Dynamical analysis of surface wind response to Arctic sea ice

Hyodae Seo
Assistant Scientist, Physical Oceanography Department
Jiayan Yang
Senior Scientist, Physical Oceanography Department

One of the most prominent features observed in global climate change is a retreat of sea ice coverage in the Arctic Ocean. Amplified by the sea-albedo feedback, dramatic decrease in Arctic sea-ice extent causes the surface-intensified warming in the Arctic atmosphere. Thus, it is critical to know how the near-surface wind and other meteorological fields would respond to, and impact, the evolution of the Arctic sea state. However, our current understanding of this boundary layer process is severely limited by the sparse meteorological observations over the Arctic sea ice and the coarse resolution climate models that do not fully represent the observed process.

The major goal of our study is to develop the credible weather forecast model over the Arctic sea ice and using it to improve the current understanding of dynamical and thermodynamical processes between the Arctic sea ice and the atmosphere. In light of the small spatial scales needed to represent such processes, we have implemented a community weather forecast model optimized for the polar environment (called Polar WRF) that is well validated against the historical observations over the Arctic sea ice (the name/tracks of the observations are shown in Figure 1a as the color-coded curves).

First, key factors that are important for skill of the Polar WRF over various sea ice conditions are identified. The skill is lower in comparison to the in situ data particularly when the uncertainties in estimates of the sea ice concentration are large. While the sea ice datasets are derived from the identical satellite datasets, the different algorithms for processing satellite datasets cause diverse estimations of the sea ice concentrations. The uncertainties are pronounced both along the periphery of the Arctic sea ice margins and in the pack ice regions in the interior Arctic which can be seen from Figure 1a showing the spatial pattern in uncertainties (color shading). The onsets of melting and freezing of sea ice also mark the period of enhanced uncertainties in sea ice estimates. Near the sea ice margin, factors such the ice thickness and the water temperatures are poorly represented by the weather models, which contribute to the errors.

Two dynamically distinctive effects of sea ice on the surface wind were examined, which act on different spatial scales. On the pan-Arctic basin scale, reduced sea ice concentration causes the lower atmosphere to be more unstable, which in turn increases the 10-meter wind speeds via increased mixing of momentum between lower and upper atmospheric boundary layer. Spatial scale of this response is comparable to the basin-scale of the sea ice difference. In contrast, near-surface geostrophic wind shows a strong response mostly near the sea ice margins, where the variations in sea level pressure directly influence how the wind converges and divergences, which in turn determines the vertical motion within the atmosphere. This process is most important on a relatively narrower spatial scale across the sea ice margins. The large amplitude and broad-scale response in the 10-meter wind implies that surface wind stress, derived from the geostrophic wind only, as is often the case for the sea ice ocean models may not fully reflect the large effect of sea ice changes on the ocean circulation and sea ice motions.

We are grateful for the support from The Clark Arctic Initiative. We are currently preparing for a major NSF grant to continue our work to develop a fully coupled atmosphere-ocean-ice model that allows for integrated assessment of the complex feedback process in the ever-changing Arctic environment.

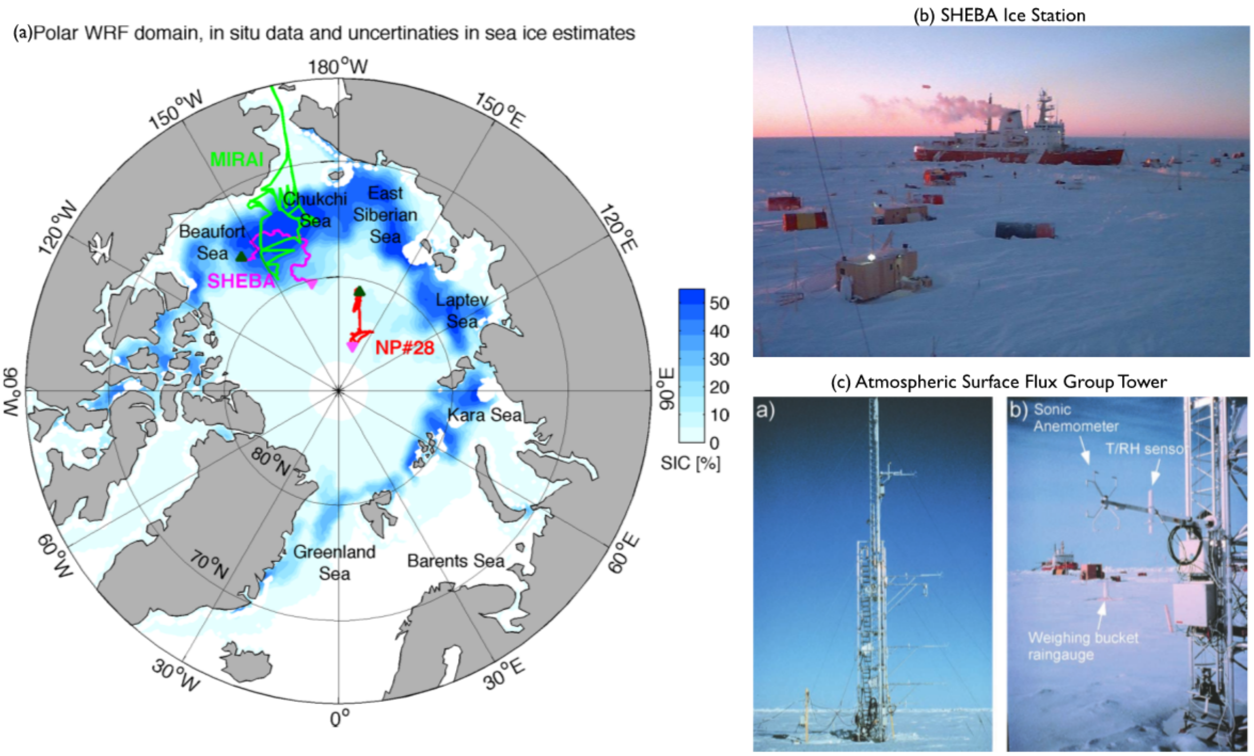

Figure 1. (Left) The geographical coverage of the Polar optimized version of Weather Research and Forecast (WRF) model in the Arctic basin. Color shading shows the uncertainties in September sea ice concentrations (SIC, [%]). The three colored curves denote the tracks of the measurement stations: (red) the North Pole station 28 (NP#28), (magenta) and (green) the R/V Mirai observations. (upper right) Photographs of the Ice Station SHEBA in the Arctic, February 8, 1998 by K. Claffey (available from earth.rice.edu) and (lower right) the Atmospheric Surface Flux Group (ASFG) tower that directly observes surface energy balance (pictures taken from Persson et al., 2002).