ANNUAL REPORT ON GEOTRACES ACTIVITIES IN CANADA

May 1, 2016 – April 30, 2017

Accomplishments

The Canadian GEOTRACES group had our first synthesis meeting coincident with the ArcticNet's 12th annual scientific meeting held in Winnipeg Manitoba Dec. 5-9th, 2016. The meeting was hosted by Dr. Feiyue Wang at the Centre for Earth and Ocean Science at the University of Manitoba and the Convention Centre Dec. 5-7th. The meeting provided the first opportunity for the group to bring together observations made on our Arctic research expedition completed on two legs aboard the Canadian Coast Guard Ship Amundsen in 2015. The first leg covered the Labrador Sea, Baffin Bay and Canadian Arctic Archipelago (July 10-August 10) and the second the Beaufort Sea (September 4-October 1st). Over the three days the project was able to hear updates from individual PI's and the highly qualified personnel, compare results and discuss plans for the future with respect to ongoing analysis and synthesis of project specific and core GEOTRACES parameters. To facilitate data synthesis activities we are using the UBC Workspace 2.0 cloud based file sharing service that provides secure data management capabilities. It is made available free of charge (50GB limit) to UBC faculty and collaborators. We are using this site as a working space and transitory data storage before submission to the international GEOTRACES Data Assembly Center. The Canadian GEOTRACES community continues to support an ongoing process study making observations of bioactive trace elements and trace element-microbe interactions on time-series cruises completed along Line P in the northeast Pacific. The project will have its next synthesis meeting in May 2017 at the Peter Wall Institute, University of British Columbia.

Our new scientific results, publications and presentations are summarized by Individual Investigator below:

Susan Allen, Department of Earth, Ocean and Atmospheric Science, University of British Columbia

Summary

We have modelled four tracers in the Arctic Ocean using the ANHA Model from Paul Myers Group at University of Alberta. Barium concentration and del^{18}O illustrate the changes in freshwater circulation, showing strong influence of large scale atmospheric patterns. The model of ^{230}Th shows that observed changes in the Canadian Basin are a result of a switch in direction of the Atlantic layer circulation. We have also modelled ^{231}Pa and are in the process of modelling Manganese, Lead and Gallium. We are coordinating with observationalists: particularly with respect to ^{230}Th and Manganese and Gallium.

Conference Presentations

- Yu X, Allen S, Hu X, Myers P. (2015). Intermediate and deep water circulation changes in the Arctic.
- (2002-2013): Inferred from the distribution of 231Pa/230Th in the water column. Arcticnet Annual Science Meeting, Vancouver, Canada.

- Sha Y, Allen S, Hu X, Myers P. (2015). A simulation study of dissolved Barium and Oxygen isotope ratio in the Arctic. ArcticNet Annual Science Meeting, Vancouver, Canada.
- Yu X, Allen S, Hu X, Myers P. (2016). Intermediate and deep water circulation in the Arctic Ocean
- (2002-2013): Inferred from the distribution of 231Pa/230Th in the water column. Canadian Meteorological and Oceanographic Society Congress, Fredericton, Canada.
- Sha Y, Allen S, Hu X, Myers P. (2016). A simulation study of dissolved Barium and Oxygen isotope ratio in the Arctic. Canadian Meteorological and Oceanographic Society Congress, Fredericton, Canada.
- Grenier M., R. Francois, M. Rutgers van der Loeff, X. Yu, M. Soon, S. B. Moran, R. L. Edwards, Y. Lu, K. Lepore, X. Hu, P. Myers, and S. E. Allen. Arctic circulation changes in the Atlantic layer from dissolved 230Th profiles measured over the last 4 decades. Aquatic Sciences Meeting, Honolulu, (Hawaii, USA), February 2017.

Roberta Hamme, School of Earth and Ocean Sciences, University of Victoria

Conference Presentations

- Timmerman, A.H.V., Hamme, R.C., Miller, L.A., Francois, R., Soon, M., Giesbrecht, K.E., Varela D.E. (2017) Spatial variability of carbon export from sub-Arctic to the Arctic Ocean (Oral Presentation) ALSO (International), Honolulu, Hawaii.
- Timmerman, A.H.V., Hamme, R.C. (2016) Comparing primary production methods to better constrain historical, current and future rates. (Poster). OSM (International), New Orleans, Louisiana.

Outreach Activities

- Timmerman, A.H.V. (2016) Do the oceans matter to us? (Oral Presentation) Golden Rods and Reels, Victoria, BC.
- Timmerman, A.H.V. (2016) Do the oceans matter to us? (Oral Presentation) Lansdowne Middle School, Victoria, BC.
- Timmerman, A.H.V. (2017) Oceanographic research (Oral Presentation) University of Victoria undergraduate course, Victoria, BC.

Chris Holmden, University of Saskatchewan

Refereed Journal Publications

- Scheiderich, K., Amini M., Holmden, C., and Francois R. (2015) Global variability of chromium isotopes in seawater demonstrated by Pacific, Atlantic and Arctic Ocean samples. Earth Planet. Sci. Lett. 423, 87–97

Conference Presentations (invited)

- Holmden C., Scheiderich K., Amini M. and Francois, R. Cr isotope variability in the oceans: implications for the Cr isotope proxy. Invited talk: Goldschmidt Geochemistry Conference 2015, Prague, Czech Republic.
- Holmden C, Scheiderich K, Amini M & Francois R., Bacconais I. (2015) A Cr isotope proxy for ocean deoxygenation. Invited. AGU Fall Meeting, San Francisco, PP31F-02

Conference Presentations

- Baconnais I, Holmden C., and Francois R. Chromium isotope variability in modern ocean. Goldschmidt Abstracts, 2016, 137

Alfonso Mucci, Department of Earth and Planetary Sciences, McGill University

Summary

We have analyzed several thousand bottle cast samples for a number of conservative and non-conservative tracers (e.g., S, T, $\delta^{18}O(H_2O)$, $\delta^{13}C(DIC)$, TA) and combined those with data (e.g., nitrate, SRP, O_2) acquired by collaborators to identify the properties of source-water types in the study area (Beaufort Sea, Canadian Arctic Archipelago, Baffin Bay/Davis Strait) and estimate the relative contribution of these throughout the water column. These water-mass reconstructions are used by our Canadian Geotraces collaborators to interpret the vertical and horizontal distributions of trace elements and their isotopes (e.g., Varela et al., 2016). In addition, we have been tracking the temporal evolution of the aragonite compensation depth (ACD) in the waters of the study area over the past decade. Our observations reveal that, in the Canada Basin, the ACD is being eroded from above by the increasing atmospheric pCO_2 and from below by intrusions of acidified North Atlantic Ocean waters (Luo et al., 2016).

Refereed Journal Publications

- Luo Y., Boudreau B.P. and Mucci A. (2016) Disparate acidification and carbonate desaturation of deep and shallow waters of the Arctic Ocean. Nature Communications 7:12821, pp. 1-8.
- Varela D.E., Brzezinski M.A., Beucher C.P., Jones J.L., Giesbrecht K.E., Lansard B. and Mucci A. (2016) Heavy silicon isotopic composition of silicic acid and biogenic silica in Arctic waters over the Beaufort Shelf and the Canada Basin. Global Biogeochemical Cycles. 30: 804-823.

Media Coverage and Outreach Activities

- **Public lecture:**
  Menace au large : L'acidification des océans
  https://coeurdessciences.uqam.ca/component/content/article/7-menu-horizontal/30-videos.html, Cœur des Sciences-UQAM, February 18, 2016

- **Media interviews:**
  Menace au large : L'acidification des océans, Canal Savoir, video interview with Sophie Malavoy, https://coeurdessciences.uqam.ca/component/content/article/7-menu-horizontal/30-videos.html, Cœur des Sciences-UQAM, February 18, 2016

  L'acidification des oceans, CKUT, interview with Julie Robert, February 18, 2016

Paul Myers, Department of Earth and Atmospheric Sciences, University of Alberta

Summary

Accomplishments to date include making improvements to our Arctic and Northern Hemisphere Atlantic (ANHA) configuration of NEMO. These include an improved river routing/freshwater discharge scheme, online passive tracers, Greenland melt inclusion, addition of a Lagrangian ice berg module, and coupling to the biogeochemical model BLING. The end result is model simulations, especially at 1/12 degree resolution, that compare very well with a broad suite of observational metrics through the Canadian Arctic and beyond. Research directions over the reminder of the project include further analysis of the model fields, focussing on transports and pathways through the CAA, as well as impact of Arctic freshwater on Baffin Bay and the sub-polar North Atlantic. We will also continue to provide model fields to all other groups who may wish to use them in their analysis of observational data.

Refereed Journal Publications

- Evolution of Baffin Bay water masses and transports in a sensitivity numerical experiment, including climate change conditions and Greenland runoff, N Grivault, X Hu and PG Myers, Atmosphere-Ocean, in press
- Water mass modification and mixing rates in a 1/12° simulation of the Canadian Arctic Archipelago KG Hughes, JM Klymak, X Hu, PG Myers, Journal of Geophysical Research: Oceans
- Potential positive feedback between Greenland Ice Sheet melt and Baffin Bay heat content on the west Greenland shelf, L Castro de la Guardia, X Hu, PG Myers, Geophysical Research Letters 42 (12), 4922-4930

Dr. Andrew R.S. Ross, Research Scientist, Institute of Ocean Sciences, Fisheries and Oceans Canada (DFO), Assistant Adjunct Professor, Biochemistry and Microbiology, University of Victoria (UVic)

Refereed Journal Publications

- Nixon, R.L., Ross, A.R.S. 2016. Evaluation of immobilized metal-ion affinity chromatography and electrospray ionization tandem mass spectrometry for recovery and identification of copper(II)-binding ligands in seawater using the model ligand 8-hydroxyquinoline. Frontiers in Marine Science 3: 246. doi: 10.3389/fmars.2016.00246 (Marine Biogeochemistry Research Topic: Organic ligands - A key control on trace metal biogeochemistry; sponsored by SCOR WG 139).

Conference Presentations

- Nixon, R.L., Ross, A.R.S. 2016. Evaluation of IMAC and Electrospray Ionization Mass Spectrometry for Recovery and Analysis of Copper-binding Ligands in Seawater. 18th Ocean Sciences Meeting, New Orleans LA, 21-26 February.

Summary

During 2016-17 we completed the development and evaluation of a novel method for recovering and analyzing organic ligands from seawater using immobilized metal-ion affinity chromatography (IMAC) and tandem mass spectrometry (MS/MS). The method was the subject of an oral presentation given by CCAR-funded graduate student Richard Nixon at the 2016 Ocean Sciences Meeting in New Orleans. A paper describing this work was also published as a Methods paper in a special issue of Frontiers Marine Biogeochemistry on Organic Ligands, sponsored by SCOR Working Group 139. The paper includes acknowledgement of the support provided by the Canadian Arctic GEOTRACES program.
IMAC extraction of samples collected during the 2015 Canadian Arctic GEOTRACES using the Trace Metal (TM) Rosette has also been carried out, providing new information about the relative abundance and UV absorption characteristics of copper-binding ligands collected at different locations and depths in the Canadian Arctic. Depth profiles for 6 stations from Leg 3b (CB-1, -2, -3, -4, CAA-8 and CAA-9) were presented at the December 2016 Project Meeting in Winnipeg, along with a brief summary of the published method. To our knowledge, these are the first depth profiles of copper ligands in Arctic waters.
These results will be presented in a talk at the 100th Canadian Chemical Conference and Exhibition in Toronto on May 29th, 2017 in a session organized by members of the Canadian Arctic GEOTRACES team.
During the final year of the project we plan to perform MS and MS/MS analysis on selected IMAC fractions in an effort to obtain molecular weight and structural information for the recovered ligands. These data will be compared with results obtained by other groups concerning primary productivity, trace element concentrations, and characterization of dissolved organic matter (e.g. thiols, humic substances, CDOM) to provide complementary information about the nature, abundance, and ecological role of organic ligands in the Arctic.

John N. Smith, Head, Atlantic Environmental Radioactivity Section, Bedford Institute of Oceanography, Fisheries and Oceans Canada, 1 Challenger Dr., Dartmouth, NS Canada B2Y 4A2

Refereed Journal Publications

- Buesseler, K., Dai, M., Aoyama, M., Benitez-Nelson, C., Charmasson, S., Highley, K., Maderich, V., Masque, P., Oughton, D. and J.N. Smith, 2017. Fukushima Daiichi–Derived Radionuclides in the Ocean: Transport, Fate, and Impacts. Annual Reviews Marine Science 9:173-203.
- J. N. Smith, V. Rossi, K. O. Buesseler, J. Cullen, J. Cornett, R. Nelson, A. M. Macdonald, M. Robert and J. Kellogg, 2017. Time series transport of the Fukushima radioactivity plume through the northeast Pacific Ocean. Environmental Science and Technology, in review.

Conference Presentations (invited)

2016 Annual PICES Meeting, San Diego, CA, Nov 2-13, 2016
J.N. Smith, Transport of Fukushima radioactivity to North America, Nov. 3, 2016.
J.N. Smith and J. F. Mercier, Canadian response to the Fukushima accident. Nov 4, 2016.

Conference Presentations

Coordinated Research Proposal (CRP) Meeting, International Atomic Energy Agency, (IAEA) Monte Carlo, Monaco, April 26-30, 2016.
J.N. Smith, Radionuclide tracer measurements in Canada's three oceans. April 27, 2016

2017 Ocean Sciences Meeting, Honolulu, Hawaii, February 28, 2017
J.N. Smith, J. Cornett, T. Guilderson and T. Kenna, Tracer ^{129}I Measurements on US and Canadian 2015 Arctic Ocean Geotraces missions

Media Coverage and Outreach Activities

Training Course on Marine Radioactivity June 8-10, 2016, Xiamen University, Xiamen, ChinaJ.N. Smith, Applications of artificial radionuclides as Fukushima tracers of marine processes, June 10, 2016

Media interviews on Fukushima issues with *Associated Press*, *Voice of America*, *Japan Times*.

Philippe Tortell, Earth and Ocean Sciences, University of British Columbia

Refereed Journal Publications

- Schuback N., Hoppe C., Maldonado M. and P. Tortell. Primary productivity and the coupling of photosynthetic electron transport and carbon fixation in the Arctic Ocean. Limnology and Oceanography, doi: 10.1002/lno.10475
- Fenwick, L. Zimmerman, S., Williams, B., Vagle, S., Capelle D.W., and P.D. Tortell. Methane and nitrous oxide distributionsacross the North American Arctic Ocean during summer, 2015. Journal of Geophysical Research-Oceans, Oct. 2016. doi: 10.1002/2016JC012493
- Jarnikova T., Dacey J., Lizotte M., Levasseur, M. and P. Tortell. The distribution of methylated sulfur compounds, DMS and DMSP, in Canadian Subarctic and Arctic waters during summer, 2015. Submitted to Journal of Geophysical Research-Oceans. Oct. 2016, ms ID 2016JC012442
- Hoppe, C, Schuback, N, Seminuik D., Giesbrecht K., Mol J., Thomas H., Maldonado M., Rost B., Tortell P. Resistance of Arctic phytoplankton to ocean acidification and high irradiance. Submitted to Polar Biology, March 10, 2017.

Conference Presentations (invited)

- 2017, Canadian Chemistry Conference (Toronto), Tortell PD, Fenwick L, Capelle DW, Damm E, Zimmermann S, Williams WJ, Vagle S. Factors Influencing the Distribution of Climate-active Trace Gases in the Canadian Arctic Ocean

Diana Varela, University of Victoria

During the 2015 Canadian Arctic GEOTRACES, our group conducted primary productivity experiments that involved 24-hr incubations throughout the euphotic zone using 13-C, 15-NO3, 15-NH4, and 32-Si isotopic tracers. We also collected samples for particulate silica concentrations and the natural abundance of silicon isotopes. Phytoplankton productivity experiments were only conducted on the first leg of the 2015 Canadian Arctic Geotraces cruise, whereas samples for particulate silica concentrations and silicon isotopes were collected on both legs of the cruise. Analysis has been completed for all samples with the exception of the silicon isotope samples, for which analysis is currently underway.

Concentrations of bSiO2 and rates of Si utilization exhibited subsurface maxima, and followed similar spatial patterns, with a general increase from east to west. Subsurface maxima in C and NO3 utilization rates were less consistent, whereas high NH4 utilization rates always occurred at the bottom of the euphotic zone where NH4 concentrations increased. Both C and NH4 utilization rates showed the opposite trend to Si, with a decrease from east to west, while NO3 utilization rates showed little spatial variability. Initial results for Si isotopes potentially reflect Si utilization in modified Pacific water as this water mass travels from east to west through the Canadian Arctic Archipelago. This observation is supported by the eastward decrease in Si utilization rates and Si(OH)4 concentrations in the same direction.

Refereed Journal Publications

- Hoppe, C.J.M, N. Schuback, D. Semeniuk, K. Giesbrecht, J. Mol, H. Thomas, M.T. Maldonado, B. Rost, D.E. Varela, and P.D. Tortell (2017) Resistance of Arctic phytoplankton to ocean acidification and high irradiance, submitted to Polar Biology (Mar 9, 2017), POBI-D-17-00051.
- Varela, D. E., M. A. Brzezinski, C. P. Beucher, J. L. Jones, K. E. Giesbrecht, B. Lansard, and A. Mucci (2016), Heavy silicon isotopic composition of silicic acid and biogenic silica in Arctic waters over the Beaufort shelf and the Canada Basin, Global Biogeochem. Cycles, doi:10.1002/2015GB005277.

Conference Presentations

- Varela, D.E.*, and Giesbrecht, K.E. (2017) Silicon Biogeochemistry in Arctic and Sub-Arctic waters during 2015 Canadian Geotraces: Biogenic silica production and natural Si isotopic signatures. (Talk). ASLO Aquatic Sciences Conference, Honolulu, HI, USA.

- Timmerman, A.*, Hamme, R.C., Miller, L.A., Francois, R., Soon, M., Giesbrecht, K., and Varela, D.E. (2017) Spatial Variability of Carbon Export from the Sub-Arctic to the Arctic Ocean. (Talk). ASLO Aquatic Sciences Conference, Honolulu, HI, USA.
- Hoppe, C.J.M.*, Schuback, N., Wolf, K., Semeniuk, D., Giesbrecht, K.E., Varela, D., Maldonado, M.T., Rost, B., and Tortell, P.D. (2016) Combined effects of ocean acidification and enhanced irradiances on Arctic phytoplankton assemblages – Why don't they care? (Poster). Gordon Research Conference on Ocean Global Change Biology, Waterville Valley, NH, USA.
- Hoppe, C.J.M.*, Schuback, N., Semeniuk, D., Giesbrecht, K.E., Maldonado, M.T., Varela, D., and Tortell, P.D. (2015) Combined effects of ocean acidification and enhanced irradiances on Arctic phytoplankton assemblages – Why don't they care? (Talk). ArcticNET Annual Scientific Meeting 2015, Vancouver, BC.

Stephanie Waterman, University of British Columbia

Activity Summary

Relevant research group activities focus on observational and realistic modelling studies of **turbulent mixing rates and mechanisms in the Canadian Arctic Ocean.** We are engaged in 3 specific projects:

1. analysis of the hydrographic and pioneering turbulence measurements collected from an autonomous robotic ocean glider in the Amundsen Gulf in association with the Arctic GEOTRACES field campaign. These measurements represent the densest turbulence sampling scheme in the western Arctic Ocean to date, and the first study to statistically demonstrate the natural variability of turbulence in this region. They are being used to quantify turbulent mixing rates and upward heat fluxes from subsurface warm Atlantic-sourced water. (= PhD thesis of Benjamin Scheifele)
2. a characterization of the spatial and temporal variability of internal waves and their effect on mixing in the Canadian Arctic Ocean based on an analysis of the historical ArcticNet (and its predecessors) data record between 1997 and 2016. The large scope of the analysis promises a more complete quantification of internal wave field energetics and mixing patterns that exist in the Canadian Arctic Ocean than has been available previously. (= MSc thesis of Melanie Chanona and in collaboration with ArcticNet Investigator Yves Gratton);
3. a study of the impact of enhanced mixing in the Arctic region via experiments with the realistic numerical model of the Arctic Ocean developed by the Myers UofA group. Specifically, we are quantifying the impact of including an additional parameterization of mixing due to the breaking of internal tides by examining the resultant changes to dense water formation, shelf--basin exchange, and the larger Arctic circulation in the model solution. (=MSc thesis of Jacquie-Lee Thibault).

Refereed Journal Publications

(3 currently in preparation)

Conference Presentations

(Apr 1 2016 - Mar 31 2017)
(KEY: presenting author in *italics*; HQP author in **bold**)

- 2016 ArcticNet Annual Scientific Meeting, Dec 2016, Winnipeg Canada Turbulent dissipation rates, mixing and heat fluxes in the Canadian Arctic from glider-based microstructure measurements. B. Scheifele, S. Waterman and J. Capenter.
- Forum for Arctic Modeling & Observational Synthesis, Nov 2016, Woods Hole USA Spatial and temporal variability of internal waves and their effect on mixing in the Canadian Arctic. M. Chanona, S. Waterman and Y. Gratton.
- Forum for Arctic Modeling & Observational Synthesis, Nov 2016, Woods Hole USA Quantifying the impact of internal tide mixing on shelf-basin exchange in a numerical model of the Arctic Ocean. J.-L. Thibault, S. Waterman and P. Myers.
- VIIIth International Symposium on Stratified Flows, Sep 2016, San Diego USA Estimating mixing rates and turbulence from glider-based microstructure measurements in the Beaufort Sea. B. Scheifele, S. Waterman and J. Capenter.
- 50th Canadian Meteorological & Oceanographic Society (CMOS) Congress, Jun 2016, Fredericton Canada Estimating mixing rates and turbulence from glider-based microstructure measurements in the Beaufort Sea. B. Scheifele, S. Waterman, J. Capenter and L. Merckelbach.

Submitted by Jay Cullen (jcullen@uvic.ca).