Summer sea ice concentration in the Chukchi Sea derived from AMSR2 and NWP data with machine learning approach

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Introduction

Passive microwave (PM) sea ice concentration (SIC) in summer in Arctic

- A primary data source for climate change prediction and ship navigation
- Typically inaccurate due to similar microwave radiation characteristics of sea ice and open water, which is attributed to atmospheric effects and ice surface melting

Objectives

- To develop superior summer SIC estimation models for the Chukchi Sea by considering atmospheric effects on the AMSR2 observations based on four machine learning approaches — Decision Tree (DT), Random Forest (RF), Multi Layer Perceptron (MLP), and Convolution Neural Network (CNN)
- To evaluate the performance of summer SIC estimation of developed machine learning models and existing SIC retrieval algorithms

Materials

Study area and Data

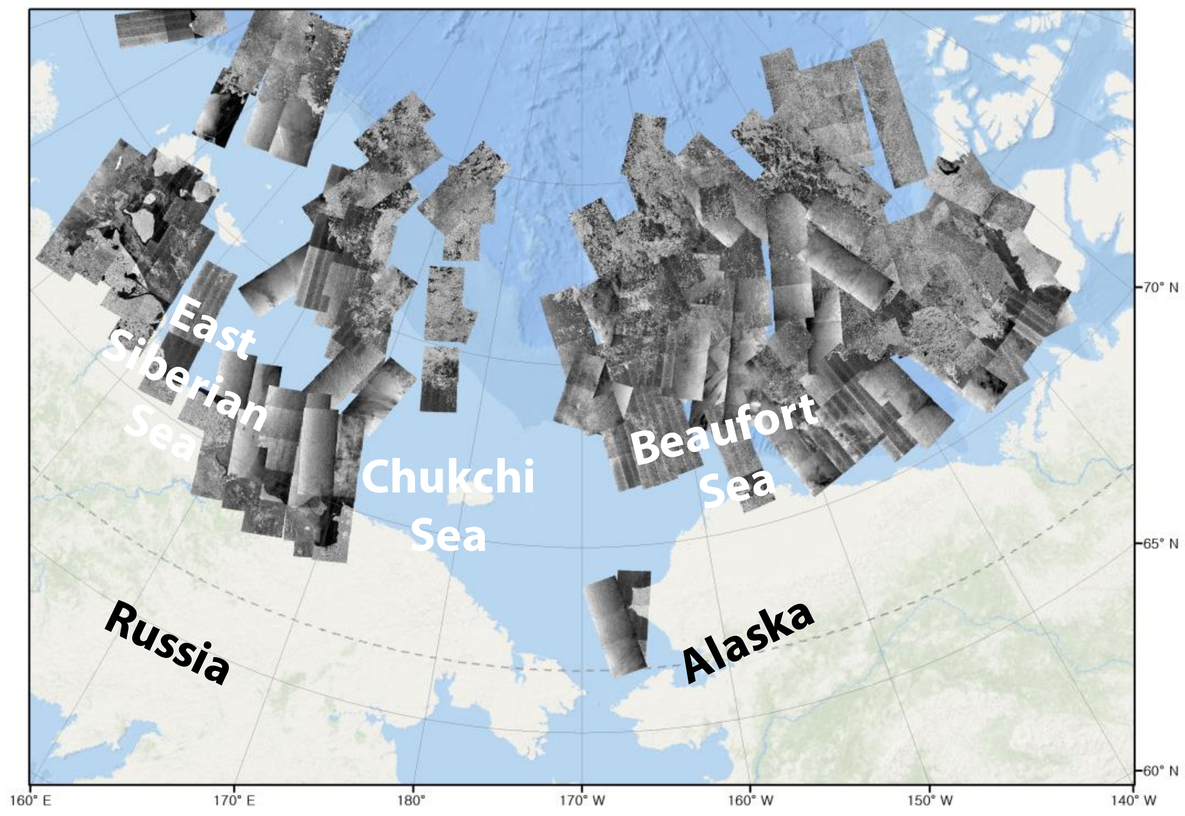

Fig. 1. Examples of KOMPSAT-5 SAR images obtained for the study area (a mosaic of the images in Aug. 2017).

KOMPSAT-5 SAR Enhanced Wide swath images
- 339 images obtained in summer (Jul. ~ Sep.) from 2015 to 2017 (6.25 m resolution)
- Used to compute SIC (training and validation data for SIC estimation models)

AMSR2 & ERA-Interim reanalysis data
- AMSR2 brightness temperature (TB) at 6.9, 10.7, 18.7, 23.8 36.5, and 89.0 GHz (V, H) in a grid size of 10 km
- ERA-Interim atmospheric parameters – total columnar water vapor, wind speed, 2 m temperature, 925 hPa temperature, and mean sea level pressure (resampled to 10 km)
- Used as input variables for SIC estimation models

Terra MODIS images
- L1B planetary reflectance of band 1, band 3 and band 4
- The sun angle-corrected broadband albedo computed from the three bands, from which SIC values in a grid size of 10 km were calculated.
- Used as test data for SIC estimation models

PM SIC products
- Bootstrap (BT) SIC products (10 km grid) from JAXA.
- ARTIST Sea Ice (ASI) SIC products (3.125 km grid) from Univ. Bremen (resampled to 10 km)

Methodology

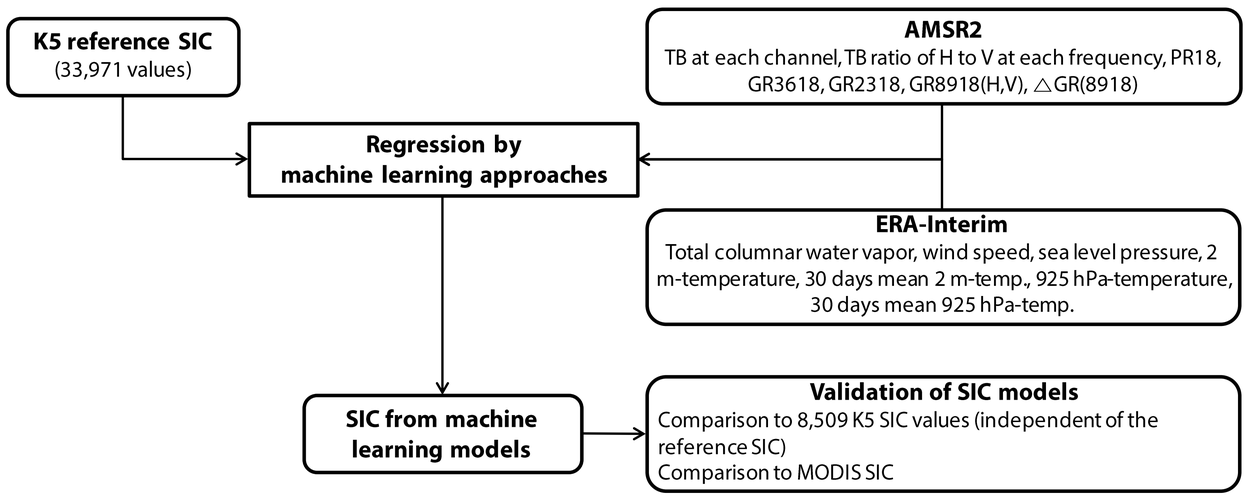

Fig. 2. Flowchart of summer SIC estimation using AMSR2 observations and ERA-Interim reanalysis based on machine learning.

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This research was supported by the Korea Polar Research Institute (KOPRI) Grant PE19120.

Summer SIC estimation model development

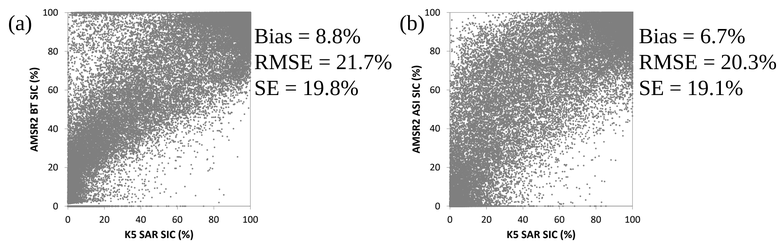

Fig. 3. Comparison of K5 SAR SIC with AMSR2 SIC from (a) Bootstrap (BT) and (b) ARTIST Sea Ice (ASI) algorithms in summer in the Chukchi Sea

- BT and ASI SIC show very large RMSE and SE, possibly due to the effects of atmospheric conditions and melt ponds on the AMSR2 TB observations.

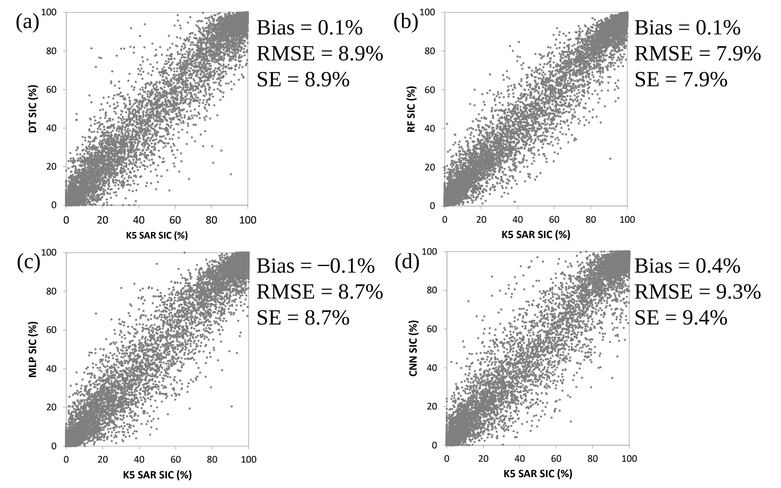

Fig. 4. Validation results of summer SIC estimation by (a) DT, (b) RF, (c) MLP, and (d) CNN.

- SIC estimation models based on DT, RF, MLP, and CNN were developed using 33,971 samples.
- The models were validated by 8,509 samples that are independent of the training samples.
- All models show lower bias, RMSE and SE than the BT and ASI algorithms.

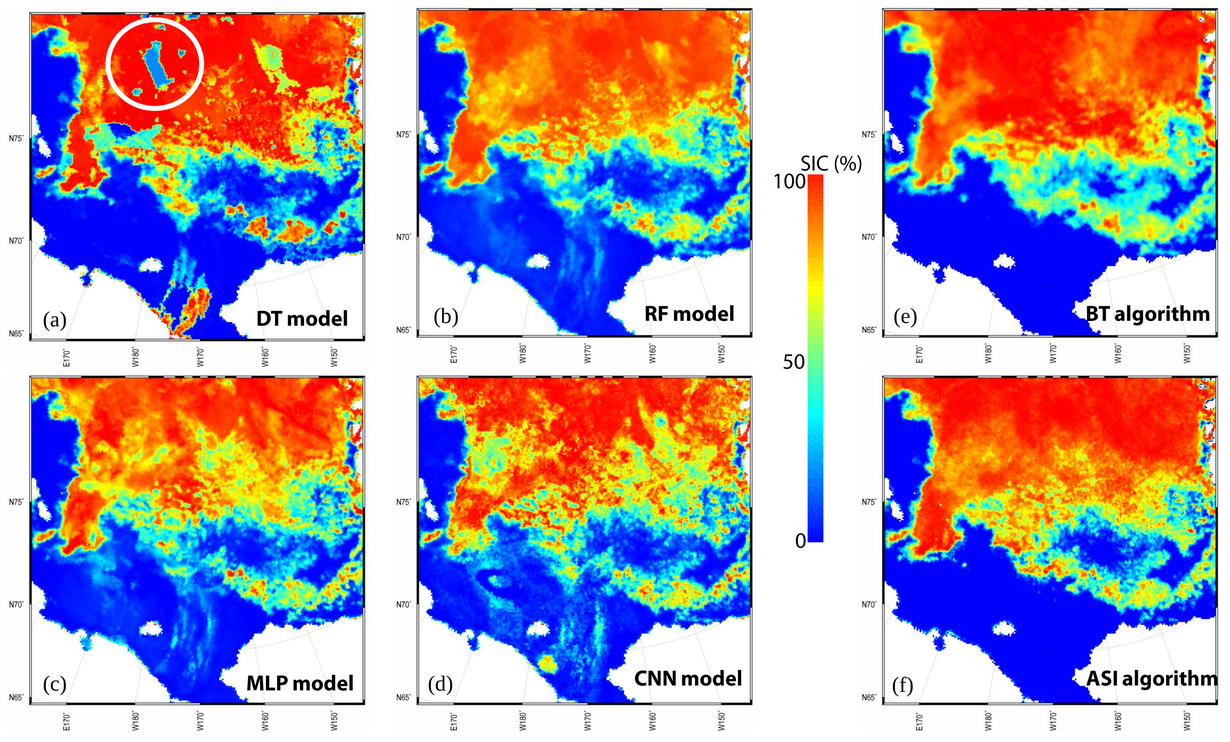

Fig. 5. SIC on 6 August 2015 in the Chukchi Sea estimated by (a) DT, (b) RF, (c) MLP, (d) CNN, (e) BT, and (f) ASI algorithms.

- The performance of DT model is poor (e.g., white circle in (a)) due to simple rule-based learning.
- The RF model produced similar results to the BT and ASI algorithms.
- The MLP and CNN models produced different SIC in marginal ice zone compared to BT and ASI algorithms.

Assessment of SIC estimation models using MODIS SIC

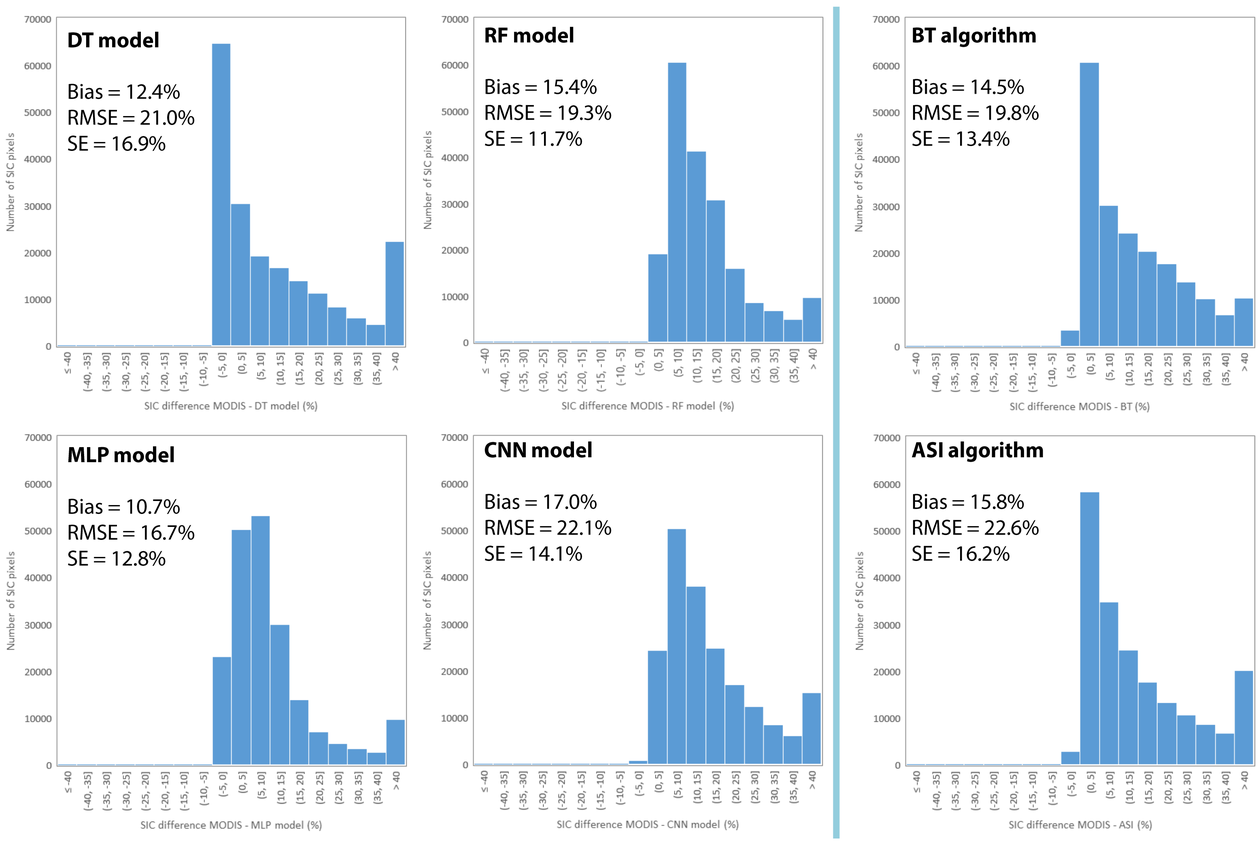

Fig. 6. Comparison of the developed models (DT, RF, MLP, and CNN) minus MODIS SIC and the existing algorithms (BT and ASI) minus MODIS SIC.

Concluding Remarks

- The summer SIC estimation models for the Chukchi Sea were developed using AMSR2 and ERA-Interim reanalysis data based on machine learning approaches.
- The models (except for DT model) showed smaller error than BT and ASI algorithms compared to KOMPSATS-5 SAR SIC.
- The performance assessment of summer SIC estimation using the MODIS SIC represented that the MLP model is superior to other machine learning models and the existing algorithms.