Assessing the Impact of Climate Warming on Ice Algal Production in the Arctic Ocean

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In polar regions, as increasing sunlight penetrates the sea ice, ice algae grow on its underside. Rising temperatures begin to melt the ice, releasing the algae that drifts through the ocean and to the seafloor. The algae become food for planktonic copepods and krill and seafloor-dwelling urchins and mussels—lower links in the ocean food chain that feed fish, seabirds, whales, seals, walruses, polar bears, and humans. Will Earth's changing climate, proceeding fastest in the vulnerable Arctic region, disrupt the choreography of this age-old ecosystem?

With support from the Arctic Research Initiative, I conducted a detailed analysis on climate warming-induced changes and their impact on ice algal production, including the effect of a dramatic decrease of ice coverage, the thinning of sea ice and snow, and the early melting of sea ice. The current major theory is that the loss of ice coverage due to warming will decrease the total area available for ice algae to grow, but the thinning of ice and snow may increase the intensity of under-ice Photosynthetic Available Radiance (PAR), a critical limiting factor for the growth of ice algae in later spring and early summer, and thus enhance ice algae production. Data from multiple sources were compiled and analyzed, including results from computer models that utilized satellite information on ice and snow cover and short wave radiation measuring heat flow. Results derived from this project contributed significantly to an ongoing NSF project that focuses on assessing the impact of climate change on plankton dynamics and biogeographic boundaries in the Arctic region. In collaboration with researchers at the University of Massachusetts, Dartmouth, and WHOI's Physical Oceanography Department, I am developing a much more complex biological-physical computer model to assess how the changes in snow and ice will impact ice algal production in the Arctic Ocean. In addition, more opportunities for future program development have emerged through increased interactions with Arctic research communities during this project.

To examine the impact of ice and snow change on ice algal production, I chose data from two years with a dramatic contrast in ice coverage and snow thickness (1988 and 2004). Model-derived monthly averaged data for short-wave radiation at the ocean surface were used for the estimation of PAR distribution in time and space and the difference between the two years was calculated. The snow and ice conditions in the Arctic Ocean have been undergoing considerable changes during the recent decades as a result of climate warming. The maps of August ice concentrations clearly showed the shrinking ice coverage during the summer of 2004 as compared to that of 1988 (Figure 1, upper panel). The total ice-covered area decreased with a range of ~4% in May and ~18% in August. In addition, the short wave radiation reaching the sea surface appeared to be much higher in 2004 (Figure 1, bottom panel), supporting the initial hypothesis that the PAR changes in response to changes in ice coverage, thickness, and snow depth. In fact, the monthly averaged short-wave radiation at the ocean surface of the ice covered region increased throughout the ice algal growth season (May to August). It was also noted that the changes in ice concentrations were significant on the Pacific side of the Arctic Ocean (e.g. Chukchi Sea), but the increase of shortwave radiation could be seen throughout the region, including areas surrounding the north pole, indicating the ice thickness and snow coverage favored the light penetration in the entire Arctic region.

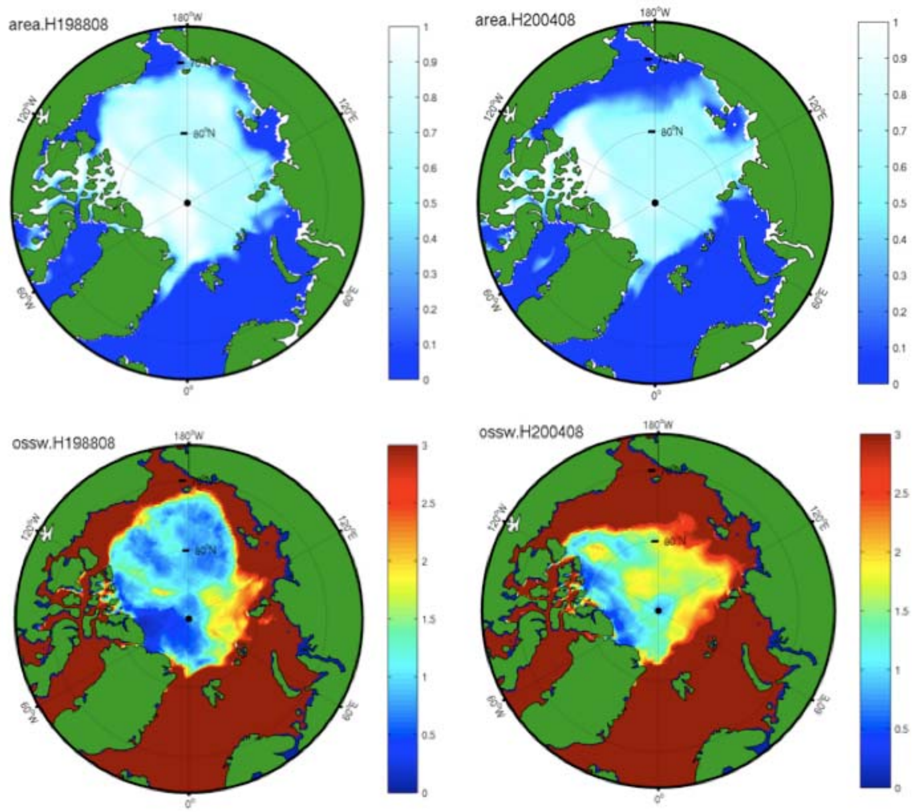

Figure 1. Comparison of ice concentration (upper panel) and short-wave radiation (bottom panel) in August between 1988 and 2004.

My results also showed that the total area that had light suitable for ice algal production (referred as "suitable area" hereafter) increased significantly from May to July as a result of enhanced surface heat flows, although the total area covered by ice was reduced by nearly 40% in both years. In August, however, the total "suitable area" dropped back to the same level as in May, likely due to the decrease of total ice-covered area, especially at relatively lower latitudes where the surface PAR is higher. The total "suitable areas" were higher in 2004 than in 1988 throughout the season, except in May when the surface PAR was low and ice was thicker. It is important to point out that, in most regions, the peak growth period for ice algae is between May and July (there is a nutrient limitation in August). Therefore, it is likely that the decline of ice algae production may not be not proportional to the decrease of ice cover; and, in some cases, the total ice algal production may increase. This increase could boost the contribution of ice algal production to the total phytoplankton production (ice algae and phytoplankton) in the central Arctic Ocean, where the ice algal contribution is already high (may reach ~57% during summer). Such a shift could significantly alter the ecosystem structure in the Arctic region, affecting higher trophic level organisms that feed on ice algae.

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