Retrieval of pan-Arctic sea ice concentration using deep learning

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Highlights

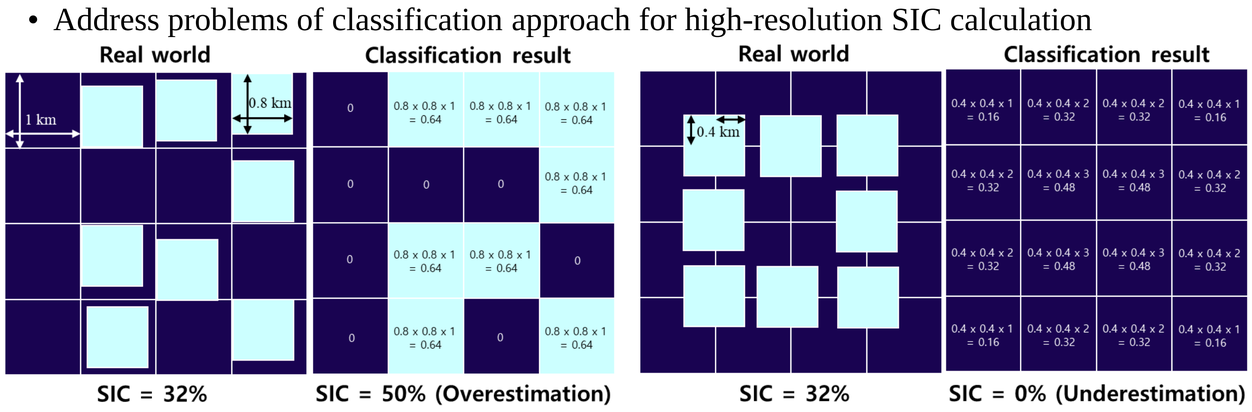
- Spectral mixture analysis (SMA)-based high-resolution sea ice concentration (SIC) retrieval algorithm from MODIS is developed
- Deep learning (DL) model for Arctic SIC retrieval from AMSR2 data is developed
- Improved Arctic SIC maps are obtained using the proposed methods
- DL-based SICs outperform the widely used SIC products in global and local regions

Abstract

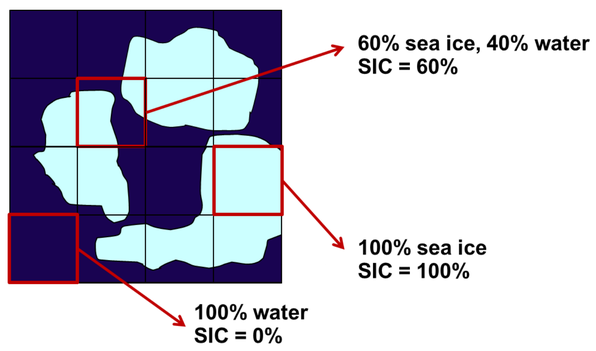
This study applies deep learning to retrieve Arctic SIC from AMSR2 data. MODIS-derived SICs are calculated based on SMA with a new ice/water endmember extraction algorithm that exploits global/local representatives, and then used to train a DL network with AMSR2 data. The resulting SIC maps outperform popular SIC products both regionally and globally. The RMSE of the proposed DL model is 5.19, whereas those of the widely used Bootstrap and ASI-based SIC images are 6.54 and 7.38, respectively, with respect to MODIS-derived SICs at global scale. In particular, our proposed method better describes regions of low-SIC and melting ice in summer, which are generally difficult-to-estimate. As the DL-based model consistently generates accurate SIC values that are not time- or region-dependent, it is considered to be an operational system. Additionally, our SICs can be used to generate initial conditions facilitating development of more accurate climate models.

High-resolution sea ice concentration from MODIS

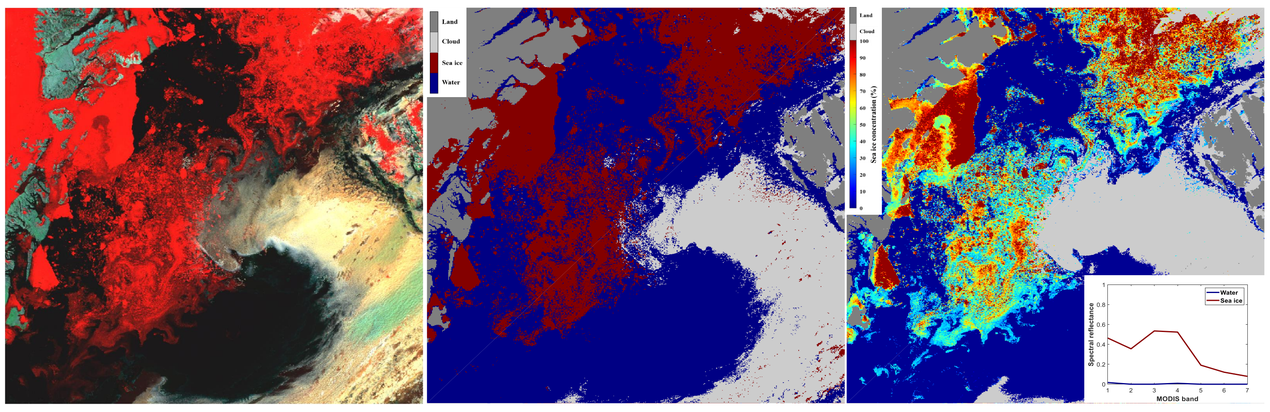
- Address problems of classification approach for high-resolution SIC calculation



- Solve mixtures at sub-pixel level using spectral mixture analysis
  - Presence of mixed pixels in remote sensing data → Consist of more than one spectral signatures
  - Ice/water abundance estimation
  : Find pure water and ice components that can be used to unmix all other pixels in the data using endmember extraction method
  : Solve least squares solution to find the abundances (α) that minimize the pixel reconstruction error $e = \|\mathbf{r} - \mathbf{M}\alpha\|^2$ where $\mathbf{r}$ is pixel vector, $\mathbf{M}$ is endmember matrix.



- Comparison of classification and SMA-based high-resolution SIC maps of the Fram Strait on August 1, 2017



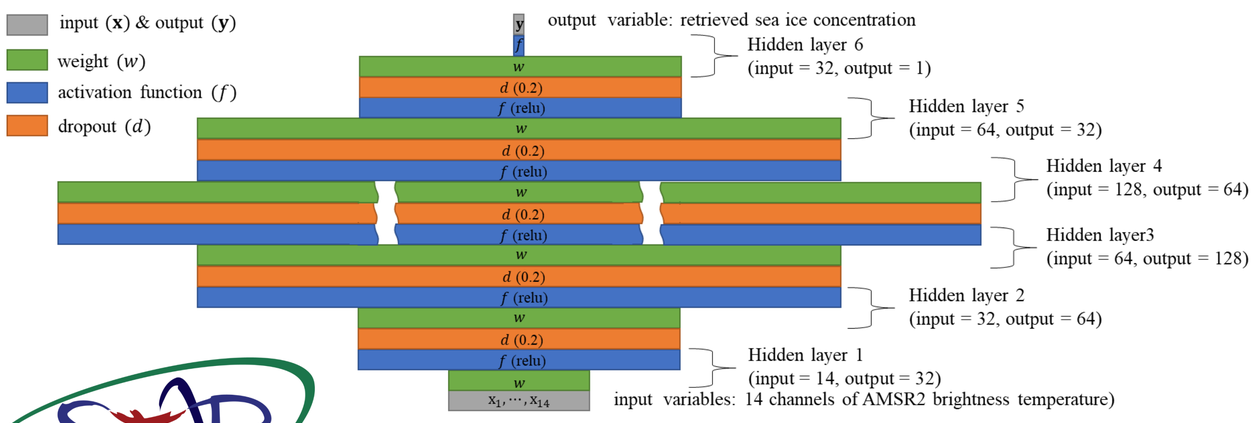
Enhanced MODIS 1/6/7 band composite | Ice/Water classification result | High resolution SIC using SMA approach

Datasets and tuned deep learning network topology

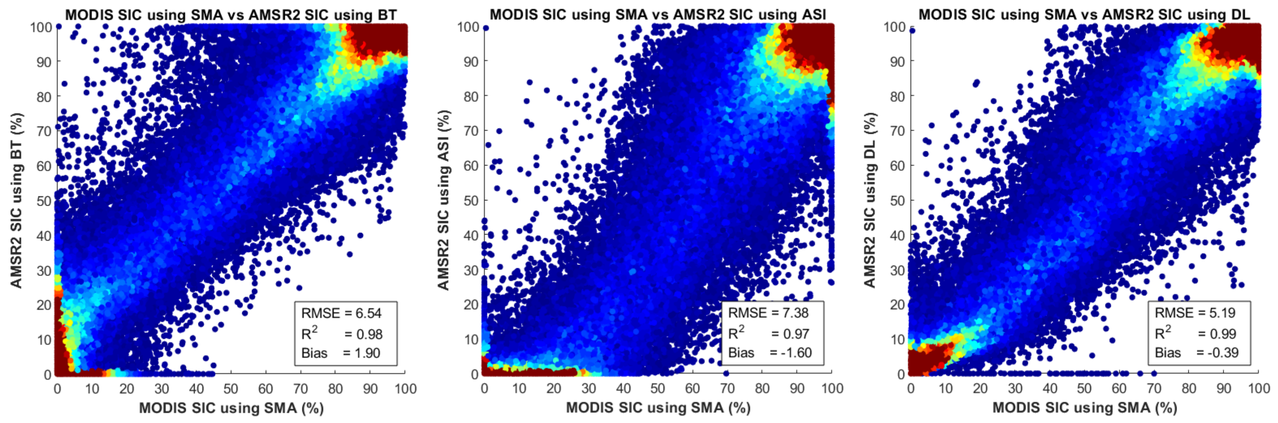
- Training sets: 4/3/2016 – 9/13/2016 (72 images*)
- Test sets: 4/2/2017 – 9/12/2017 (72 images*)

* Three consecutive images in every week

- Each dataset consists of 14 brightness temperature values of AMSR2 (input) and MODIS-based SIC values calculated the proposed SMA-based method (output)

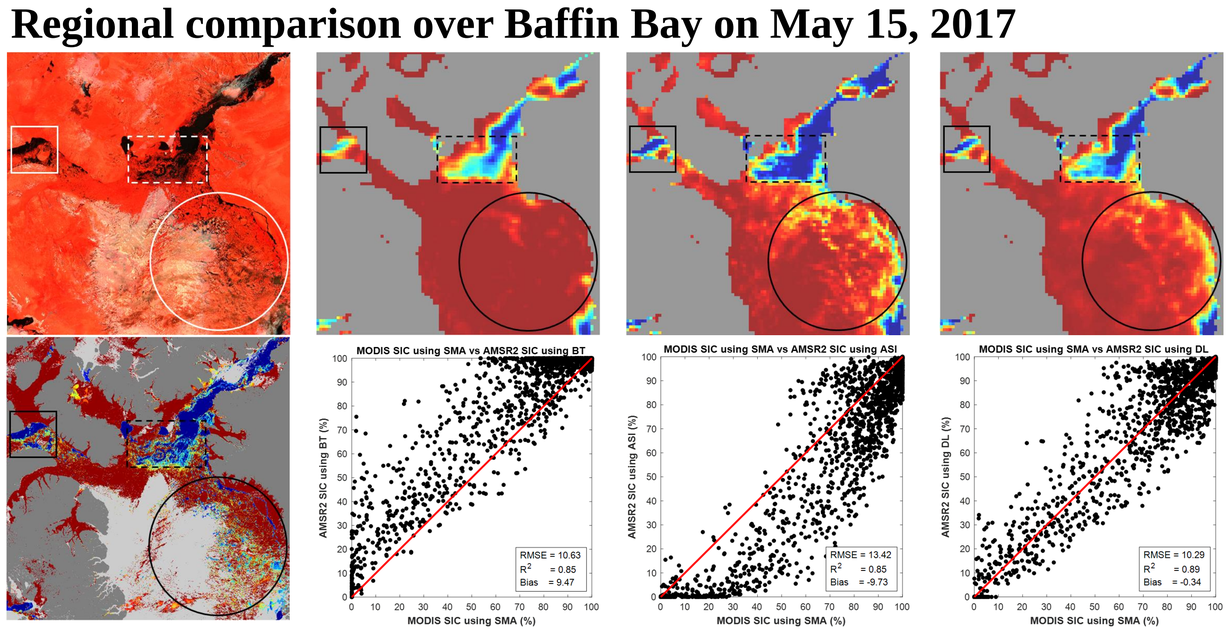


Overall statistical accuracy of three SIC retrieval models



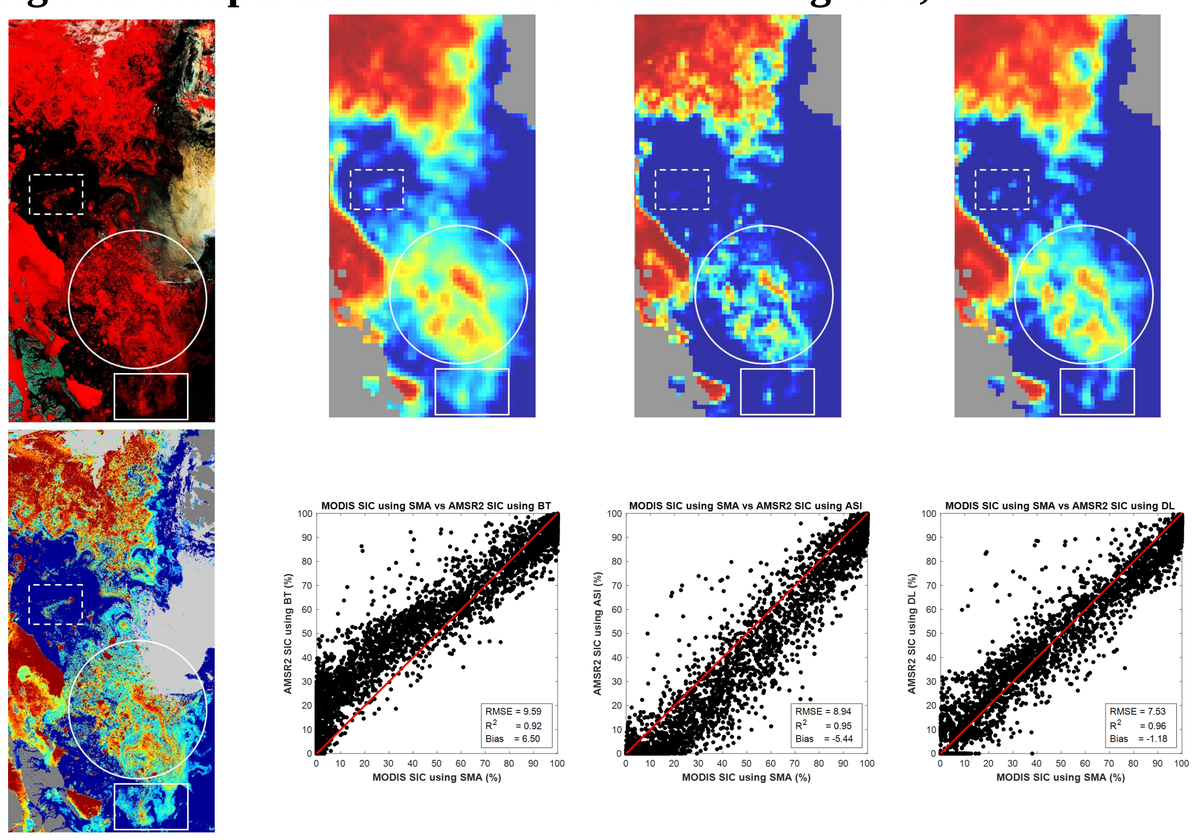
- Conducted using SMA-based SIC values as reference ($SIC_{MODIS/SMA-GLL}$; x-axis)
- Compared AMSR2-derived SICs given by three retrieval algorithms: Bootstrap, ASI and DL ($SIC_{AMSR2/BT}$, $SIC_{AMSR2/ASI}$, $SIC_{AMSR2/DL}$; y-axis)
- $SIC_{AMSR2/BT}$ values tend to overestimate the SIC, whereas $SIC_{AMSR2/ASI}$ values underestimate the SIC compared to the $SIC_{MODIS/SMA-GL}$ values
- DL-based retrieval model outperforms both BT- and ASI-based retrievals – neither underestimate nor overestimate

Regional comparison over Baffin Bay on May 15, 2017



- BT-retrieved image overestimates SIC values in regions where sea ice is not observed or covered only small portions of the MODIS image
- ASI algorithm seems exhibiting greater SIC variability and capturing mode details, but neglects low-concentration or melting ice, and yields relatively large areas of ice-free pixels
- DL approach shows better spatial agreement with the MODIS SIC image, and higher accuracy outcomes in the difficult-to-estimate range (20% – 80% SIC)

Regional comparison over Fram Strait on August 1, 2017



- Both BT and DL exhibit good agreement in the solid and dotted rectangles, whereas ASI doe not locate most of the low-SIC
- Sea ice extent identified from the BT and ASI images seem to be overestimations and underestimations, respectively, compared to MODIS-derived and DL-based SIC images
- DL result misses some low-SIC pixels that are captured by the BT-based retrieval
- $SIC_{AMSR2/DL}$ values statistically agree best with the reference, while significant overestimations of BT in 0 – 50% SIC and underestimations of ASI in 20% – 80% SIC

Reference

J. Chi et al., Deep learning based retrieval algorithm for Arctic sea ice concentration from AMSR2 passive microwave and MODIS optical data, *Remote Sensing of Environment*, *In Press*

Acknowledgements

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