SPATIAL STRUCTURES IN HUDSON BAY: A FIRST LOOK AT THE AMUNDSEN ALONG-TRACK SYSTEM DATA DURING ARCTICNET 2005 AND IMPLICATIONS FOR REMOTE SENSING APPLICATIONS

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ABSTRACT

An along-track measuring system (ATS) was used during the course of the 2005 Arcticnet expedition to measure salinity, temperature and chlorophyll in Hudson Bay. After a screening process to eliminate abnormal values, ATS data were compared to independent validation measurements. Results show that both types of measurements agreed very well for salinity while ATS temperatures show an abnormal bias towards cold values. Extracted chlorophyll values showed a relatively good fit to ATS chlorophyll fluorescence but the error appears to increase with concentration. Comparison between ATS and satellite measurements of temperature shows a good agreement not only in the large scale patterns but also in individual values. The comparison for chlorophyll however shows an overestimation of satellite measurements compared to in situ values. This is probably due to the effect of dissolved matter of terrestrial origin which affects the sea radiance in the blue wavelengths. A semi-variogram analysis was applied to a section of ATS data in southern Hudson Bay to evaluate the spatial scales of variability. Results show that salinity and temperature have relatively large spatial scales (30-160 km) allowing the use of coarse satellite sampling to study the major oceanographic features. The scales of variability for chlorophyll appear affected by the presence of dissolved matter and only shows one structure at 70 km. More work will be needed to extend the study to other regions and time and to study the finer scales of variability that should be present in the data set.

OBJECTIVES OF THE PROJECT

Biological and physical structures exist in the sea at scales varying from millimeters for turbulence to hundreds of kilometers for oceanic gyres. Normal oceanographic sampling based on the concept of individual stations dispersed throughout an experimental area can lead to serious biases in the interpretation if the scales of spatial variability are unknown. This translate into a question often asked by scientists: How do my data point fits into the big picture? As part of the Arcticnet Theme 3 scientific program, we are trying to answer that question for the Hudson Bay ecosystem.

SYSTEM DESCRIPTION

Located in the engine room, the Amundsen along-track system (ATS) is measuring salinity, temperature, chlorophyll and dissolved matter (CDOM) fluorescence using a SBE45 MicroTS and a pair of Wetlabs fluorometers (Fig. 1). The water intake is located in a seachest on the ship's port side at a depth of approximately 5 m which depends on ship's draft (Fig. 2). Water is continuously flowing through the different sensors at a rate of approximately 1,5 l min^{-1} and data from the sensors are acquired at a rate of 1 Hz. At a typical navigation speed of 10 knots, this should translate into a sample every 5 m but the seachest flushing time being unknown, it is reasonable to assume the existence of strong autocorrelation at short temporal scales.

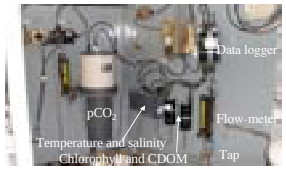

Figure 1. ATS components

Figure 2. Location of the seachest

DATA PROCESSING

The ATS provides a large number of data for each parameter. As a mean to evaluate data quality, we used the following protocol. First, histograms were plotted for each parameter allowing the selection of valid value ranges. This step allowed the elimination of abnormal values that resulted from system failures such as an ice clogged intake and also allowed the detection of systematic errors in the dataset that were resulting from bad data transmission. The remaining data were then compared to measurements taken to validate the system. For most of the 2005 Arcticnet cruise (Fig. 3), daily samples were drawn from the ATS tap and processed in the following manner. A temperature reading was immediately taken in the sampling thermos using a handheld thermistor thermometer having a precision of 0,1 ºC. The water sample was then brough to the filtration laboratory where sub-samples were taken for salinity and CDOM. A final sample was taken for chlorophyll which was processed onboard using a Turner fluorometer. Salinity samples were processed using a Guildline Autosal 8400B while CDOM was measured by its absorption at 440 nm using a Perkin-Elmer Lambda 25 dual-beam spectrophotometer.

Figure 3. Locations of the 2005 ATS validation samples

RESULTS

Figure 4 (right) shows the results of the ATS data validation exercice. From these graphs, it appears evident that some parameters were better measured than others. Salinity shows an almost perfect fit with validation measurements. Even though temperature was measured within 1 minute of sampling, some important discrepancies exists between the ATS and the validation measurements with the ATS being cooler by 1,5 deg. While this is consistent with a sample warming after its measurement by the thermosalinograph, the value appears somewhat high for a transit distance of about 1 m. Post-calibration of the handheld thermometer showed that its precision was within 0,1ºC. Further validation with another independent dataset (rosette CTD) will be needed to determine which measurement truly represent water temperature.

Figure 5. Non algal particles found in ATS system. Filter size is 47 mm.

For chlorophyll, the results show a relatively good correlation between fluorescence and chlorophyll concentration estimated by extraction. It however appears evident that the absolute error increased with concentration which could be problematic during the spring time bloom. A possible explanation for the lower correlation observed maybe the presence of non algal particles in the water sampled by the ATS (Fig. 5). These red particles of unknown origin may either affect the quality of the chlorophyll extraction process or the measurement of chlorophyll by fluorescence at 695 nm.
For CDOM, it seems evident that there is no relation between the fluorescence of CDOM and its absorption. This is indicative of CDOM of marine and not of terrestrial origin. Based on these validation results, the ATS values for chlorophyll fluorescence were converted to chlorophyll concentration and salinity was calibrated using the calibration curve. Temperature and CDOM data were left unchanged.

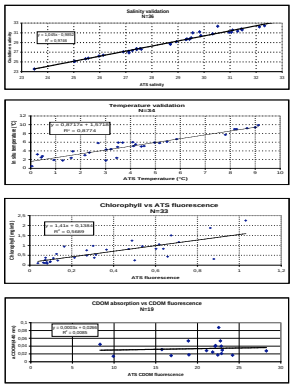

Figure 4. Validation of ATS data with water samples

COMPARISON WITH SATELLITE DATA

Figure 6a shows the temperature data measured by the ATS for Hudson Bay. Despite a large data gap on the eastern side of the bay, the ATS show temperature patterns that are consistent with concurrent satellite images (Fig 6b). A comparison of values from both types of measurements (Fig. 6c) also indicates a relatively good agreement considering that the satellite image is a 15-days time composite while ATS data are instantaneous measures. The standard deviation of the difference is 0,82 ºC for the temperature.

Figure 7a shows the ATS chlorophyll data that can be compared to a 7-days MODIS averaged chlorophyll image (Fig 7b). While patterns agree (higher values in the coastal zone), the comparison between the two types of measurements (Fig. 7c) clearly indicates the overestimation of chlorophyll concentration by remote sensing. This results from the presence of dissolved organic matter of terrestrial origin which strongly absorbs blue light (as phytoplankton) and generates a false chlorophyll signal using standard processing algorithms based on the blue-green reflectance ratio. Unfortunately, the CDOM sensor on the ATS was not functional during that portion of the cruise making direct comparison impossible. Terrestrial CDOM is normally highly correlated to salinity. Figure 8 shows that lower salinity values were measured by the ATS close to the coast and at the entrance of James Bay, corresponding to higher satellite-derived chlorophyll concentrations.

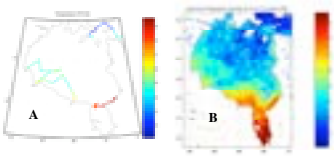

Figure 6. ATS (a) and satellite (b) temperature data for Hudson Bay and their comparison (c)

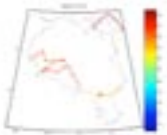

Figure 8. Salinity values measured by the ATS in Hudson Bay

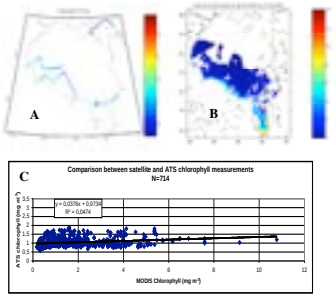

Figure 7. ATS (a) and satellite (b) chlorophyll data for Hudson Bay and their comparison (c)

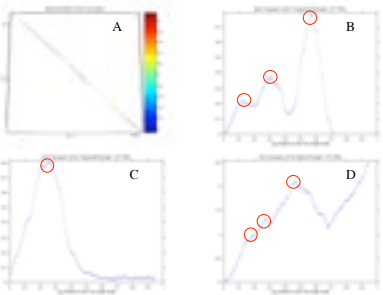

Figure 9. Transect used for the semi-variogram analysis (a), and spatial scales for temperature (b), chlorophyll (c) and salinity (d)

SPATIAL SCALES

In order to evaluate the spatial scales of variability, we selected to do a semi-variogram analysis on a relatively strait 275 km section of ATS data located in southern Hudson Bay (Fig. 9a). The data set was first processed to eliminate measurements taken when the ship was stationnary or slowly drifting. To reduce sampling noise, we also took the mean value over a distance of 50 m giving approximately 20 samples within a typical 1 km satellite image pixel size. The analysis was done for the salinity, temperature and chlorophyll parameters. For temperature (Fig. 9b), the most important scales present in that part of Hudson Bay are 35, 80 and 160 km while they are 55, 75 and 130 km for salinity (Fig. 9d). This means that the temperature and salinity signatures of the major oceanographic features can be resolved using a relatively coarse sampling size. Use of higher spatial resolution images is still needed however to study smaller scales processes such as river plumes or frontal regions. Calculations for the chlorophyll variable (Fig. 9c) indicate very different spatial scales with only one major peak at 70 km. This may result from the presence of CDOM contaminated values in the coastal zone that are superimposed on the true chlorophyll signal.
Analysis of the complete data set to determine scales in other parts of Hudson Bay and at finer scales to determine the amount of intra-pixel variability will be performed later after a sufficient amount of data covering mosts parts of the bay and different seasons will become available.

ACKNOWLEDGEMENTS

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