surface ocean solas lower atmosphere study

Report for the year 2020 and future activities

SOLAS *Canada compiled by:* *Martine Lizotte*

First things first…Please tell us what the IPO may do to help you in your current and future SOLAS activities. ?
Members of SOLAS in Canada simply wish to thank the SOLAS IPO for their constant efforts and ongoing work.

PART 1 - Activities from January 2020 to Jan/Feb 2021

1. Scientific highlights

Scientific highlight #1

A Canadian led paper discussing climate change impacts on sea-ice ecosystems and ecosystem services has been compiled linking the BEPSII community with experts in higher trophic levels, tourism and cultural services. The effort represents a rigorous synthesis of the sea-ice ecosystem and linked ecosystem services and highlights that: 1. The sea-ice ecosystem supports all four ecosystem service categories; 2. sea-ice ecosystems meet the criteria for ecologically or biologically significant marine areas (EBSAs); 3. global emissions driving climate change are directly linked to the demise of sea-ice ecosystems and its ecosystem services; and 4. the sea-ice ecosystem deserves specific attention in the evaluation of marine protected area planning. The synthesis outlines a) supporting services, provided in form of habitat, including feeding grounds and nurseries for microbes, meiofauna, fish, birds and mammals; b) provisioning services through harvesting and medicinal and genetic resources; c) cultural services through Indigenous and local knowledge systems, cultural identity and spirituality, and via cultural activities, tourism and research; d) (climate) regulating services through light regulation, the production of biogenic aerosols, halogen oxidation and the release or uptake of greenhouse gases. The ongoing changes in the polar regions have extreme impacts on sea-ice ecosystems and associated ecosystem services. While the response of sea-ice associated primary production to environmental change is regionally variable, the effect on ice-associated mammals and birds are predominantly negative, subsequently impacting human harvesting and cultural services in both polar regions. Conservation can help protect some species and functions. However, the key mitigation measure that can slow the transition to a strictly seasonal ice cover with climate change, reduce the overall loss of sea-ice habitats from the ocean, and thus preserve the unique ecosystem services provided by sea ice and their contributions to human-wellbeing is a reduction in carbon emissions.

(SOLAS Themes 1, 2, 4, 5, Integrated studies of high sensitivity systems, Science and society**)**

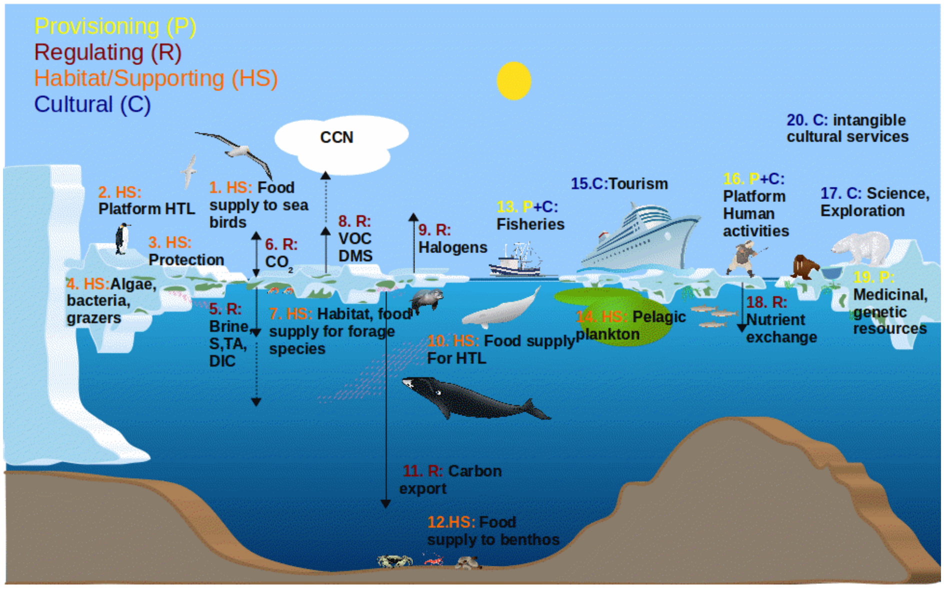


Figure. Climate change impacts on sea-ice ecosystems and ecosystem services including provisioning (P), regulating (R), habitat/supporting (HS) and cultural (C).

Citation: *N. S. Steiner, J. Bowman, K. Campbell, M.a Chierici, E. Eronen-Rasimus, M. Falardeau, H. Flores, A. Fransson, H. Herr, S. J. Insley, H. M. Kauko, D. Lannuzel, L. Loseto, A. Lynnes, A. Majewski, K. M. Meiners, L. A. Miller, L.N. Michel, S. Moreau, M. Nacke, D.i Nomura, L. Tedesco, J. A. van Franeker, M. A. van Leeuwe, P. Wongpan. Climate change impacts on sea-ice ecosystems and associated ecosystem services. Submitted to Elementa – Science of the Anthropocene.*

Scientific Highlight #2

A position analysis prepared by the Biogeochemical Exchange Processes at Sea-Ice Interfaces (BEPSII) research community, including several Canadian participants, assessed the influence of current rapid changes on Arctic sea-ice biogeochemistry and ecosystems. Increasing light penetration will initiate earlier seasonal primary production. This earlier growing season may be accompanied by an increase in ice algae and phytoplankton biomass, augmenting the emission of dimethylsulfide and capture of carbon dioxide. Secondary production may also increase on the shelves, although the loss of sea ice exacerbates the demise of sea-ice fauna, endemic fish and megafauna. Sea-ice loss may also deliver more methane to the atmosphere, but warmer ice may release fewer halogens, resulting in fewer ozone depletion events. The net changes in carbon drawdown are still highly uncertain. Despite large uncertainties in these assessments, we expect disruptive changes that warrant intensified long-term observations and modelling efforts.

(SOLAS Themes 1, 2, 4, 5, and the integrated topic on polar oceans)

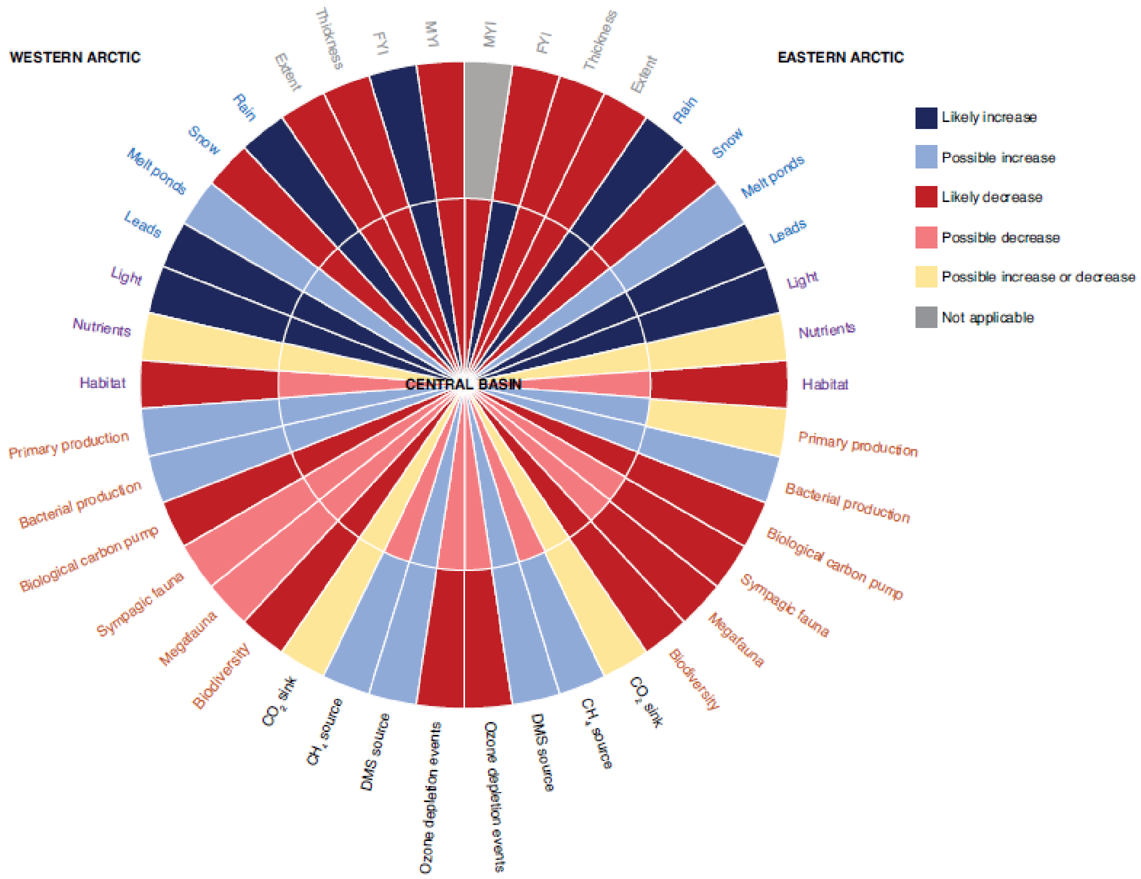
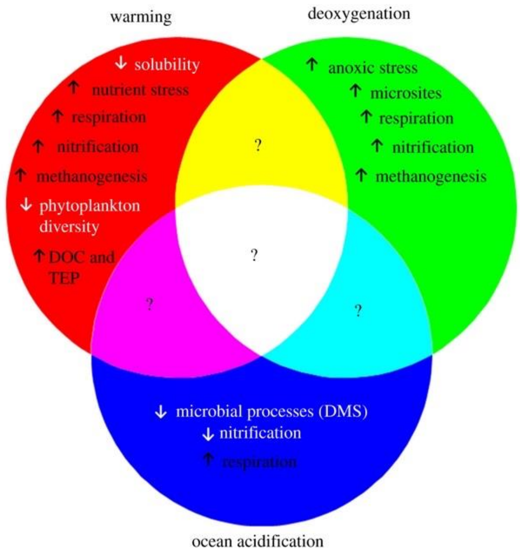


Figure. Future expectations of changes in the sea-ice biogeochemical system in the Arctic. The Western Arctic includes the Chukchi, Beaufort and Canadian Archipelago shelves, and the Eastern Arctic includes the shelves from the Barents to East Siberian Seas. The categories of changes are repeated opposite to each other in the schematic hemispheres of the Western Arctic Ocean and the Eastern Arctic Ocean of the circular diagram. Their colours indicate sea-ice changes (grey), icescape changes (blue), abiotic drivers (purple), biological changes (brow n) and changing gas fluxes (black).

Citation: *D. Lannuzel, L. Tedesco, M. van Leeuwe, K. Campbell, H. Flores, B. Delille, L. Miller, J. Stefels, P. Assmy, J. Bowman, K. Brown, G. Castellani, M. Chierici, O. Crabeck, E. Damm, B. Else, A. Fransson, F. Fripiat, N.-X. Geilfus, C. Jacques, E. Jones, H. Kaartokallio, M. Kotovitch, K. Meiners, S. Moreau, D. Nomura, I. Peeken, J.-M. Rintala, N. Steiner, J.-L. Tison, M. Vancoppenolle, F. Van der Linden, M. Vichi, and P. Wongpan, 2020. Nature Climate Change, doi: 10.1038/s41558-020-00940-4. The future of Arctic sea-ice biogeochemistry and ice-associated ecosystems.*

Scientific Highlight #3

A review paper resulting from the deliberations of United Nations GESAMP Working Group 38, 'The Atmospheric Input of Chemicals to the Ocean', assessed the current understanding (from observational, experimental and model studies) of the impact of ocean acidification (OA) on marine sources of key climate-active trace gases, including dimethyl sulfide (DMS), nitrous oxide (N_2O), ammonia and halocarbons. The article largely focused on DMS, for which available information is considerably greater than for other trace gases. OA-sensitive regions such as polar oceans and upwelling systems are highlighted and the combined effect of multiple climate stressors (ocean warming and deoxygenation) on trace gas fluxes are discussed. In order to unravel the biological mechanisms responsible for trace gas production, and to detect adaptation, the article proposes to combine process rate measurements of trace gases with longer term experiments using both model organisms in the laboratory and natural planktonic communities in the field. Future ocean observations of trace gases should be routinely accompanied by measurements of two components of the carbonate system to improve our understanding of how *in situ* carbonate chemistry influences trace gas production. These strategies will lead to improvements in current process model capabilities and more reliable predictions of future global marine trace gas fluxes. (SOLAS Themes 1, 4, 5)



Stressor	CO_2	N_2O	CH_4	DMS	NH_3	Other trace gases (halocarbons, CO, OCS, CS_2, OVOCs, isoprene)	Indirect factors affecting trace gas production & emission
				Directly influenced by climate			
Warming	↓ : ↓solubility ↑ : ↓ primary production ↑ : ↑ respiration ↑ : ↑ DOM & TEP	↓ : ↓ solubility ↑ : ↑nitrification	↓ : ↓ solubility ↑ : ↑methanogenesis ↑ : ↑ hydrate decomposition	↓ : ↓ solubility ↑ : ↑ nutrient stress ↓ : phytoplankton population shifts ↑/↓ : changes to bacterial processes	↓ : ↓ solubility	↓ : ↓ solubility (all) ↑ : global phytoplankton distribution shifts (isoprene)	↓ : ↑surface stratification & decreased nutrient supply to surface ocean ↓ : ↓ C fixation & export ↓ : changes to ventilation & thermohaline circulation ↑ : ↑ winds & storm intensity ↑ : ↑ dust deposition
Ocean Acidification	↑ : ↑ DOM & TEP ↔ : ↔ primary production	↓ : ↓ nitrification	↔ : no response	↓: phytoplankton population shifts ↓ : ↓ phytoplankton biomass ↑ : ↑ physiological stress ↑/↓ : ↑/↓ bacterial processes ↑ : ↑ grazing on phytoplankton	↓ : ↑ NH_4^+ (phase shift)	↓ : phytoplankton population shifts (iodocarbons) ↔ : no response (bromocarbons) ? : CO, OCS, CS2, OVOCs, isoprene	↑↓ : ↑↓ primary production & C export ↓ : ↓ export production (decreased carbonate production) ↑ : ↑ trace metal availability (phase shifts)
Hypoxia	↑ : ↑respiration	↑ : ↑nitrification ↑↓: ↑↓ denitrification	↑ : ↑ anaerobic microsites ↑: ↑ methanogenesis	↑ : ↑ anoxic stress	↑: ↑ammonification	?	↓ : ↓ nutrient supply in upwelling regions
				Locally variable/indirectly influenced by climate			
Increased UV-R	↓ : ↓ respiration ↑ : ↑ photoproduction	↓ : ↓nitrification	↔	↑ : ↑ photooxidative stress ↓: ↓ phytoplankton biomass	?	↑ : ↑ photoproduction (CO, halocarbons, isoprene) ↑ : ↑ photooxidative stress ↓ :↓ phytoplankton biomass	↓ : ↓ phytoplankton biomass
Increased nutrient loading	↑ : ↑respiration ↑ : ↑ DOC	↑ : ↑ nitrification ↑ : ↑denitrification	↑ : ↑ anaerobic microsites ↑: ↑ methanogenesis	↑ : ↑ primary production ↑ : ↑ phytoplankton biomass	↑ : ↑ DON	↑ : ↑photoproduction (CO, halocarbons, isoprene)	↑ : ↑ primary production & C export ↑ : ↑ occurrence of HABs ↑ : ↑hypoxia
Increased particle loading	↑ : ↑respiration ↑ : ↑ DOC	↑ : ↑nitrification ↑ : ↑denitrification	↑ : ↑ anaerobic microsites ↑: ↑ methanogenesis	↓ : ↓primary production	↑ : ↑ DON	↓ : decreased photoproduction (CO, halocarbons, isoprene)	↓ : ↓ bioturbation ↑ : ↑hypoxia

Figure. Figure 4. Summary of our knowledge on multiple stressors and their anticipated direct and indirect effects on trace gas production. Coloured arrows represent known/anticipated trace gas response (red, increase; blue, decrease; green, no net change), and black arrows describe the direction of change of the related process.

Citation: *F. E. Hopkins, P. Suntharalingam, M. Gehlen, O. Andrews, S. D. Archer, L. Bopp, E. Buitenhuis, I. Dadou, R. Duce, N. Goris, T. Jickells, M. Johnson, F. Keng, C. S. Law, K. Lee, P. S. Liss, M. Lizotte, G. Malin, J. C. Murrell, H. Naik, A. P. Rees, J. Schwinger, P. Williamson. (2020). Unravelling the impacts of ocean acidification on marine trace gases and the implications for atmospheric chemistry and climate. Proc. R. Soc. A, 476: 20190769.*

Scientific Highlight #4

We have studied the kinetics of dry deposition of gas phase ozone to simulated seawater solutions. The work was performed in the laboratory without organic components in the seawater in order to evaluate the role of iodide as the main reactive species for ozone. Ours is the first paper to diagnose that iodide depletion occurs with exposure to ambient levels of ozone. The importance of this research is that this reaction dominates the dry deposition rates of ozone to the ocean. Our next steps are to quantify the release rate of molecular iodine via this chemistry, and then add the components of a phytoplankton culture to the solution to see how it affects the iodine release.
(SOLAS theme 3).

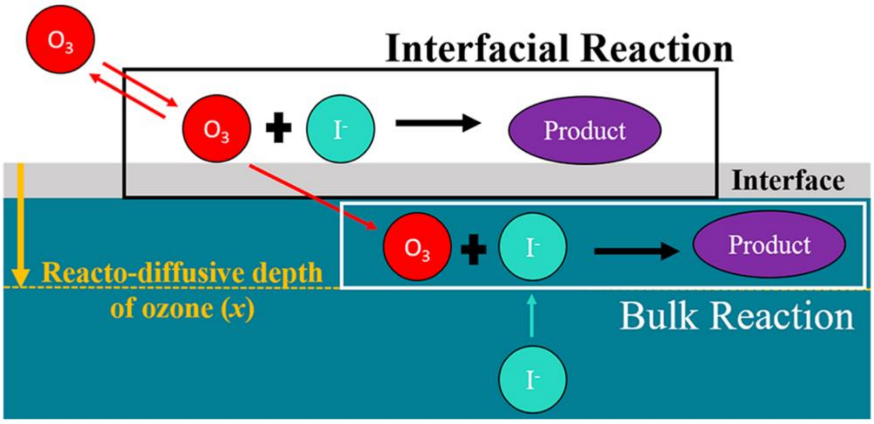


Figure. Uptake of ozone onto an iodide solution, w hich distinguishes betw een the interfacial and bulk reactions over reactodiffusive depth.

Citation: *S.R. Schneider et al. (2020). Reactive Uptake of Ozone to Simulated Seawater: Evidence for Iodide Depletion, J. Phys. Chem. A, 124(47): 9844–9853.*

Scientific Highlight #5

Seasonal biomass burning in tropical regions is a potential source of aerosol iron. To investigate aerosol iron sources to the adjacent tropical waters of Australia, the fractional solubility of aerosol iron was determined during the Savannah Fires in the Early Dry Season (SAFIRED) campaign at Gunn Point, Australia during the dry season in 2014. The source of PM10 aerosol iron was a mixture of mineral dust, fresh biomass burning aerosol, sea spray and anthropogenic pollution. Fractional Fe solubility and proxies for biomass burning were unrelated throughout the campaign likely due to the physical properties of elemental carbon, i.e., fresh elemental carbon aerosols are initially hydrophobic, however they can disperse in water after aging in the atmosphere. Combustion aerosols are thought to have a high factional Fe solubility, which can increase during atmospheric transport from the source. Although, elemental carbon may not be a direct source of soluble iron, it can act indirectly as a surface for aerosols iron to bind during atmospheric transport and subsequently be released to the ocean upon deposition. In addition, biomass burning derived aerosols can indirectly impact the fractional solubility of mineral dust. Fractional Fe solubility was highest during dust events at Gunn Point, and could have been enhanced by the mixing of biomass burning derived species. Iron in dust may be more soluble in the tropics compared to higher latitudes due to the presence higher concentrations of biomass burring derived reactive organic species in the atmosphere, such as oxalate, and their potential to enhance the fractional Fe solubility of mineral dust. As the aerosol loading is dominated by biomass burning emissions over the tropical waters in the dry season, additions of biomass burning derived soluble iron could have harmful consequences for initiating nitrogen fixating toxic algal blooms. (SOLAS theme 3).

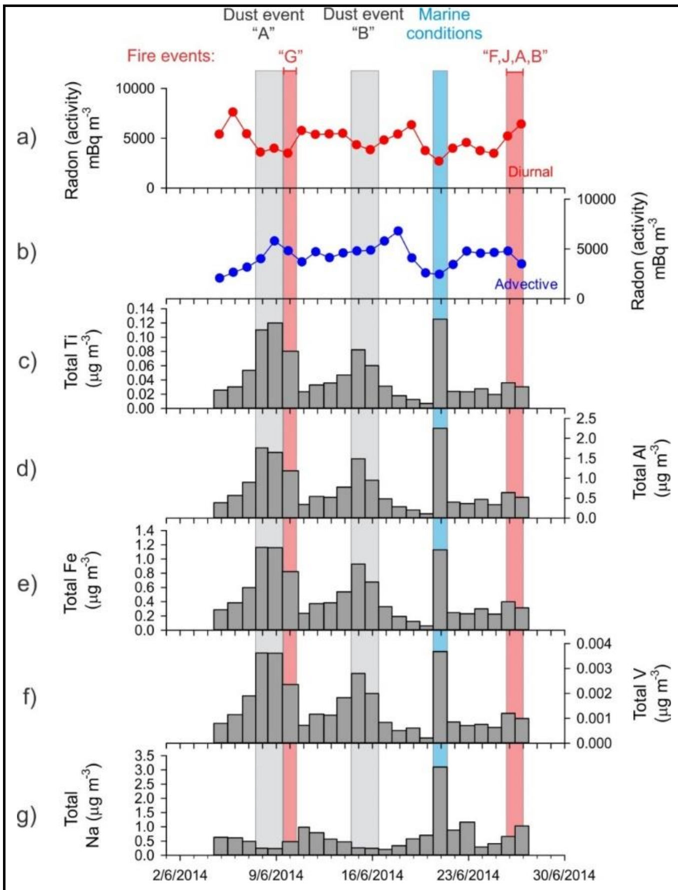


Figure: Time series of a) diurnal radon, b) advective radon, and total PM10 trace element concentrations c) Ti, d) Al, e) Fe, and f) Na during the (SAFIRED) campaign at Gunn Point, Northern Territory, Australia.

Citation: *V.H.L. Winton et al. Dry season aerosol iron solubility in tropical northern Australia. In preparation.*

2. Activities/main accomplishments in 2020 (e.g., projects; field campaigns; workshops and conferences; model and data intercomparisons; capacity building; international collaborations; contributions to int. assessments such as IPCC; collaborations with social sciences, humanities, medicine, economics and/or arts; interactions with policy makers, companies, and/or journalists and media).

BEPSII (Biogeochemical Exchange Processes at Sea-Ice Interfaces) annual meeting, hosted out of University of Victoria, August 21-28 (https://sites.google.com/site/bepsiiwg140/news/online-joint-bepsiiecvice-meeting-2020). (SOLAS Integrated topic on Polar Oceans)

Measuring Essential Climate Variables in Sea Ice (ECV-Ice) intercomparison experiment for CO_2 related parameters and other gases in sea ice, Norwich, UK, Jan–Feb 2020. (SOLAS Integrated topic on Polar Oceans)

A second Ice Algae Model Intercomparison Project (IAMIP2) was initiated (led by H. Hayashida, currently in Australia).

A BEPSII paper climate change impacts on sea-ice ecosystems and ecosystem services has been compiled linking the BEPSII community with experts in higher trophic levels, tourism and cultural services. The paper has been submitted to BEPSII's new special issue in Elementa. (SOLAS Themes 1, 2, 4, 5, Integrated studies of high sensitivity systems, Science and society**)**

A United Nations - Group of Experts on the Scientific Aspects of Marine Environmental Protection (UN-GESAMP) review paper focusing on the impacts of ocean acidification on marine sources of key climate-active trace gases, including DMS, N_2O, ammonia and halocarbons was published in the Proceedings of the Royal Society A. (SOLAS Themes 1, 4, 5)

3. Top 5 publications in 2020 (only PUBLISHED articles) and if any, weblinks to models, datasets, products, etc.

Top 5 Publications

D. Lannuzel, L. Tedesco, M. van Leeuwe, K. Campbell, H. Flores, B. Delille, L. Miller, J. Stefels, P. Assmy, J. Bowman, K. Brown, G. Castellani, M. Chierici, O. Crabeck, E. Damm, B. Else, A. Fransson, F. Fripiat, N.-X. Geilfus, C. Jacques, E. Jones, H. Kaartokallio, M. Kotovitch, K. Meiners, S. Moreau, D. Nomura, I. Peeken, J.-M. Rintala, N. Steiner, J.-L. Tison, M. Vancoppenolle, F. Van der Linden, M. Vichi, and P. Wongpan, (2020). The future of Arctic sea-ice biogeochemistry and ice-associated ecosystems. Nature Climate Change, doi: 10.1038/s41558-020-00940-4. (SOLAS Integrated topic on Polar Oceans)

L. Miller, F. Fripiat, S. Moreau, D. Nomura, J. Stefels, N. Steiner, L. Tedesco, M. Vancoppenolle (2020). Implications of sea ice management for Arctic biogeochemistry, Eos, 101, doi: 10.1029/2020EO149927. (SOLAS Integrated topics on Polar Oceans and Geoengineering)

T. Burgers, J.-É. Tremblay, B.G.T. Else, and T. Papakyriakou, (2020). Estimates of net community production from multiple approaches surrounding the spring ice-edge bloom in Baffin Bay, Elem Sci the Anth, 8, DOI: https://doi.org/10.1525/elementa.013. (SOLAS Themes 1, 2, and Integrated topic on Polar Oceans)

B. Croft, R.V. Martin, R.H. Moore, L.D. Ziemba, E.C. Crosby, H. Liu, L.M. Russell, G. Saliba, A. Wisthaler, M. Müller, A. Schiller, M. Gali, R.Y.-W. Chang, E.E. McDuffie, K.R. Bilsback, J.R. Pierce (2021). Factors controlling marine aerosol size distributions and their climate effects over the Northwest Atlantic Ocean region, Atmos. Chem. Phys., 21, 1889–1916.

D.W. Capelle, Z.Z.A. Kuzyk, T. Papakyriakou, C. Guéguen, L.A. Miller, and R.W. Macdonald, (2020). Effect of terrestrial organic matter on ocean acidification and CO_2 flux in an Arctic Shelf Sea. Progress in Oceanography 185: 102319, doi: 10.1016/j.pocean.2020.102319. (SOLAS Theme 1 and Integrated topic on Polar Oceans)

Other publications

M.M.M. Ahmed, B.G.T. Else, D. Capelle, L.A. Miller, and T. Papakyriakou, (2020). Underestimation of surface pCO_2 and air-sea CO_2 fluxes due to freshwater stratification in an Arctic shelf sea, Hudson Bay. Elem. Sci. Anth. 8(1):084. doi: 10.1525/elementa.084. (SOLAS Themes 1, 2, and Integrated topic on Polar Oceans)

H. Hayashida, G. Carnat, M. Galí, A. H. Monahan, E. Mortenson, T. Sou, N. S. Steiner, (2020). Spatiotemporal variability in modeled bottom ice and sea surface dimethylsulfide concentrations and fluxes in the Arctic during 1979–2015. Global Biogeochemical Cycles, 34, e2019GB006456. https://doi.org/10.1029/2019GB006456. (SOLAS Themes 2, 4, 5, and Integrated topic on Polar Oceans)

E. Mortenson, M. Steiner, A. H. Monahan, H. Hayashida, T. Sou, A. Shao, A. (2020). Modeled impacts of sea ice exchange processes on Arctic Ocean carbon uptake and acidification (1980–2015). Journal of Geophysical Research: Oceans, 125, e2019JC015782. https://doi.org/10.1029/2019JC015782. (SOLAS Themes 1, 4, 5 and Integrated topic on Polar Oceans)

M. Lizotte, M. Levasseur, V. Galindo, M. Gourdal., M. Gosselin, J.-É. Tremblay, M. Blais, J. Charette, and R. Hussherr. (2020). Phytoplankton and dimethylsulfide dynamics at two contrasting Arctic ice edges, Biogeosciences, 17, 1557–1581, 2020 https://doi.org/10.5194/bg-17-1557-2020. (SOLAS Themes 2, 4, 5, and Integrated topic on Polar Oceans)

H.J.S. Fernando, I. Gultepe, C. Dorman, E. Pardyjak, Q. Wang, S.W. Hoch, D. Richter, E. Creegan, S. Gaberšek, T. Bullock, C. Hocut,R. Chang, D. Alappattu, R. Dimitrova, D. Flagg, A. Grachev, R. Krishnamurthy, D.K. Singh, I. Lozovatsky, B. Nagare, A. Sharma, S. Wagh, C. Wainwright, M. Wroblewski, R. Yamaguchi, S. Bardoel, R.S. Coppersmith, N. Chisholm, E. Gonzalez, N. Gunawardena, O. Hyde, T. Morrison, A. Olsen, A. Perelet, W. Perrie, S. Wang, B. Wauer, (2020). C-FOG: Life of Coastal Fog, Bulletin of the American Meteorology Society, https://doi.org/10.1175/BAMS-D-19-0070.1

C. Chen, M. Zhang, W. Perrie, R.Y.-W. Chang, X. Chen, M. Wheeler (2020). Boundary Layer Parameterizations to Simulate Fog over Atlantic Canadian Waters, Earth and Space Science, 73(3): e2019EA000703.

F. E. Hopkins, P. Suntharalingam, M. Gehlen, O. Andrews, S. D. Archer, L. Bopp, E. Buitenhuis, I. Dadou, R. Duce, N. Goris, T. Jickells, M. Johnson, F. Keng, C. S. Law, K. Lee, P. S. Liss, M. Lizotte, G. Malin, J. C. Murrell, H. Naik, A. P. Rees, J. Schwinger, P. Williamson. (2020). Unravelling the impacts of ocean acidification on marine trace gases and the implications for atmospheric chemistry and climate. Proc. R. Soc. A, 476: 20190769.

4. Did you engage any stakeholders/societal partners/external research users in order to co-produce knowledge in 2020? If yes, who? How did you engage?

YES. In addressing impacts on sea-ice ecosystems and links to forage species we closely collaborate with the Hunters and Trappers Committees and community members in the Inuvialuit Settlement Region (ISR, Northwest Territories, Canada). This year a social scientist was added and a series of traditional knowledge interviews is being linked to changes in forage fish.

PART 2 - Planned activities for 2021 and 2022

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

Summer 2021 – Atmospheric chemistry study in Iqaluit COVID restrictions permitting (R. Wang – Dalhousie University, Halifax Canada).

Summer / Fall 2021 – ArcticNet 2021 cruise on the CCGS *Amundsen*, July-October, Baffin Bay, Canadian Arctic Archipelago, Beaufort Sea, COVID restrictions permitting (T. Papakyriakou and team)

Summer / Fall 2021 TrEx – Tracer Experiment organized by MEOPAR in the St. Lawrence (R. Wang - Dalhousie University, Halifax Canada).

Fall 2021 – Dark Edge project onboard the CCGS *Amundsen*, October-November, Baffin Bay, Canadian Arctic Archipelago, COVID restrictions permitting (M. Lizotte, M. Babin and team)

Summer 2022 – Fog and turbulence interactions in the marine atmosphere (FATIMA) led by HJ Fernando (University Notre Dame) in the Northwest Atlantic, including planned site at Sable Island for aerosol and meteorology measurements.

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

The Measuring Essential Climate Variables in Sea Ice (ECV-Ice) intercalibration experiment & BEPSII winter school in Cambridge Bay was postponed to 2022. (SOLAS Integrated topic on Polar Oceans).

The annual BEPSII meeting will be held online again in August 2021.

3. Funded national and international projects/activities underway.

Climate Relevant interactions and feedbacks: the key role of sea ice and Snow in the polar and global climate system (CRiceS). A European Union Horizon 2020 Framework Programme (J. Thomas, R. Makkonen, leads) with funded Canadian participation by B. Else, N. Steiner, and L. Miller. International collaborative project to integrate observational insights into climate and Earth system models. (SOLAS Themes 4, 5, and Integrated topic on Polar Oceans.)

Quantifying and Predicting Canada's Marine Carbon Sink, 2020-2022. Lead: R. Hamme. NSERC Advancing Climate Change Science in Canada Program. (SOLAS Theme 1.)

A co-operative, multi-platform effort to observe marine biogeochemical processes and address Arctic community research priorities, 2019-2022. Lead: B. Else. ArcticNET. (SOLAS Integrated topics on Polar Oceans and Science & Society.)

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

Feb 2023/Jan 2024 – Pacific Stratocumulus Precipitation and Seasons in San Diego to study marine stratocumulus clouds, equipment funded by US Department of Energy, support from Canadian sources TBD (R. Wang - Dalhousie University, Halifax Canada)

Summer 2023 – FATIMA part 2 in the Yellow Sea (R. Wang - Dalhousie University, Halifax Canada)

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

L. Miller (Department of Fisheries Oceans Canada, Sidney) has been appointed to the Future Earth reform Implementation Team, which is responsible for restructuring Future Earth into a community-driven sustainability science organization.

Comments