Long-Term Observatories in Canadian Arctic Waters

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Abstract

The past decades witnessed a spectacular reduction of Arctic sea ice (Maslanik et al. 2011), culminating in September 2012 when both extent (-50%) and volume (-82%) reached all time record lows relative to the recent climatology (last 1500 years). The ice cover insulates the ocean from the atmosphere. A shrinking ice cover means that more light and heat enter the surface Arctic Ocean, drastically changing the temperature, storm, and ice regimes, as well as conditions for life. The objective of this project is to track such changes in the physical, biological and geochemical properties of Canadian Arctic waters. In the past, we have deployed ocean observatories in Hudson Bay, Hudson Strait, Baffin Bay, Beaufort Sea and the Eastern Arctic Ocean. These observatories are the oceanic equivalent of atmospheric meteorological stations. They are deployed every fall and recovered one year later. While moored, they record temperature, salinity, water velocity, dissolved oxygen, nutrients, light intensity, fluorescence (an indicator of micro-algae biomass), the vertical flux of particles, and ice motion. In addition, hydrophones record the vocalization of whales and other marine mammals. The data is used to describe seasonal, annual and interannual variations in the Arctic environment and its local ecosystems. This, in turn, enables us to understand how global warming is affecting the Arctic and how fast.

Key Messages

- Shelf-break currents are very efficient in transporting the relatively fresher and cooler Pacific water of winter origin eastward along the Beaufort Sea continental slope. Shelf-break current events cause significant mixing at the upper Atlantic water layer enhancing upward heat loss, and resuspension of bottom sediments.
- In the vicinity of the critical latitude at ~74.5°N, the inertial frequency interferes with the dominant lunar semidiurnal (M2) tidal constituent, producing an instability that contributes to enhance tidal mixing in the region.
- Strong upwelling in the winter 2010-2011 likely pushed lower halocline water onto the Beaufort Sea Shelf where it cooled to form salty Beaufort Sea Winter Water (BSWW).
- Due to the persistent association between the Sub-surface Chlorophyll Maximum and the shallow nitracline, the pelagic ecosystem of the coastal Beaufort Sea is apparently characterized by a high ratio of new to total production, contrasting with the common assumption that oligotrophic systems are predominantly supported by recycled N and regenerated production.
- During the ice covered (≥ 90% cover) period, from November 2005 to mid-June 2006, sea ice deformations from internal and external forcings generated various acoustic transients due to sea ice fracturing, cracking, shearing, and ridging. A dictionary of these sounds was developed.
- The inter-annual variability of ocean circulation, acoustic particle backscattering and sediment fluxes from 2009 to 2012 over the 700 m isobath in the exploration block EL476-Ajurak revealed the recurrence of intense sedimentation events coupled with strong current surges (>40 cm s^{-1}; Figure 4). These results provide a better understanding of potential oil spill trajectories and interactions with extreme hydrodynamic features.
- The amplification of the shelf-break jet following the propagation of a large polar low over the Beaufort Sea can erode the upper slope and disperse sediments offshore. Such underwater storms and other spectacular events like the rapid export of coalescing ice algae and phytoplankton blooms could be monitored in real time with a low-power cabled observatory deployed at the shelf-break.

Objectives

The overarching objective of the Moorings project is to track decadal changes in the Arctic Ocean using moored arrays of different oceanographic instruments. We focus on ocean climate and circulation, sea-ice cover, tides, the origin of water masses, soundscapes, the vertical and horizontal fluxes of biogenic carbon and particles, nutrients, primary production, and marine mammal vocalizations. Specific scientific objectives include:

- In collaboration with other international programs, to track the penetration and circulation of Atlantic water into and around the Arctic Ocean. We also quantify the Pacific water transport, variability and water masses transformation mechanism as it reaches the Mackenzie Shelf and then bifurcates into the Amundsen Gulf. Knowing what is coming will help us understand how (and when) this water is flowing through the different straits in the Canadian Archipelago. This data is also essential to validate the circumpolar Arctic models that produce the boundary conditions for our IRIS regional models;
- In close collaboration with the Hotspots project, to document fall-to-spring conditions in identified regional biological hotspots with emphasis on interannual variability in productivity and frequentation by top predators. In particular, we want to monitor changes in nutrients availability and biological production in relation to sea-ice cover reduction and warming of the surface layer;
- To monitor the seasonal variability in the timing and magnitude of vertical carbon fluxes. In the past, it was observed that the sedimentation rates (from sediment traps) are highly seasonal and sometimes influenced by current pulses. We plan to relate the changes in vertical carbon fluxes to the reduction in sea ice cover and increasing sea water temperature that dictate changes in primary and secondary productions;
- To develop, adapt to Arctic conditions, and exploit Passive Acoustic Monitoring (PAM) technologies to monitor the frequentation of Arctic biological hot spots by marine mammals over their annual migration to feeding and breeding grounds. We hope to relate variations in habitat use to changes in ecosystem productivity, community composition, and spatial organization as climate changes;
- As part of an international effort on ocean noise and to anticipate the impacts of an eventual increase in Arctic shipping, to characterize the underwater noise patterns of the pristine Arctic Ocean and compare this soundscape to that of the lower latitude belt already strongly affected by anthropic activities.

Introduction

The Arctic is changing more rapidly than predicted by the most pessimistic climate models. In the past decade, we have witnessed a spectacular reduction of Arctic sea ice (Maslanik et al. 2011), culminating in September 2012 when both extent (-50%) and volume (-82%) reached all time record lows relative to the recent climatology. The Canadian Arctic Straits and Fram Strait connect the waters of the Arctic Ocean to those of the Atlantic. Arctic surface water moves via these straits into the Labrador Sea, thereby stabilizing a global imbalance in precipitation minus evaporation between the Pacific and Atlantic Oceans (Wijffels et al.1992). Fluctuations in the fluxes of freshwater through the Archipelago may have global significance for climate through their influence on deep convection in the Atlantic sector (Melling, 2000). The ice cover, i.e. the insulation between the atmosphere and the ocean, is shrinking and modifying the heat and momentum fluxes between the two. This freshwater will ultimately condition the surface waters of the Labrador Sea and, in the worst case scenario, will contribute to slow down the global conveyor belt circulation (Dickson et Visbeck, 2002). In the best case scenario it will modify the oceanographic conditions on the Grand Banks (Myers, 2005). Another major change is the increase in the heat transported into the Arctic Ocean by the Atlantic waters (Walczowski and Piechura 2006). Observations from the NABOS program have also shown that the temperature of North Atlantic water entering the Arctic has increased in recent years and that pulses of ocean heat occur (Polyakov et al., 2005). All these changes are linked to the global climate system and the scarcity of observations is impeding our ability to understand the linkages.

We also critically need to better understand the connections between the ecosystems and their environment in ice-covered regions to anticipate the impacts of global warming. The increase in the duration of the ice-free season will have major consequences for the marine environment. First, marine mammals relying on presence of ice to complete their annual life cycle, such as seals, belugas, narwhals, bowheads and polar bears will be directly affected by the changes in timing and duration of the ice period and indirectly by the associated ecosystem changes. Second, this region could become as productive as the Barents Sea and see the emergence of new fisheries. Third, some areas of the Canadian Arctic Ocean could contribute increasingly to the sequestration of atmospheric carbon via an acceleration of the physical, chemical and biological carbon pumps.

Activities

Time frame and study area

In 2013, the planned recovery of moorings and the deployment of new ArcticNet moorings in the Beaufort Sea were cancelled along with all operations from the *Amundsen* following the crash of the helicopter. To palliate partially the situation, the moorings deployed in 2012 by our partner program Southern and Northeastern Beaufort Sea Marine Observatories of the Beaufort Regional Environmental Assessment (ArcticNet and IMG-Golder) were successfully recovered by the CCGS *Laurier* thanks to the help of our colleagues at DFO-Nanaimo (Melling et al.). The moorings could not be redeployed this year and will be redeployed in 2014.

Research activities in 2012-2013

Research activities in 2013-2014 focused on data analysis, the completion of theses, the development of new international collaborations for the joint deployment of moorings, and the continued successful re-organization of the project.

Four ice-tethered moorings were deployed in October 2013 in the Young Sound Fjord in the eastern coast of Greenland in cooperation with Greenland Climate Center, Aarhus University, Denmark and ArcticNet (Figure 1). Two moorings are equipped with McLane Moored Profiler (MMP) profilers (Figure 1, right) provided by ArcticNet. Moorings are designed to record tidal and ice driven vertical mixing and coastal polynya impact on fjord dynamics.

As well, moorings carrying Passive Acoustic Monitoring hydrophones to detect and classify walrus vocalizations were deployed in Hudson Strait in collaboration with French colleagues.

A community white paper on the need to sustain bio-mooring arrays and long-term sediment trap time-series in a changing Arctic led by Alexandre Forest and four co-authors from Japan, Korea, Germany and Norway was presented at the Arctic Observing Summit 2013, co-sponsored by ArcticNet.

We developed a new collaboration with the Alfred-Wegener Institute for the deployment in 2014 of two MMPs moorings in Fram Strait as part of the German Hausgarten observatory. This is an initial step in the building of a larger joint program with the objective of developing a complementary observatory in Baffin Bay. This Baffin Bay observatory would also support the GreenEdge multidisciplinary program that we are trying to set up to study the ecosystem of the ice margin in Baffin Bay.

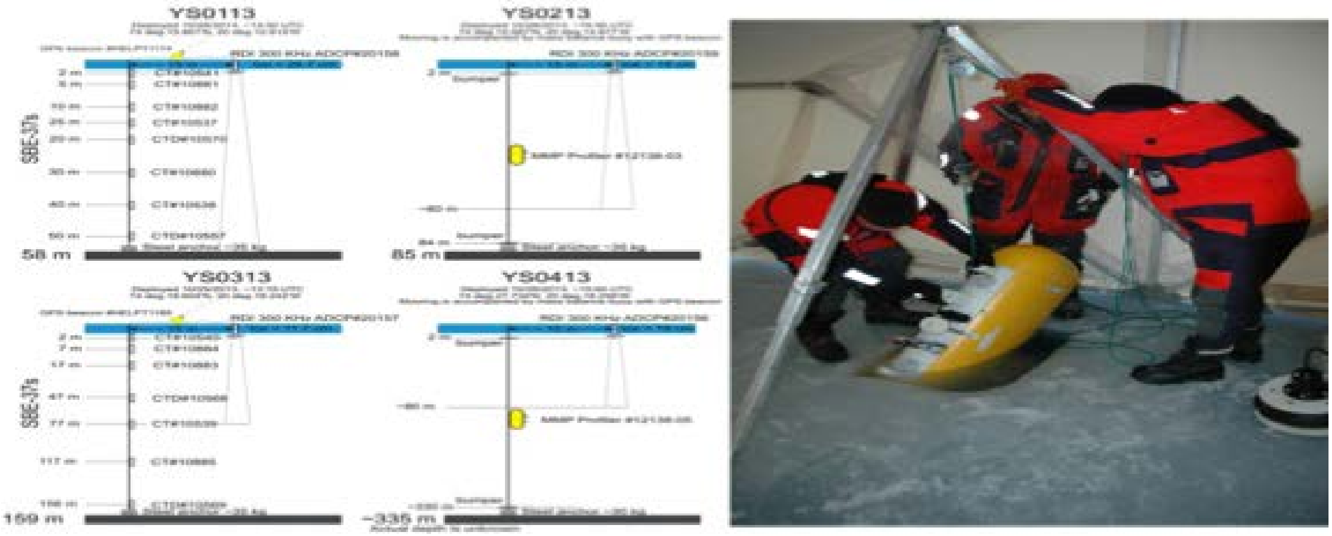

Figure 1. Schematic of moorings deployed in the Young Sound Fjord, eastern coast of Greenland (left) and deployment of the ArcticNet MMP profiler in October 2013 (right).

Discussions with our Japanese colleagues at JAMSTEC have led to a new collaboration that will see the recovery by the *Amundsen* of Japanese moorings from the Chukchi Plateau. This is potentially a long-term collaboration that will expand west the normal region of operation of the *Amundsen*, leading the way to the eventual international Arctic Ocean Drift Study.

Three students completed their PhD theses within the framework of this project in 2013-2014:

- Nahavandian, S, 2014. Temporal and Spatial Evolution of the Mixed Layer in Southern Beaufort Sea and the Amundsen Gulf. Ph.D., Institut national de la recherche scientifique, Centre eau, terre et environnement, Québec (Qc), 158 p.
- Sévigny, C. 2013. Mélange et fronts océaniques dans la couche de surface du Golfe d'Amundsen et de l'Arctique Canadien. Ph.D., Institut national de la recherche scientifique, Centre eau, terre et environnement, Québec (Qc), 247 p.
- Kinda, G. B., 2013. Acoustic remote sensing of Arctic Sea ice from long term soundscape measurements. Ph.D. GIPSA-Lab., Univ. de Grenoble. Grenoble, France.

Results

Long-term measurements of physical, biogeochemical and ecological variables in the Canadian Arctic are critical to our ability to detect significant trends in marine ecosystem change. The Long-Term Observatories (LTOO) program provides baseline information on sea ice dynamics, ocean circulation, biogeochemical fluxes and marine mammal activities. But several other teams also use our results in second-level analyses and modeling exercises intended to decipher the linkages among the different components of the Arctic System. Although several adverse situations limited field operations in 2012 and again in 2013, we have continued to maximize the various datasets collected with the mooring-based instrumentations deployed as part of the LTOO program over the last few years. The following results clearly illustrate how this project forms a vital component of the ArcticNet scientific strategy by providing key insights on marine processes.

Shelf-break circulation events and tidal velocity shear (Dmitrenko, Kirillov, Petrushevich, Komarov, Forest)

CTD and ADCP data from moorings CA04-04, CA07-04 and CA13-03, the NCEP wind data and AMSR-E sea ice data were analyzed to identify the shelf-break current events and associated modifications in the water column. It has been shown that the shelf-break currents are very efficient in transporting the relatively fresher and cooler Pacific water of winter origin eastward along the Beaufort Sea continental slope (Figures 2b-1e). It seems that the shelf-break current events cause significant mixing at the upper Atlantic water layer enhancing upward heat loss, and resuspension of bottom sediments (Figure 2f).

The ADCP velocity data from ten CASES year-long (2003-2004) moorings were analyzed to reveal the velocity shear attributed to a depth-dependent phase behavior of the semidiurnal currents (Figure 3). In the vicinity of the critical latitude at ~74.5°N, the inertial frequency is close to the frequency of the dominant lunar semidiurnal M2 tidal constituent. These two different constituents interfering at similar frequencies with different phases produce phase disturbances. Our results show that the phase-driven velocity shear dominates the tidal dynamics during the ice-free period as well as during the beginning of the winter season indicating a role of wind forcing with potential implications for shear instability and vertical mixing. In turn, this instability contributes to enhance

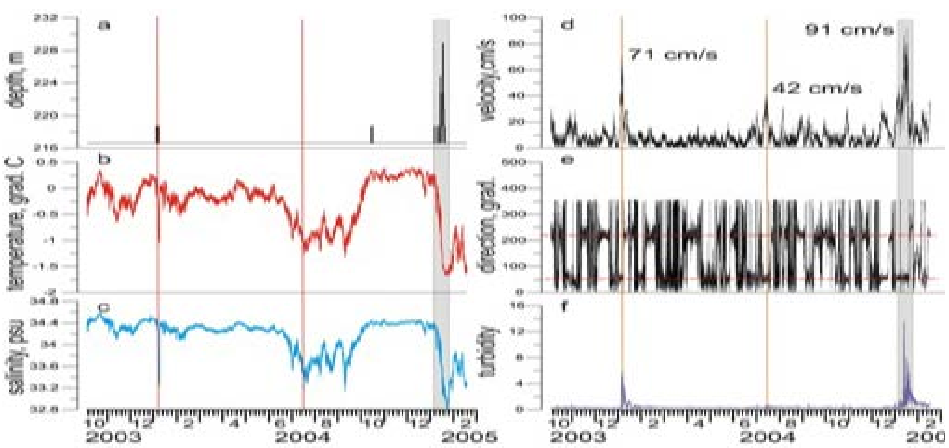

Figure 2. Time series of (a) pressure, (b) water temperature, (c) salinity, (d) velocity, (e) current direction and (f) turbidity from mooring CA13-03 at 216 m depth. Gray shading indicates shelf-break wind-forced current event in January 2005.

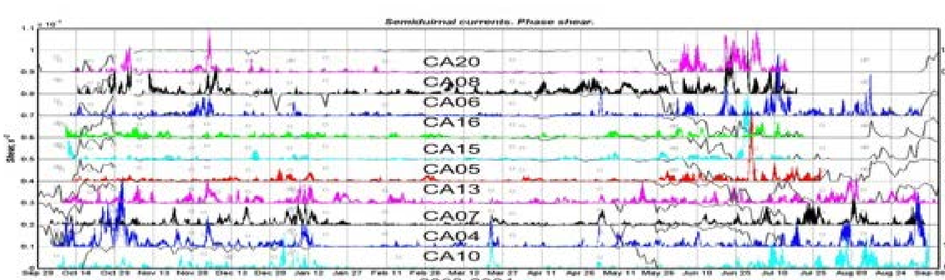

Figure 3. Velocity shear in 20-50 m layer attributed to the depth-dependent behavior of phase for the semidiurnal tidal currents. Black line indicates sea ice concentration from 0 to 100% from the AMSAR-E satellite imagery. Gray dots depict wind events exceeding 10 m/s.

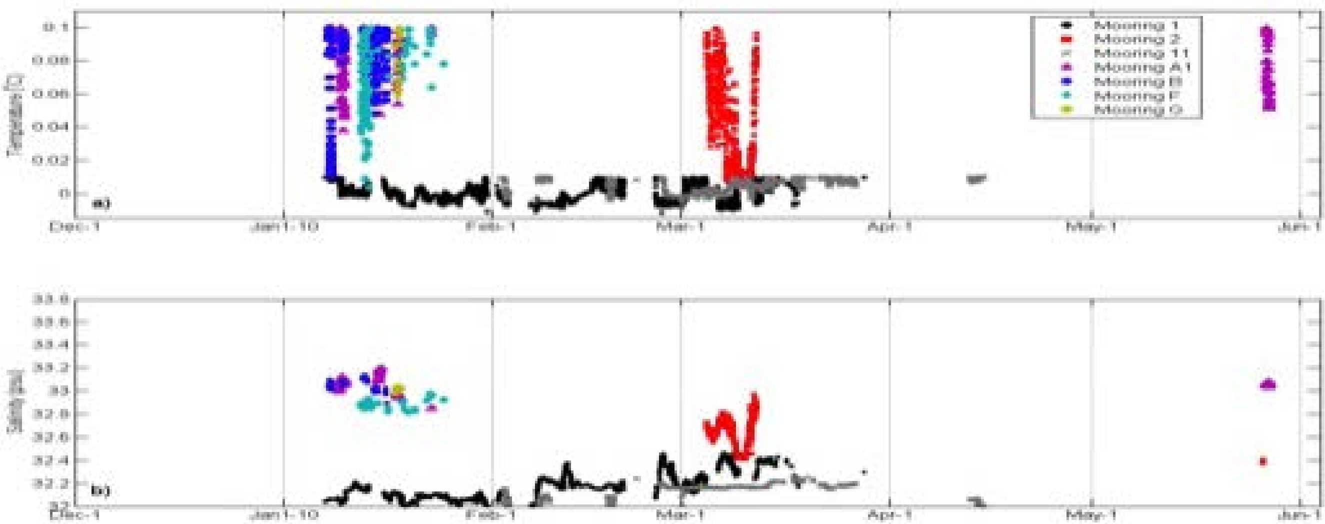

Figure 4: Temperature (top) and salinity (bottom) of Beaufort Shelf Winter Water (BSWW) and Cold Shelf-water Intrusion (CSI) observed during the winter of 2009 -2010. BSWW is formed on the shelf and CSI is observed on the slope so BSWW would be observed at moorings 1 and 11 and CSI would be observed at moorings 2, A1, B, F, and G.

tidal mixing observed over the critical latitude. The suggested mechanism competes with shear instability attributed to the baroclinicity of the tidal flow originated from interaction with bottom topography and density stratification.

The formation of Beaufort Shelf Winter Water (BSWW) (Jackson, Lukovich, Borg, Fissel, Melling, Barber)

The formation of Beaufort Shelf winter water (BSWW) helps to maintain the halocline of the Arctic Ocean and modifies the nutrient properties of Pacific water in the Beaufort. During some winters, BSWW is formed that is salty enough to form a density plume that flows from the shelf to the slope. BSWW is modified as it is advected to the slope. This modified BSWW is observed on the slope cold shelf-water intrusion (CSI). Despite the importance of these waters, the exact processes that cause BSWW and CSI to be formed are not known. Using shelf and slope mooring data collected from 2009-2011, we examine BSWW and CSI together with the environmental conditions (wind and sea ice) to understand what physical processes cause salty BSWW to form. BSWW and CSI were observed during both winters, however, during the winter of 2009-2010, BSWW was too fresh to be the source of CSI observed on the slope (Figure 4), implying that there is another source of CSI besides the western Canadian Beaufort Shelf. During the winter of 2010-2011, CSI was very similar to BSWW observed at mooring 1, suggesting that the source of CSI was BSWW that was advected from the shelf through Kugmallit Valley. Upwelling was much stronger during the winter of 2010-2011 and it is likely that this enhanced upwelling pushed lower halocline water onto the shelf where it cooled to form salty BSWW.

Subsurface chlorophyll maxima in the Beaufort Sea: a model assessment (Martin, Dumont, Tremblay)

Results from the mooring program often provide key information for the development and calibration of models of the ecosystems. In this example, physical and biogeochemical data were used to test a model of the Subsurface Chlorophyll Maximum (SCM) in the Beaufort Sea. To estimate the impacts of fluctuating or changing environmental conditions on SCM, a numerical approach combining a turbulence model and an ecosystem model was implemented for the

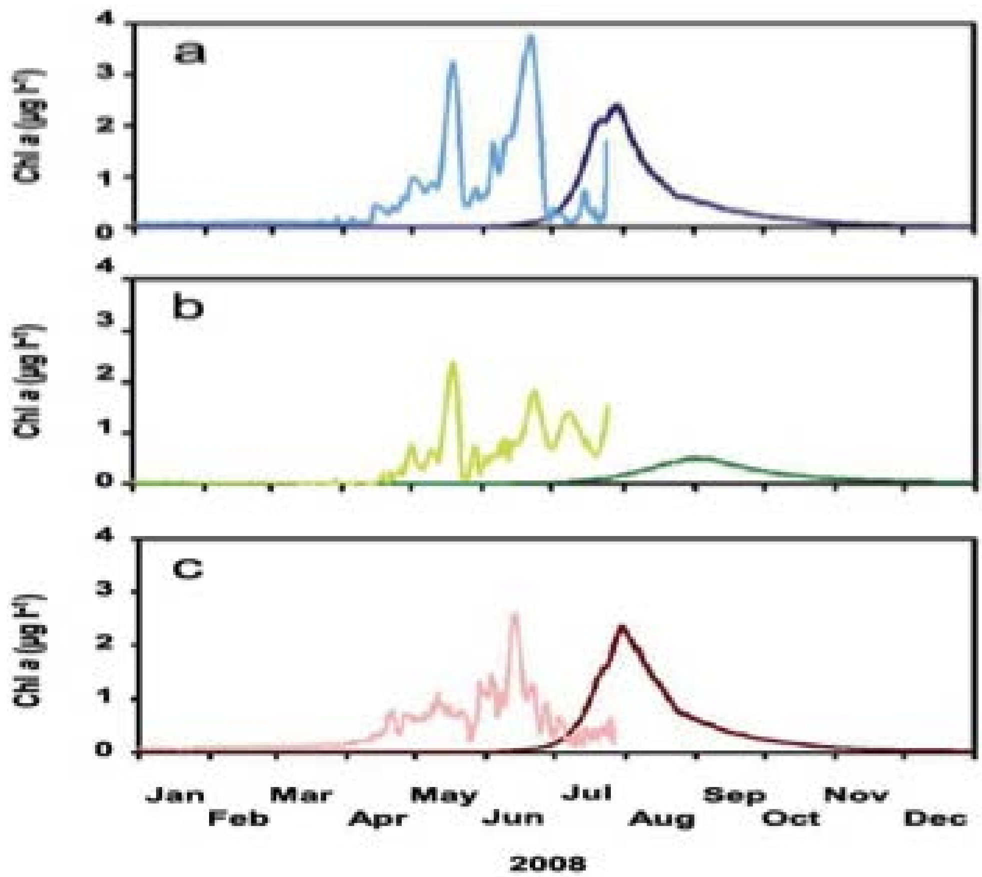

Figure 5. Time series of chlorophyll biomass recorded by moored sensors (light colour solid lines) and produced by a model of Subsurface Chlorophyll Maximum (dark colour solid lines) for mooring station CA05 at 34 m (a, blue), CA05 at 51 m (b, green), and CA08 at 37 m (c, pink) in 2008.

Beaufort Sea. An ensemble analysis of simulations suggested that SCM contribute 65–90% of total annual primary production and that this proportion is weakly affected by ice regime, winter nitrogen (N) concentration, parameter values determining phytoplankton growth and decay or the physical forcing imposed, all varying within realistic values. Due to the persistent association between the SCM and the shallow nitracline, the pelagic ecosystem of the coastal Beaufort Sea is apparently characterized by a high ratio of new to total production, contrasting with the common assumption that oligotrophic systems are predominantly supported by recycled N and regenerated production. This study demonstrated that the use of a simple model in combination with in situ data leads to novel insights into biogeochemical processes that are otherwise very difficult to measure and track (figure 5).

The acoustic signature of sea ice in Eastern Beaufort Sea (Kinda, Simard, Gervaise, Mars, Fortier)

Long-term ocean noise recordings in the marginal ice zone of the Canadian Arctic in the Eastern Beaufort Sea were analyzed to detect strong transient acoustic events from biological or physical sources using a dedicated algorithm to isolate them from ambient noise. During the ice covered (≥ 90% cover) period, from November 2005 to mid-June 2006, sea ice

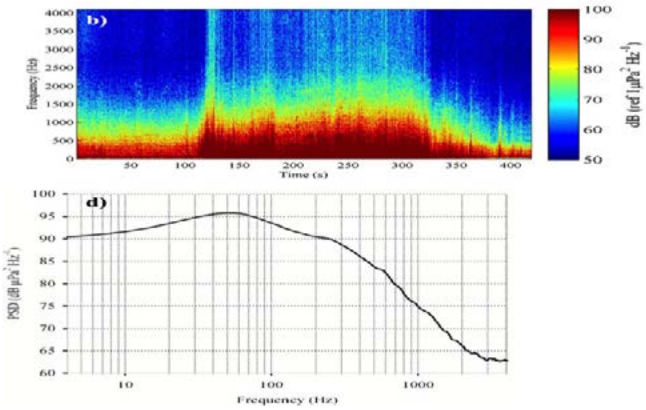

Figure 6. Spectrograms and average power spectral density of wideband transients noise events associated with the wind-driven opening of a large lead in the marginal ice zone of the Eastern Beaufort Sea ice sheet on February 6, 2006.

deformations from internal and external forcings generated various acoustic transients due to sea ice fracturing, cracking, shearing, and ridging. A dictionary of these sounds was developed. Satellite observations were used to illustrate the kind of lead opening/closing corresponding to wideband noise tones and impulses. Some transient acoustic events of variable durations are repeated with a period corresponding to surface waves and can sometimes be confounded with marine mammal songs. The correlations of the transient occurrences with the environmental variables showed that the loud acoustic transient, which can propagate over long distances, were related to sea ice shear deformations (figure 6).

High sedimentation events and high-velocity currents over the slope of the Canadian Beaufort Shelf (Forest, Osborne, Fortier, Sampei)

Recent analyses on the inter-annual variability of ocean circulation, acoustic particle backscattering and sediment trap-series on ArcticNet/Beaufort Regional Environmental Assessment (BREA) mooring A from 2009 to 2012 (deployed on the 700 m isobath in the exploration block EL476-Ajurak) revealed the recurrence of intense sedimentation events coupled with strong current surges (>40 cm s^{-1}; Figure 7). A total of six sedimentation peaks with vertical fluxes above 1.5 g dry weight (DW) m^{-2} d^{-1} were detected throughout the 3-year period. These events are currently under investigation by our industrial partner Golder Associates Ltd. through a research and development fellowship granted to former ArcticNet post-doc Dr. Alexandre Forest. The goal of this research relates to gaining a better understanding of potential oil spill trajectories and interactions with extreme hydrodynamic features and sediment clouds propagating in the water column. In particular, a better quantification of particulate matter fluxes is needed given their influence on the migration of oil in water through control on density properties, sorption, aggregate formation, and offshore transport.

Current surges and associated maxima III and VI were linked to the occurrence of strong winds that transferred large quantity of momentum to the ocean that triggered sediment resuspension and subsequent advection beyond the shelf break (Figure 7a). At this stage, it is not clear why the relatively strong winds detected in fall 2009 did not result in any intensification of sediment fluxes. In any cases, strong winds blowing from the North were dominant in the southeast Beaufort Sea in both the fall of 2010 and 2011, which resulted in the west-southwestward ocean surface flow discernable in the upper 200 m of the mooring record. Strong northerly winds in October 2010 and 2011 were related to an above-average sea level pressure centered over the northern Beaufort Sea.

Maxima I and IVa,b occurred both during winter (January-March) and can likely be related to an amplification of the shelf-break jet following the propagation of a large polar low over the Beaufort Sea. Maximum instantaneous current speed during these events reached velocities as high as >80 cm s^{-1}. Although not as intense as the so-called storm of the century detected in 2005 with the ArcticNet mooring array over the slope (Dmitrenko et al., unpublished), these events were significant enough to erode the upper slope and disperse sediment offshore. Time-series of salinity-temperature at mooring A and B (not shown) provided evidence that these events were at least partly related to a more intense production of dense brine

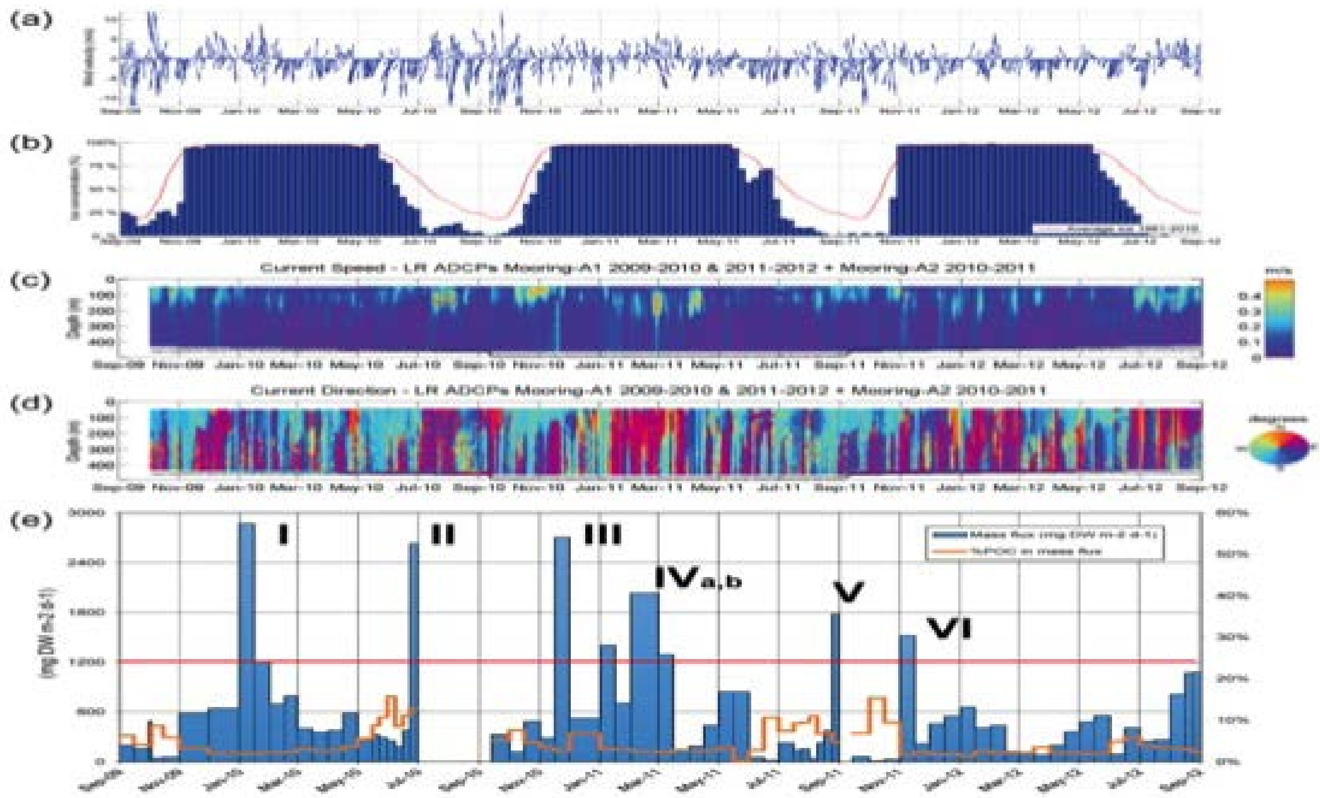

Figure 7. Time-series from September 2009 to September 2012 of (a) daily-mean wind vectors over the Mackenzie Shelf and Slope as extracted from the NCEP-NARR reanalysis; (b) total sea ice concentration over the same region as obtained from the Ice chart archives of the Canadian Ice Service (sub-region cwa01_02); (c, d) current velocity and direction measured with a Long-Ranger Teledyne RDI ADCP (75 khz) attached at ca. 450 m on mooring A; and (e) seasonal fluctuations in vertical mass fluxes and related organic carbon content as collected with a Technicap PP3/3 cylindrico-conical sediment trap (24-cups, 0.125 m^2 aperture) deployed at ~200 m depth. The roman letters I to VI depict the high sedimentation events (above 1500 mg m^{-2} d^{-1}) detected over the three-year period.

water over the shelf (e.g. following a storm-induced lead expansion) that would cascade and be laterally transported offshore. As observed previously, summer maxima II and V were likely induced by the rapid export of autochthonous material such as coalescing ice algae aggregates (June 2010) or the sinking of a senescent phytoplankton bloom (August 2011). But the exact nature of the vertical export remains to be confirmed with microscopic analyses.

Discussion

A significant advance by the Marine Observatories project in 2013-2014 was the description by several related studies of the genesis, propagation and impacts of cyclonic eddies travelling from west to east along the slope of the Beaufort Sea continental shelf (e.g. Dmitrenko et al. 2013, Forest et al 2013, Forest et al. in preparation). These transient current surges or underwater storms apparently play an important role in sediment resuspension and the reshaping of the shelf-break. The upwelling of nutrients associated with such events could also influence offshore primary production over the continental slope and explain the aggregation there of zooplankton and fish. This new understanding of the physical, biogeochemical and ecological seascape of the shelf-break is utterly relevant to our understanding and prevision of the potential impacts of exploration drilling at the shelf edge.

Again this year, progress was maintained in the integration of primary production and sediment trap data from the Beaufort Sea, Laptev Sea, North Water and Hudson Bay. Among the several dozens of articles published and presentations given so far by this component of the project, the 2013-2014 production further refines our synthesis of the functioning of the arctic pelagic ecosystem, its coupling to the benthic ecosystem, and its potential evolution as the ice cover regresses and the surface layer of the Arctic Ocean warms up. Most of the work in the current fiscal year focused on the variability in the external factors forcing the ecosystems and the vertical and horizontal carbon fluxes. Teasing out the relative contributions of local biological production, river inputs and air-sea fluxes in the Beaufort Sea, we conclude that: (1) climate change is exacerbating the already extreme biological gradient across the Arctic shelf-basin system; (2) the Mackenzie Shelf acts as a weak sink for atmospheric CO_2, implying that primary production exceeds the respiration of terrigenous and marine organic matter in the surface layer; and (3) shelf break upwelling can transfer CO_2 to the atmosphere, but massive outgassing can be attenuated if nutrients brought also by upwelling support diatom production. Cross-shelf exchange of waters, nutrients and particles is a key mechanism that needs to be properly monitored as the Arctic transits to a new state. Such information provides precious insights into the potential fate of eventual oil spills as they are dispersed over the shelf.

In 2013-2014 the Passive Acoustic Monitoring (PAM) component of the Marine Observatories project further characterized the soundscape of the Beaufort Sea, revealing of rich background of ambient noise in which the rumble of moving sea ice can sometimes be strong enough to be confounded with marine mammal vocalizations. As announced last year, the study of the causes of ambient noise unveiled an entirely new approach to study the dynamics and thermodynamics of sea ice by listening to the spectrum of sounds it produces, which ranges from murmur to thunder. Work in 2013-2014 uses these new indirect measures of wind intensity at the surface to study circulation, vertical mixing, and nutrient renewal, thus further connecting the different components of the project, from physics, to PAM, primary production and particle fluxes. Long-term records of marine mammal vocalizations are also yielding the first analyses of the frequentation of biological hotspots by the different species of whales in summer and seals throughout the year.

While further syntheses of physical measurements are needed, it is important to recall that the physical data produced by the Marine Observatories project continue to be validated, quality-controlled, and uploaded to the Polar Data Catalogue. These data are used as background information or to test specific hypotheses in a multitude of scientific studies and reports by several ArcticNet projects and by our partners in the oil exploration sector.

Conclusion

Since 2004, the Marine Observatories project has maintained long-term oceanic observatories in the Canadian High Arctic and Subarctic regions in an effort to understand ocean circulation and freshwater inputs, productivity, carbon fluxes and marine mammal activity in each of the four ArcticNet IRIS regions. The re-organization of the project announced in previous reports is now nearly completed with (1) a complete renewal of the technical team that should allow to reduce the rate of loss of instruments; (2) the rejuvenation of the equipment park thanks to contributions from industrial partners, insurance refunds, and new investments from the CERC at the University of Manitoba and our BREA mooring program; (3) the recruitment of new students and collaborators; and (4) the development of new international partnerships that provide additional expertise and capacity. The expansion of our scientific program in the Beaufort Sea through the BREA program has been a major success that enabled us to connect with the private consultant IGM-Golder Associates to tap their mooring expertise and open new markets for our graduates (e.g. Alexandre Forest has been hired by Golder). The promising new international collaborations with Denmark, Germany and Japan announced in the last report enable us to expand our observational network to the Chukchi Sea, Fram Strait and the Greenland sector of Baffin Bay. The data generated from the Marine Observatories project provides the crucial baseline information needed to assess the effects of climate change and rising anthropogenic activities (e.g. oil exploration, shipping) on the Arctic marine ecosystem and has been used in over 45 peer-reviewed articles to date.

Although the time series developed until now provide some insight into the state of the environment, the impacts of climate change in the Arctic will take a few decades to fully emerge. It is therefore crucial to maintain the observatories to build the long-term dataset needed to answer the ecosystem-level questions raised by climate change.

The abolition of NSERC's Major Resource Support program in 2011-2012 strongly impacted the management of the *Amundsen*'s pool of equipment on which this project heavily relies. ArcticNet was able to palliate in part the most crippling impacts of the MRS cancellation. At this time, the CFI Major Scientific Initiative Special Fund appears as the most promising avenue to fund the maintenance and recapitalization of the equipment pool of the *Amundsen* over the next three years starting in 2015.

Acknowledgements

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Publications

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