# Image Reconstruction and sea ice recognition based on SWIM

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The Arctic sea ice exerts significant impacts on global climate change, navigation, shipping, and natural resource development, while also influencing the detection of other marine phenomena. Therefore, sea ice monitoring holds crucial research significance and practical value. Sea ice identification and classification are fundamental components of sea ice monitoring. SWIM, a novel small incidence angle sensor mounted on CFOSAT, offers high data coverage but lacks imaging capability and has relatively low spatial resolution. Hence, this study employs image reconstruction techniques to obtain high-quality sea ice images. Present image reconstruction techniques primarily rely on medium incidence angle microwave scatterometers, which enhance spatial resolution by extracting information from overlapping regions between multiple independent measurements in the same area. This study proposes image reconstruction under small incidence angles based on SWIM data.

## Research Data And Study Area

### CFOSAT SWIM

Observing ocean surface wind and waves

Extending Sea ice detection

**Latitude**: ± 83°

Multi-small-incidence mode is a new detection pattern for the sea iceSea wave retrieval also requires sea ice information to remove its 'pollution'

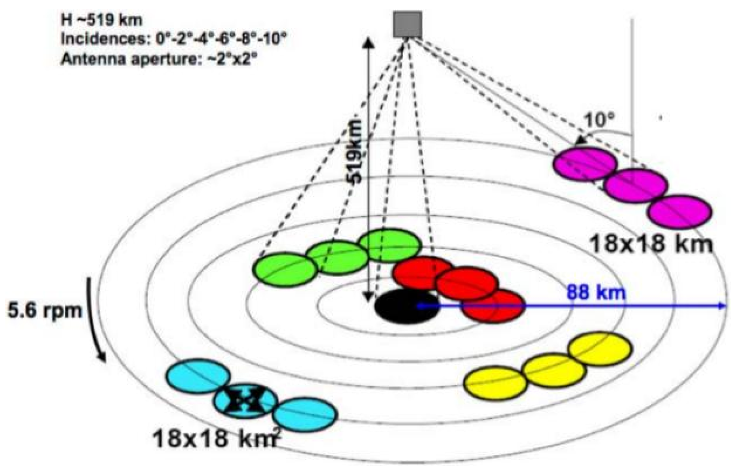


**Fig.1 SWIM Schematic diagram of detection**

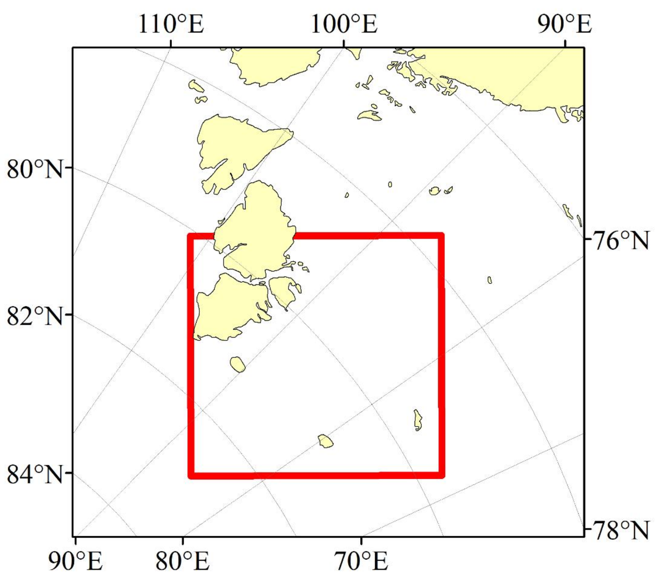


**Fig.2 The study area for image reconstruction**

### Study Area

Severnaya Zemlya Archipelago, an archipelago belonging to Russia along the coast of the Arctic Ocean.

**Longitude range** :70°-102°E

The region has a cold climate, with relatively small land area. The surrounding waters are mostly covered with annual and early ice, and there is minimal variation in ice types over short periods, making it suitable for reconstruction experiments.

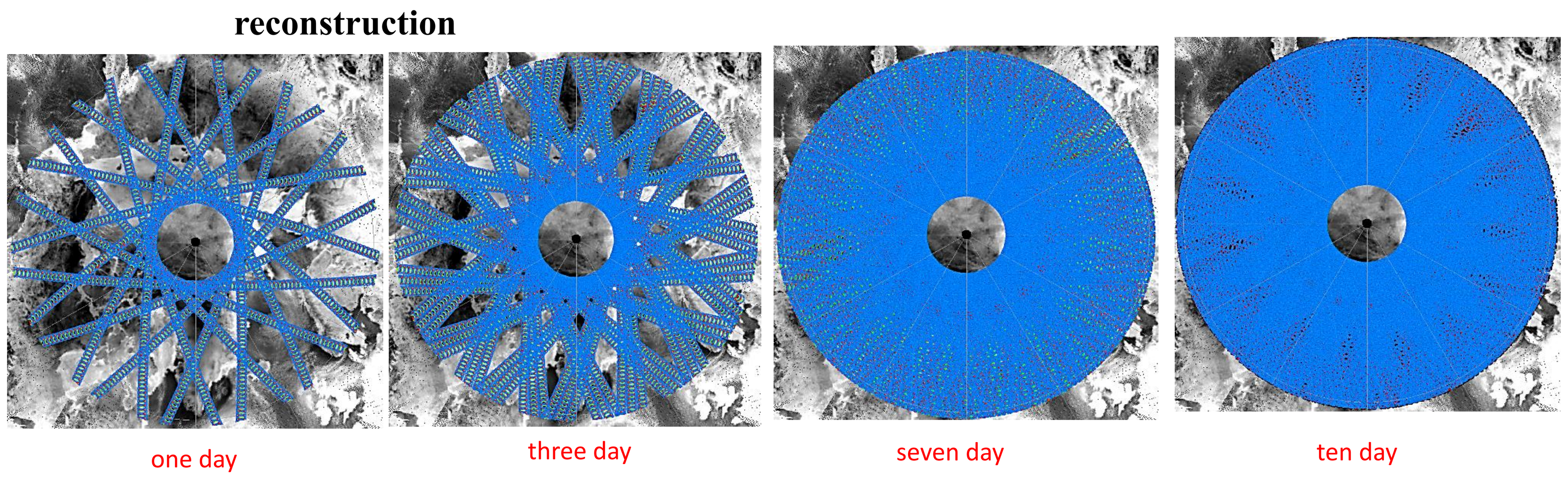


**Fig.3 SWIM footprint diagram**

### coverages of SWIM data

Daily or three-day data have may gaps in the Arctic can not cover the all Arctic region.

7-day data or more can cover almost the Arctic region.

**For single angle, 10-day data are more suitable; For multiply angles, 7-day data are appropriate.**

## Methods

### Image reconstruction theory

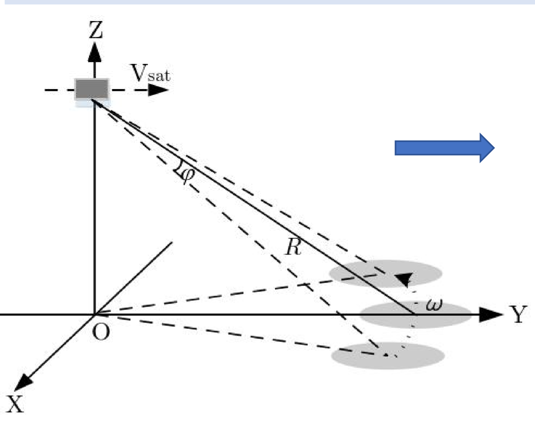


**Fig.4 Irradiation geometries of footprints or slices**

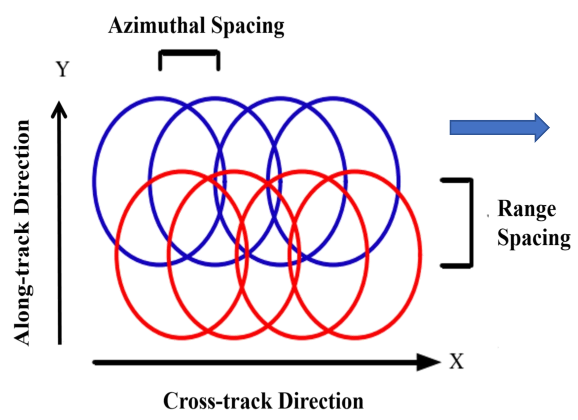


**Fig.5 Projection geometries of footprints or slices**

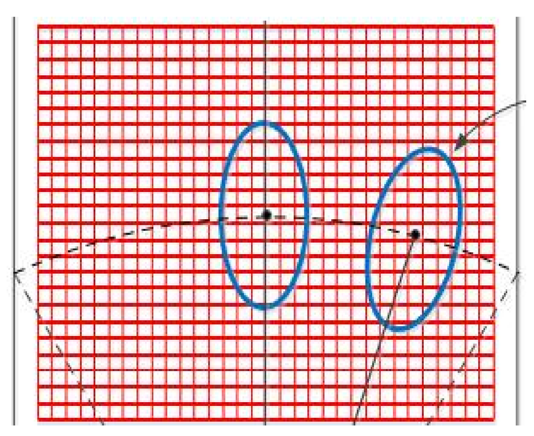

**Fig.6 Reconstruction image**

Image reconstruction methods leverage the information from overlapping , regions between multiple independent measurements in the same area to enhance the spatial resolution of the targets. Its essential strategy is to update and improve the resolution through the multiple overlapping measurements.Figure 6 shows red grids denoting reconstructed high-resolution pixels. Color ellipses represent the footprints or slices.Figure 7 gives scaling factors of each footprint or slice contributing to the reconstructed pixels it covers.

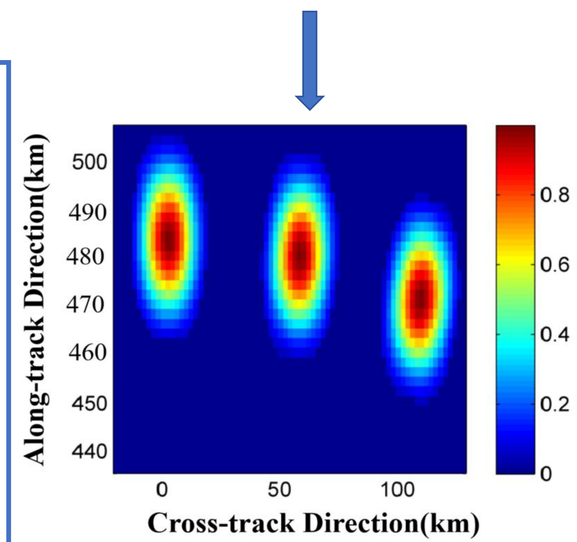


**Fig.7 Scale factors of footprints or slices**

### SWIM-IR

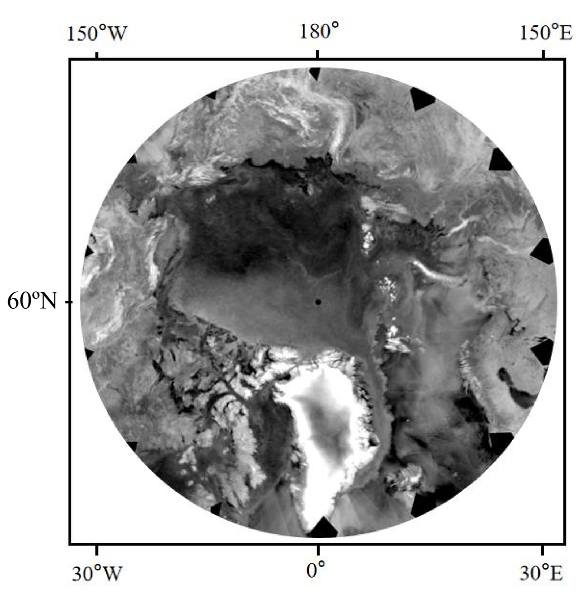


**Fig.8 ASCAT-AResolution: 4.45km/pix Feb. 1st, 2021**

SIR: $s_i^{k+1} = \frac{\sum_{j=1}^{N} h_{ji} u_{ij}^k}{\sum_{l=1}^{N} h_{li}}$

weighting function $h_{ji}$ ;update term: $u_{ij}^k =$

$$\begin{cases} \left[\frac{1}{2}\frac{1}{f_j^k}\left(1-\frac{1}{d_j^k}\right)+\frac{1}{s_i^k d_j^k}\right]^{-1}, d_j^k \geq 1 \\ \left[\frac{1}{2} f_j^k\left(1-d_j^k\right)+s_i^k d_j^k\right], d_j^k < 1 \end{cases}$$

Forward measurement project: $f_j^k = \frac{\sum_{l=1}^{M} h_{jl} s_l^k}{\sum_{l=1}^{M} h_{jl}}$

Scaling factor: $d_j^k = \left(\frac{z_j}{f_j^k}\right)^w$

The scatterometer image Reconstruction (SIR) algorithm is suitable for SWIM data. SIR is used for SWIM image reconstruction (SWIM-IR).

## Result

### Influence of incidence angles

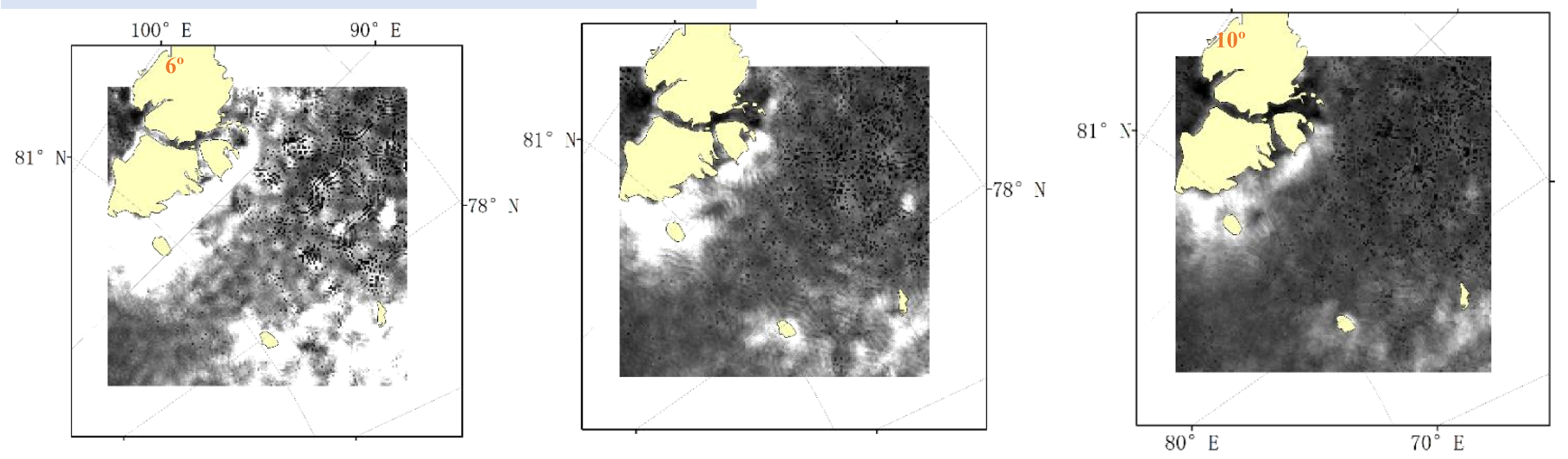


**Fig.9 Reconstructed image with different incidence angles**

The normalized backscattering coefficients among **6º - 10º** are distinctly different, implying incidence angle influence.

**At 6º**, there are numerous bright spots **indicating** reconstruction errors in the image.

**At 8º**, the bright spots decrease.

**At 10º**, the image is clear, the bright spots are fewest among the three images.

**10º** is more suitable for SWIM-IR.

### Sea ice edge verification

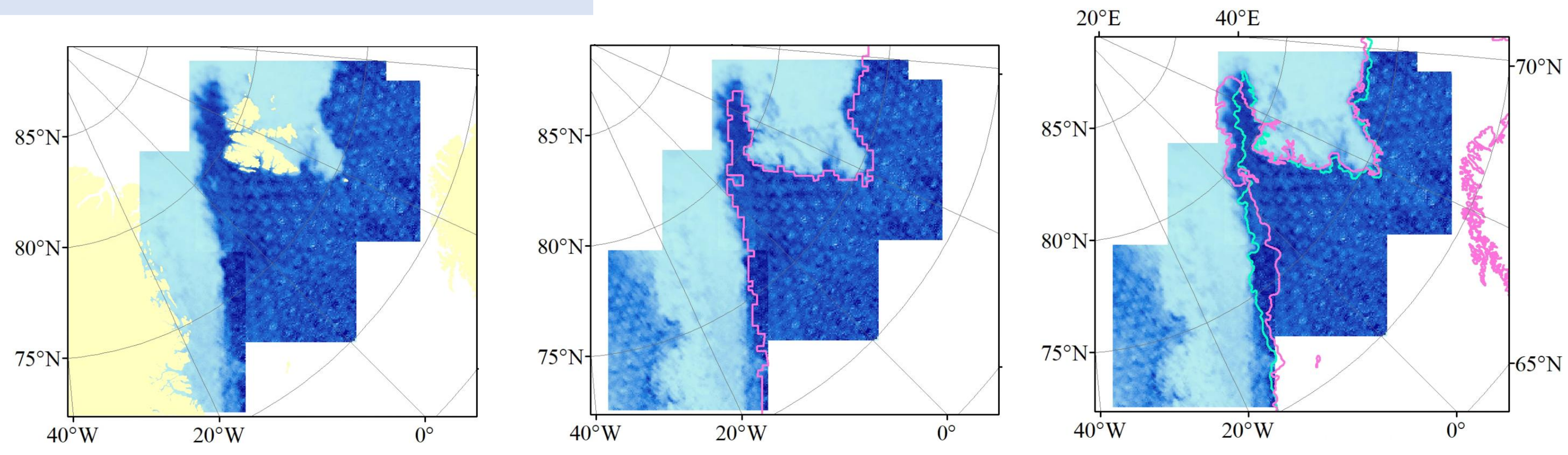


**Fig.10 Our reconstructed image** **Fig.11 Compared with SWIM(25km)** **Fig.12 Compared with AARI products**

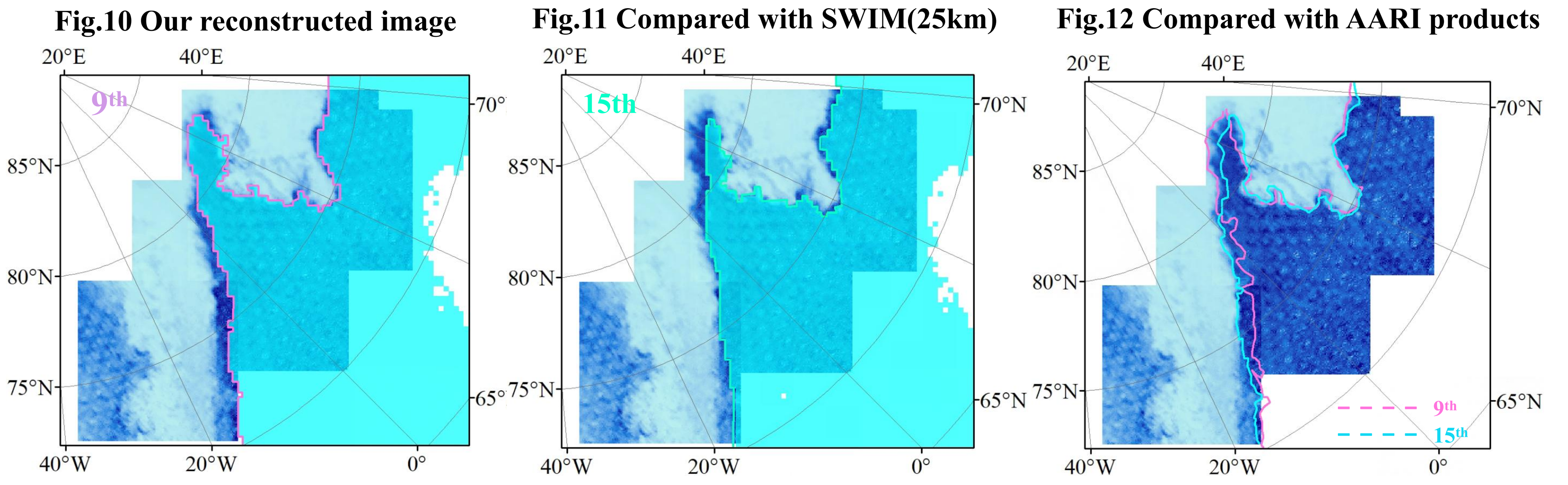


**Fig.13 Compared with NSIDC products** **Fig.14 Comparison with SSM/I**

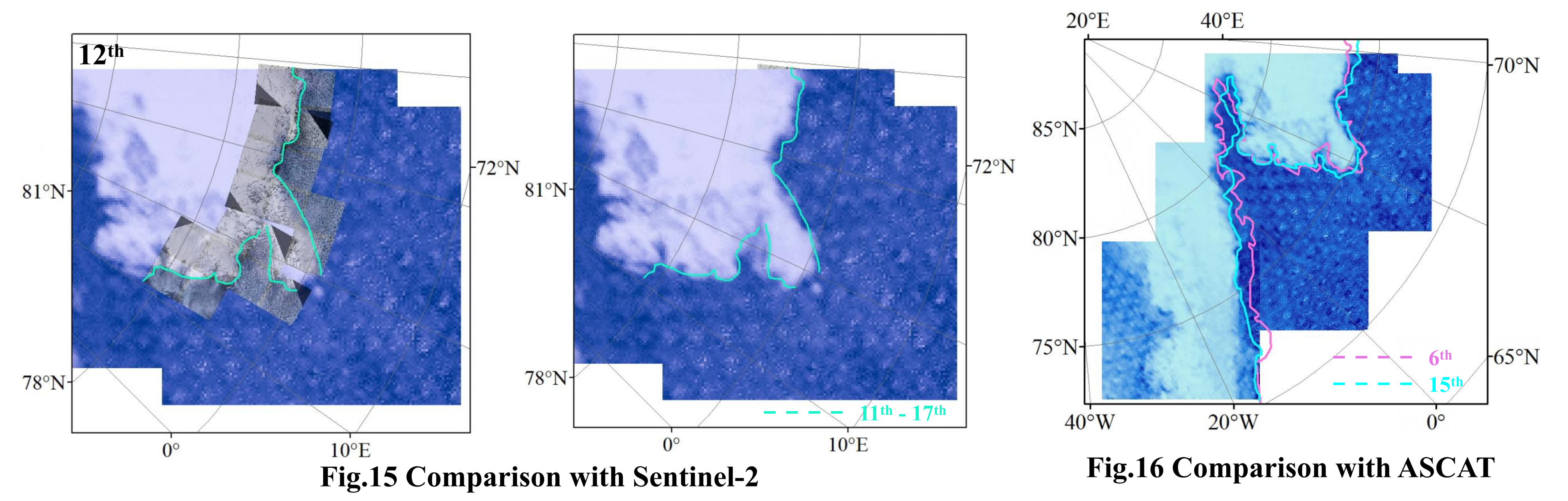


**Fig.15 Comparison with Sentinel-2** **Fig.16 Comparison with ASCAT**

The validation and application of SWIM reconstruction images are shown by the detection of sea ice edges, types and a little about drift.

Sea ice edge is with resolution of 6.25 km from March 9th – 15th, 2021.

**Sea ice distribution is without obvious variation, and sea ice edge is clear and fine.**

**SWIM image reconstruction (SWIM-IR) results are compared with other six results and products.**

## Conclusion

Comparative validation against previous studies on SWIM sea ice edge extraction, NSIDC products, AARI products, SSM/I Tb sea ice edge images, ASCAT images, Sentinel-2 images, etc., demonstrates the high accuracy of the reconstructed sea ice edges.This study fills the gap in research on image reconstruction techniques under small incidence angles, promoting the development of sea ice remote sensing detection technology and applications. It holds significant theoretical importance and practical value for polar sea ice monitoring, ice situation assessment, and forecasting.