ARCTIC SEA ICE CHANGE BASED ON SATELLITE OBSERVATION

Youngmi Kim, Mi-Lim Ou, Young-Hwa Kim

National Institute of Meteorological Research, 45 Gisagncheong-gil, Seoul, Republic of Korea

Abstract

Arctic sea ice is one of the most important parameters in climate change caused by global warming and has declined dramatically over at least the past 30 years. For analysis of sea ice change, the National Institute of Meteorological Research (NIMR) has retrieved the sea ice extent and surface roughness using microwave sensor data and has implemented a real-time sea ice monitoring system. This system uses the Special Sensor Microwave Imager/Sounder (SSMIS) data and has produced sea ice information (sea ice extent and sea ice surface roughness) every week from 2007 to the present. In 2013, the variation of sea ice appears to be similar to the variation in 2009, while showing an extent 1.5 times larger than in 2012. The sea ice of the East Siberian Sea, the Beaufort Sea, and the Laptev Sea showed less reduction than the recent 5 years. Sea ice is becoming younger and thinner.

INTRODUCTION

Sea ice is an important component of the Earth’s climate system and is particularly vulnerable to global warming. Sea ice reflects sunlight, keeping the polar region cool and moderating global climate. Arctic sea ice has declined dramatically over at least the past 30 years, with the greatest decline seen in the summer melt season. Those signs can be the results of global warming. Moreover, large amounts of greenhouse gases such as methane and carbon dioxide are stored in the frozen arctic ground, and when the ground thaws, these greenhouse gases are released into the atmosphere. Then, another self-reinforcing effect may amplify global warming. Melting of sea ice influences ocean temperature and salinity, which are important factors in the development and movement of the major ocean currents. The ocean current system and the global transport of heat may be significantly altered (Koç et al., 2009).

Because of these developments, the National Institute of Meteorological Research (NIMR) implemented a real-time sea ice monitoring system using microwave sensor data. This system utilizes the Special Sensor Microwave Imager/Sounder (SSMIS) data and has produced sea ice information such as sea ice extent and sea ice surface roughness every week from 2007 to the present. The surface roughness based on refractive index is estimated by adopting the characteristics of polarization. The NIMR has been monitoring the sea ice change through this system and analysing the status of sea ice using several parameters such as sea ice extent, sea ice surface roughness, and sea ice ages.

Figure 1: Sea ice monitoring system
SEA ICE MONITORING SYSTEM AT THE NIMR

The NIMR constructed the sea ice monitoring system for monitoring sea ice and data service using SSMIS data (Figure 1). Spatial distribution images of seven day composite sea ice extent and surface roughness are updated every week. This system provides the trend of sea ice, status of regional sea ice, etc. Here, sea ice surface roughness means small-scale roughness. Surface roughness is known to have a significant impact on the microwave emission of the sea ice/snow surface. The NIMR developed the algorithm of sea surface roughness by solving the equation of Choundary et al. (1979). This equation is expressed as follows:

\[ \sigma = \frac{\lambda}{4\pi \cos \theta} \ln \left( \frac{R_{\text{specular},H}}{R_{\text{Rough},H}} \right) \]

Here, \( \sigma \) is surface roughness (cm), \( \lambda \) is wavelength (GHz), RH is horizontal reflectivity, and \( \theta \) is incidence angle. The NIMR utilizes SSMIS data which the incidence angle is constant. The surface roughness based on reflectivity is computed using polarization of microwave. The average of small-scale surface roughness ranges between 0.2 and 0.6 cm. The rough ice (\( \sigma > 0.4 \) cm) locations have ice concentrations close to 100%. If surface roughness decreases, the sea ice is ready to melt. The minimum value of roughness is shown one month earlier than that of a sea ice area (Figure 2). The low roughness can provide a physical explanation of the ice/snow melting.

Figure 2: Long-term time series of sea ice extent (top) and surface roughness (bottom). Orange and green lines mean minimum value of ice extent and roughness, respectively.
The seasonal variation of Arctic sea ice is based on that of solar energy. The annual maximum value of sea ice extent appears in March, whereas the minimum value appears in September (Figure 3). After sea ice extent was recorded at the lowest value in 2012, it returned to the average level in March of 2013. Roughness decreased from May and reached the annual minimum at the end of July. The variation of sea ice seems similar to 2009, while showing an extent 1.5 times larger than in 2012. Both surface roughness and extent of sea ice began to decrease slowly compared with those in past years in the Beaufort, the Chukchi, the East Siberian, and the Kara seas. In particular, the sea ice of the East Siberian Sea, the Beaufort Sea, and Laptev Sea showed less reduction than in the recent 5 years (Figure 4).
Figure 5 shows the condition of the sea ice. Sea ice ages data are obtained from OSISAF (www.osisaf.met.no) and sea ice thickness data are SMOS product. Sea ice thickness image in 2003 is from Zwally (2009). First sea ice melts easier than multi-year sea ice because of increasing the temperature. Although the sea ice extent during March throughout the past four years was similar, the percentage of multi-year sea ice decreased by almost 10%, from 27% in 2010 to 17% in 2013. Furthermore, sea ice thickness also decreased. The average thickness was 1.96 m in 2003, whereas the thickness was 0.83 m in 2013.

SUMMARY

The NIMR developed the algorithm of surface roughness using SSMIS and constructed the “Arctic sea ice monitoring system”. Surface roughness is useful to physically explain melting of sea ice. In 2013, the variation of sea ice seems similar to 2009, while showing an extent 1.5 times larger than in 2012. The sea ice of the East Siberian Sea, the Beaufort Sea, and the Laptev Sea showed less reduction than in the recent 5 years. Sea ice is becoming younger and thinner. In particular, its thickness has decreased nearly 1 m in 10 years. The portion of multi-year sea ice also dropped. This phenomenon means that arctic sea ice is vulnerable to environmental changes.

ACKNOWLEDGEMENTS

This work was supported by the “Research for the Meteorological and Earthquake Observation Technology and Its Application [NIMR 2012-B-3]” of the National Institute of Meteorological Research (NIMR).
REFERENCE


http://nsidc.org/index.html