THE STATE OF ARCTIC SEA ICE FROM REMOTE SENSING OBSERVATIONS

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Remote sensing data have become more critical to observe the state of Arctic sea ice, which has undergone drastic change in recent years [1, 2]. We use decadal satellite datasets from active microwave (AM) and passive microwave (PM) sensors. We discuss Arctic sea ice change in the context of climatic change, including dynamic and thermodynamic effects exerted by both atmosphere and ocean.

We show that the extent of perennial sea ice in March (winter-spring transition) rapidly declined at a rate of 1.5×10^6 km^2 in this decade, triple the reduction rate of the three previous decades (1970-2000) [3]. No significant trend was found for the 1950s and 1960s. A record reduction of Arctic perennial ice extent was set in winter 2008, while the winter total sea ice extent has been stable compared to the average over the decade of the AM data (1999-2009). The combination of satellite and surface data confirms that the reduction of winter perennial ice extent broke the record in 2008 compared to data over the last half century. This record is matched again in spring 2009.

In the ice season of 2007-2008, perennial ice extent was reduced by 1.2×10^6 km^2 between 10/1/2007 and 5/1/2008. Satellite observations showed that the perennial ice extent was 0.5×10^6 km^2 larger on 10/1/2008 compared to the same date in 2007 due to more sea ice surviving summer melt in 2008. Nevertheless, between 10/1/2008 and 5/1/2009, the reduction of sea ice extent was 50% more rapid than the reduction rate in the same period between 2007 and 2008. On 5/1/2009, perennial ice extent was reduced to 2.1×10^6 km^2, which is a virtual tie to 2.2×10^6 km^2 of perennial ice extent on 5/1/2008 given the uncertainty of $\pm0.2\times10^6$ km^2 in AM measurements. Although the extent of perennial ice is similar, its distribution is quite different between the two years, with a significant perennial ice pack in the Beaufort Sea in 2008, and in contrast a large expanse of perennial ice along the Transpolar Drift Stream (TDS) in 2009.

We assess the consistency in derivations of sea ice extent from AM (QuikSCAT) and PM (NASA Team 2 algorithm). Furthermore, AM sea ice results have been ingested into the Seasonal Ice Zone Observing Network (SIZONet, www.sizonet.org) under International Polar Year (IPY) support, and prototype AM sea ice visualization has been developed by the Geographic Information Network of Alaska (GINA). Comparisons with ice thickness profiling and sea-ice coring north of Alaska show good correspondence between perennial ice classification from satellite data and ground truth. These results have been contributed to the Sea Ice Outlook (SIO), a community effort under the Study of Environmental Arctic Change (SEARCH) program.

While previous cases of significant dynamic ice loss in 2005 and 2007 are caused by the Polar Express (PE) driven by the dipole pattern (a Eurasian low and a Canadian high atmospheric anomaly coexisting in the Arctic), another pattern with two anomalies, both low, occurred contemporaneously in Fall 2008 at particular locations (one above the Eurasia Basin and the other above the Norwegian Sea). This different pattern can also energize the Polar Express, leading to significant loss of perennial ice. We call this anomaly pattern the *dual-pole pattern* (both low) to distinguish it from the dipole pattern (one low and one high); either one can accelerate the PE. In any case, the continuing drastic reduction of perennial ice significantly decreases the overall surface albedo, resulting in enhanced solar heat absorption in spring and summer, which further decreases the Arctic ice pack through the ice-albedo feedback mechanism and ice melt from the underside due to oceanic thermodynamic interactions. To demonstrate effects of oceanic water masses controlled by bathymetry on sea ice formation, we show maps of sea ice class distribution, which closely conform with patterns of the regional bathymetry.

Considerations associated with the United Nations Convention on the Law of the Sea (UNCLOS) and Arctic natural resource extraction have created an imminent need for accurate mapping of the bathymetry, especially in the region around the North Pole (NP). Thus, sea ice information around the NP becomes more critical to support field measurement campaigns carried out by ice breakers or submarines. For this purpose, the method to map sea ice using AM data is advanced to enable daily observations of Arctic sea ice classes as close as 42 km to the NP, which mitigates the problem of the NP data-blind area in other satellite datasets for operational applications. Results reveal a historical fact that the boundary of perennial sea ice crossed the NP in February 2008, leaving the area around the NP occupied by seasonal sea ice. Moreover, sea ice mapping products from the combination of Ku-band AM, Envisat C-band Advanced Synthetic Aperture Radar (ASAR) Global Monitoring Mode (GMM), and C-band RADARSAT SAR data demonstrate the capability for automated classification of sea ice together with identification of small features such as polynyas and leads, important for both operational navigation and scientific studies of geochemical processes, which are verified with observations from the IPY Circumpolar Flaw Lead (CFL) System Study.

In summary, based on fundamental understanding of scattering and emission signatures of sea ice, significant advances have been made in remote sensing of sea ice, which is timely for use with data collected various satellite sensors to capture the drastic change in Arctic sea ice that has profound impacts on Arctic environments, operations, wildlife, and human health.

Bibliography

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