

Detection of sea ice and evaluation of passive microwave ice concentrations in the Chukchi Sea using KOMPSAT-5 SAR images

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Arctic Sea Ice

- **Importance of Arctic sea ice**
 - **Strong indicator of global climate change**
 - **Important for biological habitats**
 - **arctic mammals (seals, polar bears) hunt, breed, and feed on the ice**
 - *Important for human activities*
 - *Shipping, exploration of resources, development of Northern Sea Route*
 - *Need of accurate sea ice map*

Remote sensing for sea ice observation

- **Satellite optic sensors**
 - reasonable detection over very wide area
 - limited by weather conditions and sun altitudes
 - not enough to observe small scale ice, especially in melting peak season
- **Passive microwave (PM) Sensors**
 - Have observed sea ice distribution and provided daily sea ice concentration (SIC) since 1970s
 - Sea ice observation regardless of weather conditions and sun altitudes
 - Large errors of SIC in summer season
 - Error assessment of PM SIC is required

Sea ice observation by SAR

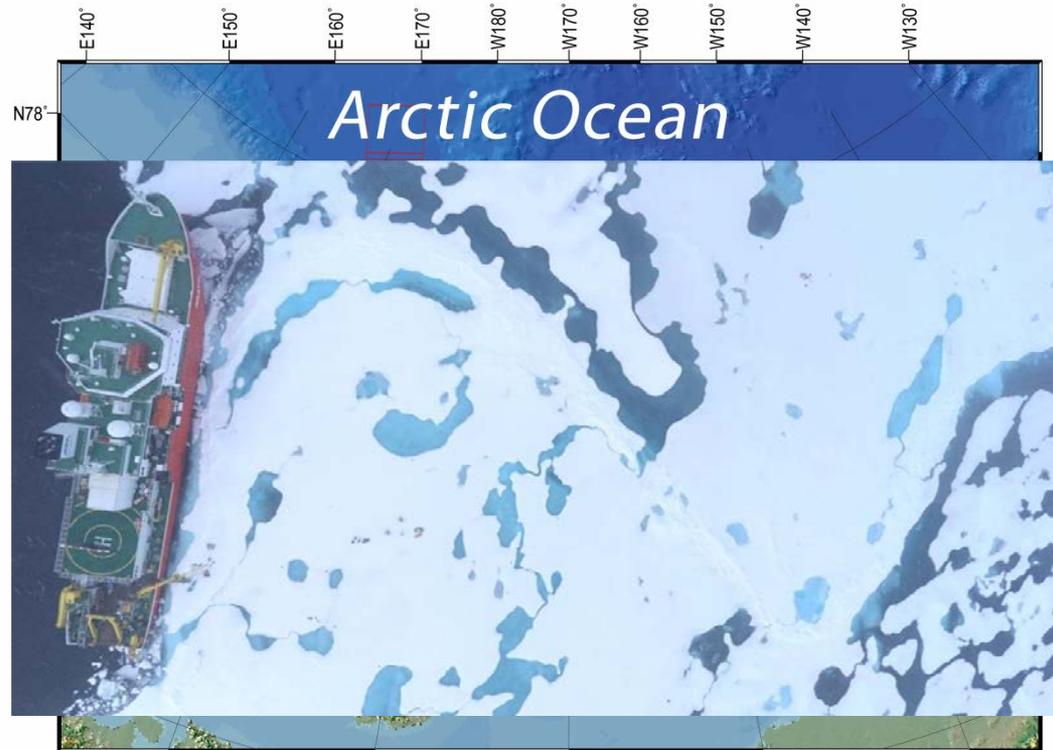
- **Synthetic Aperture Radar (SAR)**
 - all weather, day and night imaging
 - melt onset/freeze onset, sea ice characteristics
 - can observe wide area (100 ~ 500 km)
 - can detect small scale ice by present-day high-resolution SAR
- **KOMPSAT-5 SAR (X-band)**
 - South Korea's first satellite SAR operating various imaging modes (~100 km)
 - X-band SAR is more sensitive to wetness/roughness of surface than C/L-band SAR
 - Strong wind over open water -> sea ice??
 - Difficult to correct wind-induced backscattering over open water

Objectives

- **To develop sea ice mapping model for KOMPSAT-5 wide swath SAR images with various look angles using a rule-based machine learning approach**
- **To evaluate the availability of KOMPSAT-5 SAR images for mapping sea ice**
- **To evaluate passive microwave sea ice concentrations in ice melting season**

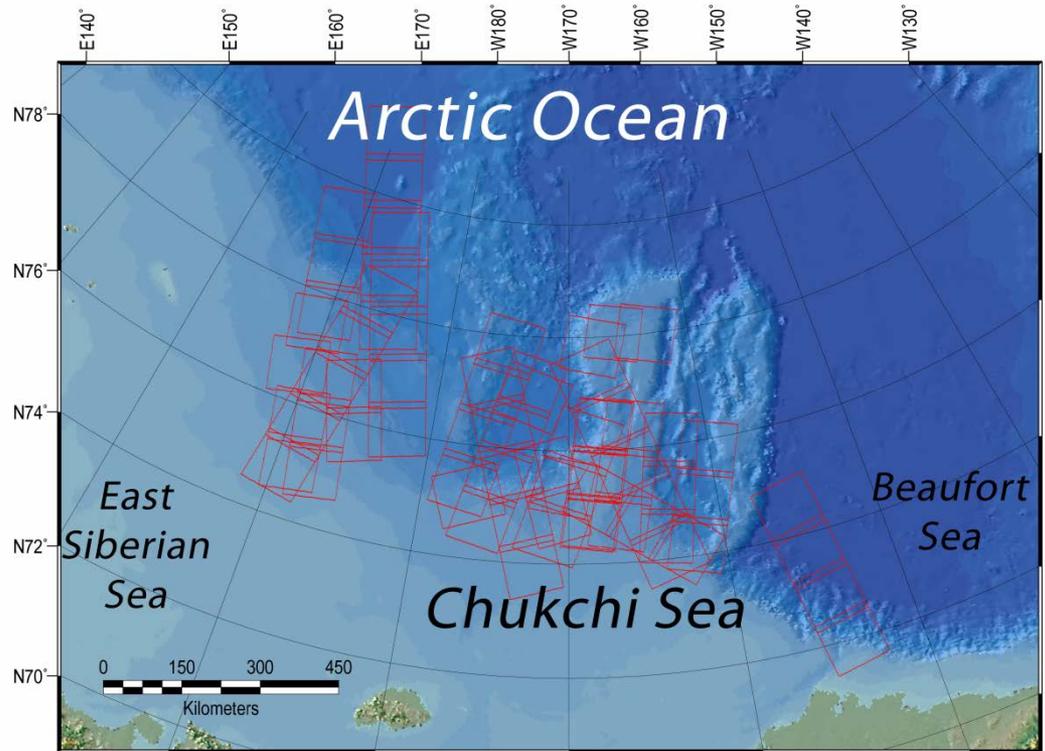
Study area

- **Chukchi Sea, Arctic Ocean**
 - **Araon expedition in 2015**
 - **Ice edge/marginal ice/compact ice zone**
 - **Sea ice with numerous ponds and leads**



Data – KOMPSAT-5

- **KOMPSAT-5 SAR data**
 - 6 Aug. – 9 Sep. 2015
 - 84 Enhanced Wide Swath (EW) images (100 × 100 km)
 - HH-pol, 6.25 m-grid spacing
 - 1-look, GEC products
 - Ascending/descending orbits
 - Various radar look angles
 - 17~49°



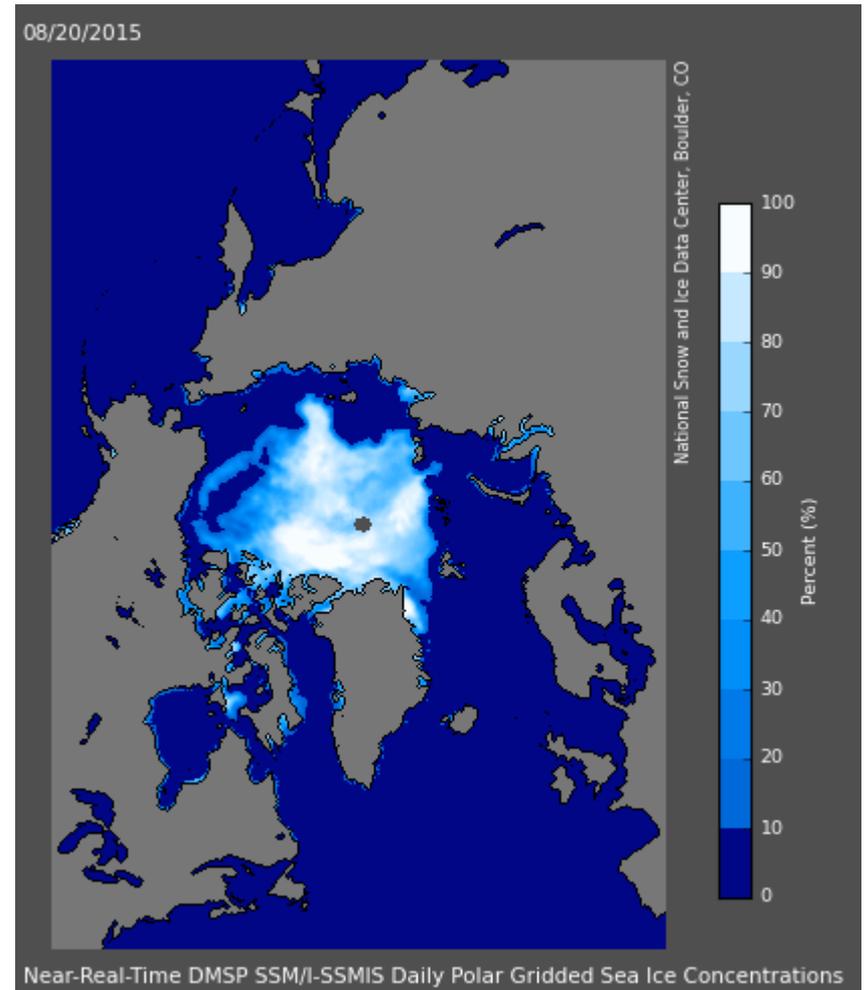
Data – PM SICs

- **SSMIS sea ice concentration**

- 6 Aug.~9 Sep. 2015
- NASA Team (NT) algorithm
- Using 19 GHz H&V, 37 GHz V
- 25 km grid

- **AMSR2 sea ice concentration**

- 6 Aug.~9 Sep. 2015
- Arctic Radiation and Turbulence Interaction STudy (ARTIST) Sea Ice (ASI) algorithm
- Using 89 GHz H&V
- 6.25 km grid

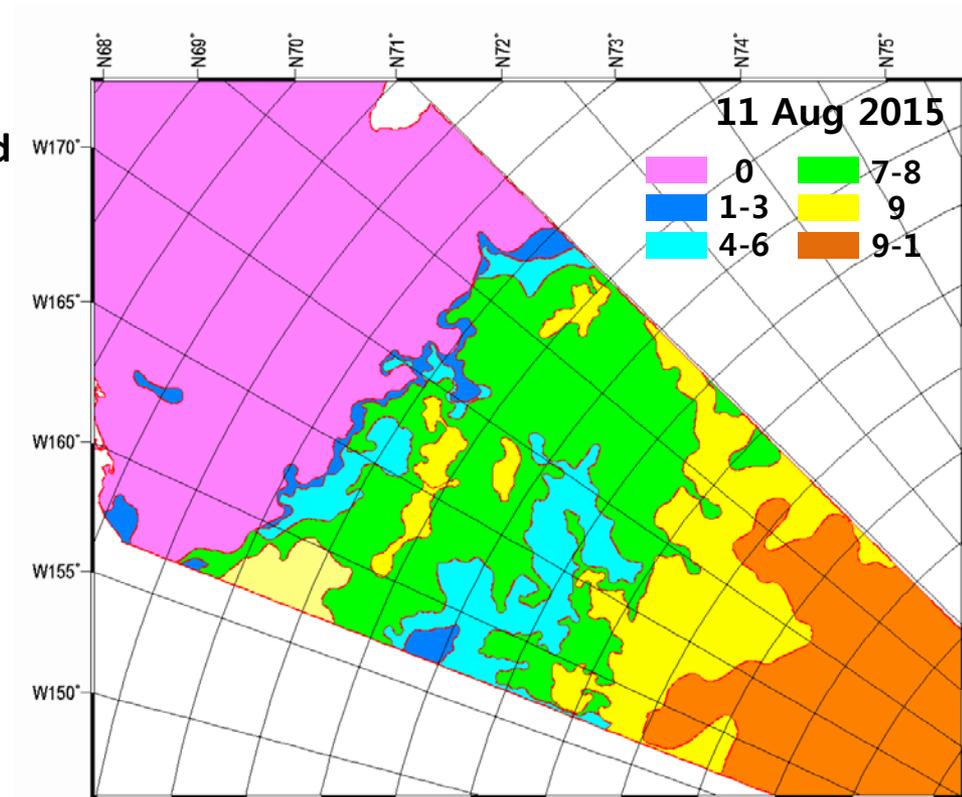


Data – AARI ice charts

- AARI (Russian Arctic and Antarctic

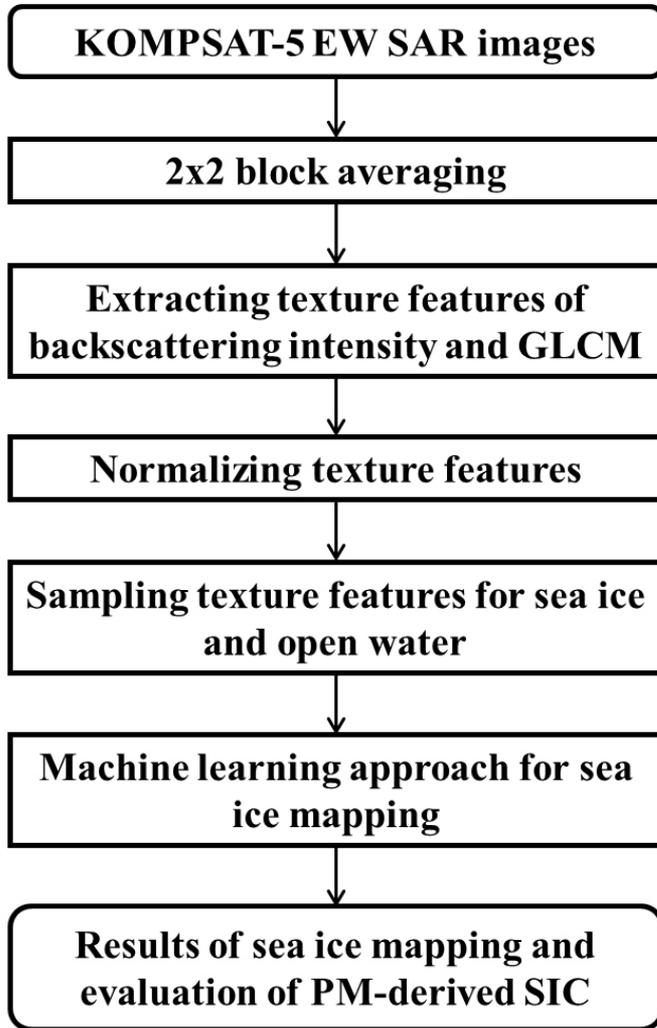
Research Institute) ice charts

- Ice types/ice concentrations analyzed from satellite dataset by ice experts
- Weekly products



Ice concentration of AARI ice chart

Sea ice mapping by KOMPSAT-5 SAR



→ 6.25 m resolution

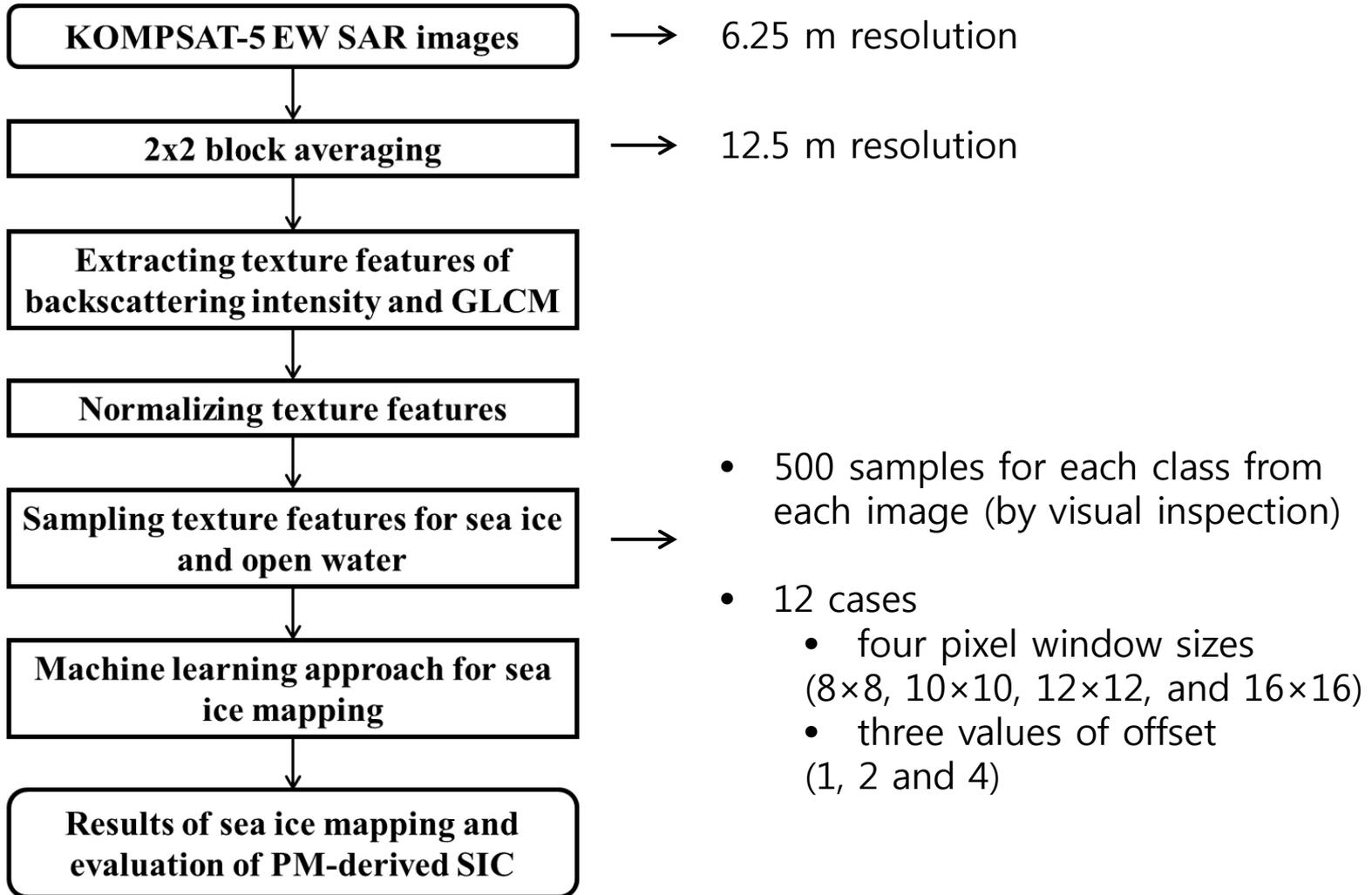
→ 12.5 m resolution

- **Gray level co-occurrence matrix (GLCM)**
- Second order statistics
 - Depends on window size, number of level, directions, and offset
 - Contrast, correlation, homogeneity, dissimilarity, entropy, etc.
 - Widely used for classification of SAR images

GLCM

	1	2	3	4	5	6	7	8
1	1	2	0	0	1	0	0	0
2	0	0	1	0	1	0	0	0
3	0	0	0	0	1	0	0	0
4	0	0	0	0	1	0	0	0
5	1	0	0	0	0	1	2	0
6	0	0	0	0	0	0	0	1
7	2	0	0	0	0	0	0	0
8	0	0	0	0	1	0	0	0

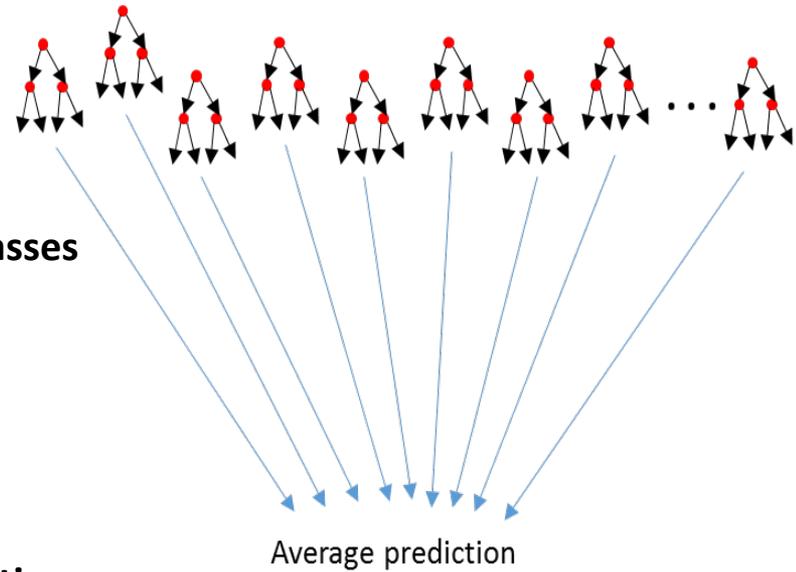
Sea ice mapping by KOMPSAT-5 SAR



Sea ice mapping by KOMPSAT-5 SAR

- **Random forest**

- A rule-based machine learning approach
- constructing a multitude of decision trees
- outputting the class that is the mode of the classes of the individual trees
- correct for decision trees' habit of overfitting

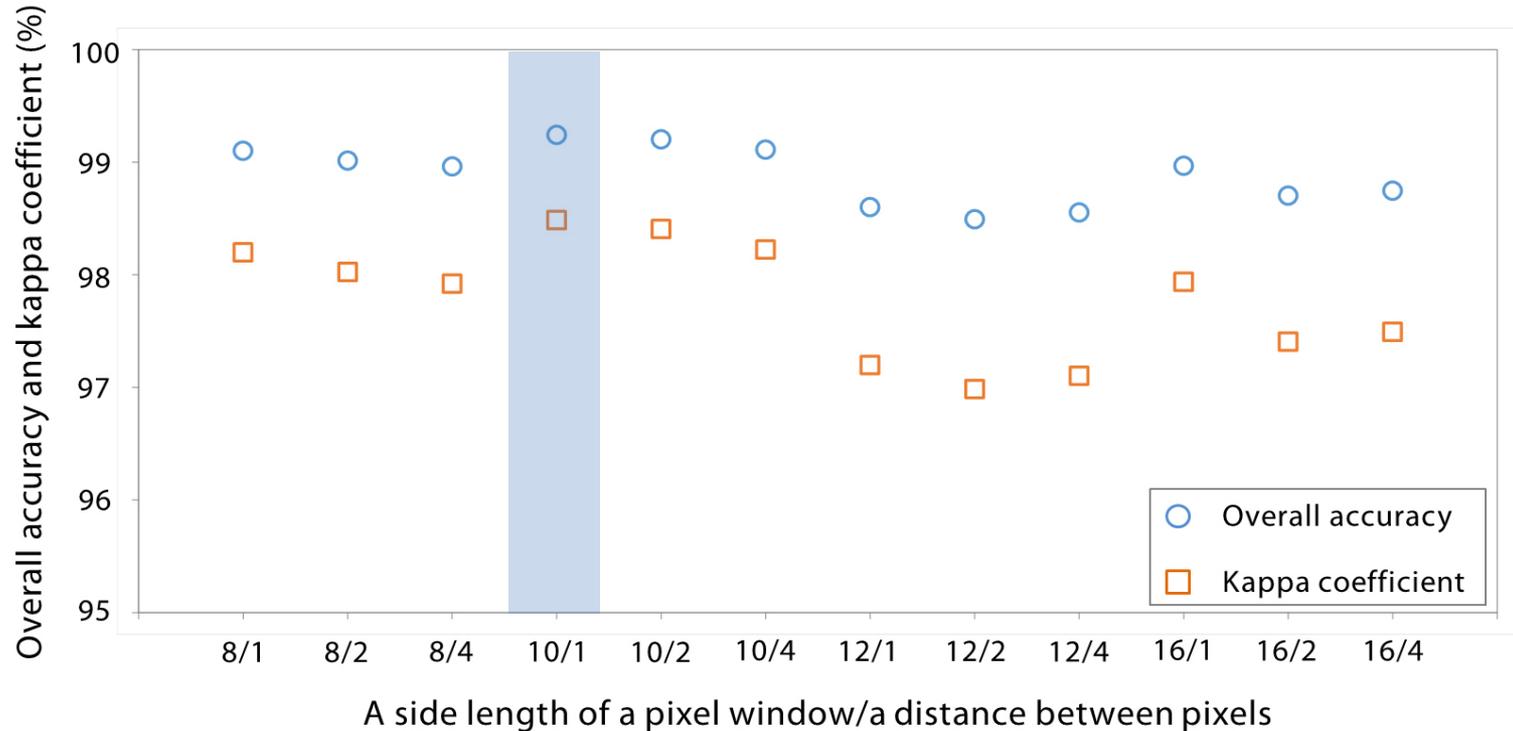


- **Samples used for sea ice/open water classification**

- 70% for training model (58,800 samples)
- 30% for validation (25,200 samples)

$$(0.23 + 0.19 + 0.34 + 0.22 + 0.26 + \dots + 0.31) / \# \text{ Trees} = 24$$

Performance of Sea ice detection models

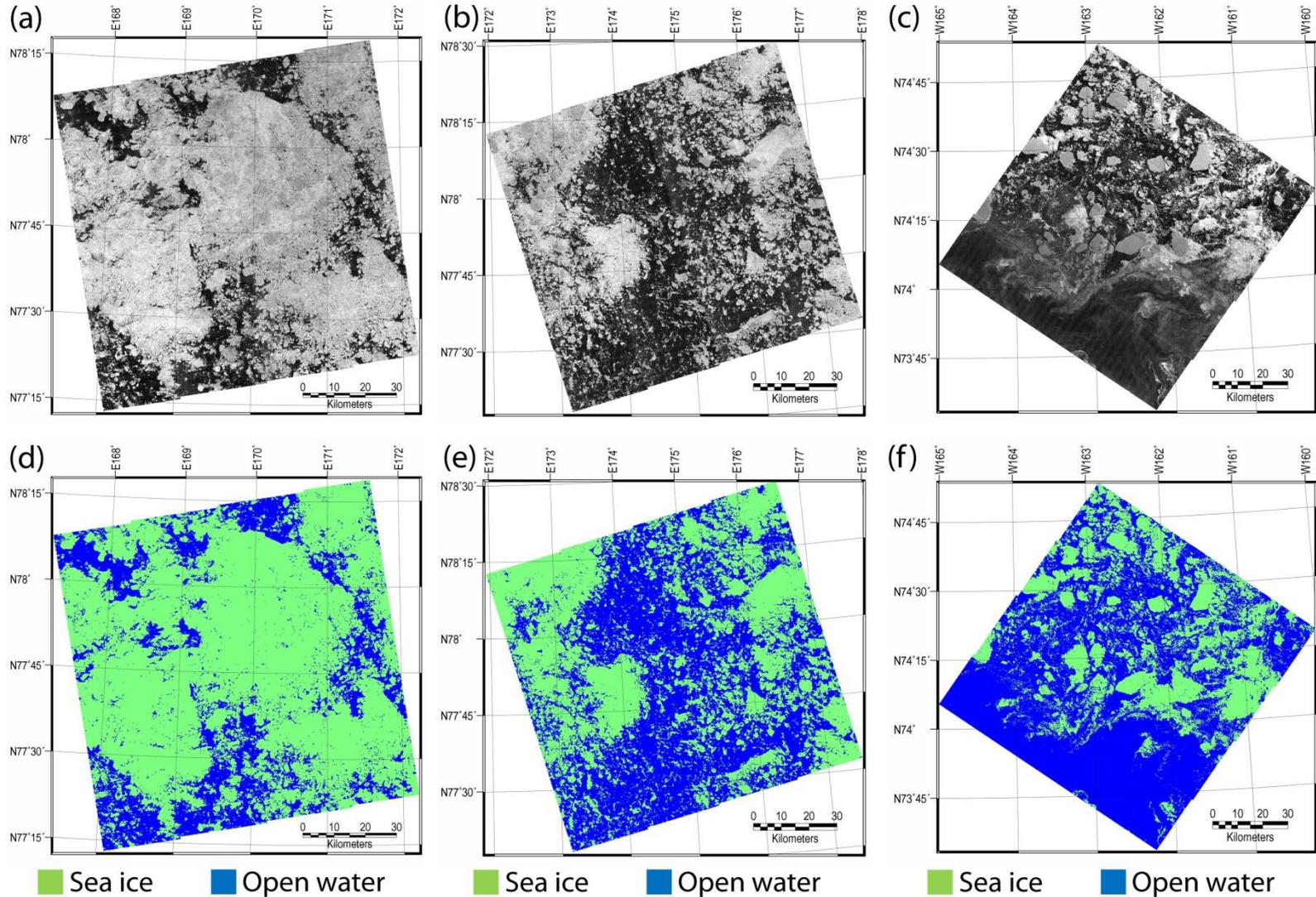


Performance of the best model

- *High performance* for sea ice/open water mapping (125 m resolution) based on KOMPSAT-5 EW SAR and machine learning approach

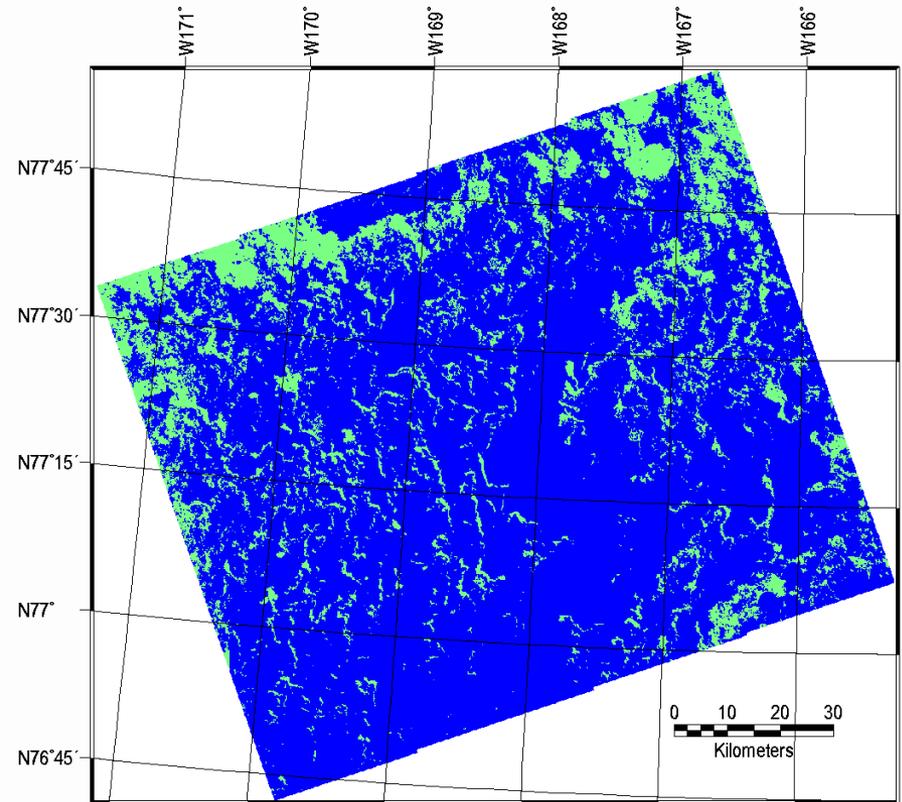
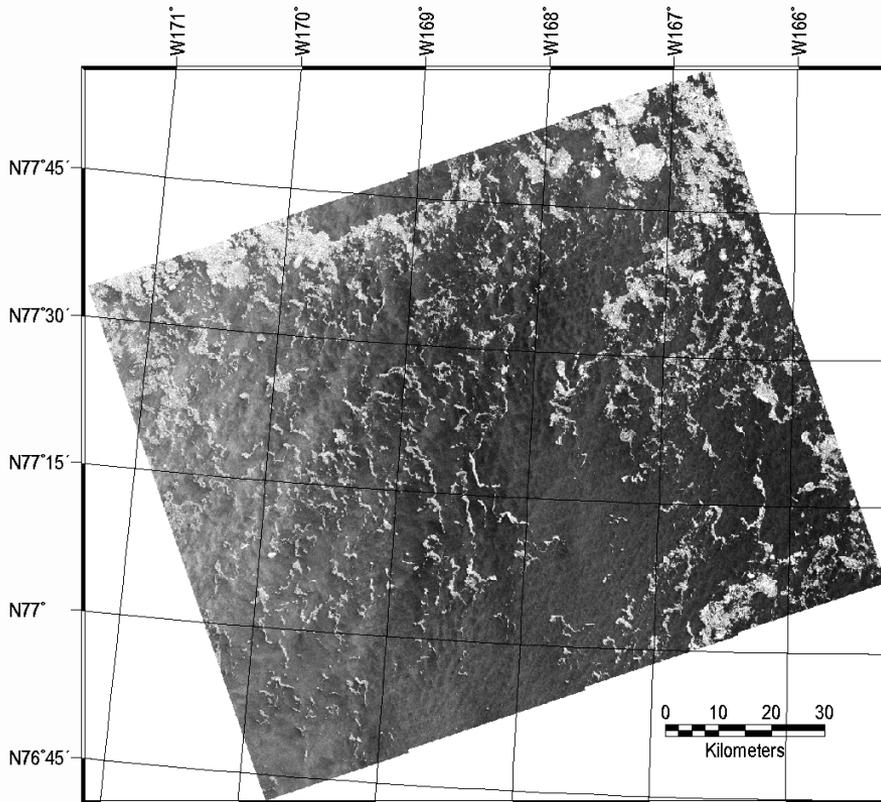
Reference Classified as	Open Water	Sea Ice	Sum	User's Accuracy
Open Water	12453	44	12497	99.64%
Sea Ice	147	12556	12703	98.84%
Sum	12600	12600	25200	
Producer's Accuracy	98.83%	99.65%		
Overall Accuracy				99.24%
Kappa Coefficient				98.48%

Examples of KOMPSAT-5 EW SAR sea ice map



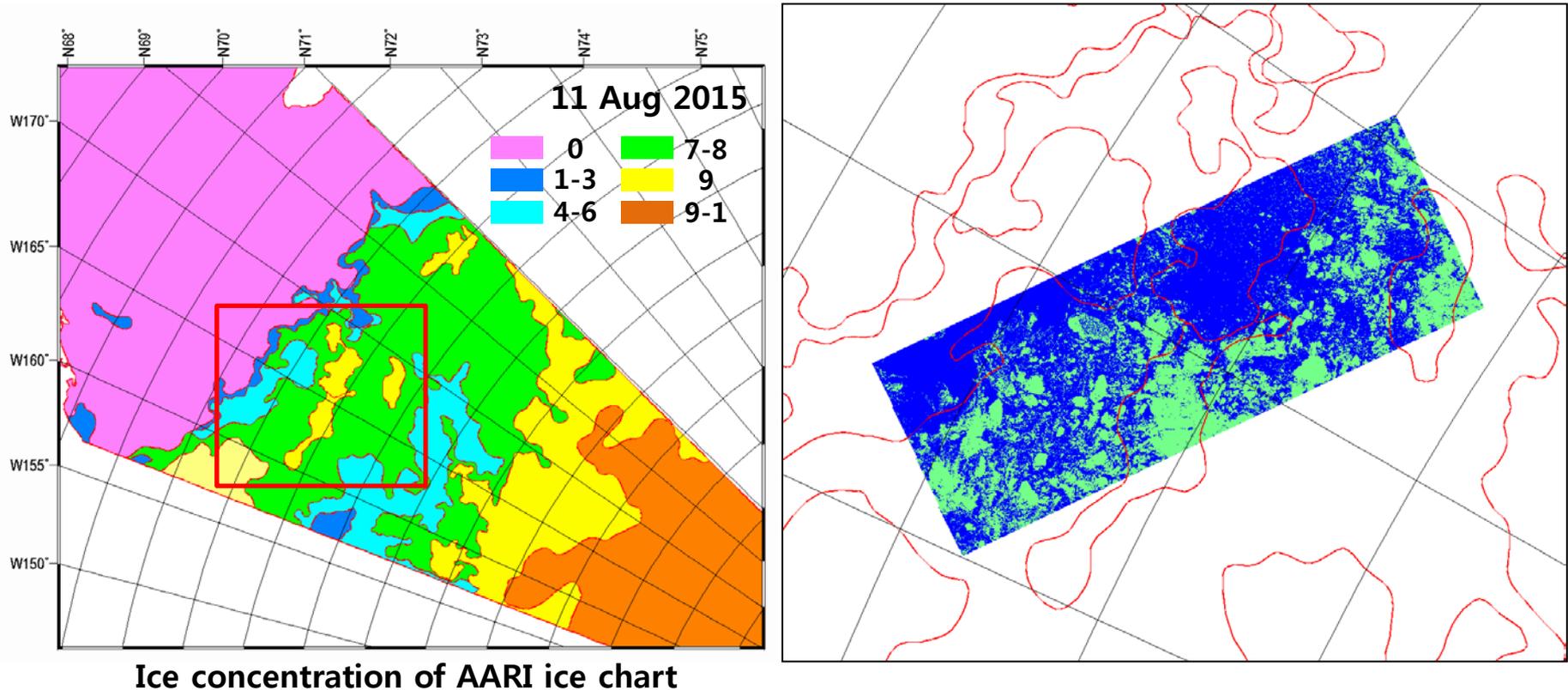
Examples of KOMPSAT-5 EW SAR sea ice map

- Strong wind blowing (~15 m/s)



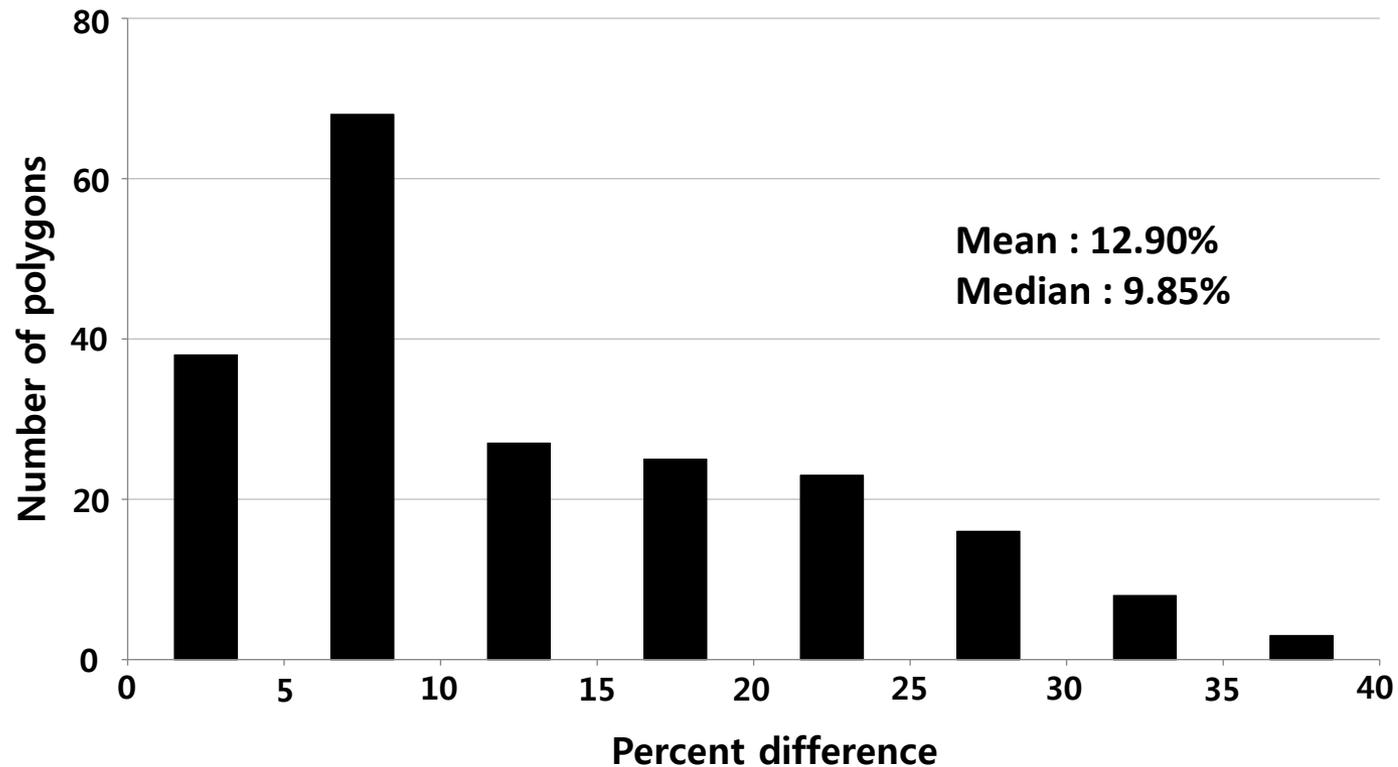
KOMPSAT-5 sea ice map vs. AARI ice chart

Comparison of sea ice concentration derived from AARI ice charts and K5 sea ice maps



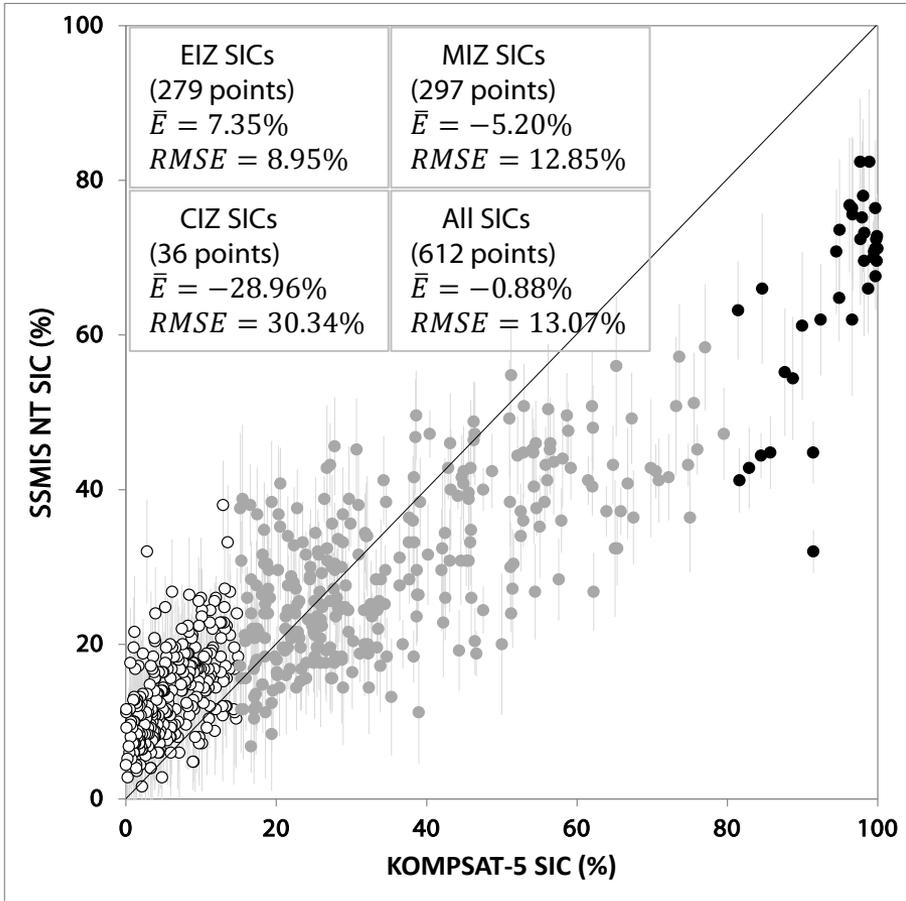
KOMPSAT-5 sea ice map vs. AARI ice chart

Distribution of sea ice concentration differences (absolute value)

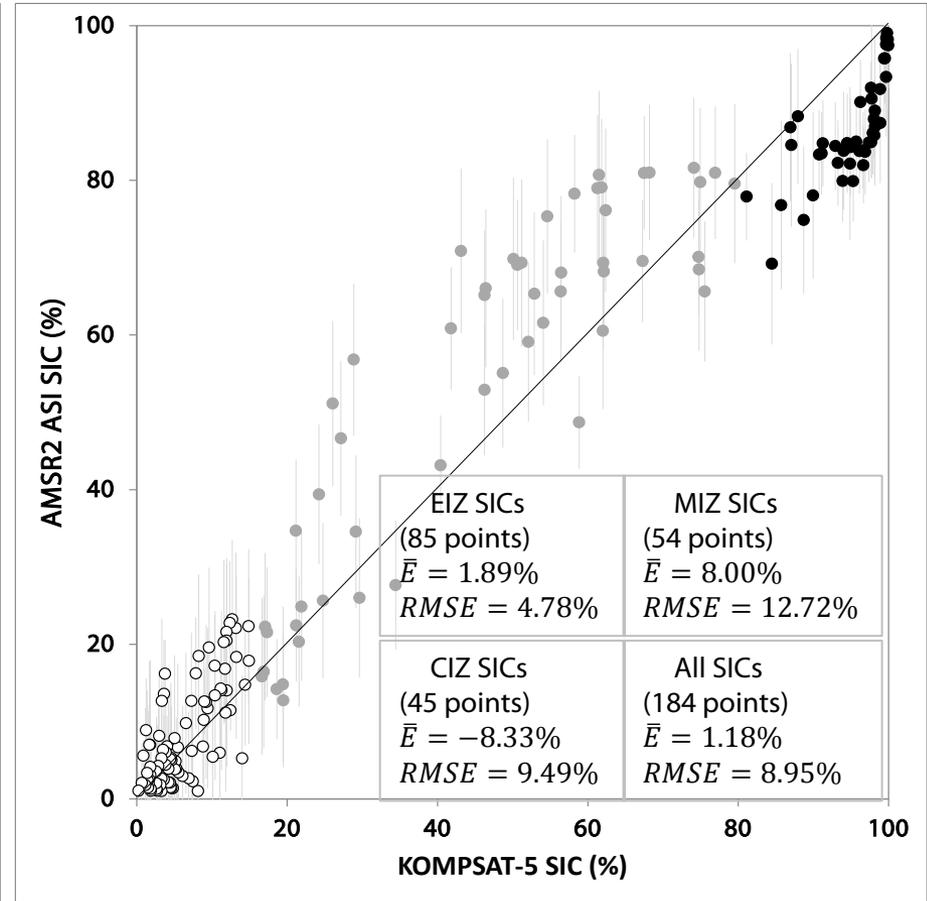


Comparison of KOMPSAT-5 SIC and PM SICs

KOMPSAT SIC vs. SSMIS NT SIC



KOMPSAT SIC vs. AMSR2 ASI SIC



Conclusion

- **A sea ice mapping model for KOMPSAT-5 EW SAR data was developed using RF-based binary classification of GLCM texture features.**
- **The sea ice mapping model exhibited excellent performance in detection of sea ice.**
- **The SSMIS NT SIC was underestimated in the MIZ and CIZ, while it was overestimated in the IEZ.**
- **The AMSR2 ASI SIC was underestimated only in the CIZ and was overestimated in other regions.**

Thank you for your attention

