Eye on the Ocean

A proposal for the unique use of *Atlantic Condor* for marine observation

A Rare and Special Oppo

The *Atlantic Condor*, a multi-purpose offshore supply vessel, makes bi-weekly return trips from Dartmouth, NS, to the Deep Panuke gas platform off Sable Island. The ship and her regular transits offer an unusually valuable opportunity for collection of important scientific data on the Scotian Shelf. Particular value lies with the following aspects of *Atlantic Condor*'s mission:

FIGURE 1 The *Atlantic Condor* regular transit in yellow, DFO monitoring lines in red.

COVERAGE The transit to Deep Panuke covers almost the entire width of the Scotian Shelf and complements sampling by the Department of Fisheries and Oceans (DFO).

FREQUENCY With up to one to three transits per week, year-round, *Atlantic Condor* allows for much higher frequency of measurement than almost any other available platform. For comparison, DFO collects samples in the same zone only two to three times per year.

REPEATABILITY The transit route taken from Dartmouth to Deep Panuke is expected to be highly consistent, allowing for measurement of changes along the route.

DURATION The availability of *Atlantic Condor* for a period of up to 10 years provides the ability to study weekly, seasonal, and inter-annual changes.

CONVENIENCE The regular returns to port in Dartmouth allow for rapid transfer of samples and data, and ease of maintenance of on-board measurement systems.

Benefits to Science, Industry and the Economy

The measurement systems envisioned here for deployment on *Atlantic Condor* can provide a very broad range of benefits:

Improved knowledge of the MARINE ECOSYSTEM on the Scotian Shelf. The data will be used to increase understanding of the resilience of our marine environment to change.

Improved knowledge of OCEAN CURRENTS. These data will be used for predicting storm surges and for prediction models used for search and rescue and contaminant dispersion.

Improved knowledge of BIRDS AND OTHER MARINE ANIMAL DISTRIBUTIONS. Long-term, simultaneous, observation of seabirds and oceanographic conditions will result in fundamental new understanding concerning how organisms respond to a changing ocean.

Measurement of SEA FLOOR CHANGES in response to storms and hurricanes. The ability to map the same part of the sea floor, repeatedly and to high accuracy for several years, will provide unique information about sea floor changes in response to extreme events with several applications including planning of sea floor installations.

Atmospheric measurements of trace gases and particles will provide valuable information concerning AIR QUALITY and remote sources of air pollution.

The proposed measurement systems for oceanographic and atmospheric properties would be of major value for collection of data to guide RESPONSE TO AN ENVIRONMENTAL EMERGENCY. The pre-installed, operational capability on *Atlantic Condor* would be superior to that which is typically available on dedicated research vessels.

Many of the measurement systems envisioned for deployment on *Atlantic Condor* are manufactured by local OCEAN TECHNOLOGY companies and can be tested and demonstrated from this platform. *Atlantic Condor* can showcase regional technologies.

While not directed specifically at effects monitoring for offshore installations, the proposed program builds on, and extends, elements of Deep Panuke's existing ENVIRONMENTAL EFFECTS MONITORING PROGRAM, thereby increasing its overall value.

The benefits will accrue to scientific understanding, environmental response capability and public protection, as well as to industry. The unique nature of the data collection opportunity implies a high potential for scientific breakthroughs. The regional provenance of many of the measurement technologies, will provide opportunities to highlight Maritime ocean science and technology capacity nationally and internationally. This could be a model program for offshore supply vessels worldwide with associated market potential for ocean tech companies from the region.

ortunity

Principles

The measurement programs proposed adhere to the following principles:

TRANSPARENCY Measurement programs must not interfere with the ship's operations and/or performance in any significant way. Operation of measurement systems must not result in increased cost or delays or complications for the crew.

SAFETY Measurement programs must adhere to the highest level of safety. Where necessary, certifications must be obtained for installations. All equipment installations and visits of scientific staff to the ship are to be approved by parties identified by the ship's owner or operator.

The modern, autonomous, sensor and measurement systems envisioned here allow for ready compliance with these principles. In a very few cases, occasional, minimal use of ship's equipment or resources is suggested (see *Operations, Installations and Requirements of Vessel*).

Operations, Installations and Requirements of the Vessel

PROJECTS # 4 AND 8 Operation of automated sensor systems, analysers and GPS receivers mounted on the ship's superstructure. Installation straightforward.

PROJECTS # 3 AND 4 Automated operation of sensor systems and a water sampler connected to a pumped water supply (from seachest), in the engine room. Requires some engine room installations (piping) during a drydocking. To be paid for by projects.

PROJECTS # 1 AND 2 Operation of two acoustic transducers. Transducers for multibeam sonar and ADCP to be installed in the ship's hull (can only be done during a drydocking). Installation costs to be paid by projects. These sorts of installations have been made on several commercial vessels already.

PROJECTS # 1, 3, 5 AND 7 Occasional ship-riding by one or two bird observers, technicians or students. Board and lodging costs to be paid by projects.

PROJECTS # 6 Hull-mounted or towed hydrophone. Installation straightforward. (Towed hydrophone may require minimal operator involvement at beginning/end of transits).

PROJECTS # 1 AND 5 Operation of a Moving Vessel Profiler while vessel is underway. (Requires installation on after-deck and some minimal operator involvement at beginning/end of transits). Installation costs to be paid by projects.

PROJECT # 1 Occasional use of vessel's ROV if possible. Costs to be covered by projects.

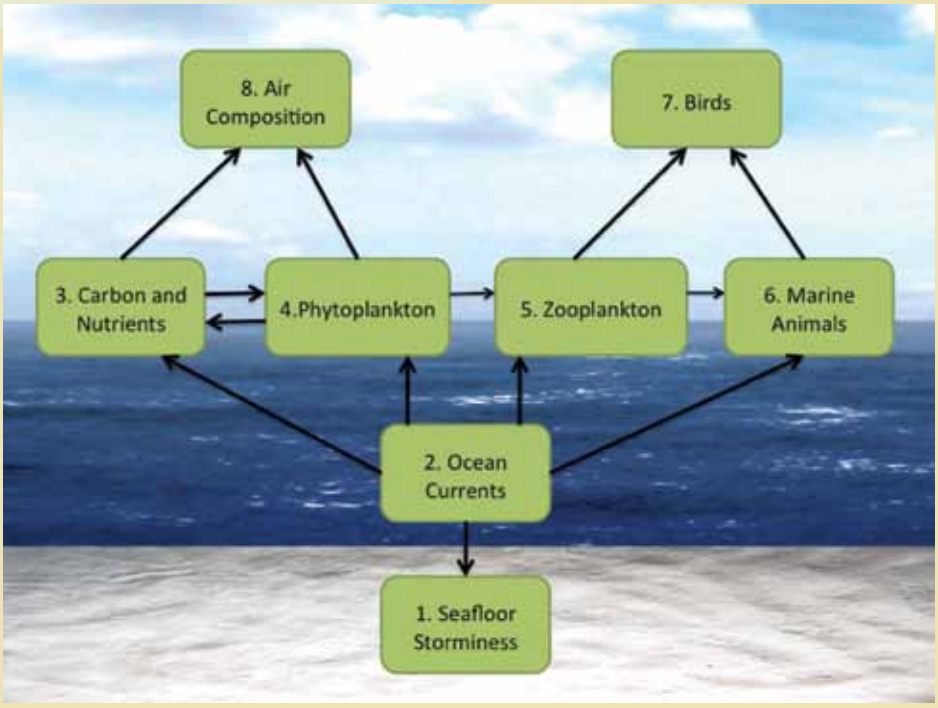


FIGURE 2 The eight project areas illustrating the interconnectivity among them.

Project Areas

A set of eight measurement programs has been identified. These are:

1 Storminess and the Seafloor
2 Ocean Currents
3 Carbon and Nutrients
4 Remote Sensing of Phytoplankton
5 Zooplankton Abundance and Size
6 Acoustically Tagged Marine Animals
7 Seabirds as Indicators of Ocean Productivity
8 Atmospheric Composition and Air Quality

These projects are intricately linked in a very special and rare manner. They effectively cover the marine ecosystem, from the bottom of the ocean, the currents and water masses, nutrients, light, the food chain, and ocean-atmosphere coupling, through to the modeling and prediction of the entire system. It is not often this kind of system in its completeness can be examined in one region, across a shelf, weekly for ten years.

1 Storminess and the Seafloor

PRINCIPAL INVESTIGATORS A. Hay, S. Kienast, M. Kienast, P. Hill (Oceanography, Dalhousie University)
COLLABORATORS D. Piper (Natural Resources Canada, Bedford Institute of Oceanography), R. Mulligan (Queen's University)

BACKGROUND

The Scotian Shelf experiences some of the strongest storms in the world. Extratropical, north-eastwards traveling cyclones ("Nor' Easters") often bring high winds during winter. Tropical cyclones, or their remnants, occasionally make landfall during summer. Climate model simulations project an increasing intensity of storms in the northern hemisphere so that storm events may have an ever increasing impact on people and infrastructure along the Atlantic coast.

OBJECTIVES

Collect repeated bathymetry data along the *Atlantic Condor* transit to study the impact of major storms on the seafloor and sediment transport over the shallow banks of the Scotian Shelf.

- Apply this information to records of sediment accumulation in the deeper basins to reconstruct the history of storminess on the Scotian Shelf over the last 10,000 years.
- Use models to investigate the effects of the observed changes to seafloor topography on circulation and currents.

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

- Repeated acoustic remote sensing of changes to seafloor roughness (e.g. sand wave and sand dune elevation and orientation) on the shallow banks. Requires use of a hull-mounted multibeam sonar, integrated with pitch-roll-heave sensors and a GPS navigation system
- Occasional collection of push cores (e.g. the upper 50 cm of sediment) with *Atlantic Condor*'s ROV in the deep basins adjacent to the shallow banks.

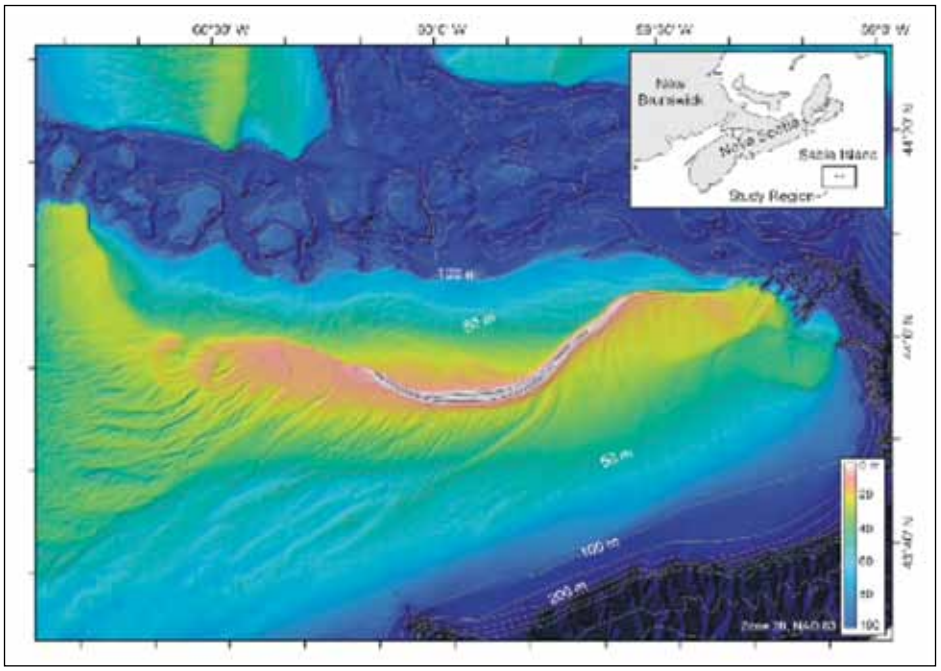


FIGURE 3 Shaded bathymetry map of Sable Island–Bank published by Li and King, *Marine Geology*, 2007.

This would be done on a time-available basis, ideally two times a year (spring/fall). Cost-sharing for ROV use may be possible via Natural Resources Canada (NRCan) and/or MEOPAR.

ADDITIONAL INFORMATION SOURCES

- Characterization of sand layers in the sediment column in the deep basins for the past 10,000 years using data and longer core records available at the BIO core archive.
- Numerical model predictions of currents and sediment transport on shallow (< 100 m deep) banks using sediment type, bottom roughness, and waves as inputs. Implement the Delft3d coupled wave-current-sediment numerical model in limited areas (i.e. banks); use output from other (wave-less) models as outer boundary conditions.
- Make comparisons between the predicted frequency of sand transport from the banks and the observed accumulation of sand in the deep basins.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor offers the novel opportunity to continuously monitor, in virtually real-time, the very complex interactions between sediment movement on the seafloor and physical forcing by wind and waves across the Scotian Shelf. This long observational time series, the first of its kind, will greatly enhance the understanding, and thus the ability to predict, sediment movement on the Shelf. *A time series like this cannot be obtained by individual research projects and use of dedicated research vessels*. Many shelf regions around the world experience a hydraulic regime not unlike that off Nova Scotia, where sediment movement and deposition are controlled by waves and storms, as opposed to tides or currents. The scientific and economic benefits generated with the *Atlantic Condor* data set will thus extend far beyond the Atlantic Provinces.

2 Currents and Along-Shelf Transport

PRINCIPLE INVESTIGATORS A. Hay (Oceanography, Dalhousie University), D. Hebert (Fisheries and Oceans Canada, Bedford Institute of Oceanography)

BACKGROUND

On the Scotian Shelf, the current at the shelf break and the current on the inner shelf vary seasonally, due in part to seasonal variations in the discharge from the upper layers of the Gulf of St. Lawrence. Knowledge of current velocities and their variation is useful for both scientific and operational purposes including: planning of seafloor installations, over-the-side deployments (e.g. of ROVs), constraint of contaminant transport or search-and-rescue models, ecosystem and climate studies, etc.

Numerical models indicate that seasonal variations in the mean currents on the inner and outer shelf are coupled, in part, through topographic steering by the Sable Island Bank of the shelf break current toward the shore. However, observations to test these predictions are limited in both spatial and temporal coverage. Most measurements have been made at point locations for periods of less than one year. Thus, little is known from observations about the quantitative variations in transports, either seasonally or year-to-year.

OBJECTIVES

- To investigate the seasonal and inter-annual variability of the currents on the Scotian Shelf along the *Atlantic Condor* transect.
- To provide shelf-wide current data as inputs to, or constraints on, numerical models of circulation, biogeochemical properties, and ecosystem dynamics.
- To better understand mechanisms governing coupling between the inner and outer shelf current systems, and the along- and cross-shelf transport of water properties

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

A hull-mounted acoustic Doppler current profiler (ADCP) will provide continuous measurements of horizontal velocity to a maximum depth of 250 m along the ship's track. The instrument will require a feed from the ship's GPS navigation system or installation of separate GPS receivers on the superstructure.

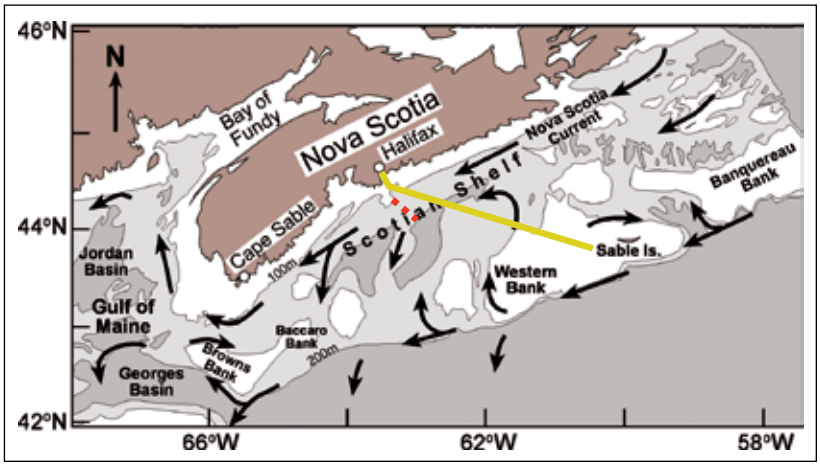
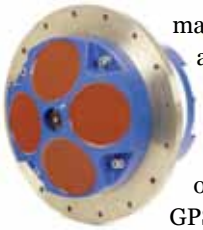


FIGURE 4 Above: The bathymetry and primary current systems on the Scotian Shelf, with *Atlantic Condor* path in yellow and ADCP locations in red.
FIGURE 5 Below: Acoustic Doppler Current Profiler (ADCP).



ADDITIONAL INFORMATION SOURCES

- Numerical model predictions of tidal currents, including the internal tide, for the time period of each shelf-wide transect.
- Satellite imagery, both infrared and visible bands, for identification of mesoscale features to compare with the de-tided ADCP velocities.
- Underway measurements of temperature, salinity, and biogeochemical properties.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor offers a timely opportunity to monitor shelf-wide currents, with high spatial resolution along the ship's track, on a weekly basis for a 10-year period, and would be the first such project in Canadian waters. The Oleander Project in the US has operated a similar ADCP on a commercial freighter sailing between New Jersey and Bermuda since 1992. The long observational time-series has greatly enhanced understanding of the circulation on the New England Shelf.

A not insignificant challenge will be to "remove" the tidal current velocities from the ADCP data. This will require use of numerical model predictions of both the barotropic and the baroclinic tidal currents along the transect. For studies of seasonal and inter-annual variations, however, the weekly measurements will allow the influence of tidal currents to be filtered, thereby revealing the weaker lower frequency current variations.

A time series like this cannot be obtained through the Atlantic Zone Monitoring Program of Fisheries and Oceans Canada, since sampling along the Halifax line is limited to three times (or less) per year. Regular observations from *Atlantic Condor* would complement, and provide a shelf-wide context, to fixed-location ADCP data that have been collected recently in the vicinity of the Nova Scotia Current by the Ocean Tracking Network.

Finally, since the current measurements are made by a surface vessel which allows access to data in near real-time, the measurements could be used for guiding offshore operations or incorporated into operational oceanographic models such as the Canadian Operational Network for Coupled Environmental Prediction Systems (CONCEPTS), a collaborative initiative with Environment Canada, the Department of National Defence, Fisheries and Oceans Canada and Canadian academic institutions.

3 Carbon and Nutrients

PRINCIPAL INVESTIGATORS D. Turk, D. Wallace, H. Thomas (Oceanography, Dalhousie University)
COLLABORATORS K. Fennel, J. Cullen (Oceanography, Dalhousie University), S. Sterling (Environmental Science, Dalhousie University)

BACKGROUND

Coastal marine regions such as the Scotian Shelf play an important role in the global carbon and nutrient cycles. Such regions serve as a link between carbon and nutrient cycling on land, the ocean interior and the atmosphere. They are subject to seasonal and interannual variations (Figure 6), and affected by eutrophication and ocean acidification caused by the uptake of fossil-fuel derived CO_2. An understanding of the coastal ocean carbon and nutrient cycles in response to both natural and human-induced forcing requires comprehensive data which resolves the important annual cycle. Such data are remarkably rare worldwide.

OBJECTIVES

Autonomous underway sensors (Figure 7) and automated water samplers will be deployed on *Atlantic Condor* to define the cross-shelf and seasonal variability of dissolved CO_2, O_2 and dissolved nutrients (e.g. nitrate and phosphate). The data will be used to address the following questions:

- How much CO_2 is transferred between ocean and atmosphere.
- What are the chemical, biological and physical processes that control carbon dynamics.
- How will the seawater chemistry and marine biogeochemical processes be effected by warming, eutrophication, ocean acidification and extreme storm events.
- How does the biogeochemistry of the Scotian Shelf compare with that of the Eastern US continental shelf and other world's coastal regions.

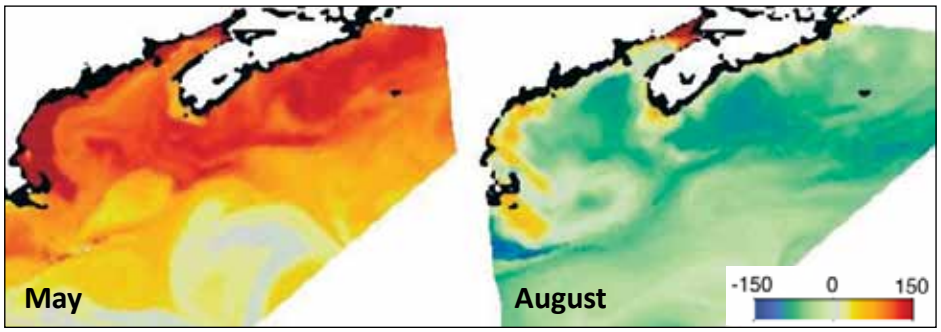


FIGURE 6 Seasonal variation of the difference of the partial pressure of CO_2 between the atmosphere and surface ocean on the Scotian Shelf. Positive values indicate uptake of atmospheric CO_2 by the ocean. (from Fennel and Wilkin, 2009).

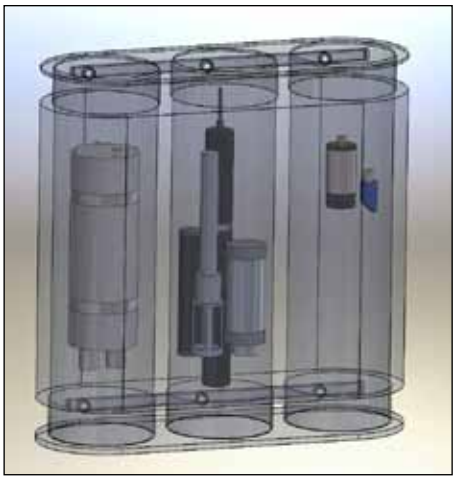


FIGURE 7 Schematic drawing of a flow-through tank containing sensors for a variety of chemical and biological parameters. The tank would be connected to a continuous supply of seawater pumped from the vessel's sea chest.

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

- Underway autonomous surveys of water temperature, salinity, partial pressure of carbon dioxide (pCO_2), oxygen, nitrogen, pH, and nitrate.
- Automated collection of water samples for properties that cannot be monitored autonomously including dissolved inorganic carbon (DIC), total alkalinity (Talk), dissolved organic carbon (DOC), phosphate.

ADDITIONAL INFORMATION SOURCES

- The proposed measurements of carbon parameters are complementary to existing moored observations of pCO_2 and monthly measurements of DIC and Talk at a single, fixed location offshore of Halifax on the Halifax Line.
- Sable Island atmospheric CO_2 monitoring.
- A more complete set of measurements made on DFO monitoring cruises three times a year.
- Satellite estimates of ocean color, sea surface temperature and winds, Ocean Tracking Network (OTN) glider measurements, and biogeochemical model output will be used to investigate the effect of synoptic scale variability on the regional measurements. This project is closely linked to projects #4, 2, 8 and 1.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor presents a unique sampling opportunity that is distinct from all other efforts in terms of its sampling frequency, coverage and duration. The data will be invaluable for measurement and interpretation of interannual variations in the air-sea flux of CO_2 in the region as well as interannual variations in the strength and timing of biological production on the Shelf. *Atlantic Condor* also offers a valuable test platform opportunity for newly developed underway sensors under development by local companies. Once proven on *Atlantic Condor*, such systems can be applied to other ocean regions nationally and internationally.

4 Remote Sensing of Phytoplankton

PRINCIPAL INVESTIGATORS S. Craig (Oceanography, Dalhousie University), M. Gibson (Process Engineering & Applied Science, Dalhousie University), S. Budge (Biology, Dalhousie University)

BACKGROUND

The colour of the ocean is determined by interactions between incident light and particles or dissolved substances present in the water. One of the most optically significant water constituents is phytoplankton – the microscopic, single celled plants that form the basis of the marine food web. By measuring the intensity of light reflected from the ocean at visible wavelengths either from a ship-based platform or space, we can estimate the amount of phytoplankton present, providing us with a powerful tool to monitor the marine ecosystem.

The North Atlantic, including the Scotian Shelf, plays home to a remarkable biological phenomenon every year: the North Atlantic spring bloom – a period of rapid, intense growth of phytoplankton. Globally, this annual event is very significant, and up to one quarter of carbon uptake by the world's oceans can occur in the North Atlantic, driven predominantly by this period of intense biological activity. By using continuous measurements of ocean colour, we can develop an understanding of the nature of this event and how it responds to climate change, anthropogenic influences, and extreme weather events.

FIGURE 8 Satlantic SAS hyperspectral radiometer, mounted on vessel superstructure

OBJECTIVES

Collect transects of ocean colour and water samples to study the response of phytoplankton to seasonally-varying, meteorological and oceanographic phenomena. The data will be used in the following ways:

- To advance the technique of remote sensing of ocean colour, with special relevance to optically complex coastal waters
- To improve understanding of the marine ecosystem on the Scotian Shelf including:
  > The biological influence on rates of carbon uptake from surface waters
  > Relationships between phytoplankton and climate- and health-relevant trace gases
  > Relationship between phytoplankton and lipid content relevant to growth of commercial fish and invertebrate species

FIGURE 9 MODIS Aqua image of phytoplankton bloom around Sable Island – July 3, 2010. (modis.gsfc.nasa.gov/gallery)

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

- Underway, autonomous measurements of hyperspectral ocean colour from a radiometer system mounted on *Atlantic Condor*'s superstructure.
- Automated collection of water samples from pumped seawater supply along the transect.
- Underway measurements of phytoplankton fluorescence, backscattering, beam attenuation, and induction-relaxation phytoplankton fluorescence. All of these measurements can be made entirely autonomously on a pumped seawater supply.

ADDITIONAL INFORMATION SOURCES

- Satellite measurements of ocean colour will be obtained from the NASA and ESA (European Space Agency) instruments, MODIS Aqua and MERIS. This will allow a comparison of satellite ocean colour model estimates of phytoplankton biomass, optical properties and phytoplankton community composition with those measured more directly from *Atlantic Condor*.
- Underway autonomous surveys of water temperature, salinity, partial pressure of carbon dioxide (pCO_2), oxygen, nitrogen, pH, and nitrate.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor offers a unique opportunity to collect a spatially and temporally resolved ocean colour data set, along with a fully comprehensive suite of validation measurements over a long time period. Datasets of this nature and quality are very few and far between, and are highly prized for the opportunity they provide both for basic research and to develop operational data products for earth observation of use for industry and ecosystem managers. In particular, a dataset of this type will make an extremely valuable contribution to coastal ocean colour algorithm development, calibration and validation efforts. The use of ocean colour in economically and ecologically important coastal waters remains a challenging technical endeavour, and the insights derived in our proposed study area will be highly relevant to scientists, managers and industry alike in coastal regions around the world.

5 Variability of Zooplankton

PRINCIPAL INVESTIGATOR C. Taggart (Oceanography, Dalhousie University)

BACKGROUND

A major component of the secondary production and biomass that supports fish, bird, whale, etc. populations on the Scotian Shelf ecosystem is the zooplankton community – primarily small crustaceans called copepods – dominated by *Calanus* species.

The primary water masses that transport *Calanus* onto the Scotian Shelf originate in the Gulf of St. Lawrence and on the Labrador Shelf. These waters contain high concentrations of *C. glacialis* and *C. hyperboreus* and *C. finmarchicus*. The water masses mix and flow along the Shelf from the NE to the SW. Variations in water mass supply and mixing are postulated to drive the variability in the production and biomass of these species and intrusions of water from the continental slope onto the Shelf appears to play a pivotal role in controlling their relative abundances and distributions. However, the ideas are derived from limited survey-based data on plankton net collections (Figure 11, the old way) and are limited in spatial and temporal resolution. Generally, the data that are available to test models of this pivotal component of the Scotian Shelf food web are restricted to seasonal and annual averages.

FIGURE 10 *Calanus finmarchicus* (www.sintef.no/projectweb/calanus---home/)

FIGURE 11 The old way

OBJECTIVES

- Collect high resolution time and space data on copepod size and abundance along the *Atlantic Condor* transect using a profiling Laser Optical Particle Counter (Figure 12, the *Atlantic Condor* way).
- Determine the time and space variation in the size, abundance and energy content of this fundamental component of Scotian Shelf food web.
- Determine water mass associations of the copepod abundance and size (biomass).
- Determine empirically-based seasonal and annual variation in copepod production (6 to 8 size classes evolve over one generation), biomass and energy content.
- Address the poorly resolved distribution 4D (x,y,z, time) source-sink variation in the biomass.
- With collaborators test and enhance coupled physical-biological models of production.

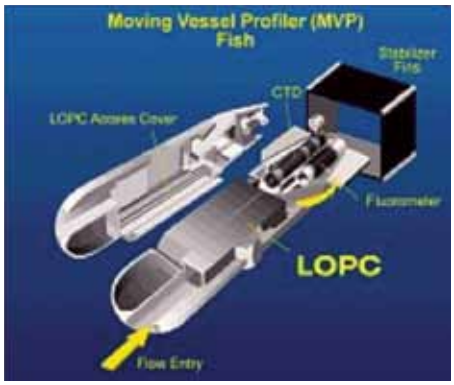


FIGURE 11 The new, *Atlantic Condor* way

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

Use a Laser Optical Particle Counter (LOPC) attached to a Moving Vessel Profiler (MVP) to collect data from outbound and inbound transits of *Atlantic Condor*. Both instruments are available for Rolls Royce (Brooke Ocean Technologies). The data are easily synchronized with CTD and other possible instruments mounted on the MVP.

ADDITIONAL INFORMATION SOURCES

The data would be compared and contrasted with the seasonally limited but annually-collected AZMP data (DFO/BIO) upstream and downstream of the *Atlantic Condor* transit (see map, page 2).

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor offers the opportunity to collect relatively high resolution data, year round. This was not previously possible. The resulting high resolution observational time and space series would be a first of its kind. It would greatly enhance our ability to test model-based predictions of zooplankton production and biomass variation on the Scotian Shelf. A time series of this nature cannot be obtained by an individual research project. There are very few, if any, comparable measurement programs of this extent and resolution elsewhere in the world. Achievement of such data resolution is highly likely to advance science in fundamental and perhaps surprising ways.

6 Tracking Acoustically Tagged Marine Animals

PRINCIPAL INVESTIGATORS

S. Iverson, R. O'Dor, F. Whoriskey (Ocean Tracking Network, Dalhousie University), COLLABORATOR D. Turk (Oceanography, Dalhousie University)

BACKGROUND

The Scotian Shelf is a major migration route for many species of marine animals moving seasonally from south to north, and back again. In addition, a number of valuable species use the shelf for varying periods during their life cycle. These distributions and movements may change as a function of variations in oceanographic conditions, and due to projected future climate alterations. The Ocean Tracking Network is tagging marine animals with acoustic tags to document their present migration routes, the marine habitats they use, and how both are changing as the marine environment changes. The information will be used to conserve and/or better manage the species.

OBJECTIVES

The Ocean Tracking Network is establishing acoustic listening devices in as many locations as possible along the Scotian Shelf. At present, a line of acoustic receivers is deployed across the Shelf offshore of Halifax and there are secondary deployments at sites of opportunity (e.g., oceanographic and meteorological buoys). Underwater autonomous vehicles are being configured to carry mobile receivers, and certain marine animals (e.g., grey seals) are carrying receiver units into the areas where they live and forage and documenting the presence of tagged animals there. Mounting of a receiver on *Atlantic Condor* will allow for regular surveys of the entire shelf to complement the fixed line of receivers off Halifax. Data will be used to:

- establish the presence of valued marine species on the Scotian Shelf, and document their patterns of residence and local movements;
- identify species undertaking long distance, international migrations (e.g. between Canadian and US waters);
- quantify survival rates for tagged species on the Scotian Shelf;

FIGURE 13 Atlantic salmon. (Kelsey Taylor)

- link species' presence and abundance to oceanographic conditions to provide data for development of models that will help predict future distributions of these animals.

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR* AND ASSOCIATED INFRASTRUCTURE

- Repeated screening of the water column for acoustically tagged animals through use of a hull-mounted or towed acoustic hydrophone.

FIGURE 14 VH180 acoustic hydrophone (Vemco), towed or hull-mounted

ADDITIONAL INFORMATION SOURCES

- Detections of tagged animals from other acoustic monitoring systems along the Atlantic seaboard will complement observations from *Atlantic Condor*.
- Numerical model predictions of currents and oceanographic conditions will be used to predict the distributions of species of interest and compare with data.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor offers the potential for an extensive monitoring of the water column for the presence of acoustically tagged marine animals. It covers a large portion of the Scotian Shelf that is not presently outfitted with acoustic receivers. The potential to collect a long time series of data on acoustically tagged animals, and the associated oceanographic data, will contribute to improving understanding and prediction of the presence and abundance of valuable marine species. Observations made here will be coupled to those made by other receivers in the Ocean Tracking Network in order to provide finer details on the movements of these marine animals, and assist with the development of ecosystem-based management plans.

7 Seabirds as Indicators of Ocean Productivity

PRINCIPAL INVESTIGATORS R. Ronconi, P. Taylor (Acadia University), M. Leonard (Biology, Dalhousie University); C. Gjerdrum (Environment Canada's Canadian Wildlife Service)

BACKGROUND

More than 50 species of seabirds inhabit the Scotian Shelf including local residents and long-distance migrants from polar, temperate, and equatorial regions. Seabirds are widely regarded as indicators of marine ecosystem health, therefore, understanding seabird response to changes in ocean productivity can help us monitor the state of Nova Scotia's marine environment. At-sea surveys, that measure the distribution and abundance of seabirds along *Atlantic Condor*'s transit, will provide valuable insight into the linkages between physical oceanographic processes, ocean productivity and marine top-predators, like seabirds.

S. Wong

FIGURE 15 Petrels

OBJECTIVES

Conduct repeated surveys of seabird abundance and distribution along the *Atlantic Condor* transit to study the spatial, seasonal, and inter-annual relationships between birds and oceanography.

- Apply these results to identify seabird species that are sensitive to variability in physical oceanography and marine primary productivity.
- Identify seabird foraging "hotspots" that are produced by oceanographic processes.
- Evaluate the efficacy of using seabird surveys as indicators of long-term oceanographic change on the Scotian Shelf.

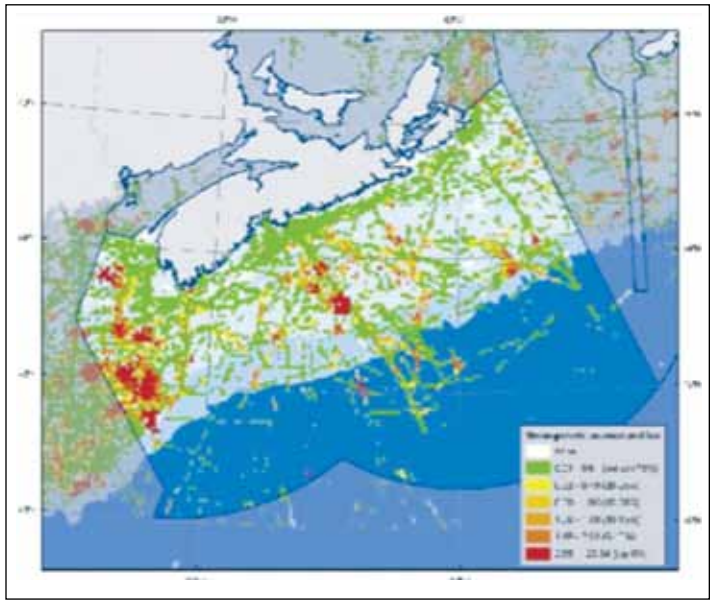


FIGURE 16 Vessel-based seabird surveys reveal the distribution and hotspots of storm-petrels on the Scotian Shelf. (Canadian Wildlife Service)

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

- Observers deployed on weekly or bi-weekly transits to count seabirds using standardized Environment Canada protocols. This will require an observer on the vessel bridge, space to set up a laptop, and a connection with the vessel's NMEA data-stream.
- Development of automated bird detection sensors that will be tested and validated against visual observations. Sensors could include use of radar, HD/thermal cameras, and other such devices, mounted to a gyroscopic stabilizing platform on top of the vessel superstructure.

ADDITIONAL INFORMATION SOURCES

- Survey data will be collated in Environment Canada's Eastern Canadian Seabirds At Sea (ECSAS) database. This database contains four decades of seabird surveys on the Scotian Shelf that are directly comparable with surveys from *Atlantic Condor*. Surveys from *Atlantic Condor* will provide a unique, year-round and fine-scale time series that will complement the historical shelf-wide surveys.
- Seabird survey data will be linked with oceanographic data also being collected by *Atlantic Condor* (see other projects in this document).
- Individual bird tracking studies from Nova Scotia seabird colonies will provide data on foraging behaviour to complement vessel survey data.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

At-sea surveys of seabirds are often broad in spatial extent but limited in temporal resolution, which makes it difficult to study interactions between seabirds and oceanography. *Atlantic Condor*'s regular transits across the Scotian Shelf offers tremendous opportunity to survey seabirds along a fixed route with exceptionally high temporal resolution. These data, in concert with synoptically sampled oceanographic data, will allow for fine-scale analysis of bio-physical coupling between ocean productivity (chlorophyll and zooplankton) and marine birds. A long time-series, across multiple seasons and years, will allow us to identify impacts of large-scale processes (e.g. Gulf Stream meanders and fluctuations in the North Atlantic Oscillation Index) on the nature, timing and magnitude of these bio-physical interactions.

8 Atmospheric Composition and Air Quality

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BACKGROUND

The Scotian Shelf Airshed (SSA) is impacted by local and long-range sources of particulate (PM) and gaseous air pollution. These include terrestrial natural and man-made sources (e.g. forest fires and smog) as well as marine emissions (ships, gas extraction and phytoplankton). These air pollutants are known to impact climate, ecosystems and health. There is currently a lack of information regarding the relative contributions and combined effects of natural and man-made PM and gaseous air pollutants within the SSA.

Monitoring of gases and emissions also improves capability to identify and respond to environmental emergencies.

OBJECTIVES

To measure, characterize, assess and model the atmospheric composition of the Scotian Shelf airshed.

- Determine the natural and man-made source contribution of PM and gaseous air pollutants within the SSA using measurements, modelling and satellites.
- Determine phytoplankton species-specific gas emissions, including halocarbons and reduced sulphur emissions, within the SSA.
- A study of sulphur cycling within the SSA.
- Develop the capacity to conduct far-field atmospheric measurements from *Atlantic Condor* to guide and augment disaster response to an environmental emergency within the SSA.

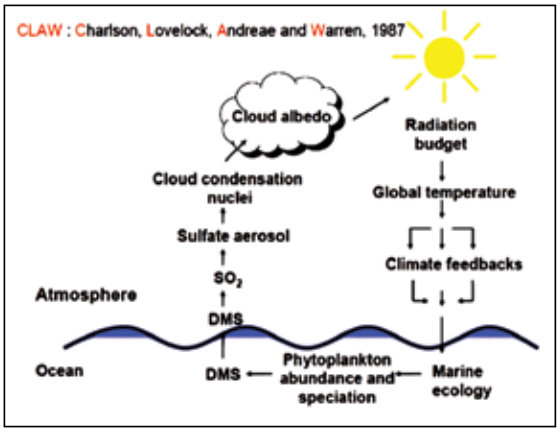

FIGURE 18 Schematic showing how natural emissions of sulphur gases from the ocean can affect climate. S. Kloster et al (2007)

PROPOSED MEASUREMENTS FROM *ATLANTIC CONDOR*

- Underway, autonomous near real-time measurements of gaseous species (including halocarbons, combustion and reduced sulphur compounds) using gas chromatography mass spectrometry/ proton transfer reaction mass spectrometry.
- Underway, autonomous near real-time measurements of PM chemical species (including DMS and MSA) and size-resolved PM number/mass using a combination of continuous and integrated sampling technology.
- Underway, autonomous integrated measurements of semi-volatile organic compounds species using filter and foam sampling technology.
- Communication with, and data acquisition from, the instruments will be possible via satellite telemetry, e-mail, text and a password protected internet data display.
- Far-field instruments to guide environmental disaster response.

FIGURE 17 Gas and particulate monitoring in Bedford Basin, 2011. (J. Kuchka)

ADDITIONAL INFORMATION SOURCES

In addition to *in situ* measurements, data from TERRA and AQUA MODIS satellites will be used to visibly identify upwind sources, e.g. forest fires and phytoplankton blooms respectively, impacting the SSA. Satellite data will also be used to estimate surface concentrations of paritculate matter within the SSA. A global/regional Chemical Transport Model GEOS-Chem and the Global Environmental Model-Modelling Atmospheric CHemistry (GEM-MACH) will be used to test sources and source regions in conjunction with the measurements from *Atlantic Condor*.

SPECIAL VALUE OF *ATLANTIC CONDOR* FOR THIS PROJECT

Atlantic Condor provides a unique opportunity to quantify the spatial and temporal variability in particulate and gaseous phase atmospheric components within the SSA. The current paucity of data addressing VOC and reduced sulphur emissions from marine phytoplankton and sulphur cycling will be addressed with monitoring of both the ocean and atmosphere from *Atlantic Condor* (projects 1, 3 and 4). The marine VOC and sulphur observations from *Atlantic Condor* would provide critical new data that can be used to improve the accuracy of emission inventories for coastal waters used in climate and chemical transport models. The air quality data generating from *Atlantic Condor* would be of great value to provincial, national and international air quality managers and the atmospheric-ocean scientific community at large. Placement of far-field instruments on board *Atlantic Condor* would enhance environmental disaster response capability within the SSA.

Linking *Atlantic Condor*

Links to Existing Projects

The envisioned measurement program builds on aspects of DEEP PANUKE'S ENVIRONMENTAL EFFECTS MONITORING PROGRAM. Notably, proposed atmospheric measurements of gases and particles would extend a recently initiated monitoring program on Sable Island (ENVIRONMENTAL STUDIES RESEARCH FUND contract to Mark Gibson et al., Dalhousie University). The oceanographic measurements will also link to and enhance a bird monitoring project supported by ENCANA'S R&D FUND.

These projects can now also be linked to the $168 million conservation project OCEAN TRACKING NETWORK (OTN) and the recently-awarded $25 million MARINE ENVIRONMENTAL OBSERVATION, PREDICTION AND RESPONSE (MEOPAR) NETWORK OF CENTRES OF EXCELLENCE. The HALIFAX MARINE RESEARCH INSTITUTE is the host institution for this network whose vision is *"to establish new partnerships in order to evaluate, predict and respond to marine environmental risks and thereby reduce economic losses, societal hardships and environmental degradation while optimising economic opportunity."*

Specific objectives of MEOPAR include: *Development and testing of science-based technologies and strategies to guide response to existing marine hazards. This includes risks from storms and extreme waves, as well as hazards to marine ecosystems and hazards that arise as a result of human activity.*

The measurements proposed for *Atlantic Condor* can provide valuable data for the new models to be developed under MEOPAR via its government and private sector partners.

Links to the World Ocean Council's *Smart Ocean/Smart Industries* Initiative

The WORLD OCEAN COUNCIL (WOC) (oceancouncil.org) is an international business organisation which: *"brings together the diverse ocean business community to collaborate on stewardship of the seas. This unique coalition is working to improve ocean science in support of safe and sustainable operations, educate the public and stakeholders about the role of responsible companies in addressing environmental concerns, more effectively engage in ocean policy and planning, and develop science-based solutions to cross-cutting environmental challenges that cannot be solved by one company or industry..."*

The WOC recently organised a *SMART OCEAN/SMART INDUSTRIES* WORKSHOP, co-sponsored by UNESCO'S INTERGOVERNMENTAL OCEANOGRAPHIC COMMISSION and A.P MOELLER-MAERSK (the world's largest container ship and supply vessel operator) and TRANSOCEAN (one of the world's largest offshore drilling contractors). The workshop worked towards a vision whereby:

> *"Leadership companies from a range of ocean industries are collabo-rating with the scientific community in the systematic, regular, sustained and integrated collection and reporting of standardized ocean and atmospheric data for input to operational and scientific programs that improve the safety and sustainability of commercial activities at sea and contribute to maintaining and improving ocean health."* (oceancouncil.org/site/smart_ocean.php)

Atlantic Condor presents a unique opportunity to implement the *Smart Ocean/Smart Industries* vision in a Canadian context and, linked closely to a major national scientific network, the possibility of high visibility as well as accrual of significant benefits for Canadians.

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OCEAN TRACKING NETWORK

MEOPAR

Halifax MARINE RESEARCH Institute