# BIAS ASSESSMENT OF NASA TEAM AND ASI SUMMER SEA ICE CONCENTRATIONS IN THE CHUKCHI SEA USING KOMPSAT-5 SAR

*Hyangsun Han and Hyun-cheol Kim*

Unit of Arctic Sea-Ice Prediction, Korea Polar Research Institute (KOPRI), Republic of Korea

**ABSTRACT**

Bias assessment of sea ice concentration (SIC) derived from passive microwave sensors is very important because it has been used as an important parameter for climate change research. In this study, we analyzed biases in SICs retrieved from NASA Team (NT) and Arctic Radiation and Turbulence Interaction STudy (ARTIST) Sea Ice (ASI) algorithm implemented for the Special Sensor Microwave Imager/Sounder (SSMIS) and Advanced Microwave Scanning Radiometer-2 (AMSR2), respectively, in the Chukchi Sea in summer using the Korea Multi-Purpose SATellite-5 (KOMPSAT-5) synthetic aperture radar images. The root mean square error of ASI SIC was smaller than that of NT SIC. The SIC values from the sea ice algorithms showed different biases by the KOMPSAT-5 SIC range due to different sensitivities to atmospheric effects and ice surface melting conditions.

***Index Terms*—** Sea ice concentration, NASA Team, ASI, KOMPSAT-5, Chukchi Sea

## 1. INTRODUCTION

Satellite passive microwave (PM) sensors have observed sea ice concentration (SIC) in polar region based on the distinct microwave emissivity between ice and water since 1970s [1–2]. SICs from PM measurements have been used for the estimation of sea ice area and extent which are the most important parameters for global climate change researches and the Northern Sea Route development.

The Special Sensor Microwave Imager/Sounder (SSMIS) and the Advanced Microwave Scanning Radiometer-2 (AMSR2) are representative PM sensors. Many algorithms have been developed to estimate SIC from the SSMIS and AMSR2 measurements. The NASA Team (NT) [3] and the Arctic Radiation and Turbulence Interaction STudy (ARTIST) Sea Ice (ASI) [2] algorithm are representative SIC retrieval algorithms for the SSMIS and AMSR2, respectively. Based on many previous studies, the sea ice algorithms estimated accurate SIC values in winter. However, they showed significant inaccuracies in the Arctic summer.

In this paper, we assessed SICs from the NT and ASI algorithms by comparing them with SICs estimated from KOrean Multi-Purpose SATellite-5 (KOMPSAT-5) SAR images obtained in the Chukchi Sea of the Arctic Ocean in summer. The biases in SICs from the algorithms were analyzed. We also investigated error sources of the SICs estimated from the algorithms.

## 2. STUDY AREA AND DATA

### 2.1. Study area

Study area is the Chukchi Sea in Arctic Ocean (Fig. 1). The Chukchi Sea is the terminus of the Northern Sea Route, where many vessels sail in summer by laying a route using PM SIC products. The sea ice distribution in the Chukchi Sea is closely linked to climate change. Therefore, evaluation of the PM SICs in the Chukchi Sea is very important.

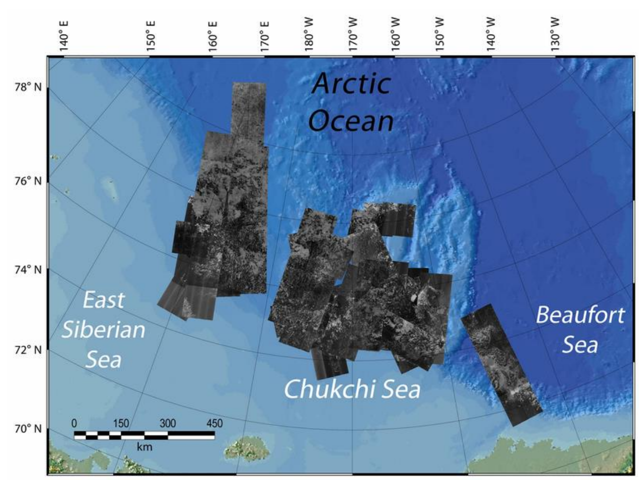


Fig. 1. A mosaic of the KOMPSAT-5 SAR images used in this study.

### 2.2. Data

KOMPSAT-5 is South Korea’s first satellite equipped with X-band synthetic aperture radar (SAR) with a center frequency of 9.66 GHz. We used a total of 78 KOMPSAT-5 SAR images (HH-polarization) obtained from August 6 to

September 9, 2015 in the Chukchi Sea (Fig. 1). All the SAR images were acquired Enhanced Wide (EW) swath mode which captures an area of 100×100 km with a spatial resolution of 6.25 m. To reduce speckle noise, a 2×2 block averaging of the SAR images was performed.

We used SSMIS NT SIC products with a grid spacing of 25 km and AMSR2 ASI SIC products with a grid spacing of 3.125 km for the same dates of KOMPSAT-5 SAR image acquisitions. The NT SIC products are provided by the National Snow and Ice Data Center (NSIDC) and the ASI SIC products are provided by the Institute of Environmental Physics at the University of Bremen.

## 3. METHOD

To derive SIC values from SAR images, we generated sea ice maps from the SAR images by using a sea ice mapping model developed by Han et al. [4]. The sea ice mapping model classifies a KOMPSAT-5 EW SAR image into ice and water by using SAR texture features based on Random Forest (RF), a rule-based machine learning approach. In the sea ice mapping model, a total of 12 texture features from the KOMPSAT-5 EW SAR images—average, standard deviation, minimum, and maximum values of the backscattering intensity, and energy, entropy, correlation, contrast, homogeneity, autocorrelation, dissimilarity, and maximum probability of gray-level co-occurrence matrix (GLCM)— were used as input variables. The GLCM textures were computed using 10×10 pixel window, 16 gray-levels, and a pixel distance of 1. This model generated sea ice maps with a spatial resolution of 125 m (Fig. 2) and showed the performance in the classification with an overall accuracy of 99.2% and a Kappa coefficient of 98.5% [4].

SIC was calculated from the KOMPSAT-5 sea ice maps and compared with the NT and ASI SICs. The ASI SIC data were resampled to 25 km to match the grid size of the NT SIC. Direct comparison of PM SICs with SAR SICs might yield large differences between them due to rapid movement of sea ice in summer, especially in the marginal ice zone (MIZ) and the ice edge zone (IEZ). To overcome such data comparison restrictions, we calculated the spatiotemporal mean ( $\bar{S}_{ST}$ ) and standard deviation ( $\sigma_{ST}$ ) of the NT and ASI SICs using a 3×3×3 cubic pixel averaging window determined by [5]. $\sigma_{ST}$ represents the spatiotemporal homogeneity of the PM SICs. NT and ASI SICs having a $\sigma_{ST}$ value of less than 10% are assumed to be stable data and compared with KOMPSAT-5 SAR SICs.

Bias assessment of the NT and ASI SICs was performed for four cases: one for data points corresponding to KOMPSAT-5 SIC below 15% (i.e., IEZ), the second for data points corresponding to KOMPSAT-5 SIC ranging from 15% to 80% (i.e., MIZ), the third for data points corresponding to KOMPSAT-5 SIC greater than 80% (the compact ice zone; CIZ), and the last for all data points.

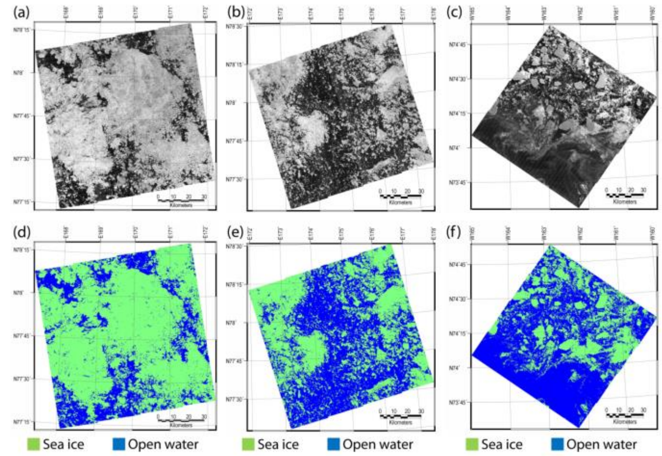

Fig. 2. (a-c) Examples of KOMPSAT-5 EW SAR images and (d-f) corresponding sea ice maps generated from the RF-based sea ice mapping model [4].

## 4. RESULTS AND DISCUSSION

The KOMPSAT-5 SIC was compared with stable NT and ASI SICs (Fig. 3). The vertical error bar of each data point is centered at $\bar{S}_{ST}$ and has a length of $\sigma_{ST}$. The ASI SIC has lower RMSE values for all regions (Fig. 3b) compared to NT SIC (Fig. 3a). For all SIC data points, the RMSE of ASI SIC was smaller than the NT SIC. The superiority of the ASI SIC is attributed to the fact that 89-GHz measurements might be less sensitive to variations in ice emissivity, a significant error source in SIC estimation by microwave radiation, than other low-frequency measurements [6].

In the IEZ, the NT and ASI SIC were positively biased (the white points in Fig. 3). This is due to atmospheric effects and the wind-induced rough surface of open water in the IEZ. Atmospheric water vapor content over open water in summer is generally high, which increases brightness temperature measured by PM sensors and be a reason for the overestimation of SIC by the algorithms [1]. The 89 GHz channels are more sensitive to atmospheric effects than other lower frequency channels. However, the positive bias of ASI SIC was smaller than that of NT SIC. This would be because the underestimation of SIC by the ASI algorithm might be compensated by increased brightness temperature of open water by wind at 89 GHz channels.

The NT SICs were largely underestimated in the MIZ (the gray points in Fig. 3) and CIZ (the black points in Fig. 3). This is due to the presence of melt ponds, which are common features on the surface of Arctic sea ice in summer. The microwave radiation characteristics of melt ponds are similar to those of open water and a significant source of SIC overestimation from the PM SIC retrieval algorithms [6]. Meanwhile, the ASI SICs were slightly underestimated in the CIZ and overestimated in the MIZ. This was possibly due to higher sensitivity of 89 GHz channels to atmospheric effects than other lower frequency channels, which can compensate the underestimation of SIC by the ASI algorithm.

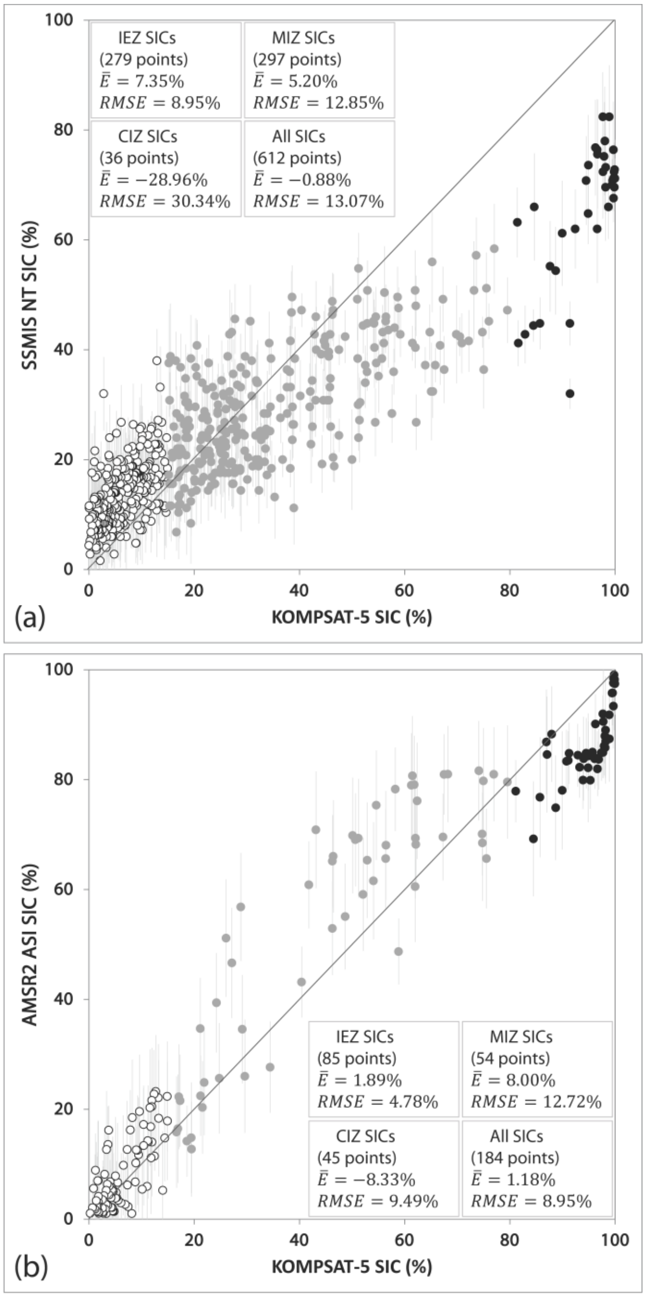


Fig. 3. Comparison of KOMPSAT-5 SIC with (a) the SSMIS NT SIC and (b) the AMSR2 ASI SIC. White, gray, and black points represent SIC in EIZ, MIZ, and CIZ, respectively.

## 5. CONCLUSION

This paper assessed biases in SICs in the Chukchi Sea in summer retrieved from the NT and ASI algorithms implemented for the SSMIS and AMSR2 by using KOMPSAT-5 SAR-derived sea ice maps. The overall error in the ASI SIC was smaller than the NT SIC over the Chukchi Sea in summer. The NT SIC was underestimated in the MIZ and CIZ, while it was overestimated in the IEZ. The ASI SIC was underestimated only in the CIZ and was overestimated in other regions. The overestimation of SIC by the algorithms was possibly due to atmospheric effects. The NT SIC values showed negative biases in MIZ due to ice surface melting. However, the ASI algorithm overestimated SIC values by atmospheric effects even though ice surface melted.

## 6. ACKNOWLEDGEMENTS

This research was supported by the Korea Polar Research Institute (KOPRI) grant PE18120.

## 7. REFERENCES


[1] S. Andersen, R. Tonboe, L. Kaleschke, G. Heygster, and L.T. Pedersen, “Intercomparison of passive microwave sea ice concentration retrievals over the high-concentration Arctic sea ice,” *Journal of Geophysical Research*, 112, C08004, Aug. 2007.

[2] G. Spreen, L. Kaleschke, and G. Heygster, “Sea ice remote sensing using AMSR-E 89-GHz channels,” *Journal of Geophysical Research*, 113, C02S03, Jan. 2008.

[3] D.J. Cavalieri, P. Gloersen, and W.J. Campbell, “Determination of sea ice parameters with the Nimbus 7 SMMR,” *Journal of Geophysical Research*, vol. 89, no. D4, pp. 5355–5369, Jun. 1984.

[4] H. Han, S.-H. Hong, H.-c. Kim, T.-B. Chae, and H-.J. Choi, “A study of the feasibility of using KOMPSAT-5 SAR data to map sea ice in the Chukchi Sea in late summer,” *Remote Sensing Letters*, vol. 8, no. 5, pp. 468–477, May 2017.

[5] H. Lee and H. Han, “Evaluation of SSM/I and AMSR-E sea ice concentrations in the Antarctic spring using KOMPSAT-1 EOC images.” *IEEE Transactions on Geoscience and Remote Sensing*, vol. 46, no. 7, pp. 1905–1912, Jul. 2008.

[6] N. Ivanova, L.T. Pedersen, R.T. Tonboe, S. Kern, G. Heygster, T. Lavergne, A. Sørensen, R. Saldo, G. Dybkjæ r, L. Brucker, and M. Shokr, “Inter-comparison and evaluation of sea ice algorithms: towards further identification of challenges and optimal approach using passive microwave observations,” *The Cryosphere*, vol. 9, pp. 1797–1817, Sep. 2015.