



AOMSUC-15 2025 FYSUC

THE 15TH ASIA-OCEANIA METEOROLOGICAL SATELLITE USERS' CONFERENCE (AOMSUC-15)
2025 FENGYUN SATELLITE USER CONFERENCE (2025 FYSUC)

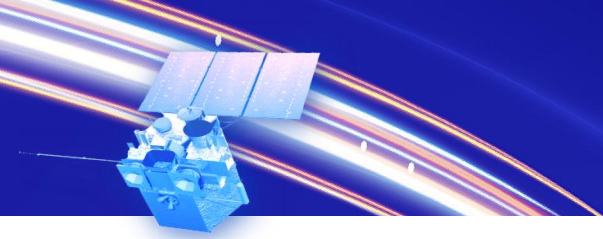
Research Progress of Polar Sea Ice Products Based on FengYun Satellites

Xiaochun Zhai¹, Cong Yin², Yufang Ye³, Qian Shi⁴, Lian He³, Haihua Chen⁴, Lele Li⁴,
Shengrong Tian¹, Yihong Bai¹, Guangzhen Cao¹, Lin Chen¹, Na Xu¹, Jian Shang¹,
Shengli Wu¹, Xiuqing Hu¹

1. National Satellite Meteorological Center
2. National Space Science Center
3. Sun Yat-sen University
4. Ocean University of China

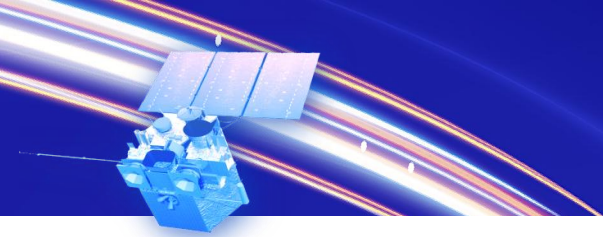


2025.10.29, Qingdao China



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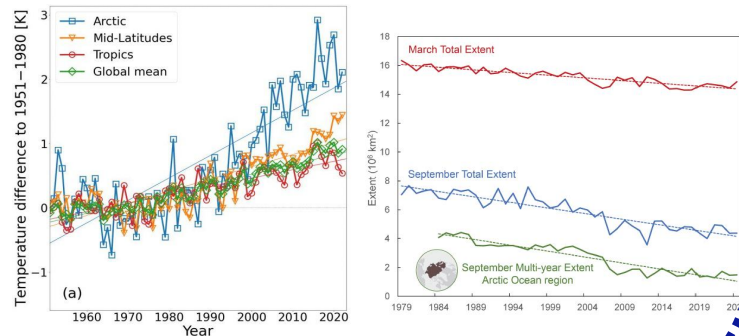
- **1. Background & Motivation**
- **2. FengYun Polar Sea Ice Products & Application**
- **3. Summary & Outlook**



1. Background & Motivation: Sea Ice: A Critical Indicator of Climate Change

Dramatic Ice Loss: A Clear Warming Signal

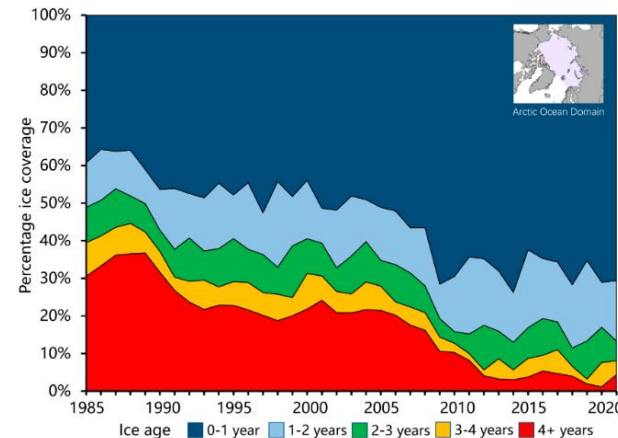
- The Arctic sea ice extent has been shrinking at a rate of approximately **3.4–4.4% per decade** since **1979**.
- The Arctic is warming **two to three times faster** than the global average. → **Arctic Amplification**



IPCC AR6

The Third Dimension: Critical Thinning

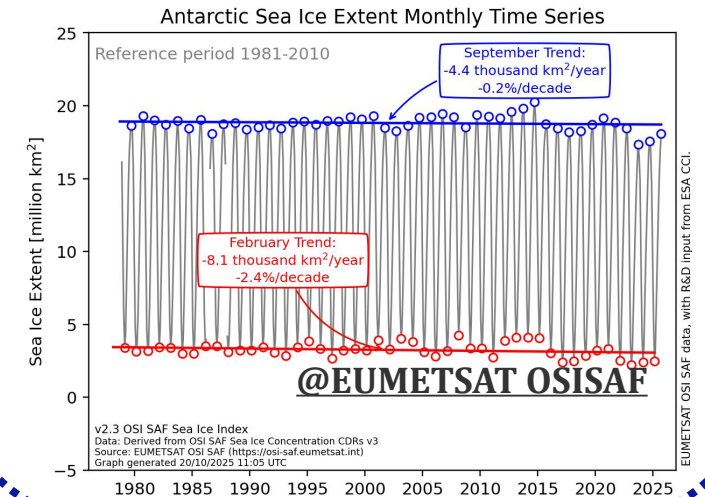
- The **Arctic sea ice** shows a **thinning and younger trend** marked notably by the steady decline of multi-year ice.
- The **Arctic** will likely **experience at least one ice-free summer before 2050**



Report Card 2024

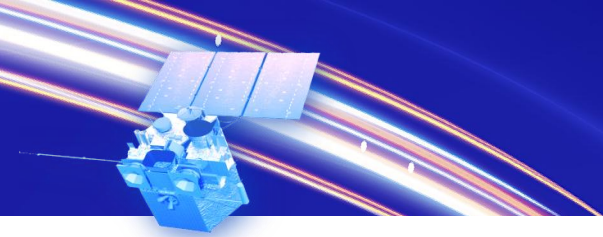
The Abrupt Retreat of Antarctic Sea Ice

- After remaining relatively stable for several decades, **Antarctic sea-ice extent hit a record low in 2023**.
- This unprecedented loss was driven primarily by the combined effects of **increased ocean heat content** due to global warming and **anomalous atmospheric circulation patterns**.

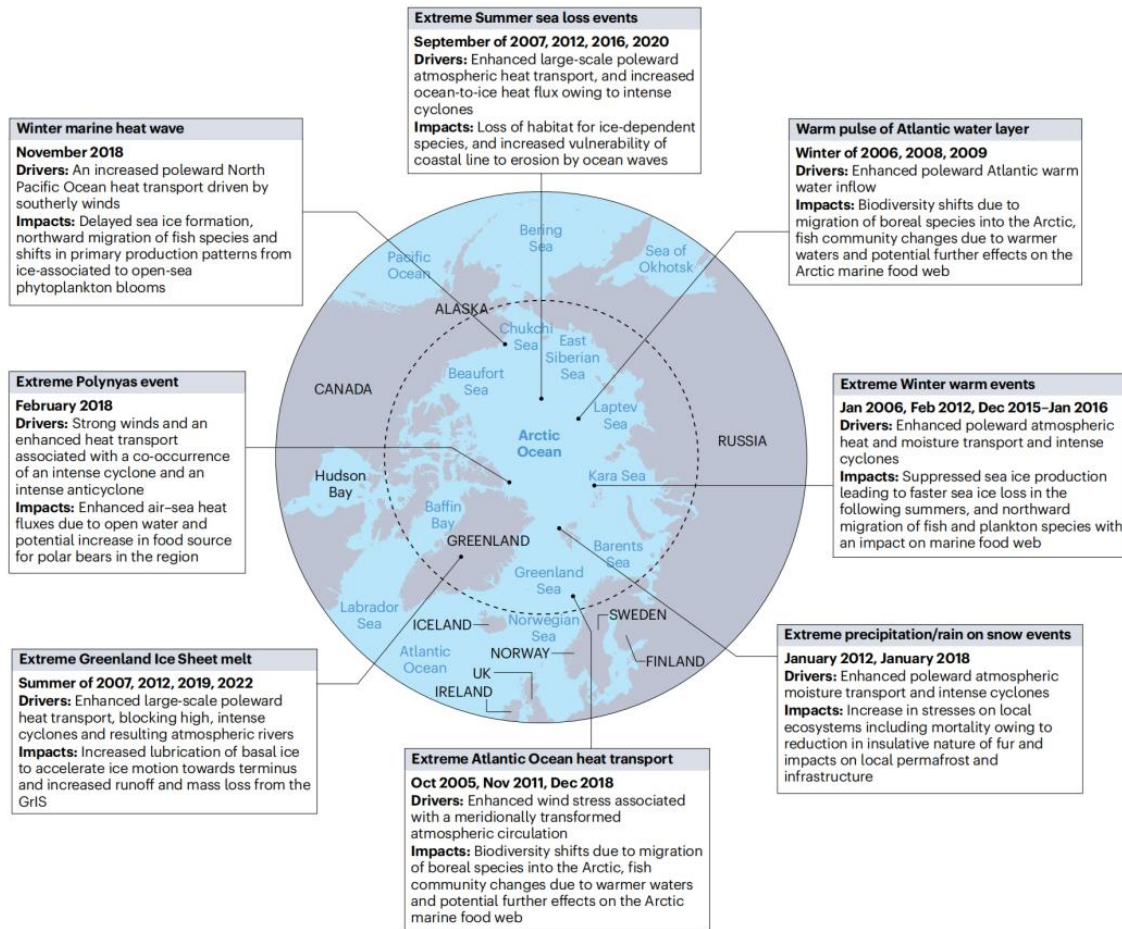


v2.3 OSI SAF Sea Ice Index
Data: Derived from OSI SAF Sea Ice Concentration CDRs v3
Source: EUMETSAT OSI SAF (<https://osi-saf-eumetsat.int/>)
Graph generated 20/10/2025 11:05 UTC

EUMETSAT OSI SAF data, with R&D input from ESA CCI.



1. Background & Motivation: A Key Driver of Increasing Extreme Weather in Mid-Latitudes



Arctic Extreme Events: Drivers and Impacts

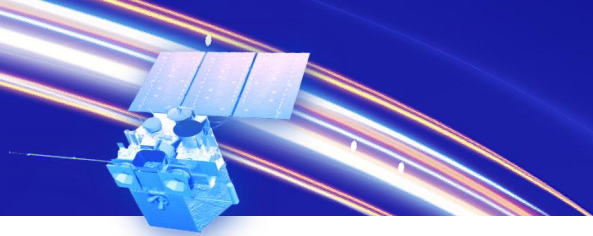
Event Type	Key Drivers
Extreme Summer Sea Ice Loss (2007, 2012, 2016, 2020)	Enhanced large-scale poleward atmospheric heat transport, intense cyclones
Winter Marine Heatwave (November 2018)	Increased poleward North Pacific Ocean heat transport driven by southerly winds
Extreme Polynya Event (February 2018)	Strong winds and enhanced heat transport from concurrent intense cyclone and anticyclone
Extreme Greenland Ice Sheet Melt (2007, 2012, 2019, 2022)	Enhanced poleward heat transport, blocking highs, intense cyclones, atmospheric rivers
Extreme Winter Warm Events (Jan 2006, Feb 2012, Dec 2015-Jan 2016)	Enhanced poleward atmospheric heat and moisture transport, intense cyclones
Extreme Atlantic Ocean Heat Transport (Oct 2005, Nov 2011, Dec 2018)	Enhanced wind stress associated with a meridionally transformed atmospheric circulation

Fig. 1 | Weather and climate extremes in the Arctic. Select examples of extreme events in the Arctic climate system, including their drivers and impacts. Increased extreme events have been observed across the Arctic region in the

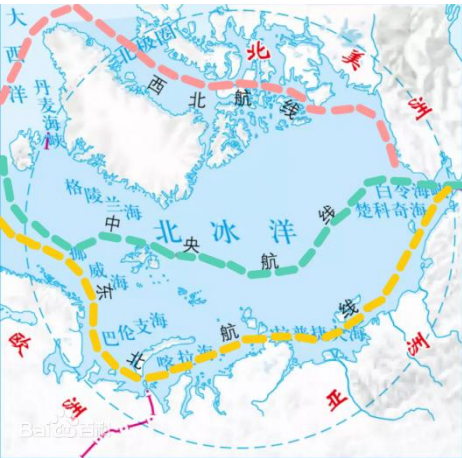
atmosphere, ocean and cryosphere since -2000, with impacts that extend across physical, ecological and social systems.

Zhang, X., et.al., Nat Rev Earth Environ (2025)

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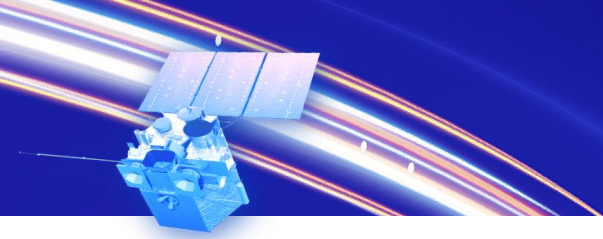
1. Background & Motivation: The Arctic Passage: Opportunities and Challenges



Chinese Name	Official English Translation	Description & Jurisdiction
中央航道	Central Arctic Route	Transits through the international waters of the central Arctic Ocean.
东北航道	Northern Sea Route	Specifically refers to the segment along the Russian northern coast (core section).
	Northeast Passage	Refers to the entire corridor connecting the Atlantic and Pacific oceans via the northeast.
西北航道	Northwest Passage	Navigates through the archipelago waters of Canada.

Aspect	Key Findings
Extended Navigation Window	• Sept ice-free days increased from ~20 (1979) to 90-110 (2024) • By 2050: Ordinary ships navigate freely in Sept; PC7-class ships >60% annual probability
Economic Advantages	• 25-55% shorter Asia-Europe distance vs. Suez Canal • Annual savings: hundreds of billions of RMB
Evolving Risks	• Multi-year ice debris: 3-4× stronger than first-year ice • More waves, fog, polar storms • Lack of ports & emergency support • Insurance: 5-8% rate change per 10 cm ice thickness error

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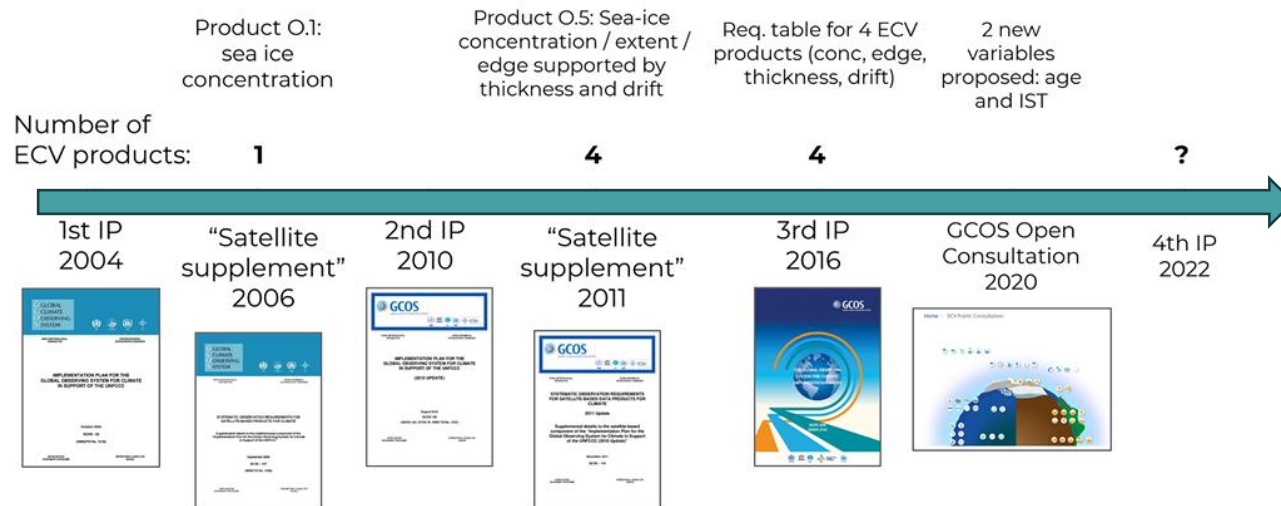
Summary of Satellite Remote Sensing Techniques for Sea Ice Observation

Remote Sensing Type	Core Sensor	Key Observables	Key Advantages	Main Limitations	Representative Satellites/Sensors
Optical & Thermal Infrared	Multispectral Imager	Ice extent, melt ponds, albedo	high accuracy and fine spatial resolution	Severely affected by clouds and polar night	Landsat/TIRS Aqua/MODIS, FY-3/MERSI
Active Microwave	Synthetic Aperture Radar (SAR)	Ice type, motion, fine-scale structure	High resolution, all-weather/day-and-night capability	large data volumes and require complex processing chains	Sentinel-1/SAR, Radarsat-2
	Radar Altimeter	Sea ice thickness, freeboard	Direct thickness measurement, large coverage	Affected by summer melt, relies on snow depth data	CryoSat-2/SIRAL, Jason-3
	Scatterometer	Ice concentration, motion	Wide coverage, short revisit period	Low spatial resolution	MetOp/ASCAT HY-2/SCAT FY-3E/WindRAD
Passive Microwave	Radiometer	Sea ice extent, concentration, type	All-weather/day-and-night capability, wide coverage, very long time series	Kilometer-scale resolution is too coarse for fine-scale process studies. Lower accuracy during melt	DMSP/SSM/I, GCOM-W/AMSR2 FY-3/MWRI
	GNSS-R	Sea ice thickness	Low-cost, light, L-band (deeper penetration)	Limited observation range	FY-3 GNOS II
Laser Altimetry	Laser Altimeter	Sea ice thickness, freeboard	Very high accuracy, sensitive to thin ice	Affected by clouds, discontinuous spatial coverage	ICESat-2/ATLAS

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- In the 2022 update of **the Global Climate Observing System (GCOS) Essential Climate Variables (ECVs)**, the sea ice ECV was expanded from **4** products to **7** products → monitor the sea ice environment and its interactions within the global climate system.



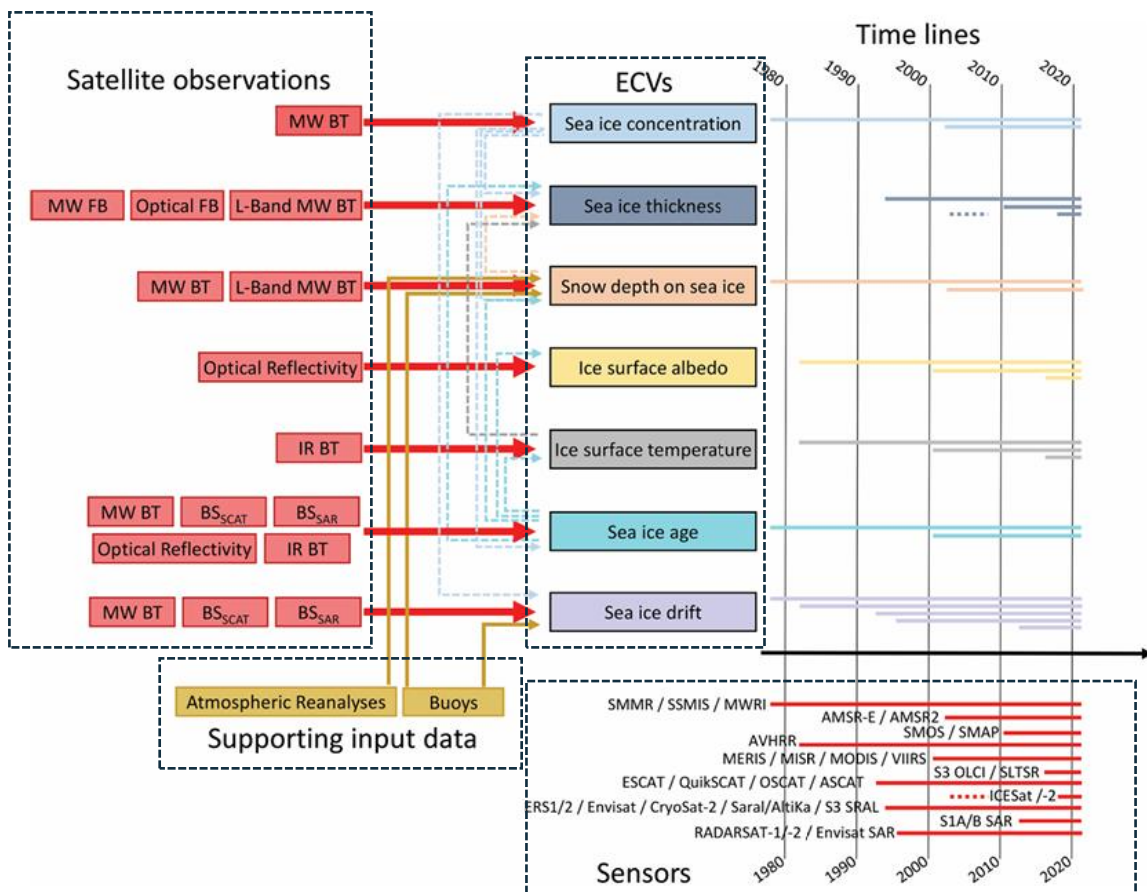
ECV	ECV product 2016	ECV product 2022
Sea ice	Sea ice concentration	Sea ice concentration
	Sea ice thickness	Sea ice thickness
	Sea ice drift	Sea ice drift
	Sea ice extent/edge	Sea ice age (or type)
		Sea ice surface temperature
		Sea ice surface albedo
		Snow depth on sea ice

Thomas Lavergne et.al, (2022). A New Structure for the Sea Ice Essential Climate Variables of the Global Climate Observing System, BAMS

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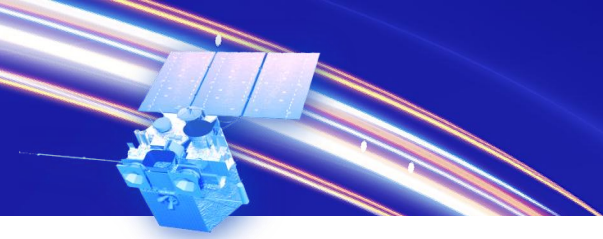
A new structure of the sea ice ECV



(Thomas Lavergne et.al., 2022, BAMS)

Parameters	FY product status	Sensors	Product maturity
Sea ice concentration	Operational release	FY-3 MWRI radiometer	High
Sea ice age (or type)	Operational release	FY-3 WindRAD scatterometer	High
Sea ice thickness	Operational release	FY-3 GNOS II GNSS-R	High
Sea ice drift	Prototype algorithm under development	FY-3 MWRI radiometer	Middle
Snow depth on sea ice	Prototype algorithm under development	FY-3 MWRI radiometer	Middle
Ice surface albedo	Prototype algorithm under development	FY-3 VIRR FY-3 MERSI	Low
Ice surface temperature	Prototype algorithm under development	FY-3 MERSI FY-3 MWRI	Low

<https://satellite.nsmc.org.cn>



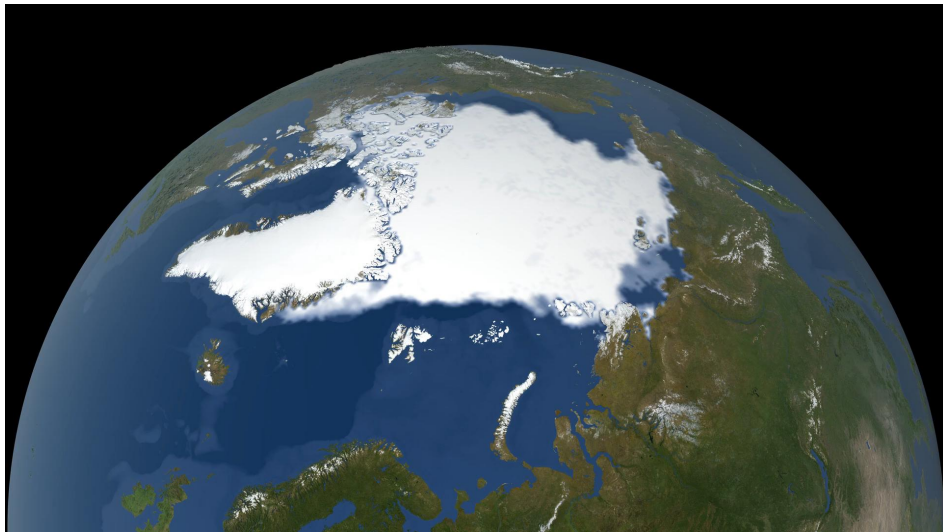
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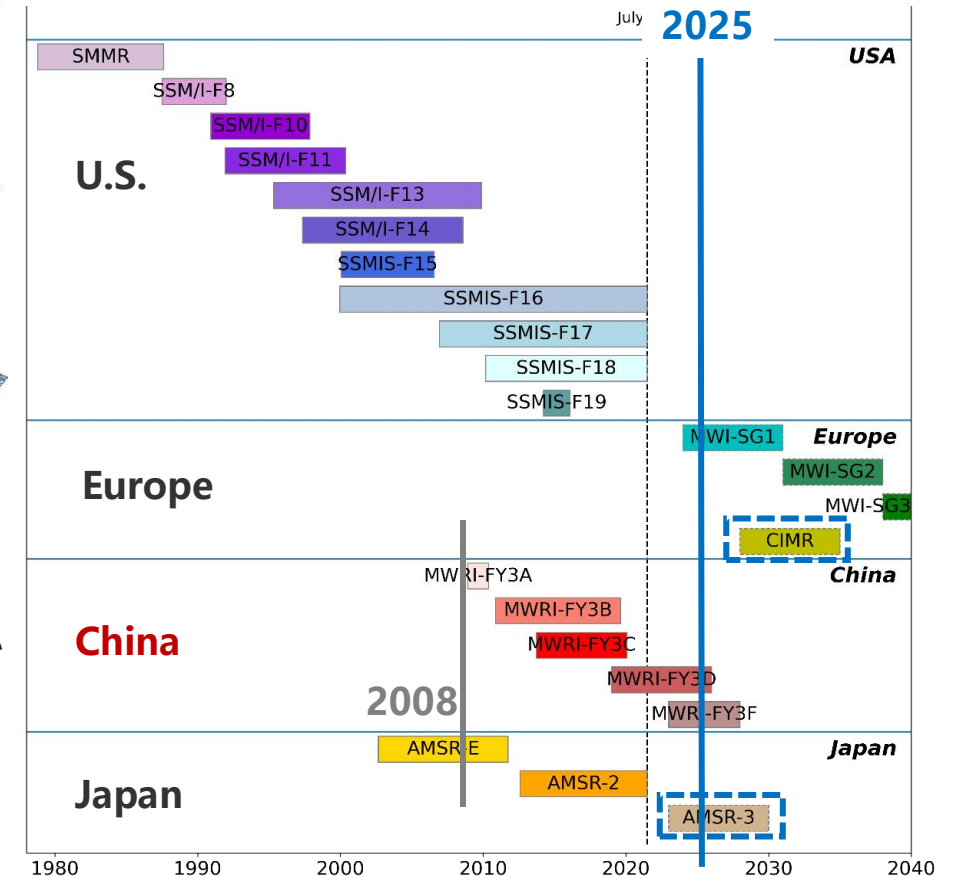
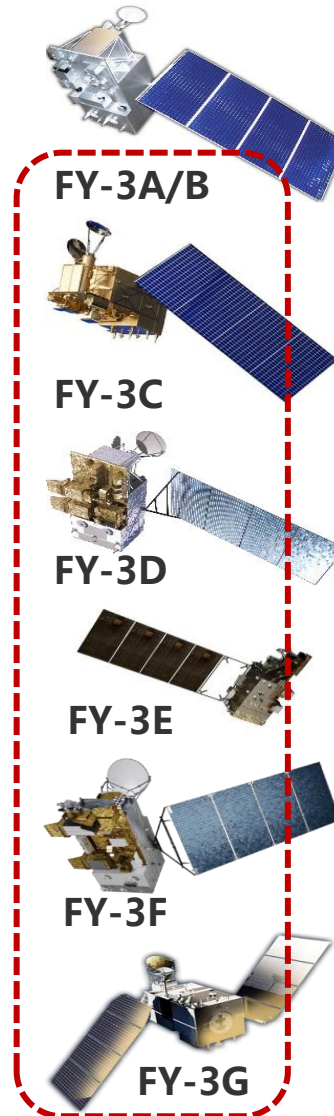
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FY-3 MWRI sea ice concentration: Background & Payloads

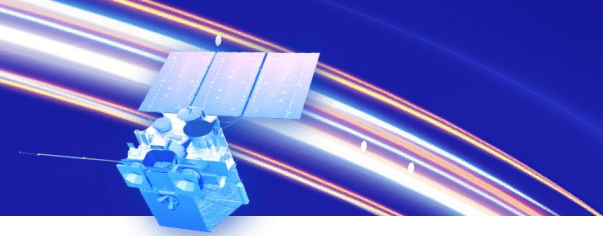
- Sea ice concentration (SIC) : one of the longest and most continuously recorded polar parameters since the inception of satellite remote sensing (1979).
- Satellite-based passive microwave radiometer: reliable tool for long-term monitoring, due to its all-weather, all-day ability to penetrate clouds and precipitation.
- FY-3 MWRI: crucial for long-term sea ice monitoring (Witze, Nature, 2017).



<https://svs.gsfc.nasa.gov/5395>



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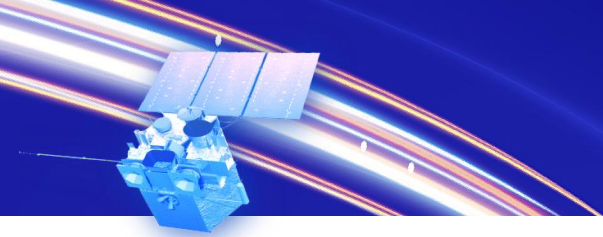


FY-3 MWRI sea ice concentration: Background & Payloads

Products	Sensor	Algorithm	Resolution	Advantages	Disadvantages
UB-ASI	AMSR2	ASI	6.25 km	High resolution , high accuracy in extremely low- and high-SIC region	sensitive to atmospheric effect
NSIDC-BT	SSMIS	BT	25 km	High accuracy in low-SIC region due to its low sensitivity to atmospheric noise	Low accuracy in high-SIC region
EUMETSAT-BTBR	AMSR2	BT+BR	12.5 km	High accuracy in low-SIC region (BT), less influence from snow (BR low sensitivity to sea-ice surface emissivity variability)	Low accuracy in marginal ice zone
NSMC-NT2	MWRI	NT2	12.5 km	Inter-mediate resolution, less influence by ice surface features	Without considering dynamic atmospheric influence

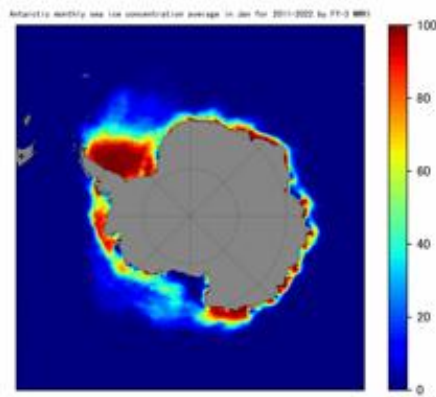
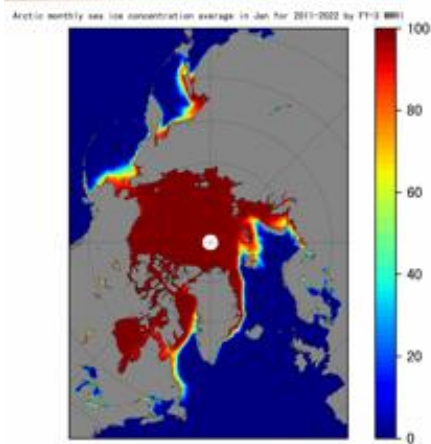
- **Status:** a "multi-sensor, multi-algorithm" operational framework has already been created.
- **Limitation:** **Summer** sea ice concentration (SIC) algorithms are generally inaccurate **due to the complex coupling of melt ponds, wet snow and atmospheric conditions**

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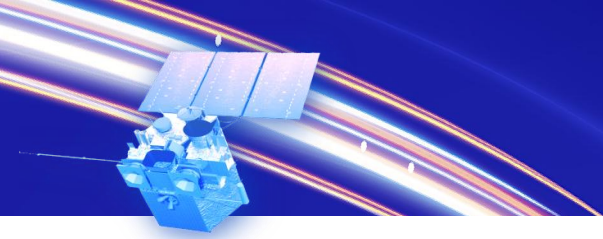
FY-3 MWRI sea ice concentration: Algorithm & Products

SIC monthly product quick-look



Satellite series / sensor	FY-3B/C/D MWRI (2011-now)	FY-3H MWRI (launched in Oct 2025)
Input data	MWRI L1 data Static look-up table	MWRI L1 data ECMWF forecast datasets
Algorithm method	NASA Team 2 (NT2) - strong dependency on observational radiative precision - overestimation in low sea ice concentration during summer period.	Hybrid algorithm (NT2+ASI2-DTP) - NT2: NASA Team 2 - atmospheric correction ASI2-DTP: combine and dynamic tie-point selection
Spatial resolution	12.5 km, NH and SH	10 km (based on L1 observational data) 3.125 km (based on L1 resolution enhancement data)
Temporal resolution	orbital (28 HDF file/day), daily, monthly	orbital (28 HDF file/day), daily, monthly
Validation& inter-comparison	Ice chart; Satellite SIC products (OSISAF, NSIDC, Bremen Uni.); MODIS, SAR-based product.	

Y. Ye., et.al., (2025). Influence of Radiative Transfer Model-Based Atmospheric Correction and Dynamic Tie Points on Sea Ice Concentration Retrieval From Near-90 GHz Algorithm With FY-3D MWRI Data, IEEE TGRS.



FY-3 MWRI sea ice concentration: Algorithm & Products

ASI2-DTP SIC algorithm: based on the traditional ASI algorithm framework

- **Atmospheric correction:** Use a **radiative transfer model** to simulate TBs under ideal conditions (Tb_{M0}) and **actual conditions** (Tb_{MA}), calculate the effects caused by the atmosphere:

$$Tb_{M0} = Tb(0,0,0, SST_{ref}, IST_{ref}, SIC, C_{MYI})$$
$$Tb_{MA} = Tb(Ws, WV, CLW, SST, IST, SIC, C_{MYI})$$

- Atmospheric parameters under **actual conditions** are derived from **reanalysis data**, and the initial SIC and C_{MYI} are calculated by the **NT algorithm**.

- Selection of **dynamic tie points**

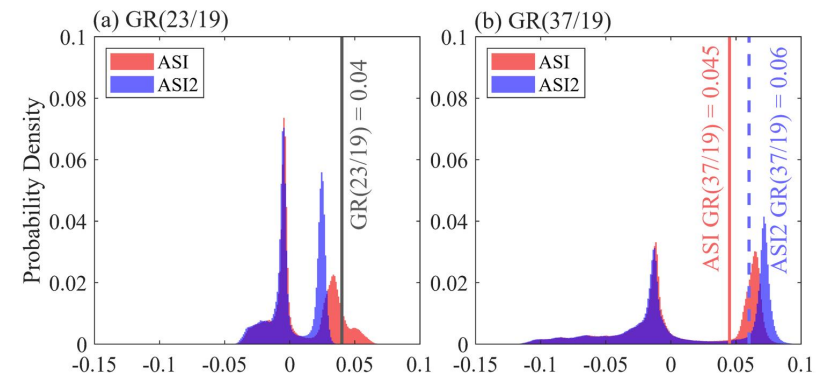
- Distance from land > 100 km, south of 87°N;
- Pure ice/water conditions for 14 consecutive days;

- Weather filter

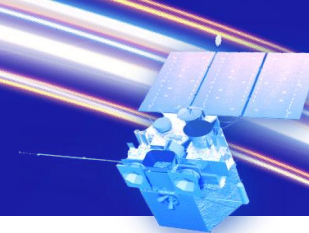
- ASI algorithm: $GR(37/19) \geq 0.045$, $GR(23/19) \geq 0.04$;
- **ASI2 algorithm**: $GR(37/19) \geq 0.06$;

Sea ice: $SIC_{NWF} \geq 95\%$; $GR(23/19) \geq 0.02$

Sea water: $-10\% \leq SIC_{NWF} \leq 10\%$;

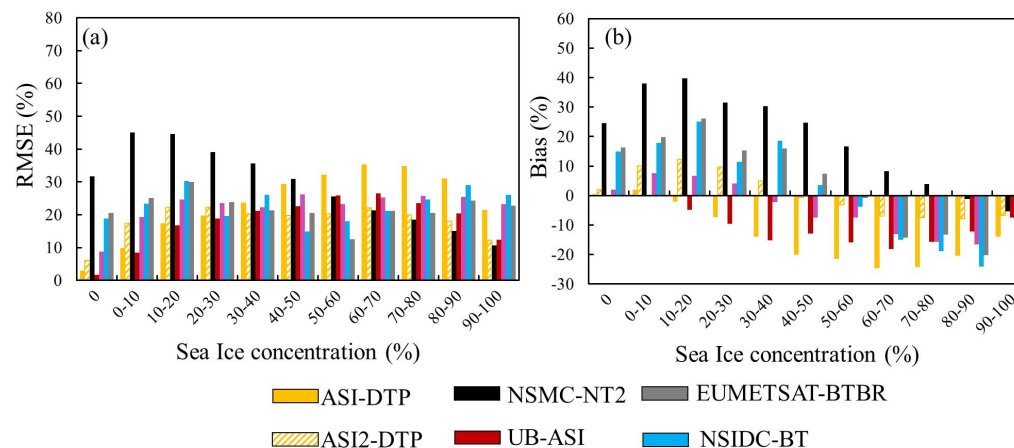
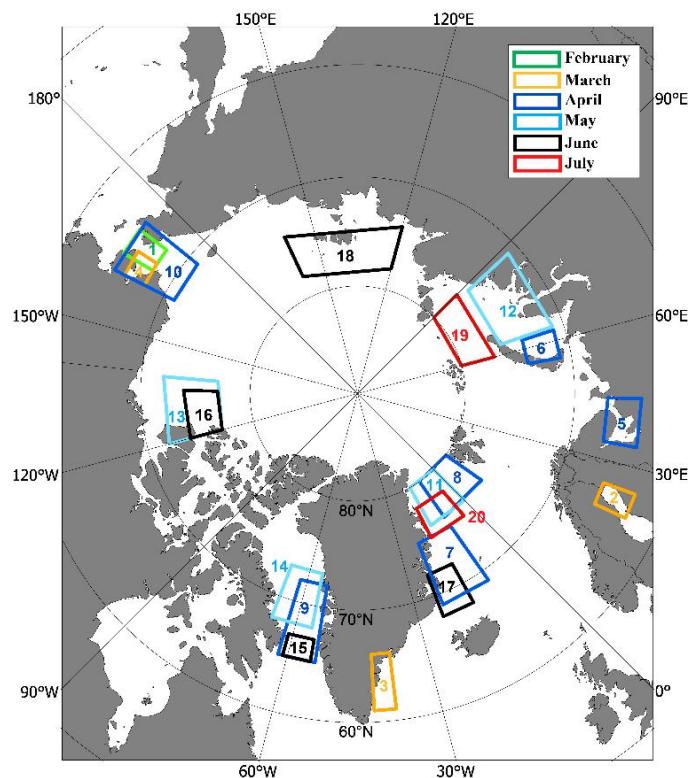


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FY-3 MWRI sea ice concentration: Algorithm & Products

- Using 20 scenes of MODIS optical imagery data, a systematic quantitative accuracy assessment is conducted on six sea ice concentration products.
- ASI2-DTP algorithm can retrieve more ice in low sea ice concentration areas, and NT2 has more reliable performance in areas with high sea ice concentration, providing a scientific basis for the integration of the two algorithms.



Products	RMSE	Cor	Bias
ASI-DTP	19.33	0.87	-6.54
ASI2-DTP	17.33	0.88	-3.62
NSMC-NT2	19.68	0.83	2.67
UB-ASI	16.44	0.93	-5.76
NSIDC-BT	23.90	0.79	-6.37
EUMETSAT-BTBR	21.94	0.82	-4.11

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FY-3B/C/D MWRI Fundamental Climate Data Record (FCDR)

MWRI:2011-2022

30 years' Chinese historical Satellite data (1998-2020)

Amount ✓ Quality ?



Goal for FY series: FCDR

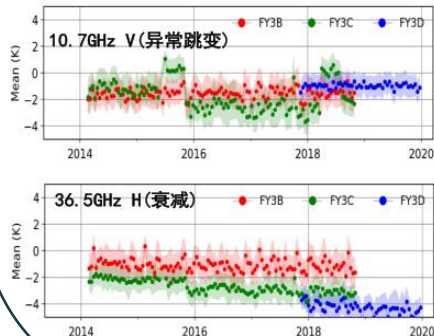
Instruments:

- VIRR: FY-1A/B/C/D FY-3A/B/C
- MERSI/IRAS/MWTS/MWHS/MWRI: FY-3A/B/C
- VISSR: FY-2A/B/C/D/E/G

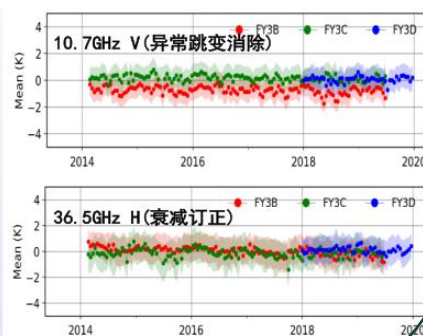
Accuracy:

- RSB: 8%(R&D), 5%(O)
- TIR: 1K(R&D), 0.5K(O)
- MW: 1K(Absorption), 1.5K(Window)

Before



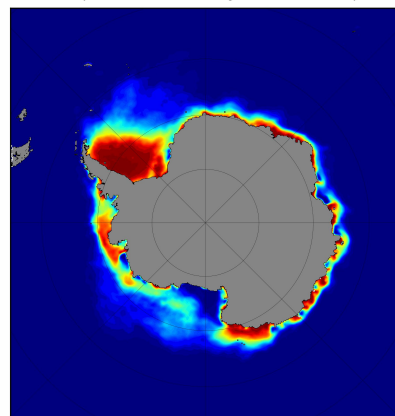
After



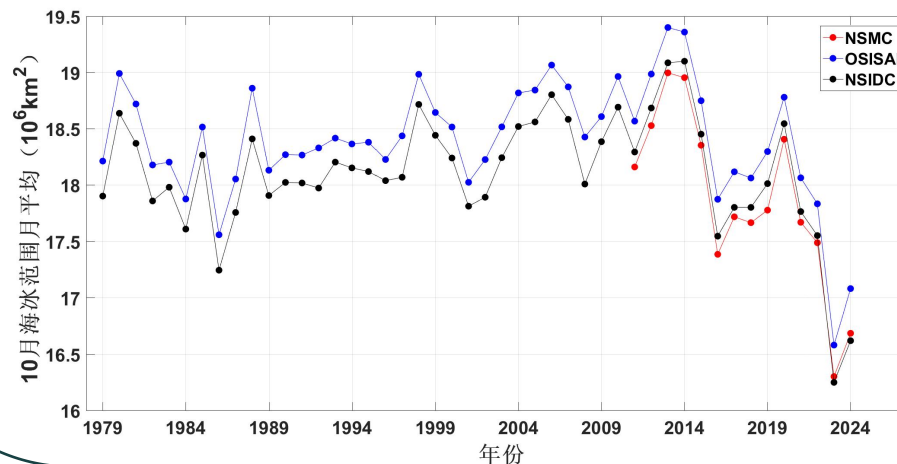
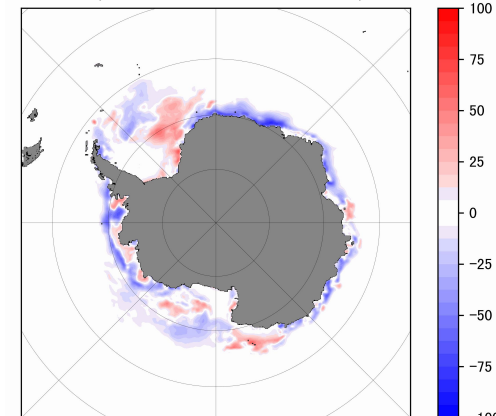
FY-3B/C/D MWRI SIC Reprocessed Datasets

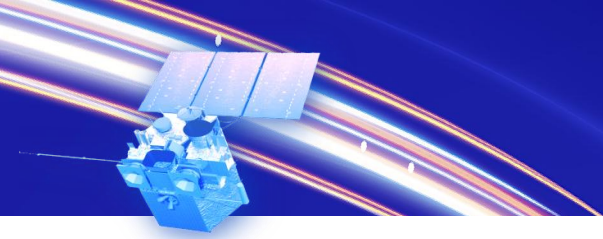
- Through quantitative assessments against international sea ice climate datasets, we have validated the accuracy of the Fengyun satellite sea ice concentration dataset for climatological analysis.

Antarctic monthly sea ice concentration average in Jan for 2011-2023 by FY-3 MWRI



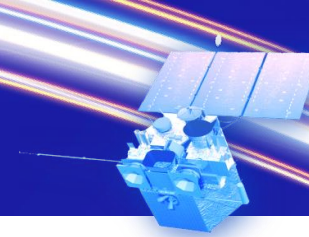
Antarctic monthly sea ice concentration anomalies in Jan for 2011-2023 by FY-3 MWRI





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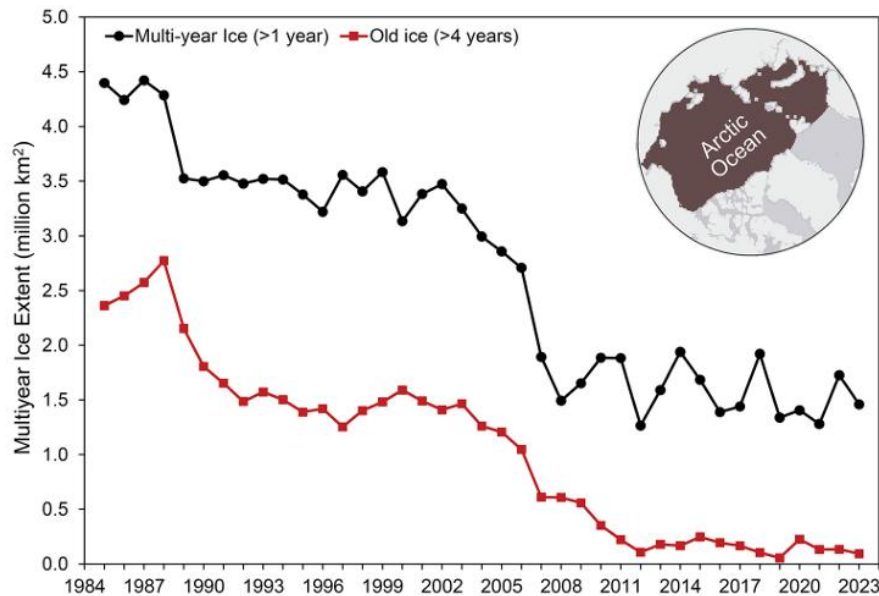
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FY-3E WindRAD Sea Ice Edge & Type: Background & Payloads

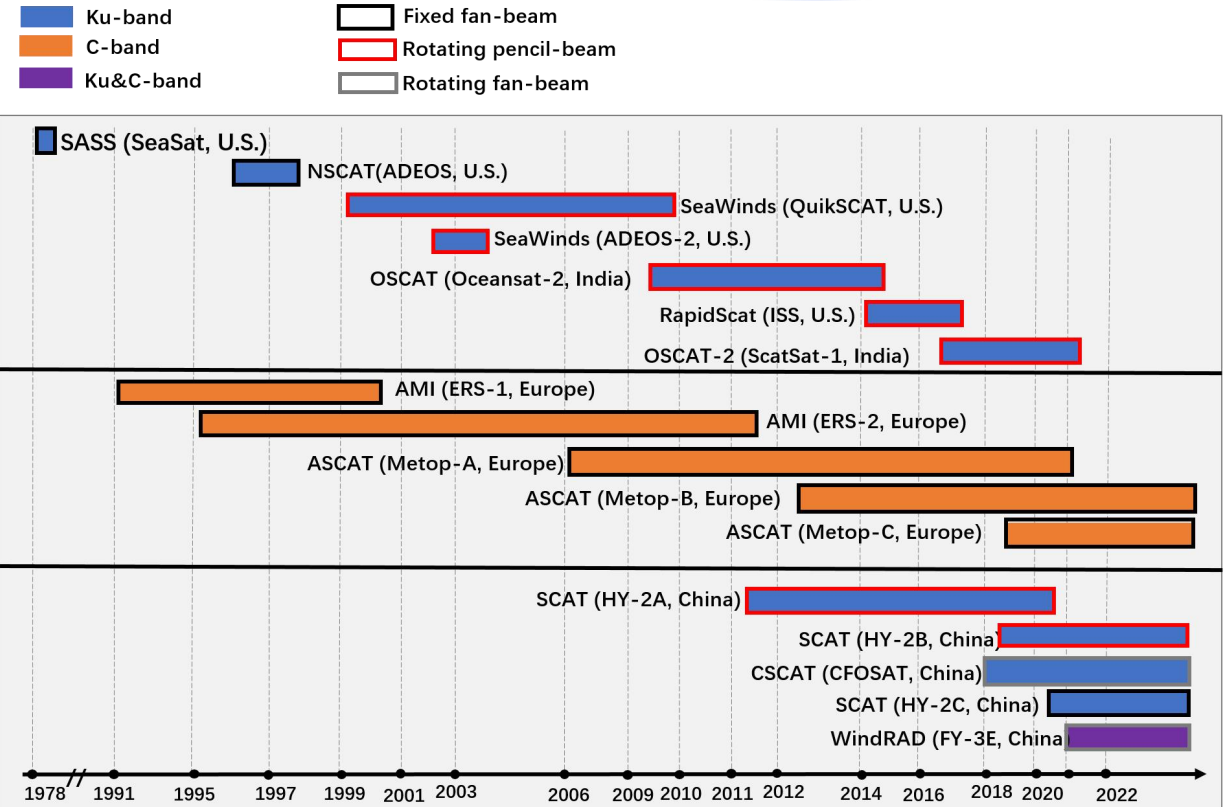
- The multiyear ice is shrinking far faster than the overall sea-ice area. → Arctic sea ice is becoming **markedly younger and more fragile**—a key signal of Arctic-system change under global warming.

Arctic Report Card 2023

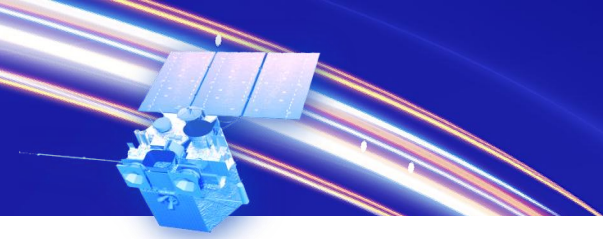


Based on ice ages:

- ✓ First-year ice (thickness: 0.2~2m)
- ✓ Multi-year ice (thickness: 2~4m, more air pockets)



- Scatterometers are mainly utilized internationally for **large-scale** sea ice type monitoring;
- Physical mechanism:** measure the **microwave backscatter coefficients** of different sea ice layer. → vary according to the physical properties of the ice, such as age, thickness, surface roughness and salinity.



FY-3 MWRI sea ice concentration: Background & Payloads

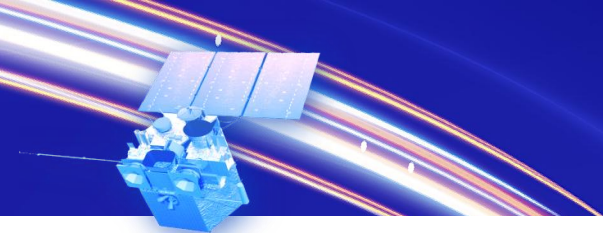
Y. Ye et al., 2023, TC

SITY retrieval method	Input parameters		Classification method	Correction method
	Radiometer	Scatterometer		
C3S-1	GR _{37v19v}	n/a	Dynamic PDF, Bayesian method	Filters for OW*, geographical mask, statistical threshold filter
C3S-2	GR _{37v19v}	n/a	Dynamic PDF, Bayesian method	Filters for OW ^a , geographical mask, statistical threshold filter, temperature-based correction
OSISAF-SITY	GR _{19v37v}	σ_0^b	Dynamic PDF ^c , Bayesian method	Filters for OW ^a , geographical mask, statistical threshold filter
KNMI-SITY	n/a	σ_0	Bayesian method, thresholds derived from March of each year	Geographical mask
IFREMER-SITY	n/a	σ_0	Day-to-day varying thresholds	n/a
Zhang-SITY	TB _{37h}	σ_0	Adaptive clustering	Ice motion confining and spatial filtering ^d

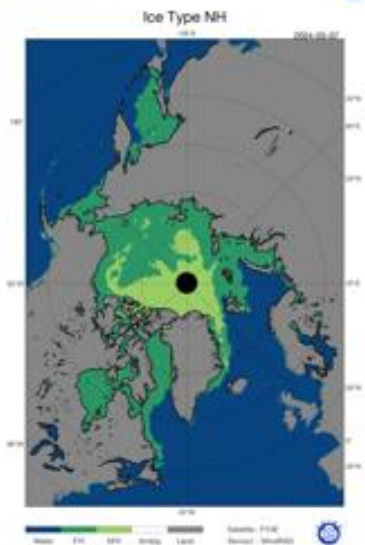
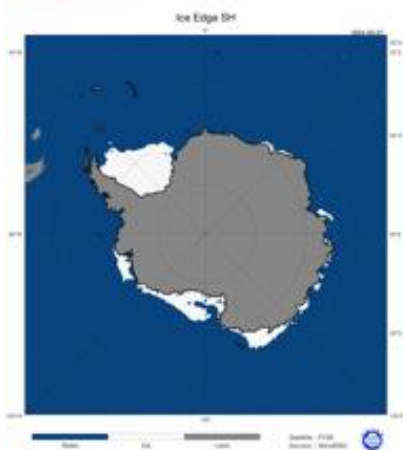
^a Filters based on gradient ratio and brightness temperatures are used to filter out spurious sea ice in the open ocean. In this study, discussion of correction methods focuses on those for MYI and FYI. ^b Scatterometer data from ASCAT were introduced to the OSISAF-SITY retrieval method in 2009. ^c Dynamical PDF based on daily training data was introduced to the OSISAF-SITY retrieval method in 2015. ^d Filters considering the impact of ice motion on the temporal changes in SITY (especially MYI) spatial distributions. n/a: not applicable.

- **Status:** multiple operational products based on radiometers, scatterometers, and multi-source data fusion
- **Limitation:** remain unstable during transitional seasons such as early winter and late spring; limited by sensor-band differences, unrepresentative training data, and divergent post-processing schemes → significant inter-product biases and poor performance in marginal ice zones and thin ice detection

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SIE& SIT daily product quick-look

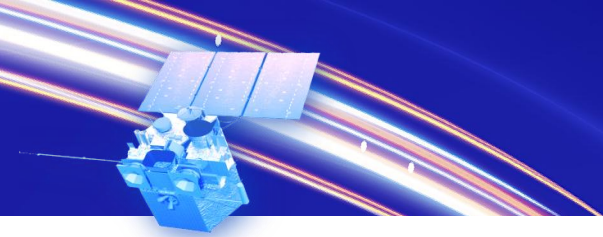


	Sea ice edge (classify sea ice or sea water)	Sea ice type (classify first-year ice or multi-year ice)
Input data	FY-3E WindRAD scatterometer first dual-band (Ku+C), dual-polarization scatterometer, adopting rotating fan-beam scanning mechanism	
Method	NH&SH: Random forest classification - different feature parameter combination for C, Ku, Dual-band model - Model training: daily update	NH: Random forest classification Model training: daily update
		SH: K-means classification for dual-band only
Auxiliary data (label sample selection)	FY-3 MWRI sea ice concentration (version 1); SAR-based SIE products (version 2)	NH SIT: Sea ice type monthly mask from NSIDC weekly sea ice age products
Operational period	NH&SH: 2021-present	
Spatial resolution	10 km grid spacing	
Temporal resolution	daily	daily, ambiguous ice type NH: June-September SH: September-February
Validation & Inter-comparison	Ice chart; Satellite SIT related products (OSISAF SIT products, NSIDC sea ice age product, Bremen Uni. MYIC products); SAR-based product, etc.	

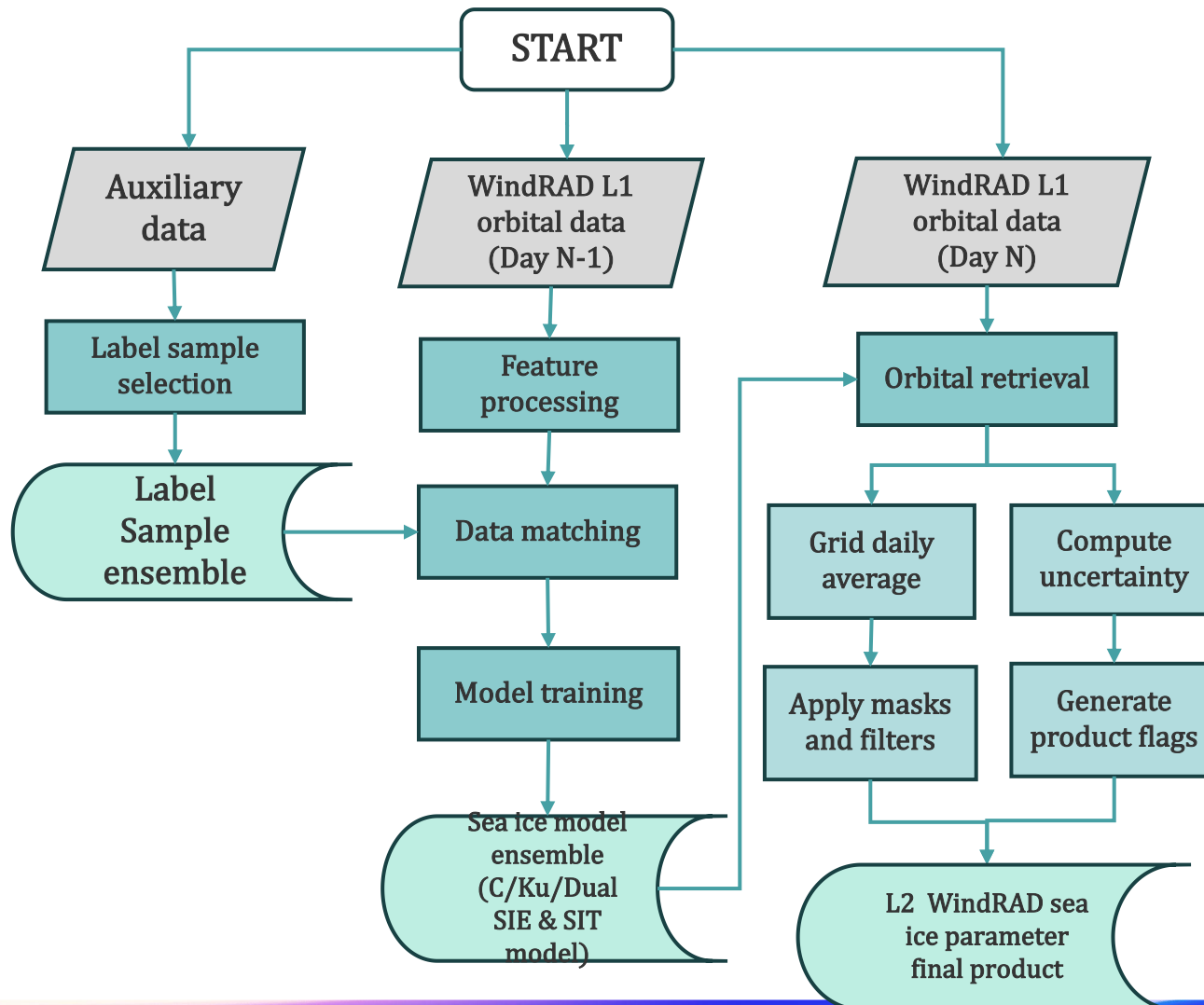
<http://fyearth.nsmc.org.cn/>

(Zhang et.al., BAMS, 2024; Shang et.al., IEEE TGRS, 2023; Zhai et al., 2025, under review)

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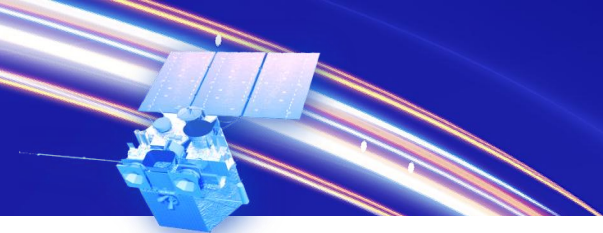
FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products



Key Points

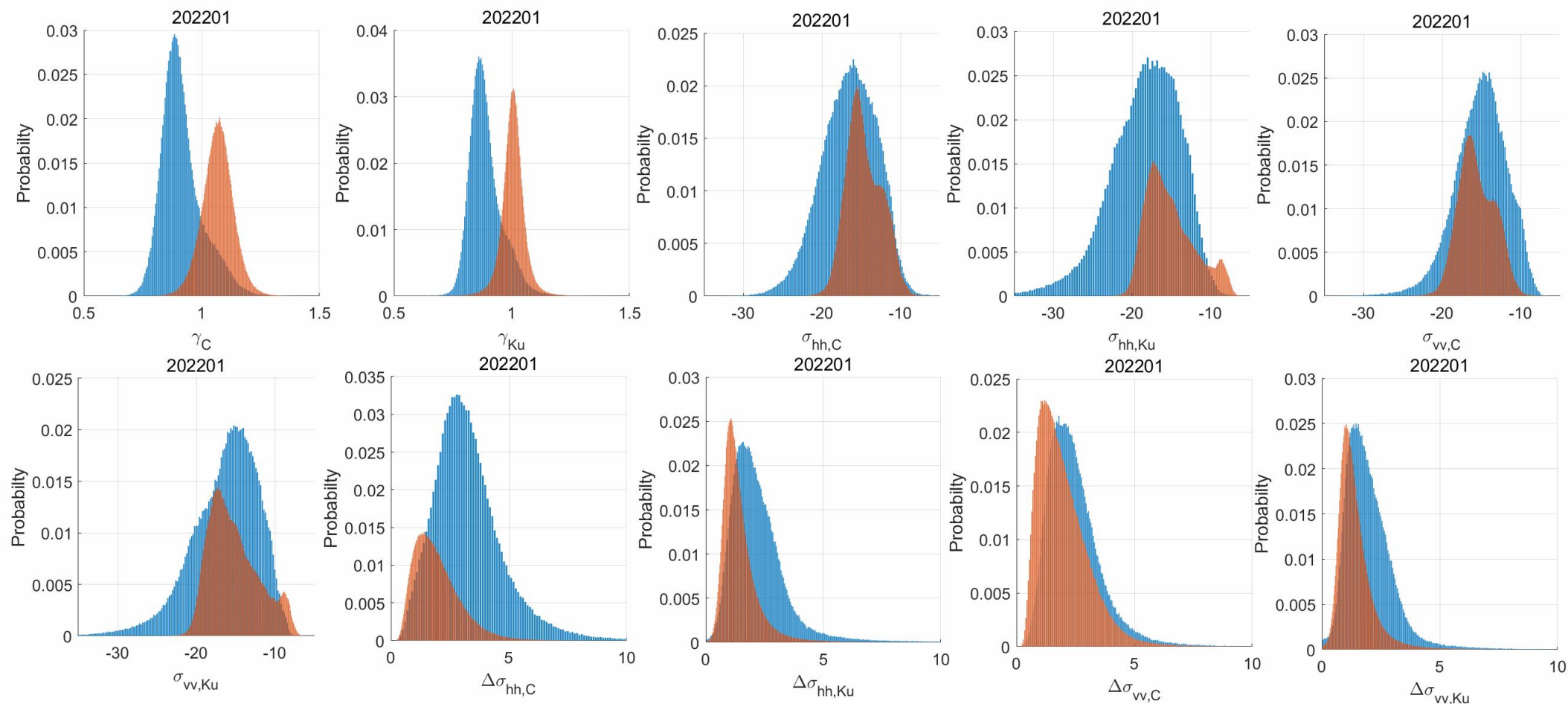
- How to **extract feature parameters** from massive L1 data?
- How to **select** representative **samples**?
- How to **integrate the Ku and C** bands?
- How to assess the advantages of **dual-band combination**?
- How to **deepen the understanding** of different microwave band behaviors from spaceborne platform?
- ...

(Zhai et.al., 2021, RS; Zhai et.al., 2023a, RS
Zhai et.al., 2023b IEEE GRSL; Zhai et.al., 2025,
IEEE TGRS, under review)



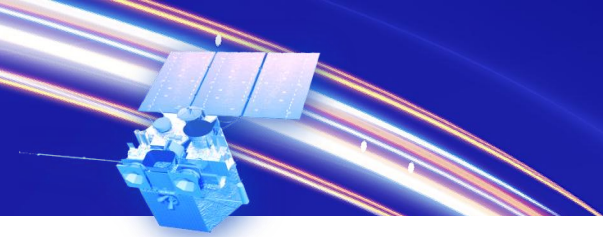
FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products

10 feature parameters monthly PDF (blue: water, orange: ice)



- **Sea ice edge:** based on the observational results, we aim to provide feedback that can deepen our understanding of **Dual-frequency detection mechanism**. → 10 feature parameters are selected. (Zhai et al., 2025, under review.)

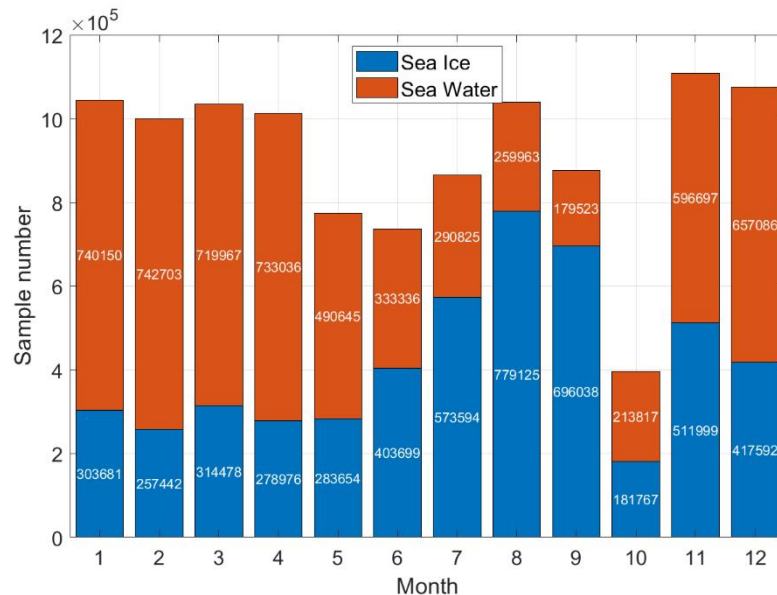
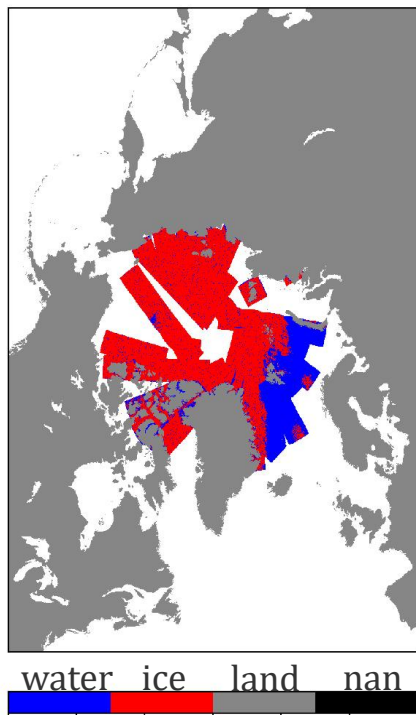
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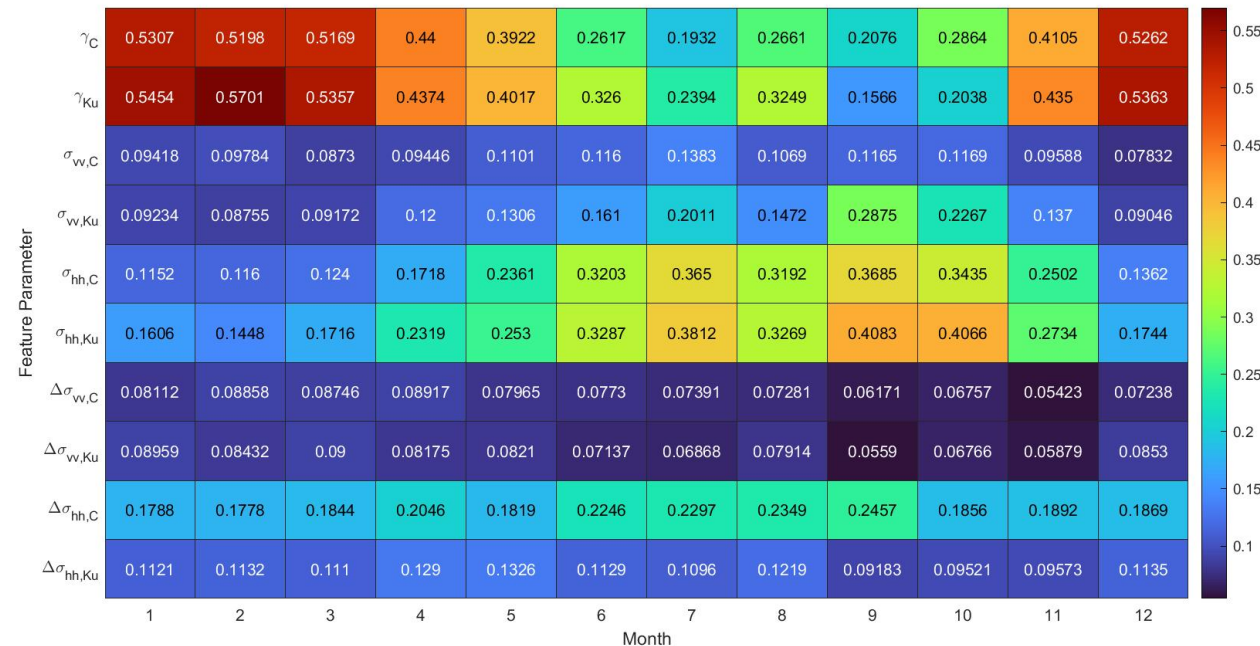
FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products

- **Label:** SAR-based sea ice cover product (monthly update)
- **Feature parameters:** Ku-band feature parameters, C-band feature parameters, Dual-band feature parameters
- **Method:** Random forest classification

SAR-based SIE products & model sample distribution during 2022

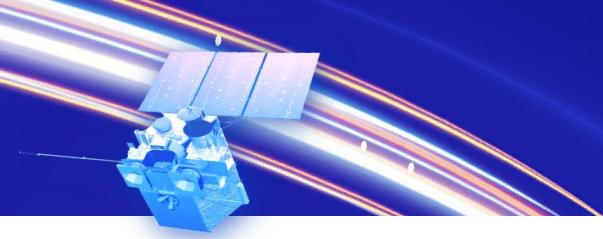


Ranking of Feature Parameter Importance from January to September 2022

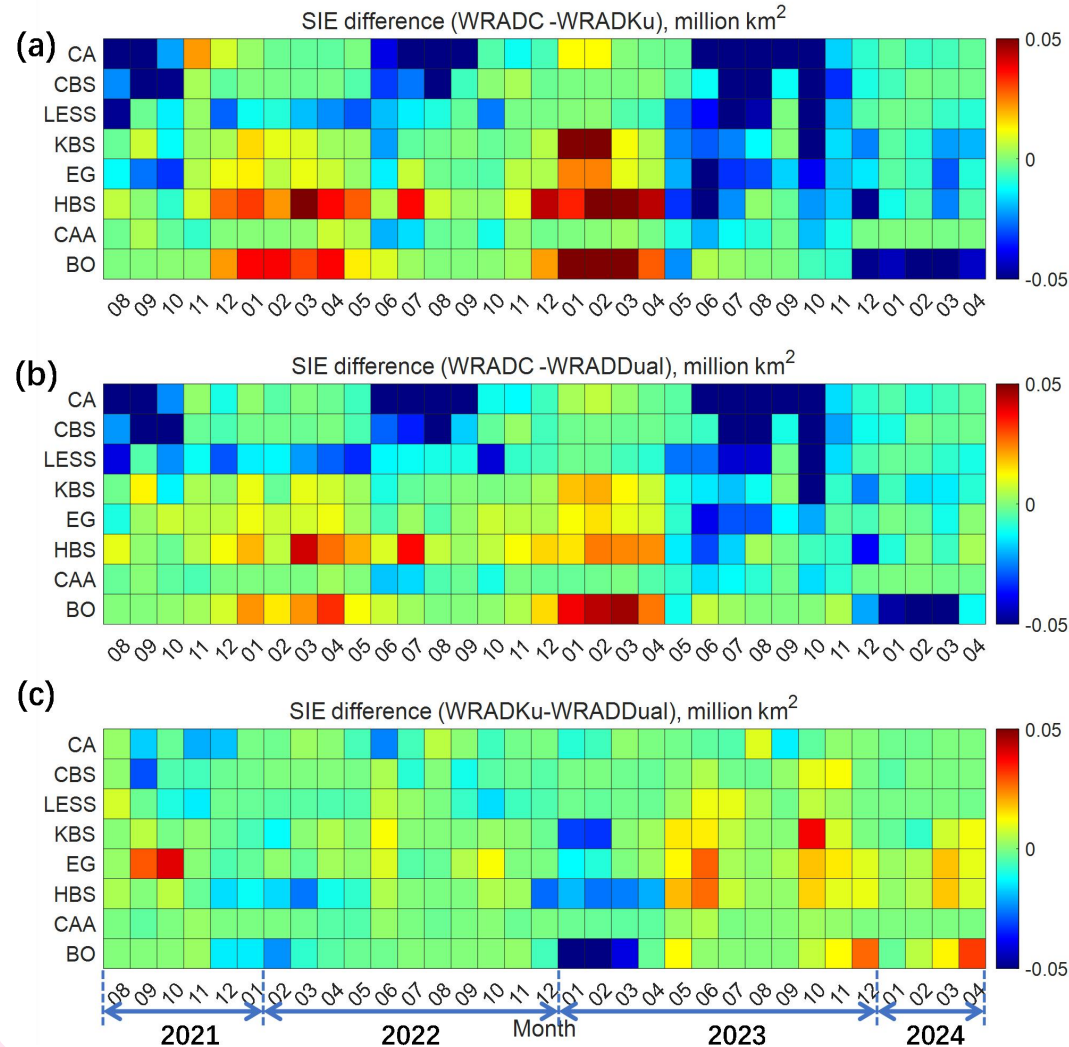


- By **ranking the importance of model parameters**, the sensitivity differences of various parameters across **different seasons** is identified. → the advantages of multi-parameter in sea ice edge detection.

(Zhai et al., 2025, under review.)



FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products

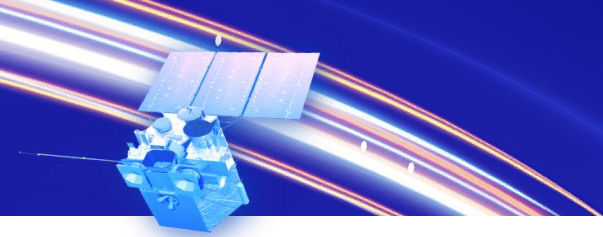


Product	All (Number = 1004)			Non-summer (Number = 637)			Summer (Number = 305)		
	Bias (10 ⁶ km ²)	RMSE (10 ⁶ km ²)	r	Bias (10 ⁶ km ²)	RMSE (10 ⁶ km ²)	r	Bias (10 ⁶ km ²)	RMSE (10 ⁶ km ²)	r
WRADC	-0.12	0.20	0.998	-0.15	0.21	0.999	-0.08	0.20	0.995
WRADKu	-0.07	0.22	0.997	-0.16	0.23	0.997	0.09	0.21	0.995
WRADDual	-0.06	0.19	0.998	-0.15	0.19	0.999	0.08	0.18	0.996

- **Distinct band-dependent physical mechanisms:** Ku-band excels in **summer** surface feature discrimination but suffers from **atmospheric interference**, while **C-band** shows sensitivity to new/thin ice formation in winter, albeit with reduced performance over **melt ponds**;
- **Dual-band** results achieve highest accuracy across all seasons compared to C-band only and Ku-band only results.

(Zhai et al., 2025, under review.)

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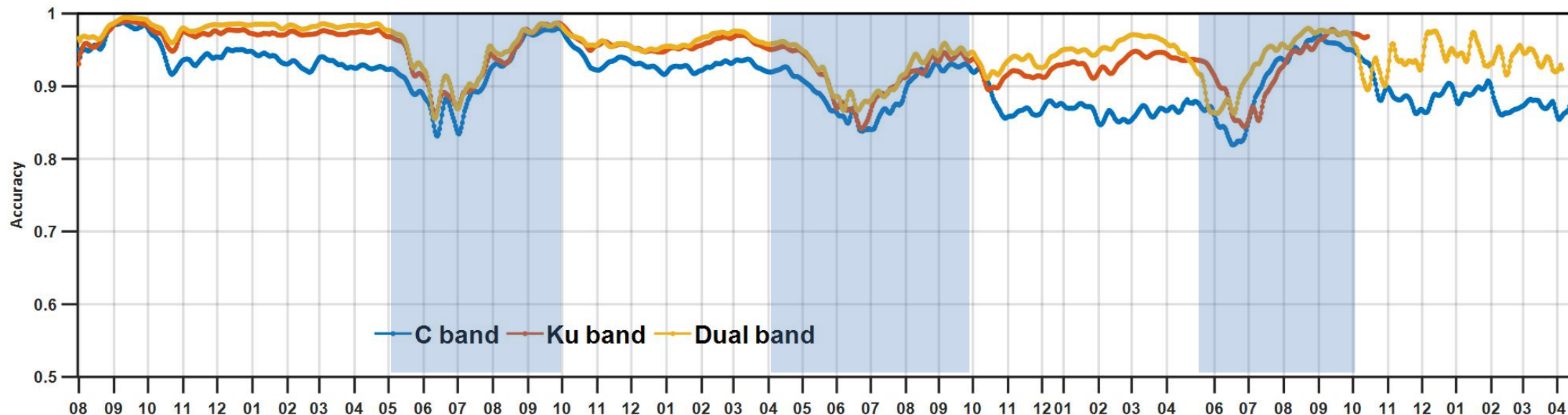
FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products

✓ Feature selection:

- **Geographical Mask:** utilize the NSIDC sea ice age dataset as a monthly-updated reference.
- **Feature Parameters:** daily-updated parameters are incorporated to ensure the timeliness and relevance of the data.

✓ Model Training

- **Target Classes:** Three distinct types are identified for classification: **open water**, **first-year ice (FYI)**, and **multi-year ice (MYI)**.
- **Model Variants:** Three separate sea ice type (SIT) models are developed, for **Ku-band**, **C-band**, and **Dual-band**, respectively



✓ Model Evaluation

- **Non-Melting Period (October-April):** high accuracy at three different models, **Dual-band > Ku > C**;
- **Melting Period (May-September):** complicated and no available to get accurate sea ice type information. → **still has some signature at the beginning of May and end of Sep in this product**, indicating potential for further refinement in these transitional periods.

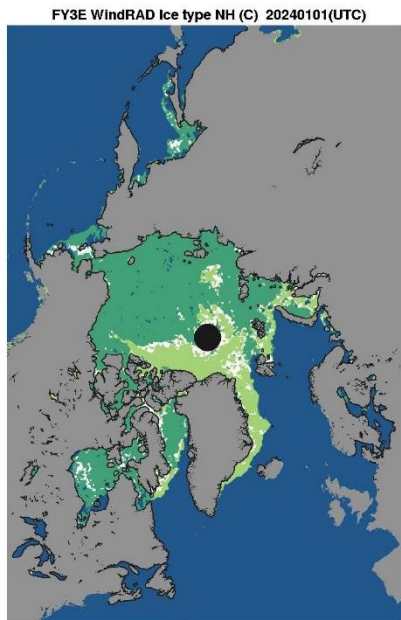
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FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products

SIT example @2024.01.01

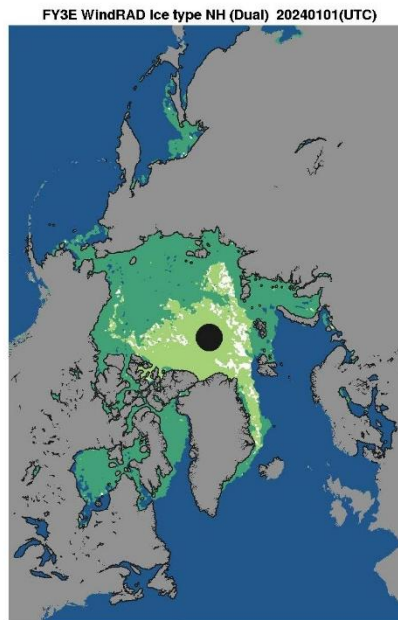
C-band



Water FYI MYI Ambig Land NaN



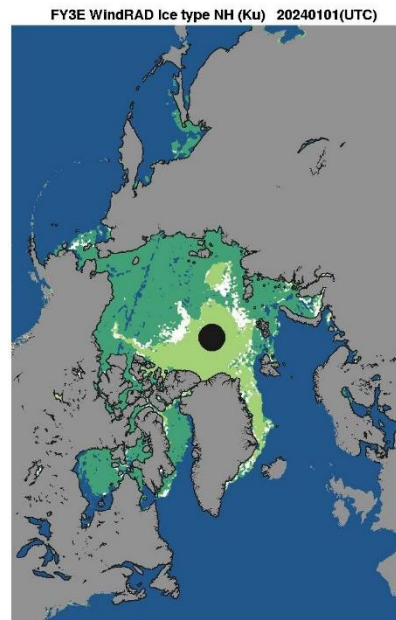
Dual



Water FYI MYI Ambig Land NaN



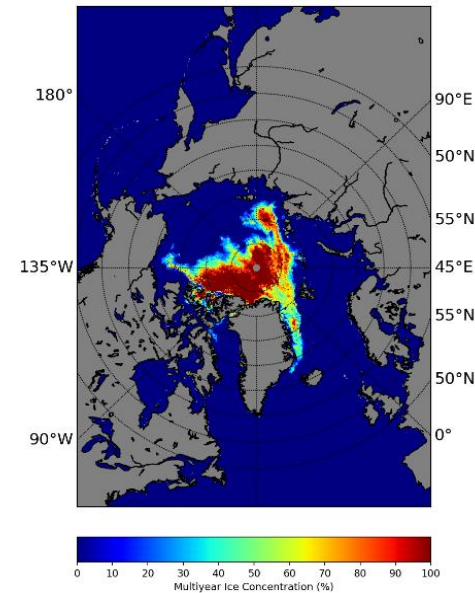
Ku-band



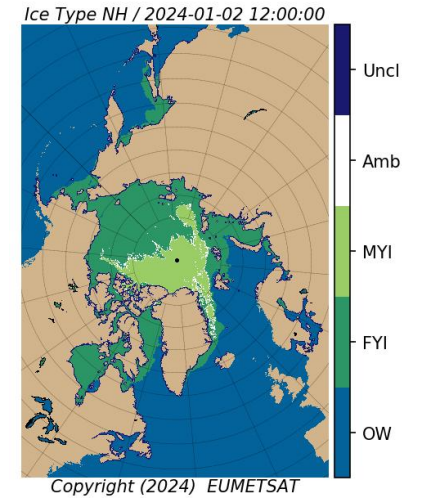
Water FYI MYI Ambig Land NaN



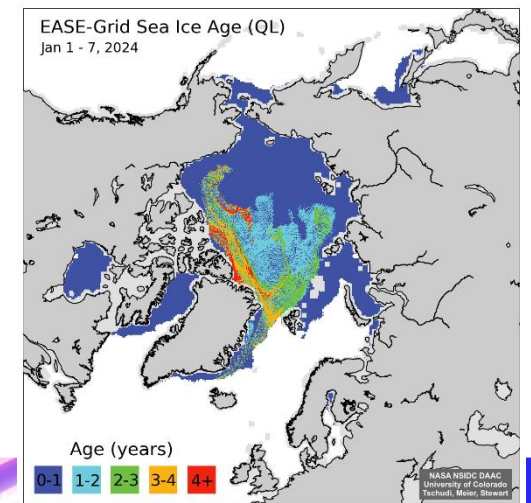
MYIC



OSISAF SIT

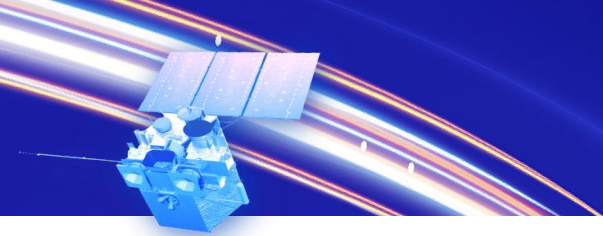


NSIDC SIA



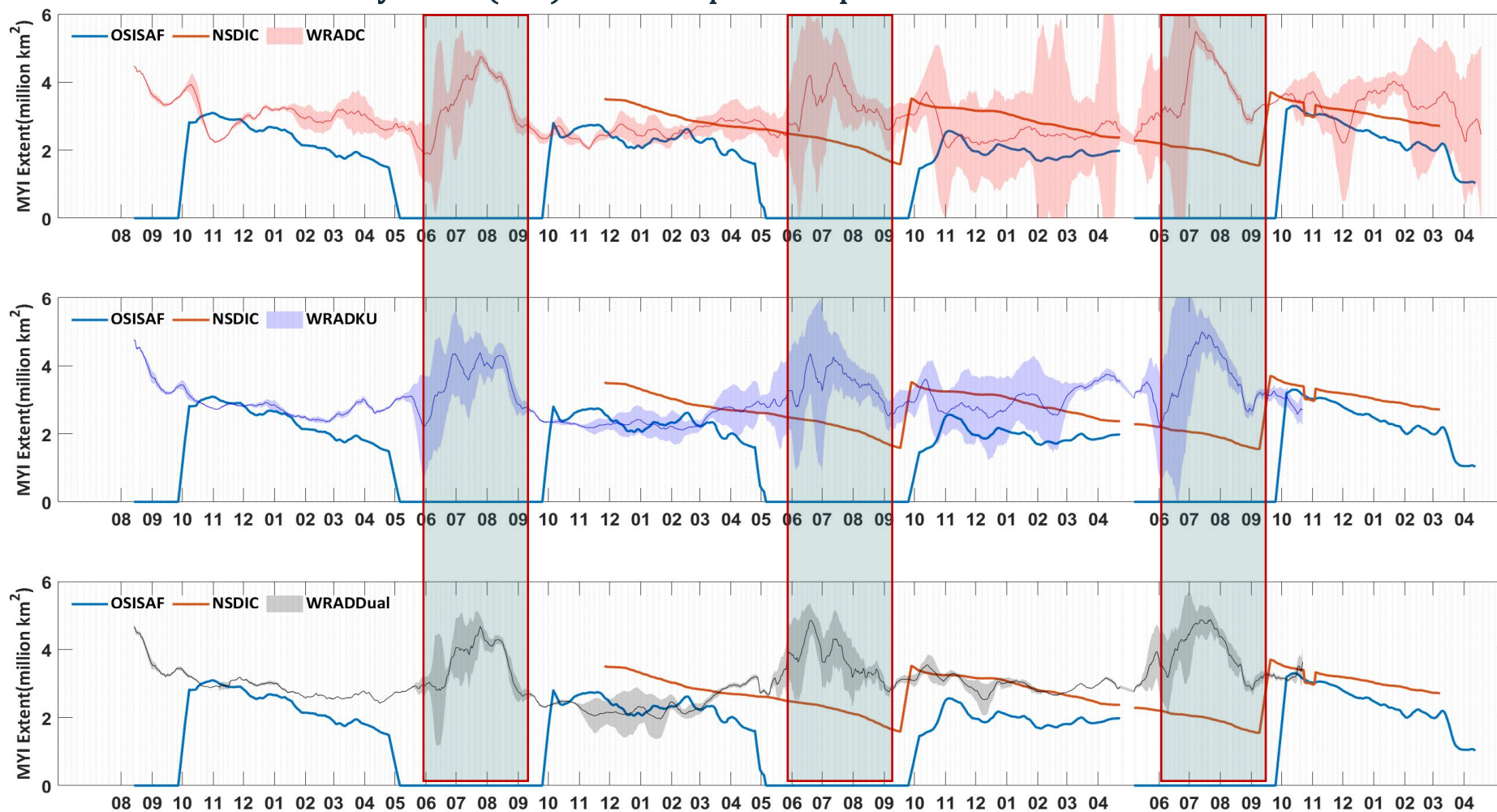
- The differences in sea ice type classification results among different bands are mainly manifested in the **boundary regions between first-year ice and multi-year ice.**

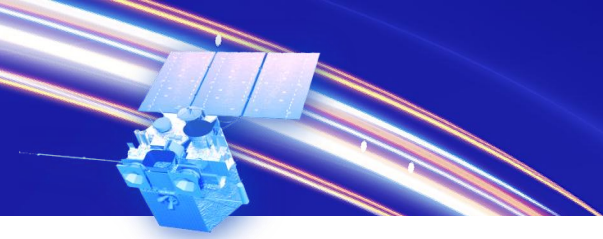
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FY-3E WindRAD Sea Ice Edge & Type: Algorithm & Products

Multi-year ice (MYI) extent temporal comparison with OSISAF & NSIDC

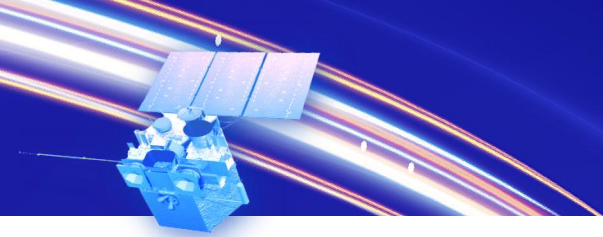




Contents

- 1. Background & Motivation
- 2. FengYun Polar Sea Ice Products & Application
 - ➔ Sea Ice Thickness
- 3. Summary & Outlook

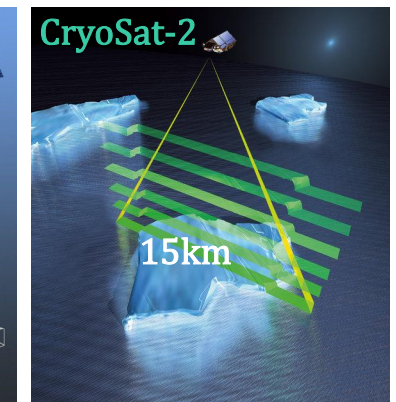
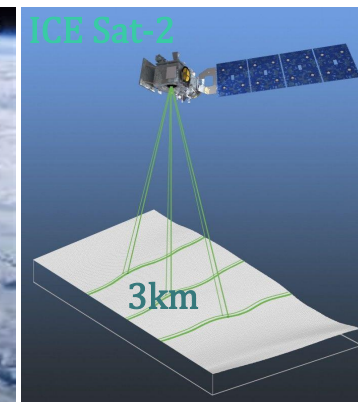
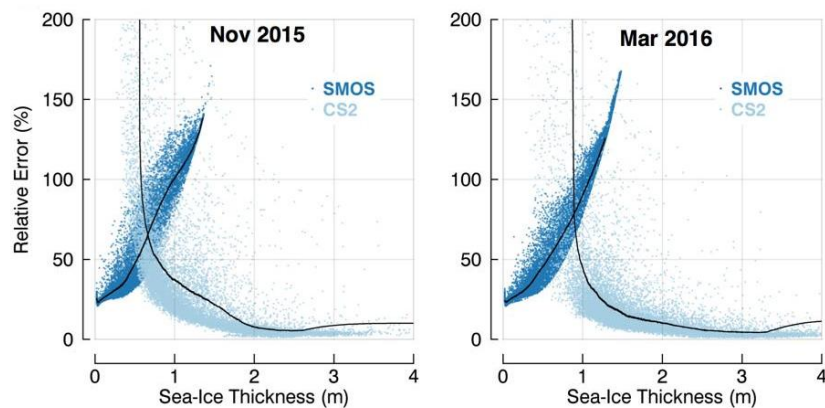
AOMSUC-15 2025 FYSUC



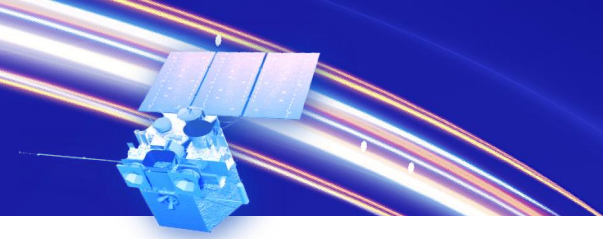
FY-3F GNOS II Sea Ice Thickness: Background & Payloads

- Accurately measuring **sea ice thickness** is crucial for **tracking changes in its volume**. It is one of the most important **yet least understood climate indicators** for understanding global climate change in polar regions.
- Currently, the primary techniques for sea ice thickness measurement are **radiometer and altimeter**. **Radiometers** are predominantly used for **thin ice detection**, whereas **altimeters** demonstrate **greater accuracy** in measuring thick ice.

Product Type	Key Products	Major Limitations
Satellite Altimetry (Radar/Laser)	CryoSat-2 (ESA), ICESat-2 (NASA)	• Physical Mechanism: Based on freeboard height measurement and hydrostatic equilibrium. • Thickness Range: Demonstrate superior efficacy in measuring thick ice (>1m).
Passive Microwave (L-band)	SMOS (ESA)	• Physical Mechanism: Based on Radiative transfer model. • Thickness Range: Only reliable for thin ice (<~0.5-1m).

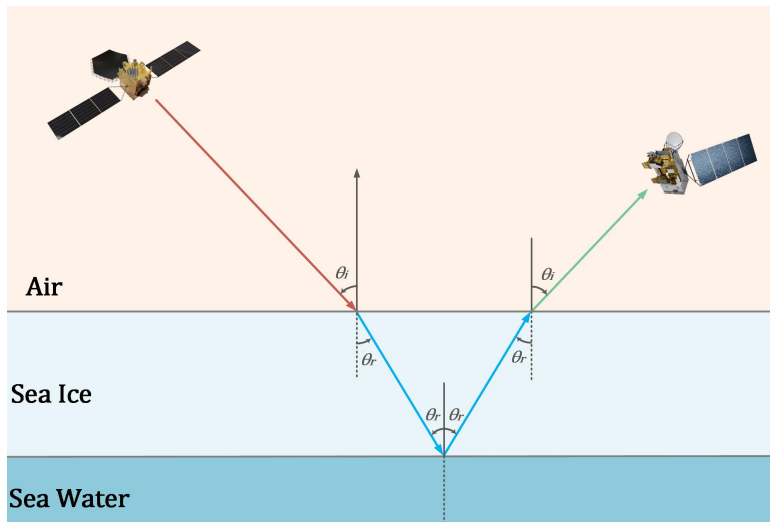


(Collaborate with Dr. Yin Cong's team, NSSC)



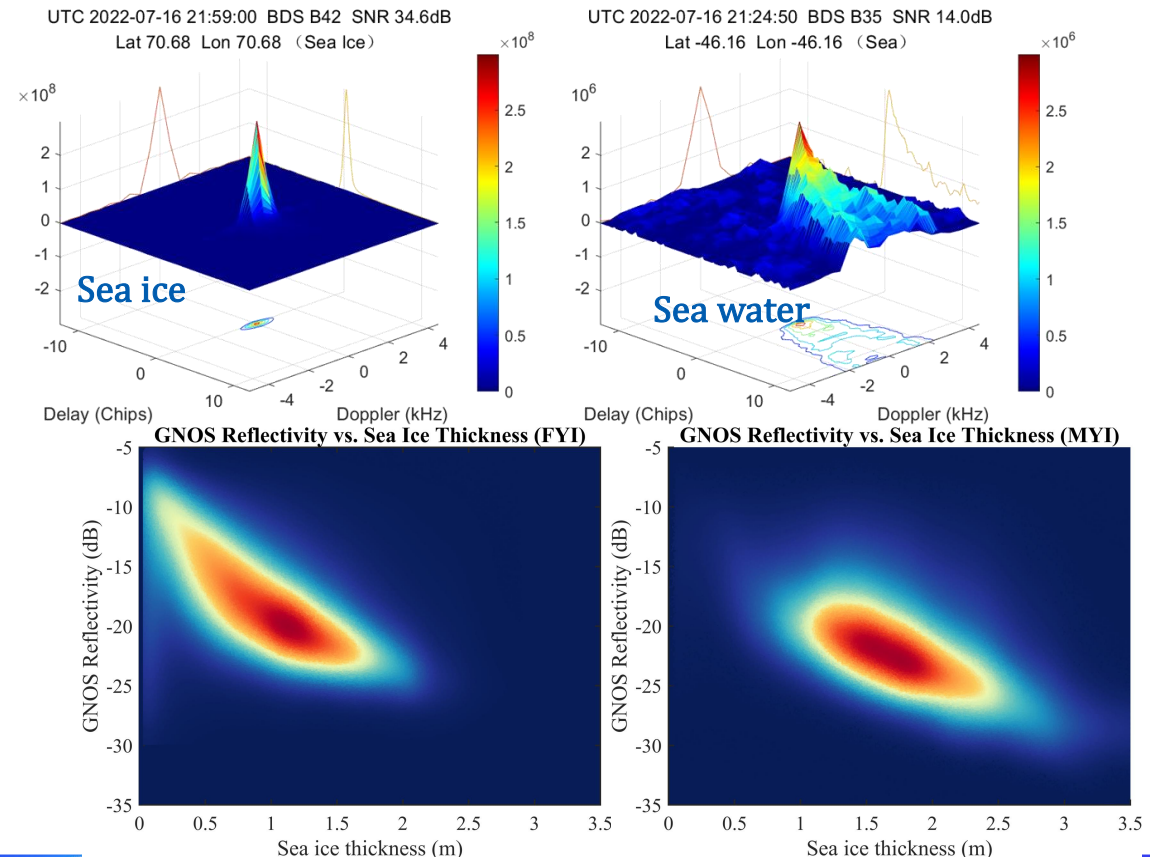
FY-3F GNOS II Sea Ice Thickness: Algorithm & Products

- GNSS-R: a novel remote sensing observation system in recent years
- **Physical mechanism**: utilizing the **reflected signals** of the Global Navigation Satellite System (GNSS) on the Earth's surface in the **L-band**, generating a **DDM (Delay-Doppler Map) correlation power spectrum**.
- The **DDM waveform** contains information such as the **dielectric constant and roughness of the reflecting surface**, which can be used to derive parameters such as sea surface wind speed, soil moisture on land, sea ice extent, and thickness.

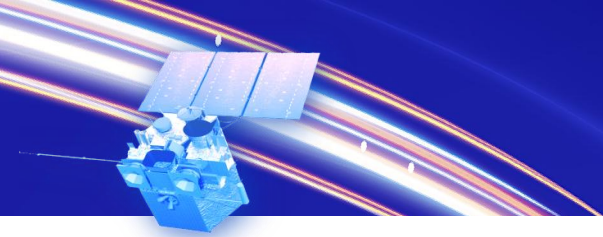


$$\Gamma = \frac{(4\pi)^2 (P_{DDM} - N)(R_r + R_t)^2}{\lambda^2 P_t G_t G_r} = \Gamma_{sw/si} e^{-4\alpha d}$$

Reflectivity of first-year ice and multi-year ice as a function of sea ice propagation path. →

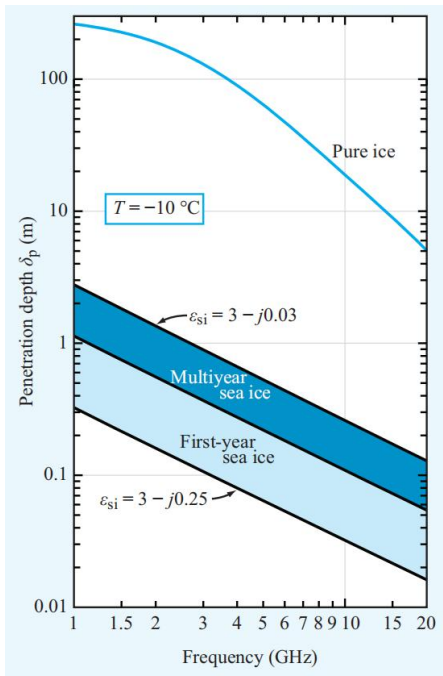


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FY-3F GNOS II Sea Ice Thickness: Algorithm & Products

- **Feature parameters:** L1 data (incidence angle, antenna gain, reflectivity, DDM features), geolocation information (Lat/Lon), Auxiliary Data (2m air temperature, sea ice salinity, sea ice type)
- **Label:** CryoSat-2/SMOS Merged Product
- **Method:** Levenberg Marquardt Neural Network Algorithm



(Ulaby, 2014)

GNSS Reflectivity:

$$\Gamma = \frac{(4\pi)^2 (P_{DDM} - N)(R_r + R_t)^2}{\lambda^2 P_t G_t G_r} = \Gamma_{sw/si} e^{-4\alpha d}$$

Attenuation Coefficient:

$$\alpha = \frac{2\pi}{\lambda} \left| \text{Im} \left\{ \sqrt{\epsilon_i} \right\} \right|$$

Attenuation path:

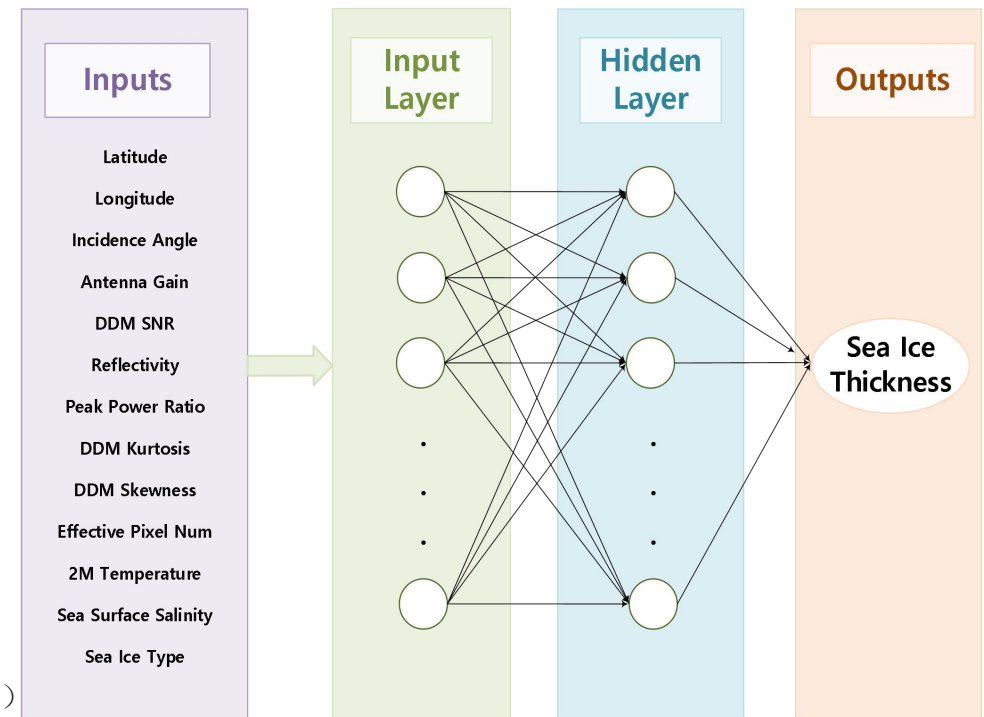
$$d = SIT / \cos(\theta_r)$$

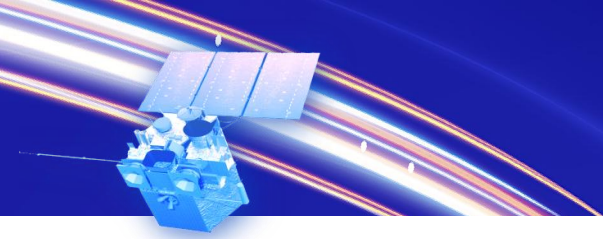
Sea ice permittivity:

$$\epsilon_i = a_0 + a_1 \cdot v_b - i \cdot (b_0 + b_1 \cdot v_b)$$

Brine:

$$v_b = 10^{-3} S_i \left(-\frac{49.185}{T} + 0.532 \right) \quad (-0.5^\circ\text{C} \geq T \geq -22.9^\circ\text{C})$$

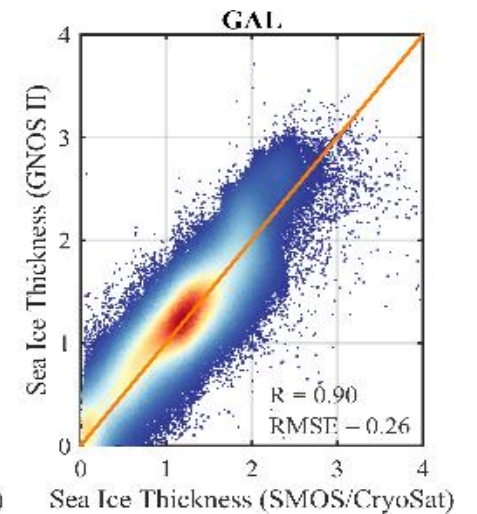
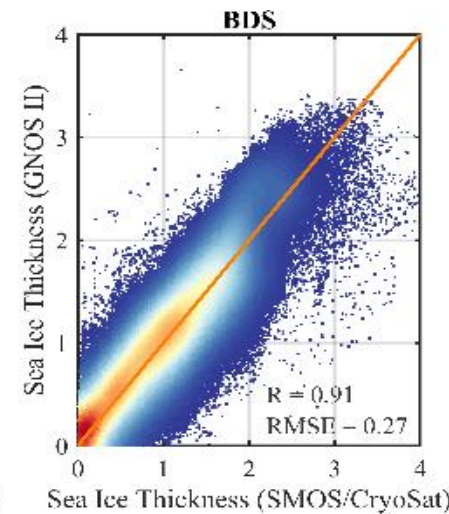
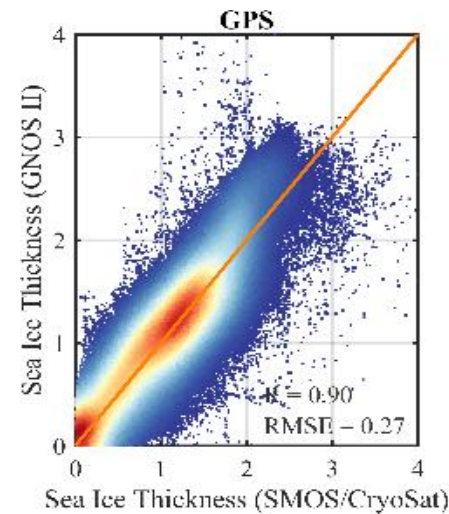
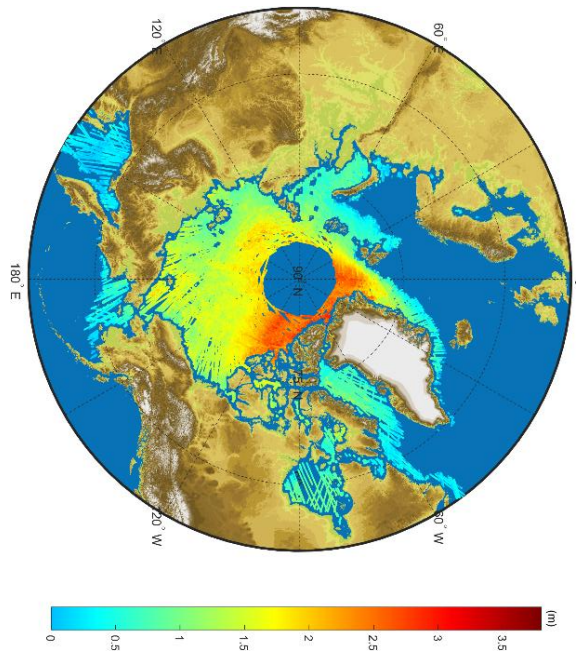




FY-3F GNOS II Sea Ice Thickness: Algorithm & Products

- The FY-3F GNOS II sea ice thickness product, as a newly developed product, was operationally released in 2024
- Original observation resolution: 1x6 km (Cross-track resolution: 1 km, along-track resolution: 6 km);
- Projection method: Stereographic projection (10 km).

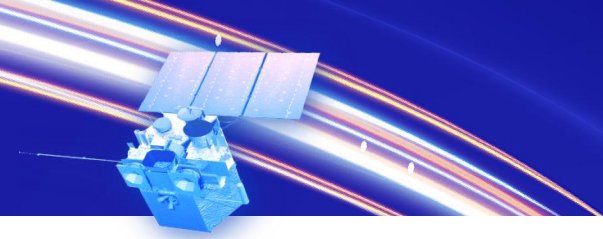
FY3E/F Sea Ice Thickness
(20240305-20240311)



In comparison with CryoSat-2/SMOS merged sea ice thickness(SIC>90%):

	GPS	BDS	GAL
RMSE (m)	0.27	0.27	0.26
CORR. COEFF.	0.90	0.91	0.90

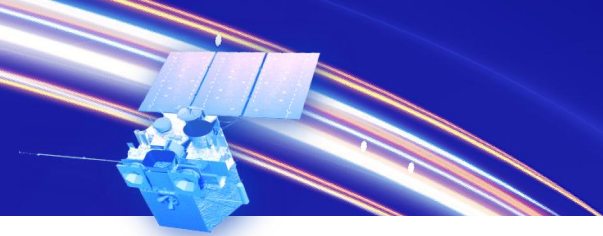
- Meets the precision requirement of RMSR (Root Mean Square Root) less than 0.3 meters within 2 meters.



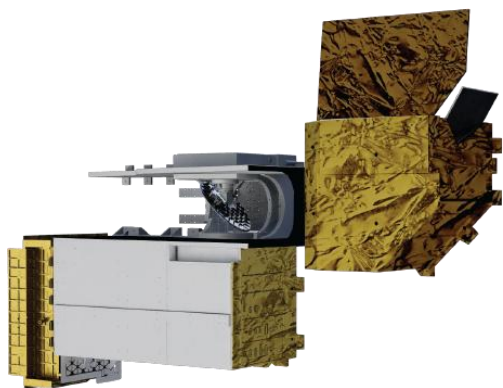
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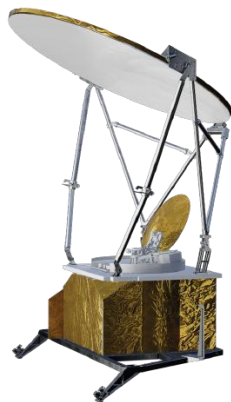
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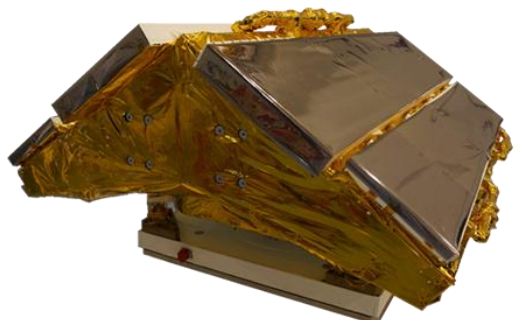
- ✓ **Recent Advances:** the development of Fengyun various sea ice products has enhanced our understanding of sea ice variability and its impact on climate change.



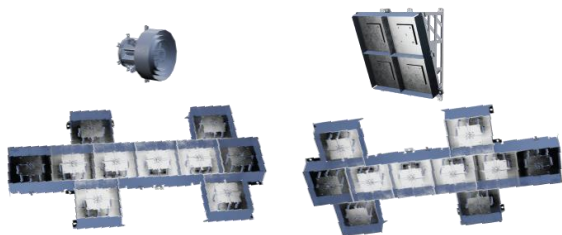
FY-3F/MERSI-III



FY-3F/MWRI-II



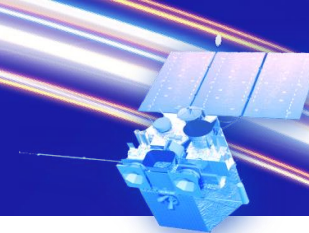
FY-3E/WindRAD



FY-3F GNOS-II

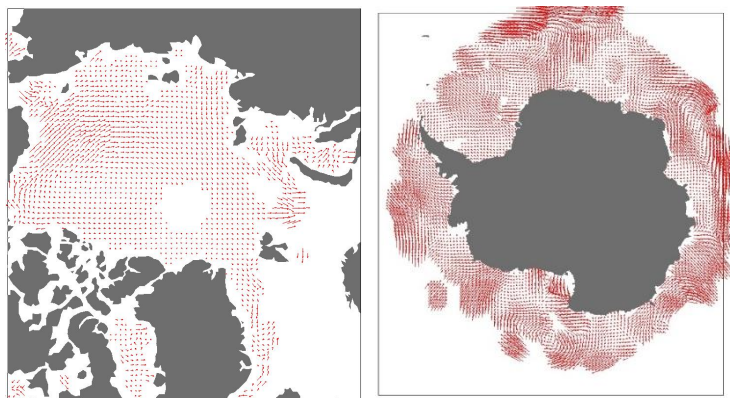
Parameters	Sensors	Product maturity	Product status
Sea ice concentration	FY-3 MWRI radiometer	High	Operational
Sea ice age (or type)	FY-3 WindRAD scatterometer	High	Operational
Sea ice thickness	FY-3 GNOS II GNSS-R	High	Operational
Sea ice drift	FY-3 MWRI radiometer	Middle	To be operational in FY-3H
Snow depth on sea ice	FY-3 MWRI radiometer	Middle	Prototype algorithm under development
Ice surface albedo	FY-3 VIRR FY-3 MERSI	Low	Prototype algorithm under development
Ice surface temperature	FY-3 MERSI FY-3 MWRI	Low	Prototype algorithm under development
Leads	FY-3 MERSI FY-3 MWRI	Low	Prototype algorithm under development

AOMSUC-15 2025 FYSUC



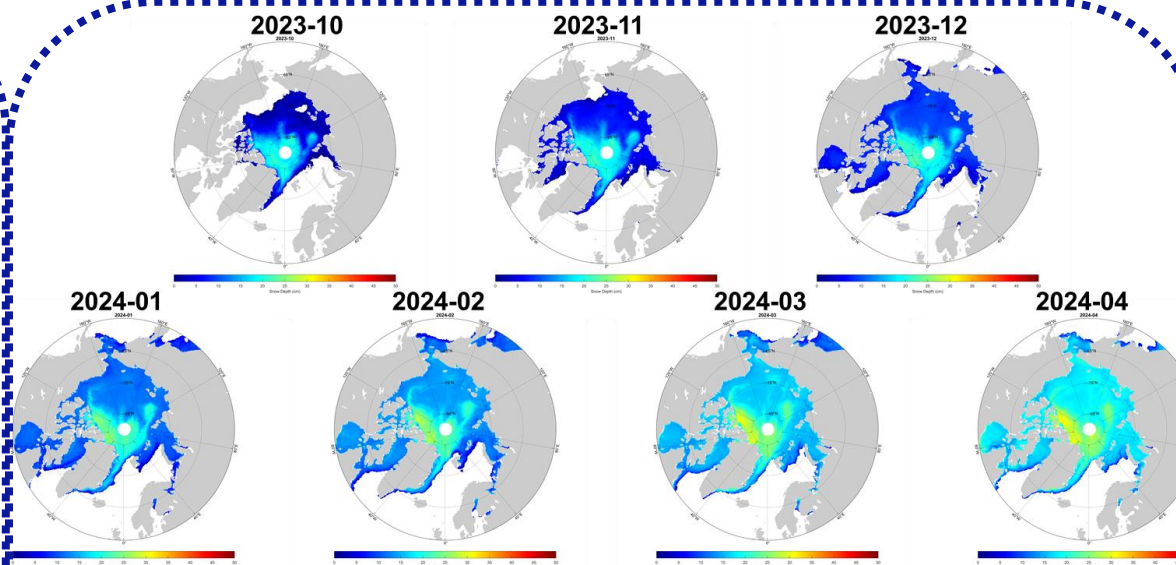
1. A more comprehensive product suite for polar ice and snow observations

- Extending microwave payload capabilities



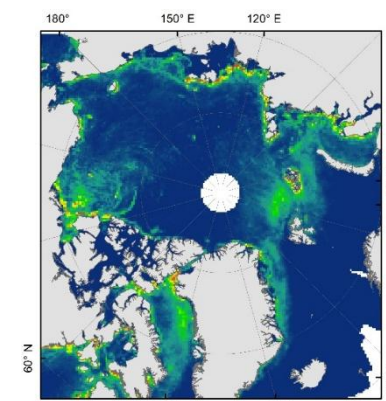
- **Product:** Sea ice motion
- **Input:** FY-3 MWRI SIR L1
- **Algorithm:** CMCC
- **Temporal resolution:** 24h
- **Spatial resolution:** 18.75 km

Dr Shi Qian's team



- **Product:** Snow depth on sea ice
- **Input:** FY-3 MWRI L1
- **Algorithm:** statistical model
- **Temporal resolution:** daily
- **Spatial resolution:** 25 km

Dr He Lian's team

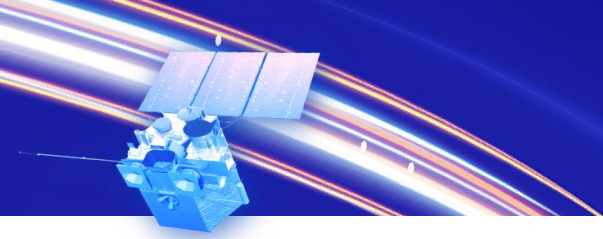


Lead fraction (%)

0 10

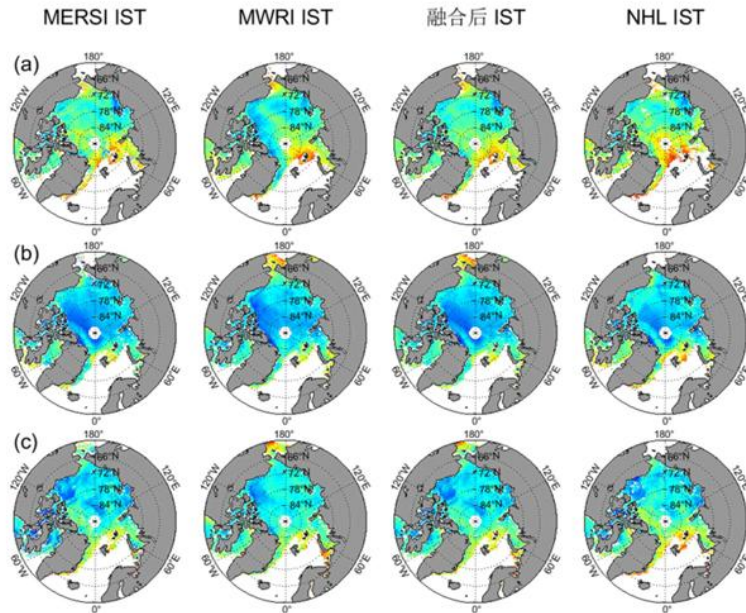
- **Product:** sea ice lead
- **Input:** FY-3 MERSI and MWRI
- **Algorithm:** deep learning
- **Temporal resolution:** daily
- **Spatial resolution:** 6.25 km

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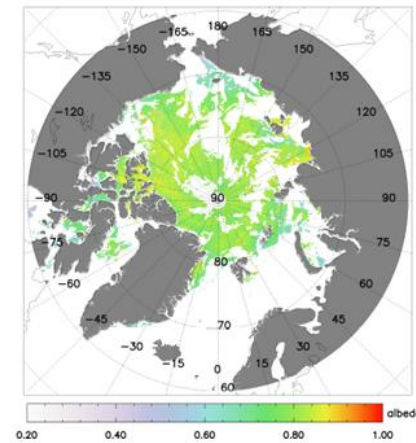
1. A more comprehensive product suite for polar ice and snow observations

- Expanding from microwave to optical + microwave fusion
- From sea ice to ice sheets and atmosphere

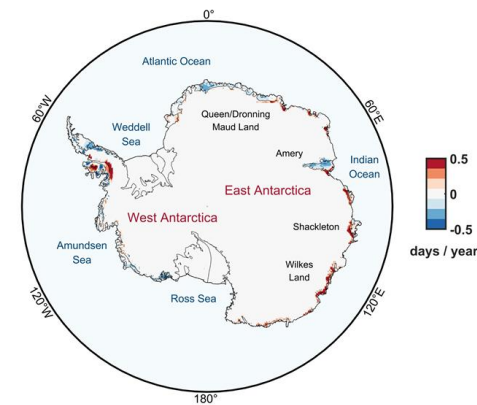


Ice surface temperature based on FY-3
MERSI and MWRI

Dr Chen Haihua's team

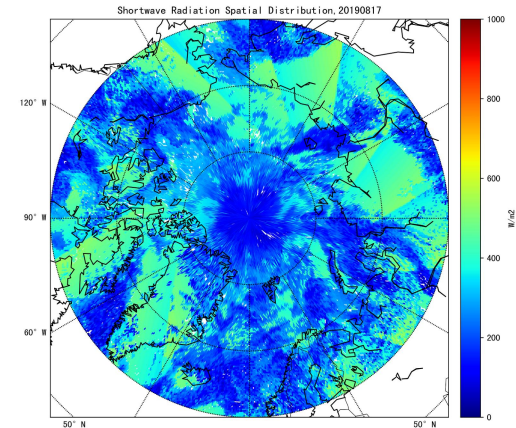


Clear-sky sea-ice albedo
Prof. Guan Lei's team



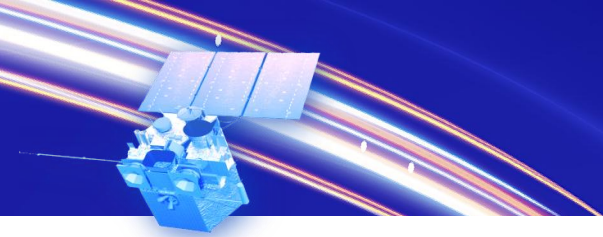
Interannual trend changes of
surface melting of the Antarctic
Ice Sheet (1979-2020)

Prof. Zheng Lei's team



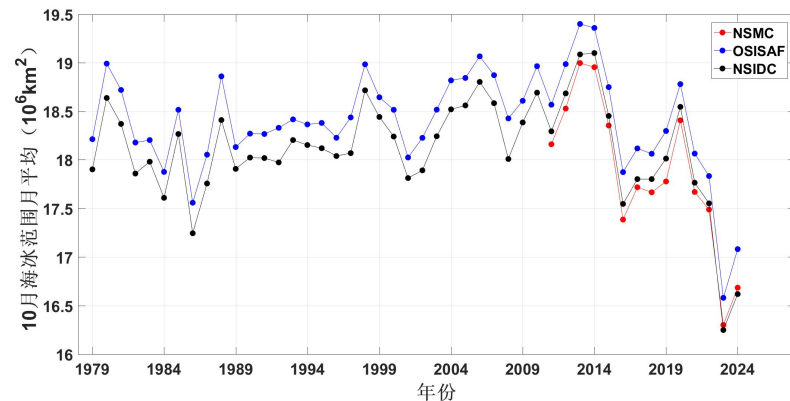
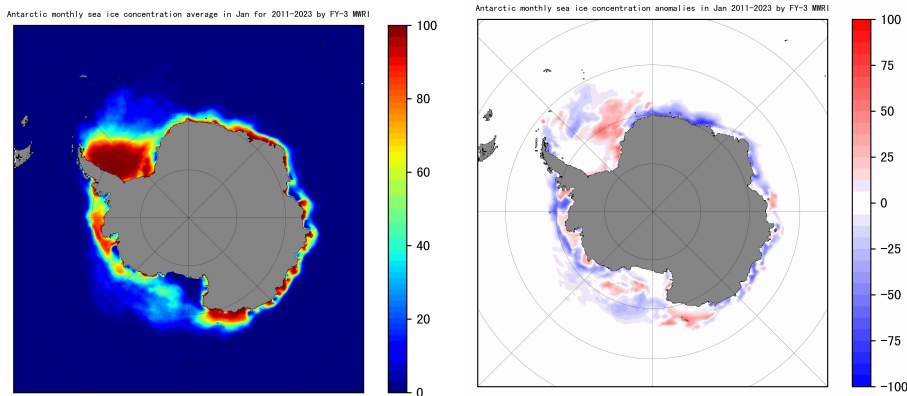
Arctic Surface Shortwave
Radiation

AOMSUC-15 2025 FYSUC

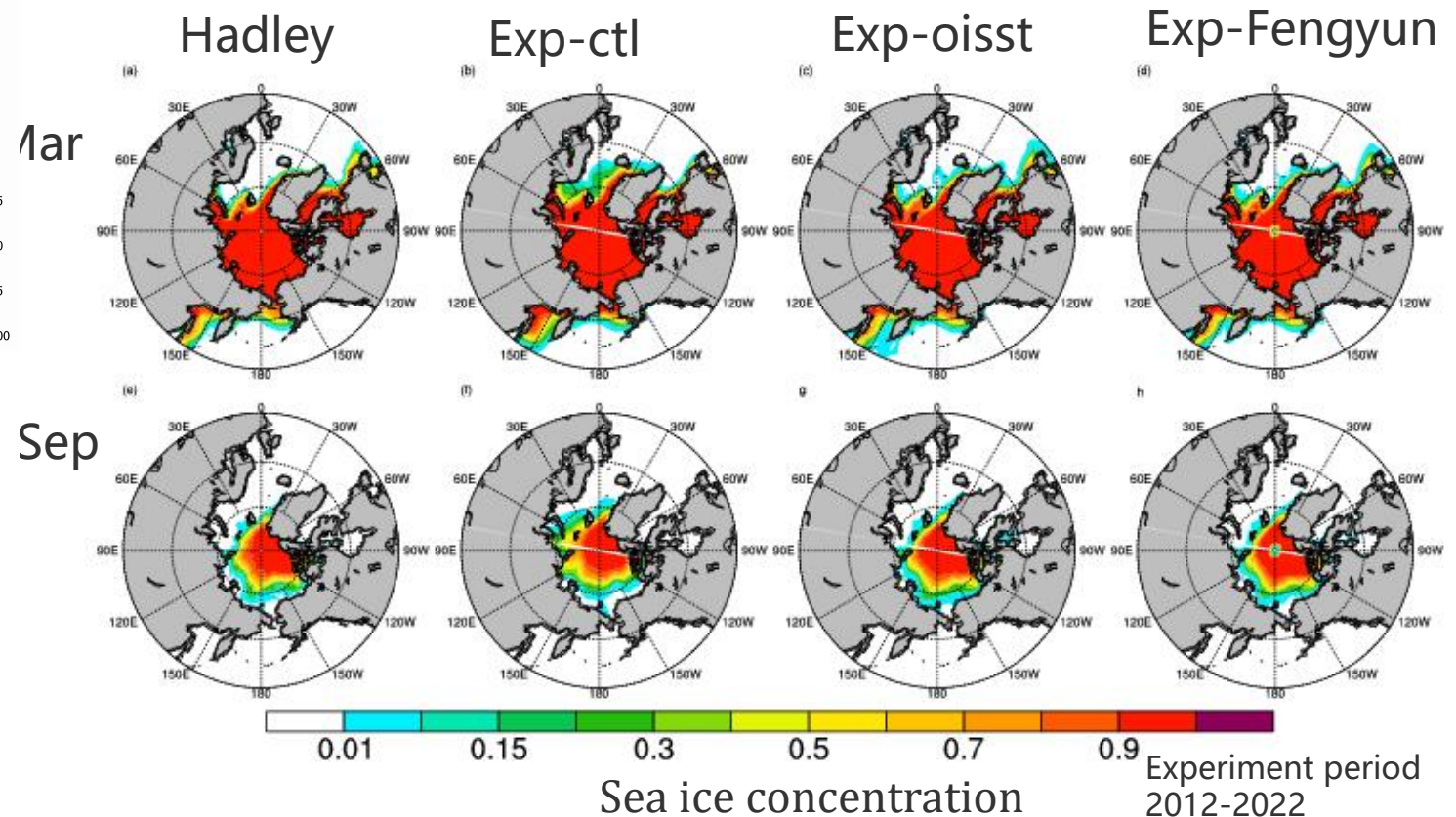


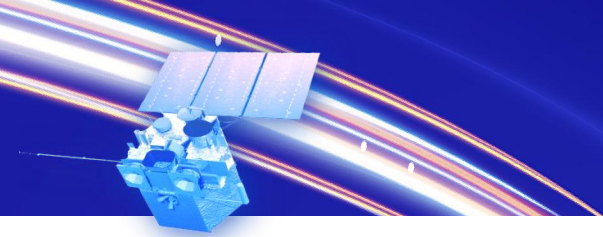
2. Deepened applications

- Moving from product generation to long-term climate data records
- Advancing from climate-change observation support to full data-assimilation applications



FY-3B/C/D MWRI sea ice concentration datasets





Thanks for your attention!

zhaixc@cma.gov.cn

National Satellite Meteorological Center (NSMC),
China Meteorological Administration (CMA)



✓ Please download related data at:
<https://satellite.nsmc.org.cn/DataPortal/cn/home/index.html>

