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ArcticSIG – Reflections

By Ann McMillan

Our ArcticSIG newsletter, the ARCTICSIGnal has started its second year of operation. We recognize we have a way to go to deliver on our vision of what a timely, professional-looking newsletter ought to be. Still, we hope you're engaged by it. If you have comments or suggestions or, even better, if you have something to contribute, please do so. Send input to me at mcmillan@storm.ca.

This issue includes some slightly heavier material for those techies out there who are curious as to how all the research that has been done in the Arctic is coming together. The CONCEPTS article has a look at weather prediction of the near future, based on our understanding of "coupled" atmosphere/ocean/ice system. The climate trends and projections article synthesizes many, many separate studies related to climate in the North and provides an integrated picture of what we know about primary productivity in the Arctic and acidification of the Arctic Ocean. Let me know if you enjoy "feature articles" of this level and length.

The CMOS Arctic Special Interest Group is pleased that the CMOS Congress, June 1-4 in Whistler has:

- five of eight Plenary talks are on the Arctic including David Fissel and Nadja Steiner on Wednesday morning
- eight scientific sessions on Arctic/Polar topics: three on Monday, three on Tuesday, seven on Wednesday (including Helen Joseph's panel) and one on Thursday
- Public Lecture on Tuesday: "Tropics To Poles: Advancing Science in High Latitudes".

In This Issue

WORKING GROUP

The ArcticSIG working group for this issue has been:

- **Martin Taillefer – Chair**
- **Andrew Bell – CMOS Executive Director – SIG Advisor**
- **David Fissel, Ann McMillan, Doug Bancroft, Helen Joseph - Members**

COUPLED ENVIRONMENTAL PREDICTION WITHIN CANADA: THE **CONCEPTS** INITIATIVE AND THE YEAR OF POLAR PREDICTION (2017-19)

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With increased refinement of numerical weather prediction systems, describing the interactions across the air-ice-ocean interface is becoming more important. This leads to a need for a new generation of fully-integrated environmental prediction systems composed of atmosphere, ice, ocean, and wave modeling and analysis systems. Such systems are in increasing demand as the utility of marine information products (e.g. for emergency response) becomes more widely recognized. This is particularly relevant in polar regions, as small-scale features of the sea ice cover (leads, ridges, melt ponds) can strongly modulate heat, moisture and momentum fluxes between the atmosphere and the ocean.

The World Weather Research Program has initiated a Polar Prediction Project (PPP; www.polarprediction.net) to promote cooperative international research enabling the development of improved weather and environmental prediction services for the polar regions on time scales from hourly to seasonal. A key activity of the PPP is the Year of Polar Prediction (YOPP) planned for 2017-19 (Jung et al, 2014; Smith et al., 2015a). The objective of YOPP is to enable a significant improvement in environmental prediction capabilities for the Polar Regions and beyond, by coordinating a period of intensive observing, modelling, verification, user-engagement and education activities.

Within Canada, this need for new and enhanced environmental products and services is being addressed through a government initiative called the Canadian Operational Network of Coupled Environmental PredicTion Systems (CONCEPTS), between Environmental Canada, Fisheries and Ocean Canada and National Defense (Davidson et al, 2013; Smith et al., 2013a). CONCEPTS is developing a hierarchy of coupled forecasting systems to provide new and improved forecast products on global and regional spatial scales, and timescales from hours to seasons.

A fully coupled atmosphere-ice-ocean forecasting system for the Gulf of St. Lawrence (GSL) has been developed (Faucher et al., 2010) and has been running operationally since June 2011. This system demonstrated the strong impact that a dynamic sea ice cover can have on 48hr atmospheric forecasts leading to large changes in surface air temperature (up to 10°C), low-level cloud cover, and precipitation (Pellerin et al., 2004).

The CONCEPTS regional coupled prediction system builds on the experience of the coupled GSL system and extends the domain to cover Canadian ice-infested waters. This system will serve as the preparation service to provide marine information products as part of the Global Marine Distress and Safety Service (GMDSS) for the new Arctic METAREAs 17 & 18.

Development of an improved version of RIPS using regional coupled NEMO-CICE ice-ocean model at 2-8km resolution is nearly complete. Multi-annual simulations and forecast trials have shown improvements following the inclusion of tides and modifications made to the surface flux formulations and the turbulent mixing parameterization (Dupont et al., 2015; Roy et al., 2015). A higher-resolution ocean configuration is also being tested over the Grand Banks (Zhai et al., 2015) and will be used in the CONCEPTS regional system in future.

A particular challenge is the development of an accurate sea ice forecasting system in areas of rapidly evolving ice cover to meet the needs of marine traffic through the Canadian Arctic Archipelago (CAA). This requires kilometer-scale resolution models and analyses able to resolve narrow channels and bays in the CAA as well as details of the ice edge in the marginal ice zone (MIZ). Sea ice models have been primarily developed for climate applications and their use at such high resolution requires innovations to sea ice rheologies (formation of ridges and leads, landfast ice; Lemieux et al., 2015a) and numerical algorithms. Work is currently underway in both these areas as part of the Regional Ice Prediction System (RIPS; Lemieux et al., 201b). A first version of RIPS is running experimentally at CMC producing four 48hr forecasts per day on a 5km resolution grid.

In addition, an accurate representation of the MIZ requires coupling of ice and wave models as waves can penetrate tens of kilometers into the pack breaking ice floes. Moreover, the sea state can have a strong impact on surface fluxes between the atmosphere and ocean. As a result, development of improved wave guidance has become a priority, and work is underway to couple the sea ice model to the WWIII wave model.

Longer timescale forecasts of polar regions is being supported by the Global Ice Ocean Prediction System (GIOPS) now running experimentally at CMC (Smith et al., 2015b). Figure 1 shows an example of the skill of GIOPS in producing sea ice forecasts. GIOPS provides global ice and ocean analyses and 10 day forecasts daily at 00GMT on a 1/4° resolution grid. GIOPS includes a multivariate ocean data assimilation system that combines satellite observations of sea level anomaly and sea surface temperature (SST) together with in situ observations of temperature and salinity. In situ observations are obtained from a variety of sources including: the Argo network of autonomous profiling floats, moorings, ships of opportunity, marine mammals and research cruises. Ocean analyses are blended with sea ice analyses produced by the operational global ice analysis system running at CMC.

Efforts are underway to couple GIOPS to global atmospheric forecasting systems at CMC. Initial results are promising (Smith et al., 2013b) and highlight the potential benefits of coupling for environmental prediction. A particular focus in the coming years for CONCEPTS is the preparation and participation in YOPP (2017-2019). YOPP provides a number of opportunities for the Government of Canada, in terms of improving core weather and environmental prediction services as well as providing visibility for the world class systems and services currently being provided. This is especially relevant given EC's role as the Preparation and Issuing Service for METAREAs 17 & 18 in the Canadian Arctic.

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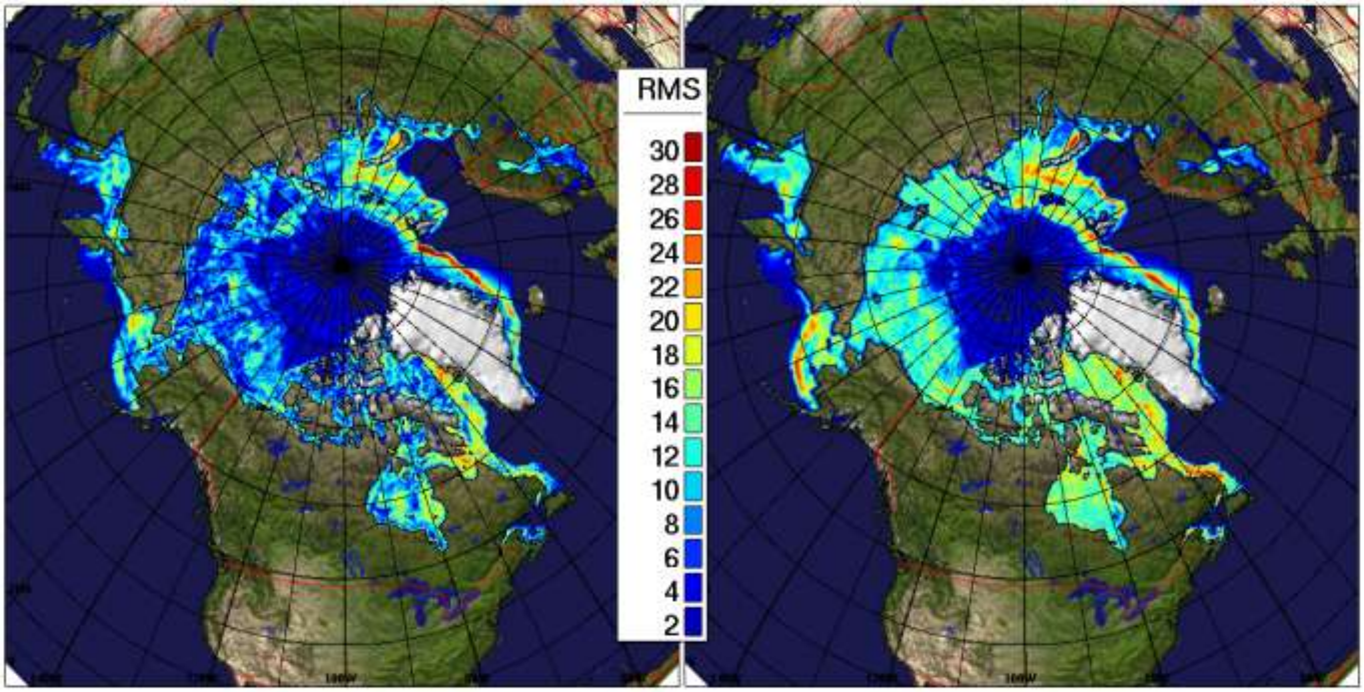

Figure 1: Verification of sea ice forecasting skill for the Global Ice Ocean Prediction System (GIOPS). Colours indicate the root-mean-squared (RMS) 7 day forecast error evaluated over the year 2011 for GIOPS (left) as compared to persistence (right). Figure reproduced from Smith et al. (2015b).

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At the event "Unraveling of the Arctic" (see page 13), Ed Struzik shared some of his amazing pictures. These illustrate perfectly what Northerners are seeing and the scientists are explaining. Clockwise from the upper left: glaciers are thinning; permafrost is thawing; the ecosystem is changing (red and Arctic fox compete) and travel on ice is becoming more dangerous.

TRENDS AND PROJECTIONS OF ACIDIFICATION AND PRIMARY PRODUCTION IN THE CANADIAN ARCTIC

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Climate change forces multiple stressors on Arctic marine ecosystems, such as warming, sea-ice retreat, ocean acidification and enhanced stratification limiting nutrient supply. New stressors, including human habitation, overharvest, industrial and agricultural activities, anthropogenic contaminants, altered food webs, and the introduction of invasive species put additional pressure on those ecosystems (Meltofte et al. 2013). Many changes are faster and more profound in the Arctic than in any other region of the world ocean. With retreating sea ice in summer exposing the underlying water to solar radiation, sea surface temperatures (SST) and upper ocean temperatures in all the marginal seas of the Arctic Ocean are increasing. These changes have direct and indirect effects on the marine ecosystem including increasing ocean primary production in some regions (Frey et al. 2014) and reduced production in other regions. Allard and Lemay (2012) point out that climate warming, combined with changes in the natural and socio-economic environment, is creating cascading effects on the ecosystem and society with significant impacts on human health and quality of life, particularly via the impacts on food resources. These links to human health and socio-economics as well as sea-ice related prospects for Arctic shipping and resource exploration are what initiated a flurry of assessments, particularly within the Arctic Council's Arctic Monitoring and Assessment Program (e.g., AMAP 2012, AMAP 2013, CAFF 2013), but also within Canada. Latter include the ArcticNet IRIS assessments (e.g., Allard and Lemay 2012), Natural Resources Canada technical reports (e.g. Warren and Lemmen 2014) and several recent Fisheries and Oceans Canada technical reports (Steiner et al 2013b and references therein). Many of the assessments identify the limited availability of baseline observations, particularly but not exclusively of the marine ecosystem, as a severe limitation in establishing trends as well as initializing projections. Hence, with a variety of projects including intense measurement programs, Canada somewhat belatedly struggles to establish some baseline information before potentially irreversible system changes occur (Wassmann et al. 2011). Examples are ArcticNet and several projects within the NSERC Climate Change and Atmospheric Research program. Several projects now include a distinct socio-economic component, e.g., ArcticNet, and the SSHRC OceanCanada partnership.

Projecting future ecosystem responses to climate change and other potential stressors requires the application of numerical ecosystem models, the first instance being Earth system models (ESMs, model systems with fully coupled atmosphere, ocean, sea ice and land components including interactive biogeochemical modules for all components), allowing the study of future projections in the Arctic environment with effects on the marine carbon cycle and ecosystem behavior. However, the still fairly coarse horizontal and vertical resolution of those models restricts the ability to resolve biological or chemical processes happening in the euphotic zone as well as small-scale physical processes important for biogeochemistry. Hence regional climate models and basin scale models need to be developed which utilize the ESM output as boundary conditions. One such model is currently under development within Fisheries and Oceans Canada and preliminary results are presented here. The model is forced with climatological mean forcing combined from the Canadian Earth System Model (CanESM2, Arora et al 2011, Christian et al. 2010) and die Canadian Regional Climate Model (CanRCM4, Scinocca et al. 2015, Steiner et al. 2015) for current (2006-2025) and future (2066-2085) times. The ocean model is based on NEMO with set up following Hu and Myers (2013) and is currently coupled to the PISCES ecosystem model. For this contribution I will focus on trends and projections in Arctic primary production and ocean acidification. A full review of observed trends and climate projections affecting marine ecosystems in the Canadian Arctic is given in Steiner et al. (2015).

Arctic Ocean acidification trends and projections

Approximately one quarter of the anthropogenic carbon dioxide to date has been absorbed by the ocean worldwide. The uptake has increased the acidity of seawater and reduced its carbonate-ion concentration. Increasing atmospheric CO2 emissions and consequent ocean uptake further enhance ocean acidification which can significantly affect growth, metabolism, and life cycles of marine organisms (e.g. Gattuso and Hanson 2011). Ocean acidification in the Arctic is intensified due to low temperatures as well as increased

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freshwater supply from river runoff, ice melt, and Pacific water. Colder water temperatures increase CO_2 solubility, while regional oceanographic features (high freshwater inputs relative to volume into large continental shelf areas) limit the Arctic Ocean's capacity to compensate for increased acidity. E.g., the Beaufort and Chukchi Sea continental shelves experience naturally corrosive Pacific seawater inflows with pH as low as 7.6. Changes in sea ice affect the CO2 exchange between atmosphere and ocean either directly (via changes in open water area) or indirectly (e.g., via changes in biological uptake). Cai et al. (2014) indicate that while the Chukchi Sea is a dominant site for CO2 uptake (high nutrient concentrations lead to seasonally high production and subsequent sea surface CO2 depletion), the Beaufort Sea and Canadian Archipelago take up much less and the latter may even become a weak source during certain times of the year. Local, seasonal effects on the shelves are highly influential: Bates and Mathis (2009) point out that riverine carbon flux in the Arctic Ocean is similar in magnitude to the direct CO2 flux from the atmosphere to the ocean. Base cations are diluted by inflows from the Mackenzie and Yukon Rivers and from sea-ice melt. High productivity over the shelves in summer, as well as major terrestrial organic carbon supplies from rivers and rapid coastal erosion, ultimately result in further reduction of pH and $CaCO_3$ saturation state (AMAP 2013). Localized upwelling of acidic waters can further increase acidification in surface and near-surface waters (Chierici and Fransson 2009; Carmack and McLaughlin 2011).

Aragonite and calcite are the two forms of calcium carbonate minerals (CaCO3) commonly produced by marine organisms. The saturation state (Ω) of seawater with respect to CaCO3 is a measure of its potential to corrode the CaCO3 shells and skeletons of marine organisms and is defined as the product of the carbonate and calcium concentrations divided by the solubility product. CaCO3 shells start to dissolve when the waters become undersaturated with respect to CaCO3, i.e., when $\Omega < 1.0$. While enhanced primary production can seasonally increase the CaCO3 saturation state, subsequent remineralisation of sinking organic material releases CO2 which further reduces the saturation state in the subsurface waters (Bates and Mathis 2009; Yamamoto-Kawai et al. 2009, 2011; Denman et al. 2011). These combined effects make Arctic waters especially vulnerable to a declining saturation state of CaCO3.

Miller et al. (2014) find substantial changes in the marine carbonate system of the western Arctic since the 1970s with upper halocline waters and deep waters now regularly showing aragonite undersaturation. Similar conclusions have also emerged from annual surveys of the Beaufort gyre since 2003, indicating that by 2008, waters at 100 – 200 m depth had become under-saturated with respect to aragonite (Yamamoto-Kawai et al. 2009; 2011). Aragonite saturation (Ω_A) values as low as 0.8 have been recorded in surface and bottom waters of the Chukchi and Beaufort Seas. Measurable downstream effects on seawater chemistry are propagated via M'Clure Strait and Amundsen Gulf into waters of the Canadian Arctic Archipelago and beyond (AMAP, 2013).

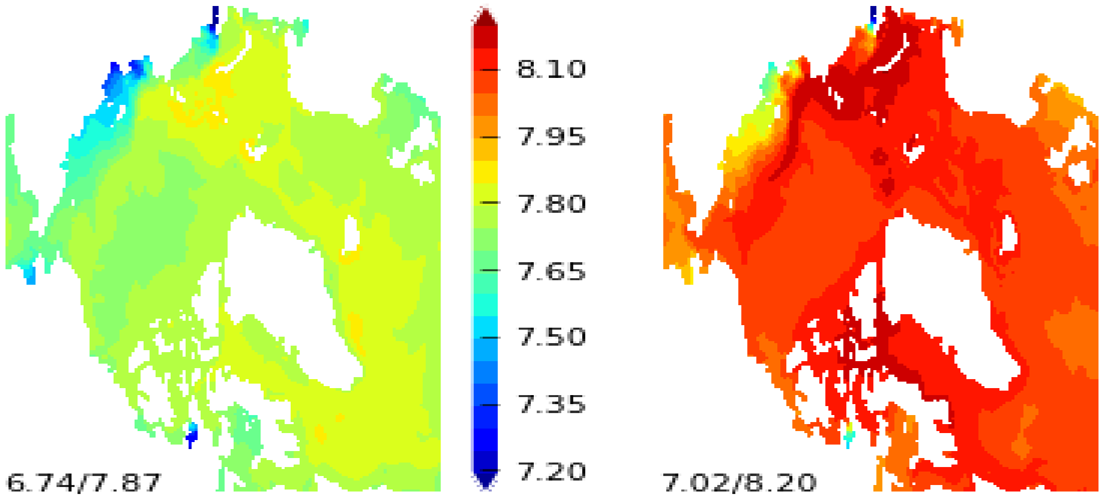
So far, model simulations of biogeochemical changes such as future Arctic Ocean acidification are largely limited to global ESMs (e.g., Schneider et al. 2008; Steinacher et al. 2010; Denman et al. 2011, Steiner et al. 2014). The ESM results consistently show enhanced ocean acidification in polar regions and suggest Arctic Ocean acidification will continue over the next century with accelerated reductions in calcium carbonate saturation state at least until the sea ice cover reaches a new steady state with largely ice-free summers (Steiner et al. 2014). Projections following the Representative Concentration Pathways (RCP) 8.5 (Moss et al. 2010) for the Canada Basin show reductions in the bidecadal mean surface pH from about 8.1 in 1986 – 2005 to 7.7 by 2066 – 2085, closely linked to reductions in the calcium carbonate saturation state $\Omega_{A,C}$, from about 1.4 (2.0) to 0.7 (1.0) for aragonite (calcite), which strengthens earlier results based on SRES scenarios (e.g., Steinacher et al. 2009). Simulated changes in the annual mean surface saturation state of CaCO3 over sixty years are about -0.5 for Ω_A and -0.8 for Ω_C and the Beaufort Sea surface is projected to become undersaturated around 2025 (Ω_A) and around 2065 (Ω_C). The top 350 m in the Canada Basin are simulated to become undersaturated with respect to aragonite by 2066 – 2085 (Steiner et al. 2014, 2015). Preliminary results from the higher resolution Canadian Arctic ecosystem model are shown in Fig. 1 and indicate a reduction in surface pH in a similar range. An emission scenario with mitigation (RCP4.5) reduces the progress of acidification (pH of 7.9 is reached about 25 years later in RCP4.5 than in RCP8.5). However, the emergence of undersaturated surface waters, which is projected to occur within the next decade, differs little between the scenarios (Steiner et al. 2014).

Retreating sea ice is one of the main components leading to increased acidification of the Arctic Ocean, both due to the addition of melt water from multi-year ice and due to the increase in open water areas allowing for enhanced air-sea exchange. The latter leads to a more pronounced seasonality in atmosphere-ocean carbon fluxes with a later maximum uptake in fall, and reduced uptake or even outgassing in summer (Steiner et al. 2013a) when a limit in uptake capacity is reached (Cai et al. 2010). A model study by Yamamoto et al. (2012) suggests that future reductions in pH and aragonite saturation states could be significantly faster than previously projected with increased pace in sea ice reduction.

Nutrients and primary production trends and projections

Arctic marine ecosystems are hosts to over 2000 species of algae, tens of thousands of microbes and over 5000 animal species. Numerous smaller domain ecosystems within the larger systems are characterized by unique physical and biological features making them hotspots for marine productivity and biodiversity (Michel et al. 2013). The Arctic marine ecosystem is constituted of benthic, pelagic and sympagic (ice-associated) ecosystems with different features over shelves or deep water, strong riverine influence and hot spots like polynyas and marginal ice zones. Marine ecosystems in the Canadian Arctic are characterized by a short productive period in spring-summer, driven by the high seasonality in solar radiation and often limited nutrient supply. Nelson et al. (2014) summarize the biodiversity and biogeography of the lower trophic taxa in the Pacific Arctic Region with sensitivities to climate change. They indicate that range shifts and changes in the relative abundance of particular taxa have occurred within the last decade and suggest the relative proportions of major bacterial groups could be an indication of recent productivity and be used to track ecological shifts, e.g. associated with climate change. A recent Arctic data synthesis based on observations from 1954 – 2007 provides a baseline for primary production (Matrai et al. 2013; Hill et al. 2013) and nutrients (Codispoti et al. 2013). Due to the extreme sparseness of the observations both temporally and spatially, the data has been averaged over ecotypological regions (EaseGrid, Matrai et al. 2013). Within the Beaufort Sea summer-time cruise average data have revealed a warming, freshening upper ocean and increasing density stratification; Picoplankton, having a larger surface-area-to-volume ratio and slower sinking rate, do better under these conditions than larger nanoplankton (Li et al. 2009). Meanwhile, total phytoplankton biomass did not change.

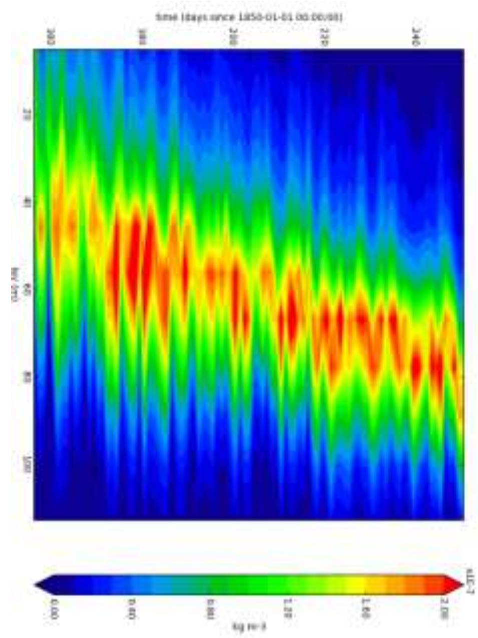
Fig 1. Canadian Arctic Ecosystem Model projections of surface pH: future times (2066-2085) on the left and current times (2006-2025) on the right Numbers give the minimum and maximum in the area.



Due to the limited observations, publications on climate change driven biological changes in the Arctic marine ecosystem focus on qualitative changes. Observations by McLaughlin et al. (2011) showed a decrease in the subsurface deep Chl-a maximum from about 45 m in 2002 to 65 m in 2010/2012 in the Canada Basin. Bergeron and Tremblay (2014) also describe a deepening in the subsurface Chl-a maximum in association with a deepening of the median depth of the nitracline by 3.6 m/yr from 2003– 2011 in the southeast BS. The position of the halocline was unaffected indicating a greater vertical extent of biological consumption. Fujiwara et al. (2014) find shifts in the algal community composition in relation to the timing of sea-ice retreat and a combined model- satellite observation analysis by Ji et al. (2013) indicates a strong correlation between the timing and variability of sea-ice retreat and pelagic production at any specific location. Ardyna et al. (2014) identify a recent development of a secondary bloom in the fall coinciding with delayed freeze-up and increased exposure of the sea surface to windstress. Tremblay et al. (2012) summarized the current state and recent trend in Canadian Arctic primary productivity in six points: 1: Offshore, the warming and freshening of the surface layer is leading to a displacement of large nanophytoplankton species by small picophytoplankton cells, with potentially profound bottom-up effects within the marine food web. 2: In coastal areas, primary production increases as favorable winds and the deeper seaward retreat of ice promote upwelling. 3: Multiple upwelling events repeatedly provide food to herbivores throughout the growth season. 4: A substantial amount of pelagic primary production occurs under thinning ice (e.g., Arrigo et al. 2012) due to enhanced light penetration through the sea ice (Frey et al. 2011) and cannot be detected by orbiting sensors. (Changes in irradiance transmitted through snow and sea ice also directly influence the production of sea ice algae with consequences to secondary producers, Leu et al, 2015). 5: Early primary production in spring does not imply a trophic mismatch with key herbivores (publications diverge on this subject, e.g. Leu et al., 2011) 6: The epipelagic ecosystem is very efficient at retaining carbon in surface waters and preventing its sedimentation to the benthos. Tremblay et al. (2012) conclude that while enhanced primary production could result in increased fish and marine mammal harvests for Northerners, it will most likely be insufficient for sustainable large-scale commercial fisheries in the Canadian Arctic.

Arrigo et al. (2008) suggested that in the Arctic, the loss of ice during spring could boost overall productivity more than 3-fold above 1998 – 2002 levels, potentially altering marine ecosystem structure and the degree of pelagic-benthic coupling. Vancoppenolle et al. (2013), in an assessment of projected primary production, nutrient and sea ice concentrations in 11 CMIP5 ESMs, find that despite a good representation of the ensemble mean Arctic-integrated primary production for 1998 – 2005, models neither agree on what limits primary production today, nor on the sign of future change. A balance of a decrease in available nutrients due to increased stratification and increased light availability due to a reduced sea ice cover operates in all models; however it depends on the model if the benefits of the light increase are sufficient or not to overcome the decrease in available nitrate. Steinacher et al. (2010) and Vancoppenolle et al. (2013) suggest that the main cause for the large intermodel spread is a poorly constrained observational data set of Arctic nitrate concentrations. ESMs projections suggest a sixty-year change in NO3 with largest change in the central Arctic (-3 mmol m^{-3}) and smaller losses near the BS coast (-1 to -2 mmol m^{-3}) correlated with changes in sea-ice concentration. The annual mean pattern is dominated by losses in March, the time of maximum replenishment (Steiner et al 2013b). Focusing on the Canada Basin Fig. 2 shows a continued deepening of the subsurface chlorophyll–a maximum as projected with the Canadian Earth System Model (CanESM2), in correspondence with a deepening of the nutricline (not shown). The regional model indicates temporal shifts along with the deepening, with earlier ice thinning and break up initiating earlier surface blooms, followed by earlier formation of the deep chlorophyll–a maximum.

Figure 2 a) Projected deepening of the subsurface chlorophyll-a maximum in the Canadian Earth System model CanESM2 in the Canada Basin (140W, 75N).



Summary

Despite large gaps in biogeochemical observations in the Arctic and difficulties in establishing baseline information, observations indicate significant changes within the Arctic marine ecosystem as well as indications of feedbacks to higher trophic levels. Earth system models project consistent ocean acidification as well as a deepening of the chlorophyll-a maximum in the Canadian Arctic, but lack agreement in projected primary production. Inconsistencies are related to a limited nutrient data base and variations in sea-ice projections (affecting stratification). An increased focus on high resolution/basin scale biogeochemical modelling in the Arctic is needed. The Multiple stressor environment for Arctic marine ecosystems which is created by climate change (warming, changing sea-ice, species invasion, acidification) and enhanced human activities (potential pollution and oil spills, overfishing) suggests the potential for reduced resilience of Arctic marine ecosystem components. Latter might need consideration in ecosystem models in order to improve future ecosystem projections.

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SAON UPDATE

Sustaining Arctic Observing Networks (SAON) Canada is pleased to release the next issue of the SAON Canada Results Bulletin, which highlights results from monitoring initiatives occurring across the Canadian North, along with their links to policy. This Bulletin was developed in partnership with the Canadian Polar Commission and the Association of Polar Early Career Scientists (APECS) Canada.

Website: http://www.arcticobservingcanada.ca

Contact: contact@arcticobservingcanada.ca

REPORT ON "UNRAVELING OF THE ARCTIC"

Megan McGarrity, Director of Projects, CANADIAN CLIMATE FORUM

This past Earth Day (April 22), a large crowd gathered at City Hall in Ottawa, Canada, to hear from leading Arctic science and policy experts as they shared their research and views about the impacts of a changing climate on the North.

The Canadian Climate Forum (the Forum) hosted this bi-national (Canada/USA) event, in partnership with Arctic21 (US) and World Wildlife Fund (WWF) Global Arctic Programme primarily to raise public awareness about the science of the issues. Another reason this event was held in Canada's capital was to spotlight the Ministerial meeting in Iqaluit, Nunavut to mark the transition of the Chairmanship of the Arctic Council from Canada to the United States government taking place just days later. This was the only public event held in Ottawa to mark the transition of the Arctic Council leadership.

Six world renowned experts summarized serious climate related changes and impacts in two panel sessions that covered glaciers, sea ice, permafrost, biodiversity, black carbon and the indigenous perspective. US Ambassador Bruce Heyman provided an overview of the US government's Arctic Council Chairmanship priorities for the next two years. The morning closed with a visually captivating summary by award winning author and photographer Ed Struzik.

At the conclusion of the two panels' presentations, it was clear that there was a common message delivered by all experts: climate change is affecting the Arctic in unprecedented ways. Glaciers are melting at never before seen rates; Permafrost - the once stable and secure arctic ice chest- is melting and releasing massive stores of carbon dioxide and methane as it disappears; and the oldest multi-year sea ice is melting and not being reformed; it is at the lowest levels ever recorded. The impacts on Arctic wildlife are pervasive: much earlier ice-free waters lead to mistimed attempts at reproduction for some species, for others the icy habitat they prefer for reproduction has simply melted away. Warmer temperatures are leading to an influx of southern flora and fauna to the north, hybridization is being observed, and competition for already scarce Northern resources is increasing.

Melting Glaciers - Dr. Martin Sharp
"Why do glaciers matter?" According to Dr. Sharp the mass of glaciers plays a critical role in the control of sea level and also provides the potential for release of pollutants entombed in the ice. "The last decade in the Canadian Arctic has been unlike anything we've seen in the last 9000 years". The rate of loss in the total mass of glaciers has been accelerating at an alarming rate since the 1990s. For Sharp, "this is not an Arctic problem, it is a global problem. Places like Bangladesh will be most affected by sea level rise and are not equipped to deal with these effects."

Thawing Permafrost – Dr. Antoni Lewkowicz
"What is permafrost and why does it matter?" Permafrost is "earth materials that remains below 0^{0}C for two years or more". According to Dr. Lewkowicz the top "active layer" at the surface freezes and thaws annually with the permafrost present beneath at depths of a few inches to several thousand meters. Permafrost is a climatic phenomenon; in the Northern Hemisphere it influences 24% of ice-free land, and due to climate change, it is warming in all parts of the Arctic and completely thawing in some areas." In addition, permafrost can be likened to a "freezer full of carbon." As Arctic permafrost continues to warm and thaw, massive stores of carbon will be released into the atmosphere, accelerating climate change trends.

Disappearing Sea Ice – Dr. Bruno Tremblay
Scientists use satellite images to examine sea ice extent measured at the end of the summer (typically in September). A decline of about 10% per decade has been observed since 1979 when the first images were taken. Dr. Tremblay noted that while there is annual variation in ice extent there is a clear and significant decrease in sea ice with 2012 revealing a 50% loss and 2014 being declared the year with the lowest level in recorded history. Dr. Tremblay notes that the sea ice extent must be considered in context with the sea ice volume, which also continues to decline. "The amount of very old ice in the Arctic has shrunk to almost

nothing". Dr. Tremblay dismisses the ideas that we have reached a "tipping point", a place where there will no longer be sea ice. "If we reduce our emissions soon and bring the CO2 levels back down, chances are that the sea ice will resume its course in the Arctic Ocean".

Changing Biodiversity - Dr. Risa Smith

Dr. Smith provided a summary of the work by the Conservation of Arctic Flora and Fauna (CAFF) Work Group of the Arctic Council. She focused primarily on impacts being witnessed due to climate change on biodiversity and in turn, the peoples of the Arctic. According to Dr. Smith, the Arctic has unique species not found anywhere else. Climate change is causing changes to populations levels, monitored via the Arctic Species Trend Index. Between 1970 and 2004, populations in the high Arctic regions decreased by an average of 26%, whereas populations in the low arctic have declined by 20% (with the exception of migratory geese). Warmer northern temperatures are bringing new vegetation north and causing biting insect populations to explode, causing southern species to move north to try to escape the insects. The influx of Southern species, like the grizzly bear and the red fox, creates contact with northern species like the polar bear and Arctic fox, causing conflict and in some cases, hybrid populations.

Policy Action and Black Carbon – Ms. Erika Rosenthal

Ms.Rosenthal's work in the Arctic and with the Arctic Athabascan Councils has exposed her to the many changes faced by peoples of the North. With regards to black carbon and methane, Ms. Rosenthal says there is a better understanding today how these "short-lived climate forcers", are having a significant impact in the Arctic. Black sediment is deposited from the atmosphere on the snow and ice covered surfaces of the Arctic amplifying sunlight absorption, which in turn amplifies melting and warming. Reducing black carbon sediments will have immediate beneficial outcomes for stabilizing the situation in the Arctic. She said that such reductions are being pursued via 'The Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions' which was by signed by Member Nations of the Arctic Council in collaboration with the Permanent Participants on April 24th at the Arctic Council's Ministerial meeting in Iqaluit, Nunavut'. This agreement includes targets for emissions inventories from each of the eight member nations, action plans on mitigation strategies, and national reporting on progress to the Arctic Council. Ms Rosenthal noted that this Framework agreement was a major accomplishment and while it could have included more robust targets, we've got a tremendous amount to work with."

Indigenous Perspectives - Mr. Terry Audla

Mr. Terry Audla, President of Inuit Tapiriit Kanatami (ITK) described the Arctic as home to a people with generations of knowledge of the unique Northern environment, and its many challenges. He underscored that "the Arctic is not the last frontier, it is our home" and that , "traditional knowledge is inextricably linked to scientific knowledge, especially in Canada's Arctic". He went on to say that in all regions of the Arctic, people are describing that the environment and weather are more unpredictable, and that sea ice is changing, and emphasized that these changes have had serious impacts on livelihoods, especially hunting. He stated that 70% of Inuit food supply depends on hunting, and 90% of those who harvest wildlife share with other households. "Food insecurity in the North is six times what it is for the average southern Canadian family."

Furthermore, the warming climate means shifting economic prospects in the Arctic. Mr. Audla notes "resource extraction and tourism (are) on the rise" but that "the Inuit people support development, but not development at all costs". Northern unemployment rates remain four times higher for aboriginals versus non-aboriginals. In closing, Mr. Audla addressed the Inuit call for action on climate change noting that Southerners' lack of knowledge of the Inuit way of life, and misinformed campaigns can have negative impacts on the Inuit and "real conservation efforts".

Future Arctic – Mr. Ed Struzik (see photos page 5)

"What will the Future Arctic look like?" While weaving stories from his decades photographing and writing about the Arctic, Mr. Struzik warned of many threats including increased shipping in the Arctic ocean. According to Mr. Stuzik, it is "not if, but when there is an oil spill, the closest ice breaker could be a week away. Then once a cleanup crew finally arrives, separating oil from ice becomes a nearly impossible task." He notes that global actions are needed to control carbon dioxide, and those taken to date are too little to stabilize the changes. Finally, he stated that one of the greatest challenges relates to who has jurisdiction over the Arctic. This is especially relevant in light of the many, current claims being made by various nations who see great economic opportunities related to ice-free shipping, and an abundance of fossil fuels and other natural resources to exploit.

Looking Ahead – The Arctic Council

Under the US government's 'One Arctic, Shared obligations' mandate, US Ambassador Heyman described the three main objectives being established to guide the Arctic Council's activities over the next two years:

1. Arctic Ocean Safety, Security and Stewardship - plans to examine the establishment of marine protected areas, discuss a regional seas agreement and launch joint search and rescue exercises.

2. Addressing the Impacts of Climate Change - developing a strategy aimed at reducing black carbon and methane in key sectors, which is a priority for President Obama and Secretary Kerry.

3. Improving Economic and Living Conditions in the North- strategies for improving or increasing the availability and/or quality of renewable energy, water, sanitation, mental-health services and telecommunications services.

The 'Unraveling of the Arctic' event delivered some alarming facts about the unprecedented changes already affecting the Arctic. However all speakers were optimistic that many of these impacts can be reduced if action is taken soon. As Chair of the Arctic Council, the US government has a long list of initiatives to fulfill in the pursuit of reversing such trends. Meaningful impact will come from continued development of policy frameworks, such as the one recently signed on black carbon and methane, to in turn institutionalize the mechanisms that will guide needed change. What is clear is this is not solely an Arctic challenge, but rather a global one. All nations, particularly major greenhouse gas (GHG) emitters, will need to step up at the upcoming United Nations Convention of the Parties (COP) meeting in Paris (December) and commit to ambitious reduction targets. As Ambassador Heyman stated, this is about 'shared obligations' and a collective hope for a binding agreement in Paris, and the US government's success in meeting its goals and objectives as they lead the Arctic Council into a new era.

TwoWays of Knowing – Scientists and Inuit Knowledge Holders

Whistler Conference Centre - Wednesday, June 3rd – 15:30 -17:00

Rainbow Room

Clockwise from the left, Hal Richie, Baba Pederson, Frank Pokiak and Bill Williams will examine the interactions between Inuit knowledge holders and northern researchers. Discussions will look at new and innovative ways of addressing communicaton between the "Two Ways of Knowing" by examining lessons learned and opportunities for scientists and Inuit knowledge holders to work better together in Arctic Science.

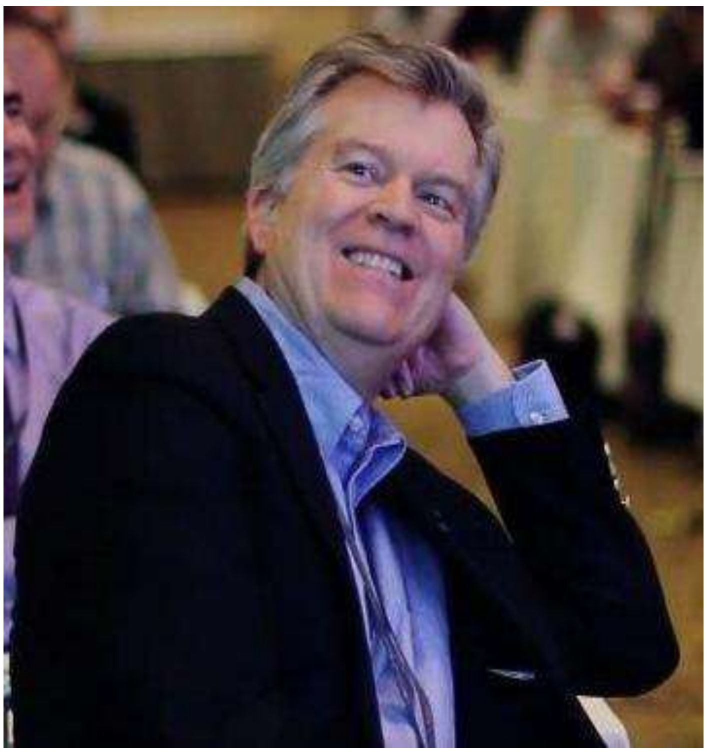
We hope that some recommendations will be forthcoming on how to work more closely together in the future. The Arctic Special Interest Group will take those for action

THE END OF AN ERA

After nearly 35 years, Russel Shearer has announced he will be retiring from the public service. His staff and many colleagues and friends have let him know that we won't be letting him slip into retirement quietly!
Please join us at the Heart & Crown, 67 Clarence Street (Byward Market) on June 11, 2015 (3-6pm) for a celebration of Russ's distinguished career in northern & circumpolar science. Whether you are here in town (Ottawa, that is) or far away, there are ways to take part in the celebration of Russ's years of dedication, hard work and camaraderie; to reminisce about some "legendary" and other lesser known moments in his career; and to wish him well in his retirement.
Please RSVP via https://www.surveymonkey.com/s/6G7Q5SV by May 22 (sorry this notice is late)

We are also inviting all of you to submit well-wishes & thoughts by email (PLCN-NCP@aadnc-aandc.gc.ca) or via a short audio or video clip (to Martin Fortier at martin.fortier@arcticnet.ulaval.ca), by May 30.
Further, if you have any photos of Russ from any time throughout his career that we may use to create a unique photo montage, please send these to Martin (martin.fortier@arcticnet.ulaval.ca), also by May 30. Humourous pictures are encouraged!
As Russ's professional circles have reached far and wide, please feel free to forward this message to other colleagues of Russel who we may have missed.
We look forward to seeing you in large numbers in Ottawa on June 11!

Best regards,
All of us at the Northern Contaminants Program Secretariat
Sarah Kalhok Bourque, Jason Stow, Simon Smith, Scott Tomlinson, Natasha Chartres, Ewa Lifsches& Rami Yassine.



For additional information, please contact Natasha Chartres at Natasha.Chartres@aadnc-aandc.gc.ca

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Après près de 35 ans, Russel Shearer a récemment annoncé qu'il prendra sa retraite de la fonction publique. Son personnel et de nombreux collègues et amis lui ont fait savoir qu'ils ne le laisseraient pas partir à la retraite paisiblement! Joignez-vous à nous au Heart & Crown, 67 rue Clarence (marché Byward) le 11 juin prochain (15:00-18:00h) pour une célébration de la remarquable carrière de Russ en science nordique et circumpolaire. Que vous soyez ici à Ottawa ou ailleurs sur la planète, vous pourrez prendre part à la célébration ses nombreuses années de dévouement, de travail acharné et de camaraderie. L'événement sera aussi le moment idéal pour souligner plusieurs moments "mémorables" et moins connus de sa carrière!
Veuillez s'il vous plaît confirmer votre participation via ce sondage (https://www.surveymonkey.com/s/6G7Q5SV) **d'ici le 22 mai.**

Nous vous invitons tous également à soumettre des bons voeux ou à partager des anecdotes par courriel (PLCN-NCP@aadnc-aandc.gc.ca) ou sous forme de courtes capsules audio ou vidéo (martin.fortier@arcticnet.ulaval.ca), avant le 30 mai. De plus, si vous avez des photos de Russel prises au cours de sa carrière, veuillez svp les envoyer à Martin Fortier (martin.fortier@arcticnet.ulaval.ca), d'ici le 30 mai. Les photos loufoques sont encouragées! Nous désirons faire un montage photo soulignant sa carrière.
Les réseaux personnel et professionnel de Russel sont vastes et dépassent les frontières, nous vous encourageons à partager ce message aux collègues de Russel qui ont pu nous échapper.
Au plaisir de vous voir en grand nombre le 11 juin à Ottawa.

Salutations,
Les membres duSécrétériat du programme du lutte contre les contaminants dans le Nord
Sarah Kalhok Bourque, Jason Stow, Simon Smith, Scott Tomlinson, Natasha Chartres, Ewa Lifsches& Rami Yassine.

Pour autresinformations, veuillez contacter Natasha Chartres (Natasha.Chartres@aadnc-aandc.gc.ca