Bio-optical properties and in-water constituent relationships in the Chukchi and Beaufort regions of the Arctic Ocean

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Background

The Impacts of Climate change on the Eco-Systems and Chemistry of the Arctic Pacific Environment (ICESCAPE) is a NASA-funded, multidisciplinary project whose field component was carried out during the summers of 2010-2011. The project's main objective is to improve our understanding of the impact of climate change on the biogeochemistry and ecology of the Chukchi and Beaufort seas. Recent documented changes in summer ice cover, accompanied by a transition from thick multiyear ice to a seascape increasingly dominated by thinner, first-year ice. Climate models predict that ice cover changes may accelerate in the future. Current and future Ocean Color missions will play a central role in the monitoring of these predicted changes.

While most of the science by the participating groups was conducted onboard the US Coast Guard Cutter Healy, the NASA-Goddard group conducted a large portion of its science activities from the Arctic Survey Boat (ASB), a 30ft landing craft that deployed off the Healy almost daily during both expeditions. The ASB provided a more suitable platform for accurate measurements of the underwater light field, avoiding ship shadow and disturbance of the surface stratification by the much larger cutter.

At each of the ASB deployments, profiles of spectral radiometric flux (Ed and Lu) and spectral absorption (a), scattering (b) and backscattering (bb) were conducted. Surface water samples were collected from the ASB for the analyses of phytoplankton pigments using HPLC, particulate organic carbon (POC), suspended particulate matter (SPM), dissolved organic carbon (DOC), spectral light absorption by particulates (ap), and colored dissolved organic matter (aCDOM). These data will be valuable for the development and further refinement of algorithms for the determination of phytoplankton pigments and other novel data products (e.g., DOC, POC) from remote sensing platforms.

Preliminary Results

Chorophyll *a*

Observed chlorophyll *a* (chl a) concentrations determined using HPLC varied over three orders magnitude (Figure 1). Samples collected exclusively on ASB deployments were generally low (< 1 mg m-3). However, derived chl a from blue-green band ratios of in situ remote-sensing reflectances (Rrs) from AOP profiles were considerably higher than in situ HPLC values (Figure 2). Historically, satellite ocean color algorithms have underperformed in high latitude environments, with chl a usually underestimated at high and mid-range values, and overestimated at low (<0.6 mg m-3) concentrations (1-4). The current operational algorithm for SeaWiFS and MODIS (OC4V6), performed on average similarly to the regionally tuned, high-latitude algorithm OC4L (4). However, OC4L, performed much better at low chl a concentrations below 0.1 mg m-3, while OC4V6 overestimated chl a by an order of magnitude in that range.

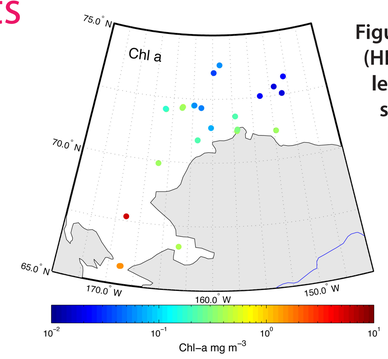

Figure 1. Chlorophyll *a* concentration (HPLC) from surface water samples collected on ASB deployments and a few selected Healy stations during the ICESCAPE 2011 campaign.

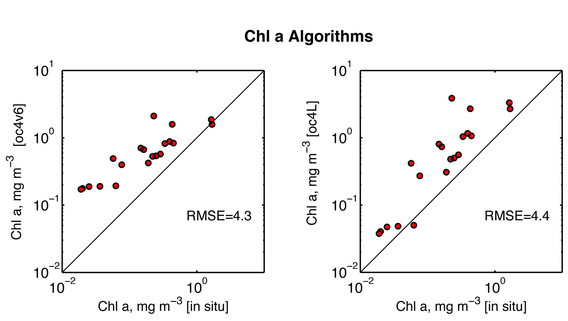

Figure 2. Algorithm derived (OC4V6 & OC4L) vs. in situ chl a collected during ASB deployments. RMSE is the relative root mean squared error.

Particulate Organic Carbon

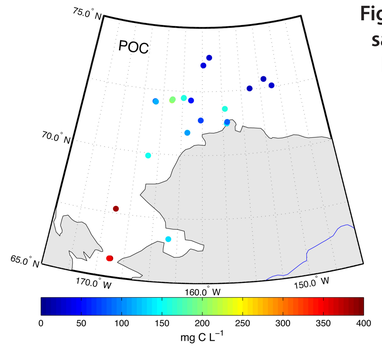

Figure 3. Particulate organic carbon from surface water samples collected on ASB deployments and a few selected Healy stations during the ICESCAPE 2011 campaign

Values for particulate organic carbon (POC) measured in water samples collected during the ICESCAPE 2011 campaign (Figure 3) were typical (<400 mg m-3) of those reported for summer season in high latitude oceans (5, 6). The POC algorithms proposed by Stramska & Stramski (6) performed with varying success in predicting POC (Figure 4). The one that performed best (RMSE=0.37), "algorithm 4" --the current operational global POC algorithm--is based on the blue-to-green (490/555nm) Rrs ratio. This algorithm was developed using data collected at a wide range of latitudes that included subtropical, temperate, and Southern Ocean, as well as a variety of trophic conditions, such as the California Current and the Atlantic near Bermuda. Notably, algorithms 1-3 are based on data collected almost exclusively in the Polar North Atlantic, however the underlying theoretical principles are somewhat different from those for option 4 –option 1 being the exception since it is also based on the blue-to-green band ratio (6).

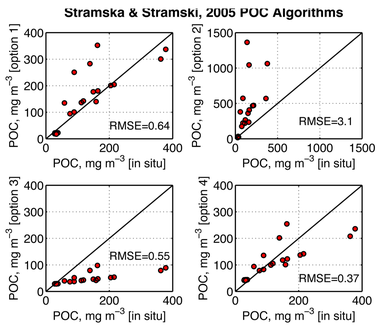

Figure 4. Algorithm derived (Stramska & Stramski) vs. in situ POC collected during ASB deployments. RMSE is the relative root mean squared error.

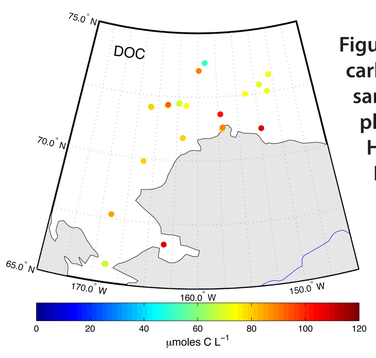

Figure 5. Dissolved organic carbon from surface water samples collected on ASB deployments and a few selected Healy stations during the ICESCAPE 2011 campaign

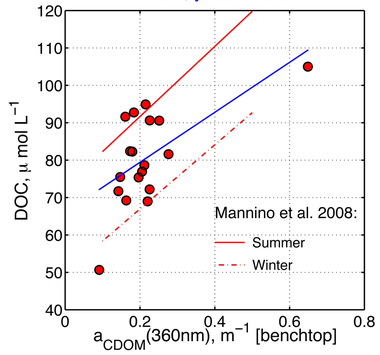

Figure 6. Surface dissolved organic carbon (DOC) concentrations vs. CDOM absorption at 360 nm.

Dissolved Organic Carbon and CDOM

The Arctic Ocean, by volume, receives the greatest loads of organic C and freshwater of any ocean (7). Given the importance of this basin in the global C cycle, remote sensing tools for the measurement of DOC in the Arctic Ocean will be valuable in the monitoring and prediction of the climate change effects to the C cycle.

Recent approaches for the development of DOC algorithms are based on the optical characteristics of chomophoric dissolved organic matter (CDOM) (e.g., 8, 9, 10). Here, we preliminarily apply an approach developed by Mannino et al. (9) for the U.S. mid-Atlantic Bight (MAB). Concentrations of DOC measured in surface water samples during the ICESCAPE 2011 campaign (Figure 5) are in the lower quartile of those used to develop the MAB DOC algorithm (9). DOC concentrations in that range showed weak correlation with CDOM absorption at 360 nm (Figure 6). Not surprisingly, given expected differences in the local biogeochemistry of the Artic versus the MAB, the overall trend only weakly mimics that found by Mannino et al. (9). However, the relationship between aCDOM and in situ Rrs ratios was robust and markedly similar to that found by Mannino et al., even for these lower magnitudes (Figure 7). This suggests that regional aCDOM, and potentially DOC, algorithms could be developed for the Arctic. The challenge remains to establish a well-characterized predictive relationship between CDOM optical qualities and DOC concentration in this region.

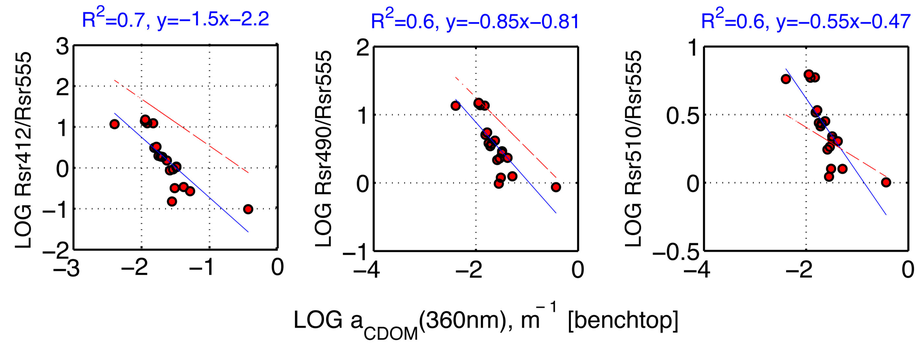

Figure 7. Log of blue-green band ratios vs. log aCDOM at 360nm for surface water samples.

References
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