

Report for the year 2017 and future activities

SOLAS Canada

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This report has two parts:

- **Part 1:** reporting of activities in the period of January 2017 – Jan-Feb 2018
- **Part 2:** reporting on planned activities for 2018/2019 and 2020.

The information provided will be used for reporting, fundraising, networking, strategic development and updating of the live web-based implementation plan. As much as possible, please indicate the specific SOLAS 2015-2025 Science Plan Themes addressed by each activity or specify an overlap between Themes or Cross-Cutting Themes.

- 1 Greenhouse gases and the oceans;
 - 2 Air-sea interfaces and fluxes of mass and energy;
 - 3 Atmospheric deposition and ocean biogeochemistry;
 - 4 Interconnections between aerosols, clouds, and marine ecosystems;
 - 5 Ocean biogeochemical control on atmospheric chemistry;
- Integrated studies;
Environmental impacts of geoengineering;
Science and society.

IMPORTANT: *This report should reflect the efforts of the SOLAS community in the entire country you are representing (all universities, institutes, lab, units, groups, cities).*

PART 1 - Activities from January 2017 to Jan/Feb 2018

1. Scientific highlight

Mungall, J.P.D. Abbatt, J.J.B. Wentzell, A.K.Y. Lee, J.L. Thomas, M. Blaise, M. Gosselin, L.A. Miller, T. Papakyriakou, M.D. Willis, and J. Liggio, 2017. *Proc. Natl. Acad. Sci. USA*. 114(24): 6203-8, doi: 10.1073/pnas.1620571114. Microlayer source of oxygenated volatile organic compounds in the summertime marine Arctic boundary layer. (Theme 5, Integrated Studies – polar oceans)

This paper is one of the first studies to show that a large source of oxygenated volatile organic compounds (OVOCs) may arise from the microlayer on the top of the sea surface. NETCARE measurements from the CGCS Amundsen in the summer of 2014 revealed that these OVOCs were correlated with the DOC content of the water, but some of the compounds are too soluble to be liberated from the ocean water, implicating the microlayer. These compounds are sufficiently oxygenated that they, or their larger analogues, may be intimately involved in new particle formation and growth. This was a collaborative study involving ocean biogeochemists and atmospheric chemists.

2. Activities/main accomplishments in 2017 (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, social sciences, and media).

2012-2018 NETCARE, Network on Climate and Aerosols: Addressing Key Uncertainties in Remote Canadian Environment. Relevant to SOLAS 2015-2025 Science Plan Core Themes 1 and 4. 2017 was devoted to data analysis and publications (Many researchers)

Analysed ambient measurements of ice nucleating particles (INP) that were collected on the Amundsen during summer 2014 (Bertram). This has resulted in the following manuscript, which will be submitted to ACPD: *Ice nucleating particles in the marine boundary layer in the Canadian Arctic during summer 2014*, Victoria E. Irish, Sarah J. Hanna, Jenny Thomas, Ana Cirisan, Swarup China, Alwin Bucher, Greg Wentworth, Jeremy Wentzell, W. Richard Leitch, Jennifer Murphy, Jonathan P.D. Abbatt, Alex Laskin, Eric Girard, and Allan K. Bertram

Analysed measurements of INP in the microlayer collected on the Amundsen during the summer 2016 (Bertram). This has resulted in the following manuscript, which will be submitted to ACPD: *Properties and concentrations of ice nucleating particles in the sea surface microlayer and bulk seawater in the Canadian Arctic during summer 2016 and comparison with summer 2014*, Victoria E. Irish, Yu Xi, Allan K. Bertram, Matthew Boyer, Lisa Miller, Jonathan P.D. Abbatt, Elena Polishchuk, and Jessie Chen.

Carried out a series of laboratories studies on the freezing properties of phytoplankton exudates to explain concentrations of INPs measured in the microlayer in the Arctic (Bertram).

2015-2018. ArcticNet funded project "Marine biogeochemistry and surface exchange of climate active gases". Relevant to SOLAS 2015-2025 Science Plan Core Themes 1 and 4. Goal: Pursue the annual monitoring of DMS concentrations and related parameters across the high Canadian Arctic (Levasseur).

2016-2018 GreenEdge (GE) - Participation to the GE expedition in Baffin Bay, Canada. Goal: Conduct high frequency measurements of DMS and related parameters across a marginal ice zone in the Arctic (Levasseur).

2017-2020 BOND (Beacons Of Northern Dynamics: developing light-based sensing

technologies to monitor climate active gases in a mutating Arctic), a Sentinel North project (Canada First Research Excellence Fund). Relevant to SOLAS 2015-2025 Science Plan Core Themes 1 and 4. Goal: Develop and deploy at sea an Automated Cryogenic Trap Membrane-Inlet Mass Spectrometer (ACT-MIMS) for continuous underway DMS measurements during the 2017 ArcticNet/GreenEdge expedition on the icebreaker CCGS Amundsen (Lizotte).

During the 2015 ArcticNet cruise, targeted incubation experiments were undertaken in order to assess the impacts of environmental stressors on the development of planktonic communities in the Arctic Ocean and their involvement in the cycling of sulfur compounds. This led to the following paper:

Hussherr H, Levasseur M, Lizotte M, Tremblay J-É, Mol J, Thomas H, Gosselin M, Starr M, Miller L, Jarniková T, Schuback N, Mucci A. 2017. Impact of ocean acidification on phytoplankton and dimethylsulfide dynamics during simulated ice-free and under-ice phytoplankton blooms in the Arctic. *Biogeosciences* 14, 2407-2427. doi:10.5194/bg-14-2407-2017

Martí Galí finalized the development of a new satellite-based model allowing the estimation of DMS at the global and regional scales. This will lead to two articles. The first article describes the algorithm, shows its application at the global scale, and how the model-results compare favorably with the current climatology:

Galí M, Levasseur M, Devred E, Simó R, Babin M. Diagnosing sea-surface dimethylsulfide (DMS) concentration from satellite data at global and regional scales. *Biogeosciences Discussion*.

Laval, UQAR, UBC, Dalhousie, U of T colleagues collaborated on meshing oceanic measurements of primary production and biomass, dissolved organic carbon, and marine DMS with atmospheric measurements of the distribution of aerosol number size, leading to the following paper:

Collins DB, Burkart J, Chang R Y-W, Lizotte M, Boivin-Rioux A, Blais M, Mungall EL, Boyer M, Irish VE, Massé G, Kunkel D, Tremblay J-É, Papakyriakou T, Bertram AK, Bozem H, Gosselin M, Levasseur M, Abbatt JPD. 2017. Frequent ultrafine particle formation and growth in Canadian Arctic marine and coastal environments. *Atmos. Chem. Phys.*, 17, 13119-13138, 2017. doi.org/10.5194/acp-17-13119-2017

Melt ponds are an important but understudied component of the Arctic sea-ice system. Our team led the sampling efforts of several melt ponds in the Canadian Arctic Archipelago to identify key biogeochemical and physical properties of these transient

features and their role as potential emitters of DMS. A paper is currently under review: Gourdal, M., Lizotte, M., Massé, G., Gosselin, M., Scarratt, M., Levasseur, M. Dimethylsulfide dynamics in first-year sea ice melt ponds in the Canadian Arctic Archipelago. Biogeosciences discussions, doi.org/10.5194/bg-2017-432, 2017.

SOLAS/NETCARE workshop on the impacts of Arctic DMS emissions on future climate, Sidney, British Columbia, Canada, 17-18 January 2017. Levasseur, Steiner, von Salzen hosted this workshop in order to accelerate the transfer of knowledge between NETCARE's researchers and climate modelers from the Canadian Government. The attendees were mostly from Canada, with one from USA (Trish Quinn) and one from Japan (Sohiko Kameyama).

United Nations GESAMP – Dr Martine Lizotte is collaborating within the United Nations GESAMP (joint Group of Experts on the Scientific Aspects of Marine Environmental Protection) WG38: Impact of ocean acidification on fluxes of atmospheric non-CO₂ climate-active species. Her specific contribution is geared towards assessing the impact of Ocean Acidification on DMS production in the Arctic using data collected during NETCARE campaigns. A community paper is underway: "Changing ocean acidity as a modulator of atmospheric biogeochemistry and climate" to be submitted to PNAS.

Contributions to a Special Issue on the SOLAS sponsored SOAP program (Surface Ocean Aerosol Production):

Lizotte M, Levasseur M, Law CS, Walker CF, Safi KA, Marriner A, and Kiene RP (2017) Dimethylsulfoniopropionate (DMSP) and dimethyl sulfide (DMS) cycling across contrasting biological hotspots of the New Zealand subtropical front, *Ocean Sci.*, 13, 961-982.

Law, C.S., Smith, M.J., Harvey, M.J., Bell, T.G., Cravigan, L.T., Elliott, F.C., Lawson, S.J., Lizotte, M., Marriner, A., McGregor, J., Ristovski, Z., Safi, K.A., Saltzman, E.S., Vaattovaara, P., Walker, C.F. Overview and preliminary results of the Surface Ocean Aerosol Production (SOAP) campaign. *Atmos. Chem. Phys.* 17(22): 13645-13667, 2017

Participation to the Cryosphere and Atmospheric Chemistry (CATCH): an emerging IGAC/SOLAS activity on chemistry, biology and physics in cold regions. LATMOS, Guyancourt, France, April 2017. As part of the community workshop focused on coordinating research across disciplines or borders and research initiatives on key questions (eg. polar climate change, sea ice and biogeochemical cycles), M. Lizotte, M. Willis and J. Murphy gave talks.

Dr Martine Lizotte acted as a mentor for School's on Board, an ArcticNet Outreach

Program. She gave theoretical classes and field tutorials to students from the Inuit Nunangat during a 1-week cruise on board the CCGS *Amundsen* in the Canadian Arctic Archipelago (July 2017) with a focus on SOLAS/Netcare-related issues (production and cycling of DMS in the Canadian Arctic Archipelago).

As the Vice-Chair for International Relations at APECS Canada, M Lizotte has been involved in several Polar Outreach Activities notably during the Arctic Change 2017 Conference (Student Day) held in Quebec City (December 2017).

Interaction with Provincial Government – Ministry of Sustainable Development and Fight against Climate Change with the following forum presentation given by M Lizotte.

Lizotte M, M Levasseur, M Gourdal, R Husserr, M Galì, V Galindo, G Massé, T. Jarnikova, P. Tortell November 2017. Plancton and clouds in the Arctic: a constraint to climate warming? 61^e Forum Science Environnement (Partnership between Amundsen Science and the Quebec Ministry of Sustainable Development and Fight against Climate Change MDDLCC), Quebec City, Canada, November 2017.

Polar Data Catalogue (PDC) submissions:

Levasseur, M., Gourdal, M., and Lizotte, M. (2017) Dimethylsulfide dynamics in first-year sea ice melt ponds in the Canadian Arctic Archipelago. Waterloo, Canada: Canadian Cryospheric Information Network (CCIN). Unpublished Data Additional information: Gourdal, M., Lizotte, M., Massé, G., Gosselin, M., Scarratt, M. and Levasseur, M. Submitted to Biogeosciences, NETCARE special issue in October 2017.

Husserr, R., Levasseur, M. and Lizotte, M. (2017) Incidence of light and ocean acidification on microbial community, dimethyl sulfide, dimethylsulfoniopropionate and macronutrients in Baffin Bay, Nunavut, Canada. Waterloo, Canada: Canadian Cryospheric Information Network (CCIN). Unpublished Data Additional Publication- can be accessed: Husserr R. et al., Impact of ocean acidification on Arctic phytoplankton blooms and dimethylsulfide production under simulated ice-free and under-ice conditions, Biogeosciences Discuss., doi:10.5194/bg-2016-501.

Transfer of data to the Canadian Government: DMS measurements collected during the NETCARE program have been transferred to the modeling team of the Department of Environment and Climate Change Canada (ECCC) and the Department of Fisheries and Oceans Canada (DFO) and are currently used to improve current Arctic climate models. In addition, DMS obtained from the satellite-based DMS model developed by Galì et al. are used by ECCC investigator Knut von Salzen.

Atmospheric data from the NETCARE program are being archived for public access through Environment and Climate Change

Laboratory experiments on the role of sea ice in CO₂ drawdown (Miller). A Canadian-Swiss collaboration (Institute of Ocean Sciences and ETH Zurich) examined the impact of sea-ice formation rate on CO₂ export with rejected brines using temperature-controlled experiments, confirming greater CO₂ export when ice forms more slowly at higher temperatures. Resulted in a Master's thesis: Carbon dynamics during the formation of sea ice at different growth rates, Dept. of Environmental Systems Science, ETH Zürich. (Themes 1 & 2, & Integrated studies)

3. Top 5 publications in 2017 (only PUBLISHED articles) and if any, weblinks to models, datasets, products, etc.

Macdonald, K M., Sharma, S., Toom, D., Chivulescu, A., Hanna, S., Bertram, A K., Platt, A., Elsasser, M., Huang, L., Tarasick, D., Chellman, N., McConnell, J R., Bozem, H., Kunkel, D., Lei, Y D., Evans, G J., and Abbatt, J P D., 2017: Observations of atmospheric chemical deposition in the high Arctic snow, *Atmospheric Chemistry and Physics*, 17(9), p. 5775-5788, DOI: 10.5194/acp-17-5775-2017.

Vergara-Temprado, J., Murray, B J., Wilson, T W., O'Sullivan, D., Browse, J., Pringle, K J., Ardon-Dryer, K., Bertram, A K., Burrows, S M., Ceburnis, D., DeMott, P J., Mason, R H., O'Dowd, C D., Rinaldi, M., and Carslaw, K S., 2017: Contribution of feldspar and marine organic aerosols to global ice nucleating particle concentrations, *Atmospheric Chemistry and Physics*, 17(5), p. 3637-3658, DOI: 10.5194/acp-17-3637-2017.

Irish, V E., Elizondo, P., Chen, J., Chou, C., Charette, J., Lizotte, M., Ladino, L A., Wilson, T W., Gosselin, M., Murray, B J., Polishchuk, E., Abbatt, J P D., Miller, L A., and Bertram, A K., 2017: Ice-nucleating particles in Canadian Arctic sea-surface microlayer and bulk seawater, *Atmospheric Chemistry and Physics*, 17(17), p. 10583-10595, DOI: 10.5194/acp-17-10583-2017.

Collins DB, Burkart J, Chang R Y-W, Lizotte M, Boivin-Rioux A, Blais M, Mungall EL, Boyer M, Irish VE, Massé G, Kunkel D, Tremblay J-É, Papakyriakou T, Bertram AK, Bozem H, Gosselin M, Levasseur M, Abbatt JPD. 2017. Frequent ultrafine particle formation and growth in Canadian Arctic marine and coastal environments. *Atmos. Chem. Phys.*, 17, 13119-13138, 2017. doi.org/10.5194/acp-17-13119-2017

Husherr H, Levasseur M, Lizotte M, Tremblay J-É, Mol J, Thomas H, Gosselin M, Starr M, Miller L,

Jarniková T, Schuback N, Mucci A. 2017. Impact of ocean acidification on phytoplankton and dimethylsulfide dynamics during simulated ice-free and under-ice phytoplankton blooms in the Arctic. *Biogeosciences* 14, 2407-2427, doi:10.5194/bg-14-2407-2017

Irish, V.E., Elizondo, P., Chen, J., Chou, C., Charette, J., Lizotte, M., et al. (2017). Ice nucleating particles in Canadian Arctic sea-surface microlayer and bulk seawater. *Atmos. Chem. Phys.*, 17, 10583–10595, 2017, doi.org/10.5194/acp-17-10583-2017

Hayashida H, Steiner N, Monahan A, Galindo V, Lizotte M, Levasseur M Implications of sea-ice biogeochemistry for oceanic production and emissions of dimethylsulfide in the Arctic. 2017. *Biogeosciences*, 14, 3129-3155, doi.org/10.5194/bg-14-3129-2017

Ghahremaninezhad R, Norman A-L, Croft B, Martin RV, Pierce JR, Burkart J, Willis MD, Bozem H, Kunkel D, Thomas JL, Aliabadi AA, Wentworth GR, Levasseur M, Staebler RM, Sharma S, Abbatt JPD, Leaitch WR. 2017. Vertical profile of atmospheric DMS in the Arctic Spring and Summer. 2017, *Atmos. Chem. Phys.*, 17, 8757–8770, doi.org/10.5194/acp-17-8757-2017

Lizotte M, Levasseur M, Law CS, Walker CF, Safi KA, Marriner A, and Kiene RP (2017) Dimethylsulfoniopropionate (DMSP) and dimethyl sulfide (DMS) cycling across contrasting biological hotspots of the New Zealand subtropical front, *Ocean Sci.*, 13, 961-982.

Burgers, L.A. Miller, H. Thomas, B.G.T. Else, M. Gosselin, and T. Papakyriakou, 2017. *J. Geophys. Res. Oceans* 122: 9663-78, doi: 10.1002/2017JC013250. Surface water $p\text{CO}_2$ variations and air-sea CO_2 fluxes during summer in the eastern Canadian Arctic. (Theme 1, Integrated studies – polar oceans)

Mungall, J.P.D. Abbatt, J.J.B. Wentzell, A.K.Y. Lee, J.L. Thomas, M. Blaise, M. Gosselin, L.A. Miller, T. Papakyriakou, M.D. Willis, and J. Liggio, 2017. *Proc. Natl. Acad. Sci. USA*. 114(24): 6203-8, doi: 10.1073/pnas.1620571114. Microlayer source of oxygenated volatile organic compounds in the summertime marine Arctic boundary layer. (Theme 5, Integrated Studies – polar oceans)

Ghahremaninezhad, R., Norman, A.L., Croft, B., Martin, R.V., Pierce, J.R., Rempillo, O., Willis, M., Bozem, H., Kunkel, D., Thomas, J.L., Aliabadi, A.A., Wentworth, G.R., Levasseur, M., Staebler, R.M., Sharma, S., Leaitch, W.R. (2017). Boundary layer and free tropospheric dimethyl sulfide in the Arctic spring and summer. *ACP*: 17(14) 8757-8770.

Christiciello, A., Marshall, S., Evans, M., Kinnard, C., Norman, A.L., Sharp, M. (2016) Marine aerosol source regions to Prince of Wales Icefield, Ellesmere Island, and influence from the tropical Pacific, 1979-2001. *Journal of Geophysical Research Atmospheres*, 121 (16), 9492-9507. August 2016. DOI: 10.1002/2015JD024457.

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2017? If yes, who? How did you engage?

Many of the publications above proceeded through collaborations between government and academic scientists.

PART 2 - Planned activities for 2018/2019 and 2020

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

Two studies of visibility, fog and aerosols are planned for this summer, one in Halifax (May-July 2018) and one in Tuktoyaktuk (July-Sept 2018), the latter being part of the Year of Polar Prediction (Chang). In both of these studies, the effect of ocean emissions and temperature on resulting fog events are of primary interest. The investigators are also planning on participating in the MOCCHA campaign onboard the Swedish icebreaker Oden (PI Caroline Leck, Stockholm University) this summer (Aug-Sept 2018) to study marine contributions to Arctic aerosol and their ability to act as cloud condensation nuclei.

Field study (Levasseur) - Participation to the ArcticNet/Sentinel North expedition in the Canadian Arctic (Baffin Bay) on the icebreaker CCGS Amundsen: Deployment of optical sensors to monitor climate-active gases at high frequency during BOND July 2017.

SCOR working group, #152, on Measuring Essential Climate Variables in Sea Ice (ECV-Ice) is conducting intercalibration experiments on methods for determining primary production and gas fluxes in sea ice in Japan and the UK (at the Roland von Glasow Air-Sea-Ice Chamber), with strong Canadian participation. In 2019, another intercalibration experiment focussed on primary and secondary production will be conducted in Cambridge Bay, Canada, with extensive international participation. (Miller) (Integrated Studies – polar oceans)

Collaboration with government scientists to model trends in aerosol sulfate from DMS over the period 1993-2003 in the Arctic with Canadian Center for Climate Modeling and Analysis (Knut von Salzen). Collaboration with Environment and Climate Change Canada on modelling DMS oxidation with Weimin Gong.

Laboratory collaboration between University of Toronto and Laval University on the atmospheric multiphase chemistry of materials formed from phytoplankton cultures.

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

Participation of M Lizotte as an invited Mentor during the Sentinel North International PhD School “ Shedding light on marine ecosystem services”, July 2017,
<http://sentinellenord.ulaval.ca/en/baffin2018>

BEPSII is planning a ‘Winter School’ on sea-ice biogeochemistry in Cambridge Bay, Canada, in 2019, along side the ECV-Ice intercalibration experiment. A COST Action proposal has been submitted to support this and other BEPSII activities (Miller). (Integrated Studies – polar oceans)

3. Funded national and international projects / activities underway.

A large part of the SOLAS-related funding, to NETCARE, will expire in 2018.

The Oceans Frontier Institute at Dalhousie University has begun funding. Chang is part of the module led by Randall Martin on Atmospheric Composition and Visibility, which focuses on aerosols and liquid droplets in the North Atlantic and Canadian Arctic Gateway. A fog study in Halifax is being funded through this project.

Levasseur is involved with: 2017-2020 BOND (Beacons Of Northern Dynamics: developing light-based sensing technologies to monitor climate active gases in a mutating Arctic), a Sentinel North project (Canada First Research Excellence Fund). Relevant to SOLAS 2015-2025 Science Plan Core Themes 1 and 4. The goal is to develop and deploy novel optical sensors for the monitoring of climate-active gases (CO₂-CH₄-N₂O-DMS) in contrasting polar environments: from terrestrial thermokarst lakes to arctic marine waters.

4. Plans / ideas for future projects, programmes, proposals national or international etc. (please indicate the funding agencies and potential submission dates).

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

See interactions with ECV-Ice and BEPSII, above (Miller)