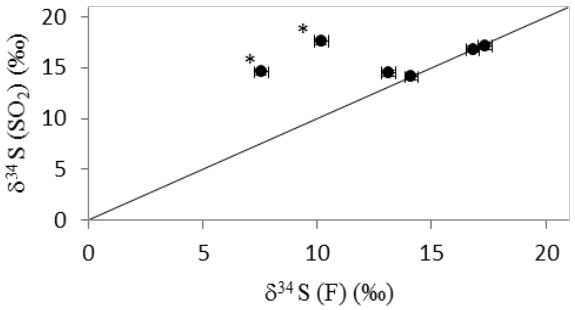

Figure 1: δ^{34}S values for $F_{<0.49\ \mu m}$ and SO_2 relative to a 1:1 line. Four of six samples show good correspondence between δ^{34}S values for SO_2 and sulfate. These four sample sets have δ^{34}S values that are quite near the expected value for biogenic sulfur (+18 permil). Two samples with lower δ^{34}S values for sulfate than SO_2 suggest a greater proportion of anthropogenic sulfate was present (asterisks) at times.

Ghahremaninezhadgharelar, R, Norman, A.L., Abbatt, J., Levasseur, M., Biogenic, anthropogenic and sea salt size-segregated aerosols in the Arctic summer. Atmos. Chem. Phys. Discuss., acp-2015-1010, 2016.

3. Effects of dust additions on phytoplankton growth and DMS production in high CO_2 northeast Pacific HNLC waters

Ocean acidification (OA) is likely to have an effect on the fertilizing potential of desert dust in high-nutrient, low-chlorophyll oceanic regions, either by modifying Fe speciation and bioavailability, or by altering phytoplankton Fe requirements and acquisition. To address this issue, short incubations (4 days) of northeast subarctic Pacific waters enriched with either $FeSO_4$ or dust, and set at pH 8.0 (in situ) and 7.8 were conducted in August 2010. We assessed the impact of a decrease in pH on dissolved Fe concentration, phytoplankton biomass, taxonomy and productivity, and the production of dimethylsulfide (DMS) and its algal precursor dimethylsulfoniopropionate (DMSP). Chlorophyll *a* (chl *a*) remained unchanged in the controls and doubled in both the $FeSO_4$-enriched and dust-enriched incubations, confirming the Fe-limited status of the plankton assemblage during the experiment. In the acidified treatments, a significant reduction (by 16-38%) of the final concentration of chl *a* was measured compared to their non-acidified counterparts, and a 15% reduction in particulate organic carbon (POC) concentration was measured in the dust-enriched acidified treatment compared to the dust-enriched non-acidified treatment. $FeSO_4$ and dust additions had a fertilizing effect mainly on diatoms and cyanobacteria. Lowering the pH affected mostly the haptophytes, but pelagophyte concentrations were also reduced in some acidified treatments. Acidification did not significantly alter DMSP and DMS concentrations. These results show that dust deposition events in a low-pH iron-limited Northeast subarctic Pacific are likely to

stimulate phytoplankton growth to a lesser extent than in today's ocean during the few days following fertilization and point to a low initial sensitivity of the DMSP and DMS dynamics to OA.

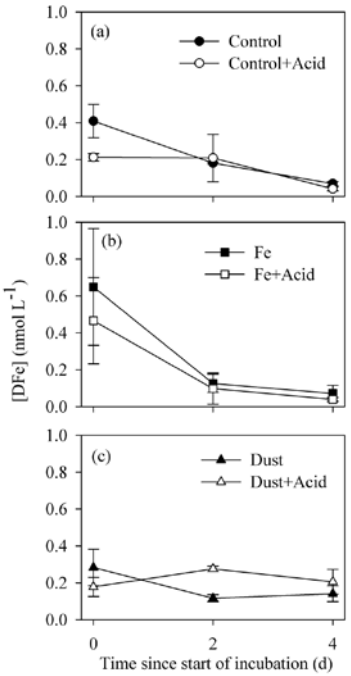

Figure 1: AVERAGE CONCENTRATION OF DFE IN EACH TREATMENT DURING THE INCUBATIONS MEASURED AT T0, T2 AND T4. (A) CONTROL AND CONTROL+ACID. (B) FE AND FE+ACID. (C) DUST AND DUST+ACID. ERROR BARS INDICATE STANDARD DEVIATIONS. N = 3 EXCEPT FOR ACID, T0, T2, DUST+ACID, T0, AND CONTROL (ALL TIMES) WHERE N = 2.

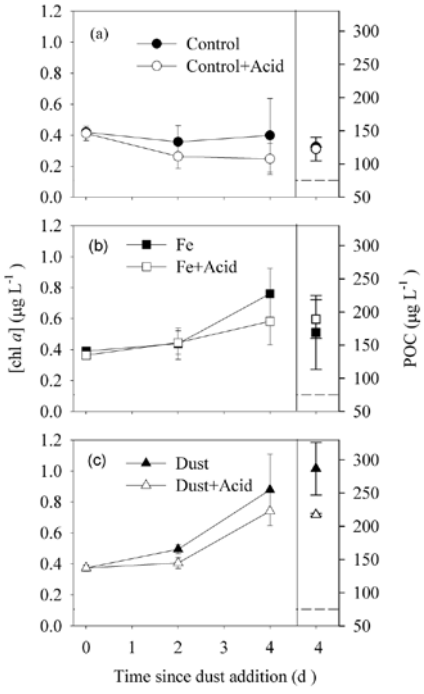

FIGURE 2: AVERAGE CONCENTRATION OF CHL A (LEFT AXIS) DURING THE INCUBATIONS AND POC AT T4 (RIGHT AXIS) IN EACH TREATMENT. (A) CONTROL AND CONTROL+ACID. (B) FE AND FE+ACID. (C) DUST AND DUST+ACID. ERROR BARS INDICATE STANDARD DEVIATIONS. DASHED LINE INDICATES POC CONCENTRATION AT T0. CHL A: N = 3 EXCEPT FOR ACID, T0, DUST+ACID, T4, FE+ACID, T0 AND CONTROL (ALL TIMES) WHERE N=2 BECAUSE OF MISSING/UNRELIABLE DATA OR CONTAMINATION (CONTROL 1). POC: N=3 EXCEPT CONTROL WHERE N=2.

Mélançon J, Levasseur M, Lizotte M, Scarratt M, Tremblay J-É, Tortell P, Yang G-P, Shi G-Y, Gao H-W, Semeniuk DM, Robert M, Arychuk M, Johnson K, Sutherland N, Davelaar M, Nemcek N, Peña A, Richardson W (2016). Effects of dust additions on phytoplankton growth and DMS production in high CO_2 northeast Pacific HNLC waters. Biogeosciences 13.

2. Activities/main accomplishments in 2015 (projects, field campaigns, events, model and data intercomparisons, capacity building, international collaborations, contributions to int. assessments such as IPCC, interactions with policy makers or socio-economics circles, etc.)

1. Cambridge Bay ocean CO_2 observatory
A new CO_2 monitoring program was established at Cambridge Bay, Nunavut, Canada. The observatory includes a cabled bottom (8 m) node with in-situ sensors for pH and pCO_2 200 m from the Cambridge Bay dock, and a CO_2 flux tower on a small island about 35 km across the bay.

2. ArcticNet 2015 annual cruise
The annual ArcticNet cruise completed a survey of autumn pCO2 fluxes through the eastern Canadian Archipelago, across the Northwater Polynya, and down the western side of Baffin Bay. In addition, onboard incubation experiments were conducted in July on the combined effect pH and light on phytoplankton bloom dynamics and DMS production during the spring arctic bloom. The aim of this project was to compare the sensitivity of marginal ice bloom and under ice bloom to the predicted decrease in pH for Arctic waters (NETCARE/SOLAS student Rachel Hussherr).

3. GreenEdge ice camp (Qikiqtarjuaq, Baffin Island, May-July 2015)
Participation of Levasseur's group to the program GreenEdge (Leader: Marcel Babin, Université Laval,Takuvik) allowed to further assess the importance of melt ponds as a source of DMS for the Arctic atmosphere (work of the NETCARE/SOLAS PhD Student Margaux Gourdal).

4. NETCARE-POLAR6 aircraft campaign (March-April 2015)
This was a joint flight between Canadian NETCARE and AWI researchers. 86 flight hours were completed on 10 sciences and 12 ferry flights. The campaign started in Longyearbyen, Svalbard, and moved to Alert, Eureka and Inuvik. A new development related to these flight was the first deployment of a Far-Infrared Radiometer (FIRR). FIRR development and deployment was funded by the Canadian Space Agency under a project led by Co-I Blanchet, UQAM. A focus of NETCARE is to better understand the role of ice crystals to affect the radiation budget, which occurs largely in the far-infrared. A critical link with anthropogenic aerosol has been identified through ice nucleation processes.

5. Snow sampling at Alert (2014-2015)
Close to 50 snow samples were collected at Alert during the fall-winter-spring season of 2014-2015. These samples are being analyzed for their BC, OC, metal, and ionic content, as a joint project between NETCARE co-investigators and Environment Canada collaborators. These measurements will provide information on aerosol fluxes to the snowpack in the high Canadian Arctic, and will be used for detailed source-receptor analysis and comparison to chemical transport model predictions. This is the first data set of this type yet collected, where the snow is not from the ground but from a snow table instead.

6. Ice nucleation particles
Activities to measure the number and character of INPs in remote environments started at Ucluelet in 2013, and have progressed with measurements from the Amundsen (2014), POLAR6 (summer 2014, spring 2015), Whistler (2015) and Alert (2014 and 2015). This work has shown that: a) a large fraction of the INPs are in the supermicron mode for all sites investigated presumably from mineral dust or biological particles and b) at Ucluelet (a remote coast site) a large fraction of the ambient ice nuclei were most likely biological particles from terrestrial sources. These results will be useful when modelling ice cloud formation and the indirect effect of aerosols on climate.

7. Modelling of Arctic sulphur cycle (Nadia Steiner)
Progress has been made with the development of a 1-D ocean-ecosystem model with sulphur cycling in the Arctic. The model now includes sea-ice and a sea-ice ecosystem with ice algal contributions to DMS from sympagic and pelagic systems.

8. Further models development (Knut Von Salzen)

Overall, focus in this activity has been upon assessments of processes included in the models and comparisons to existing data. Activities within the past year with the GEOS-Chem model include interpretation of 1) the Amundsen measurements to understand sources of DMS and NH3, 2) aerosol optical depth from AEROCAN observations to understand processes affecting their variation, 3) Whistler black carbon measurements to understand controlling processes, and 4) measurements at Alert to understand black carbon sources and processes controlling aerosol number.

We have completed a fine, coarse and total aerosol optical depth (AOD) climatology for the polar winter at Eureka and Ny Alesund (2 years) and an analogue 4-year climatology for the polar summer at five Arctic stations. As mentioned, these climatologies have been compared with GEOS-Chem simulations and are being worked up in two draft papers.

Impacts of emissions of BC on Arctic temperatures in CanAM4.2 were investigated based on simulations with 4 models, in collaboration with the Expert Group on Black Carbon and Ozone, Arctic Monitoring and Assessment Programme (AMAP); results were documented in an AMAP assessment report and in a paper in Nature Climate Change (Sand et al.). For the first time, the study provided evidence that present-day emissions of BC from domestic sources and vegetation fires in Asia cause significant warming of the Arctic.

In addition, simulated concentrations of BC in snow in CanAM4.2 and associated radiative forcings were compared to observations and results from other models (Namazi et al.), complementing earlier comparisons with observations at surface sites and aircraft data (Eckhardt et al.).

3. Top 5 publications in 2015 (only PUBLISHED articles) and if any weblinks to models, datasets, products, etc.

For journal articles please follow the proposed format:
Author list (surname and initials, one space but no full stops between initials), year of publication, article title, full title of journal (italics), volume, page numbers, DOI.

SOLAS TOP FIVE

Wentworth, G. R. J. G. Murphy, B. Croft, R. V. Martin, J. R. Pierce, J.-S. Côté, I. Courchesne, J.-É. Tremblay, J. Gagnon, J. L. Thomas, S. Sharma, D. Toom-Sauntry, A. Chivulescu, M. Levasseur, and J. P. D. Abbatt, "Ammonia in the summertime Arctic marine boundary layer: sources, sinks and implications", Atmos. Chem. Phys., 16, 1937-1953, 2016. doi:10.5194/acp-16-1937-2016
http://www.atmos-chem-phys.net/16/1937/2016/

Mélançon J, Levasseur M, Lizotte M, Scarratt M, Tremblay J-É, Tortell P, Yang G-P, Shi G-Y, Gao H-W, Semeniuk DM, Robert M, Arychuk M, Johnson K, Sutherland N, Davelaar M, Nemcek N, Peña A, Richardson W (2016). Effects of dust additions on phytoplankton growth and DMS production in high CO_2 northeast Pacific HNLC waters. Biogeosciences 13.

Wilson TW, Ladino LA, Alpert PA, Breckels MN, Brooks IM, Browse J, Burrows SM, Carslaw KS, Huffman JA, Judd C, Kilthau WP, Mason RH, McFiggans G, Miller LA, Najera JJ, Polishchuk E, Rae S, Schiller CL, Si M , Vergara Temprado J, Whale TF, Wong JPS, Wurl O, Yakobi-Hancock JD, Abbatt JPD, Aller JY, Bertram AK, Knopf DA, Murray BJ, 2015. A marine biogenic source of atmospheric ice nucleating particles. *Nature* **525**: 234-8.

Brown KA, Miller LA, Mundy CJ, Papakyriakou T, Francois R, Gosselin M, Carnat G, Swystun K, Tortell JP, 2015. Inorganic carbon system dynamics in landfast arctic sea ice during the early-melt period. *J. Geophys. Res. Oceans* **120**, doi: 10.1002/2014JC010620.

Croft B, Martin RV, Leaitch WR, Tunved P, Breider TJ, D'Andrea SD, Pierce JR, 2015, Processes controlling the seasonal cycle of Arctic aerosol number and size distributions, *Atmos. Chem. Phys. Discuss.*, 15, 29079-29124.

OTHER SOLAS TOP FIVE...

Mason RH, Si M, Li J, Chou C, Dickie R, Toom-Sauntry D, Pöhlker C, Yakobi-Hancock JD, Ladino LA, Jones K, Leaitch WR, Schiller CL, Abbatt JPD, Huffman JA, Bertram AK. 2015. Ice nucleating particles at a coastal marine boundary layer site: correlations with aerosol type and meteorological conditions. Atmospheric Chemistry and Physics Discussions, 15, 16273-16323, doi:10.5194/acpd-15-16273-2015.

Steiner N, Deal C, Lannuzel D, Lavoie D, Massonnet F, Miller LA, Moreau S, Popova E, Stefels J, Tedesco L, 2016. What sea-ice biogeochemical modellers need from observers, *Elem*. *Sci. Anth.* **4**: 000084, doi: 10.12952/jounal.elementa.000084.

Miller LA, Fripiat F, Else BGT, Bowman JS, Brown KA, Collins RE, Ewert M, Fransson A, Gosselin M, Lannuzel, Meiners KM, Michel C, Nishioka J, Nomura D, Papadimitriou S, Russell LM, Sørensen LL, Thomas DN, Tison J-L, van Leeuwe MA, Vancoppenolle M, Wolff EW, Zhou J, 2015. Methods for biogeochemical studies of sea ice: The state of the art, caveats, and recommendations. *Elem*. *Sci. Anth.* **3**: 000038, doi: 10.12952/journal.elementa.000038.

Mason RH, Si M, Chou C, Irish VE, Dickie R, Elizondo P, Wong R, Brintnell M, Elsasser M, Lassar WM, Pierce KM, Leaitch WR, MacDonald AM, Platt A, Toom-Sauntry D, Sarda-Estève R, Schiller CL, Suski KJ, Hill TCJ, Abbatt JPD, Huffman JA, DeMott PJ, Bertram AK. 2015. Size resolved measurements of ice nucleating particles at six locations in North America and one in Europe, *Atmospheric Chemistry and Physics Discussions*, 15, 20521-20559, doi:10.5194/acpd-15-20521-2015.

Namazi M, von Salzen K, Cole JNS, 2015, Simulation of black carbon in snow and its climate impact in the Canadian Global Climate Model, *Atmos. Chem. Phys.*, 15, 10887-10904.

Pierce JR, Croft B, Kodros JK, D'Andrea SD, Martin RV, 2015, The importance of interstitial particle scavenging by cloud droplets in shaping the remote aerosol size distribution and global aerosol-climate effects, *Atmos. Chem. Phys*., 15, 6147-6158, doi:10.5194/acp-15-6147-2015, 2015.

Galí M, Devred E, Levasseur M, Royer S-J, Babin M. 2015. A remote sensing algorithm for planktonic dimethylsulfoniopropionate (DMSP) and an analysis of global patterns. *Remote Sensing of Environment* 171, 171-184.

Darroch LJ, Lavoie M, Levasseur M, Laurion I, Sunda WG, Michaud S, Scarratt M, Gosselin M, Caron G. 2015. Effect of short-term light stress on dimethylsulfoniopropionate (DMSP), dimethylsulfide and DMSP lyase potential activity in *Emiliania huxleyi* (CCMP 1742). *Aquatic Microbial Ecology* 74, 173-185.

Lavoie M, Levasseur M, Sunda WG. 2015. A steady-state physiological model for intracellular dimethylsulfoxide in marine phytoplankton. *Environmental Chemistry*, http://dx.doi.org/10.1071/EN14221.

Lavoie M, Levasseur M, Babin M. 2015. Testing the potential role of dimethylsulfoniopropionate in marine phytoplankton: A modeling study. *J. of Plankton Res*. 1-13.

Galindo V, Levasseur M, Scarratt M, Mundy CJ, Gosselin M, Kiene RP, Gourdal M, Lizotte M. 2015. Under-ice microbial dimethylsulforniopropionate metabolism during the melt period in the Canadian Arctic Archipelago. *Mar. Ecol. Prog. Ser.* 524. 39-53.

PART 2 - Planned activities from 2016 to 2018/19

1. Planned major field studies and collaborative laboratory and modelling studies, national and international (incl. all information possible, dates, locations, teams, work, etc.)

1. NETCARE 2016 MISSION (SEVERAL NETCARE PIs)

Planning is now intensively underway for the second and last Amundsen campaign on the CCGS Amundsen (July 14 – Aug 25, 2016). As described in detail in the original proposal, novel activities to be pursued on the ship involve the deployment of a remotely-controlled microlayer sampler and the use of a MART-like tank for in situ generation of primary marine aerosol. We will couple aerosol characterization instruments to the tank (e.g. to measure CCN, INPs, particle distributions), sometimes amending ocean water with microlayer samples. Water DMS concentrations will also be measured at high spatial/temporal resolution with a new MIMs (Lizotte and Levasseur).

2. NETCARE MODELING (SEVERAL NETCARE PIs)

Modeling activities with the Environment Canada chemical transport model, GEM-MACH, have included implementation of different ice nucleation schemes and comparison to cirrus cloud observations during the ISDAC field campaign. This work is being extended to evaluation of the relationship between INPs and modeled aerosol concentration and composition during the NETCARE Amundsen and POLAR 6 campaigns.

A final project assesses how sensitive future global, and regional, climate projections are to a model's representation of aerosol radiative forcing (ARF). We are building multiple (five) equally plausible versions of a single GCM (NCAR CESM1), each with different strengths of sulfate and black carbon ARF, and will compare future projections of global and regional climate from these five versions. We have recently completed historical simulations and testing of the five versions, and are beginning the future simulations now (runs should be complete by end of 2015, with analysis and write-up to come in 2016).

3. NETCARE NH3 WORK (Jennifer Murphy)

The NH3 work to date is particularly interesting because the measurements from the Amundsen can only be matched by the GEOS-CHEM chemical transport model if sea bird emissions are included. This is the first indication that marine wildlife can have a major effect on the polar atmosphere, with impacts on particle formation and composition. We anticipate this will be one of NETCARE's major achievements, and so we plan extending these novel measurements in 2016 by prolonging the planned Alert campaign into two phases, one in the spring to study INPs (see above), and a second in the summer to study new particle formation and its relationship to key gaseous precursors, such as NH3, H2SO4 and OVOCs. Planning for both phases of the Alert measurements is underway with major participation by Environment Canada, involving collaboration with Sharma, Leaitch, Liggio, Wentzell, Platt and Toom-Sauntry. Scientists from both the Climate and Air Quality Divisions are involved.

4. Expansion of observatories in the Canadian Archipelago (Lisa Miller)

An additional 3 moorings are planned, to include CO_2 system measurements in the Canadian Arctic waters.

5. R/V Endeavour cruise (Rachel Chang)

R Chang will participate to a R/V Endeavour cruise on Sep 25 – Oct 25, 2016, as part of a project funded by the NSF (Chemical Oceanography; PI: D. Kieber, SUNY Albany. The objective of the project is to understand the role of primary marine organic aerosol on the ocean carbon cycle.

2. Events like conferences, workshops, meetings, schools, capacity building etc. (incl. all information possible)

1. NETCARE ANNUAL WORKSHOP

The NETCARE annual workshop will take place on November 14-16 at University of Toronto, Ontario, Canada. Based on previous years, about 60 participants are expected.

2. Joint Quebec-Qingdao workshop on the Impact of ocean acidification on marine resources and biogeochemical cycles in estuaries

The workshop will take place in Qingdao in October or November 2016 (date to be determined). It will gather participants to the Quebec and China joint program on the impact of ocean acidification in coastal waters led by M Levasseur and G-P Yang.

3. NETCARE special issue

Results from NETCARE researches will be published in a special issue entitled "NETCARE (Network on Aerosols and Climate: Addressing Key Uncertainties in Remote Canadian Environments) (ACP/AMT/BG inter-journal SI)" as part of the journals ACP, AMT and BG. The guest editors are L. Bopp, K. Carslaw, D.J. Cziczo, and L. M. Russell.

3. Funded national and international projects / activities underway (if possible please list in order of importance and indicate to which part(s) of the SOLAS 2015-2025 science plan the activity topics relate – including the themes on 'SOLAS science and society' and 'Geoengineering')

1. NETCARE 2012-2018 (Network on Climate and Aerosols: Addressing Key Uncertainties in Remote Canadian Environments)

NETCARE is a network led by Jon Abbatt of the University of Toronto. It includes researchers from ten Canadian universities (Toronto, UBC, UQAM, Waterloo, UQAR, Laval, Dalhousie, Calgary, Sherbrooke, Victoria) and five partner institutions (Environment Canada, Fisheries and Oceans Canada, Alfred Wegener Institute, Max Planck Institute, Johannes Gutenberg University). NETCARE is one of seven Canadian networks funded by the Climate Change and Atmospheric Research (CCAR) program at NSERC.
SOLAS theme: Greenhouse gases, ocean biogeochemical control on atmospheric chemistry, integrated systems.

2. ArcticNet – Project: Marine Biogeochemistry and Surface Exchange of Climate Active Gases in a Changing Arctic System, 2015-18
PIs: T. Papakyriakou, B. Else, and 6 others. $154,000/year.
SOLAS theme: Greenhouse gases, ocean biogeochemical control on atmospheric chemistry, integrated systems.

3. BaySys 2015-2018
Contributions of climate change and hydro-electric regulation to the variability and change of freshwater-marine coupling in the Hudson Bay System. With D. Barber and many others (pan-Canadian research network). NSERC Collaborative Research and Development Grant. $4,540,000.
SOLAS theme: Greenhouse gases, integrated systems, SOLAS and society.

4. Plans / ideas for future projects, programmes, proposals national or international etc. (please precise to which funding agencies and a timing for submission is any)

Polar Knowledge Canada and the Canadian High Arctic Research station are really gearing up, with increasing support for marine and terrestrial monitoring activities throughout the Canadian Arctic. A call for marine proposals is anticipated soon (likely this year?), and numerous plans are being developed for large, integrated projects in which SOLAS issues of marine controls on atmosphere chemistry, greenhouse gas dynamics, and sea ice biogeochemistry are prominent.

5. Engagements with other international projects, organisations, programmes etc.

Wrap-up of BEPSII SCOR working group 140, on sea-ice biogeochemistry. A number of publications in a special feature in *Elementa: Science of the Anthropocene* (https://home.elementascience.org/special-features/biogeochemical-exchange-processes-at-sea-ice-interfaces-bepsii/). Development of next phase, in the form of a joint SOLAS-CliC activity to build on the tools developed in the SCOR working group to begin addressing big-picture questions of the role of sea ice in the global system and climate change feedbacks. There is major Canadian leadership in the ongoing development of BEPSII.

Comments

The possibility to implement a national (international) program on the impact of volcanic ash on ocean biogeochemistry has been discussed. Interested parties for now are at Dalhousie University and Laval University. Too early to publicise, but good to know...More to come.