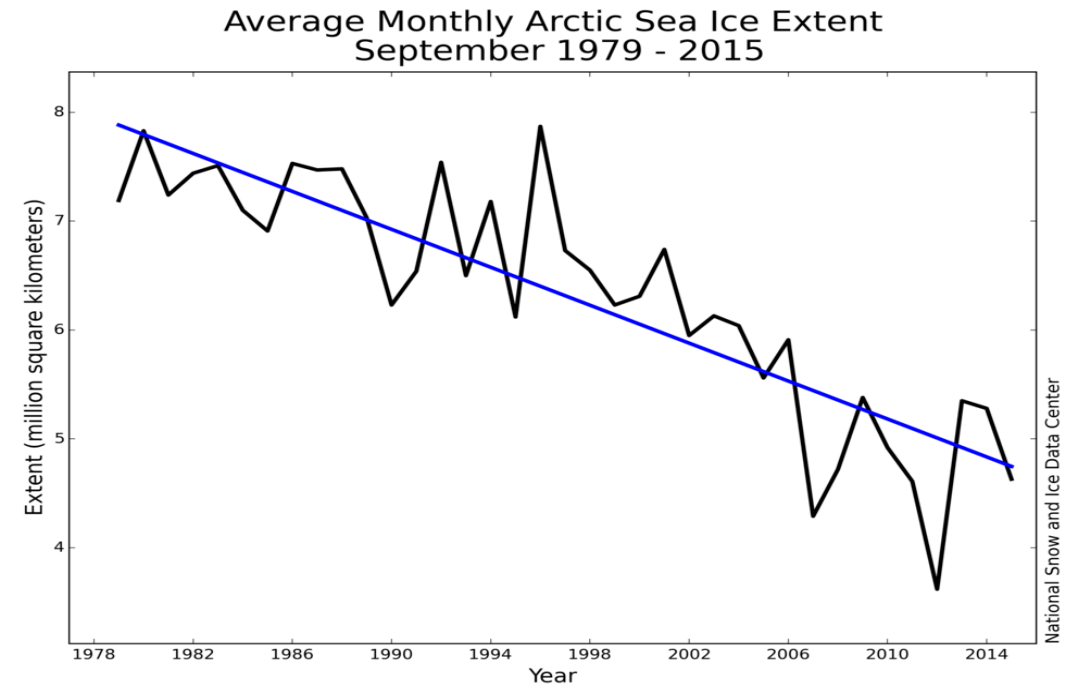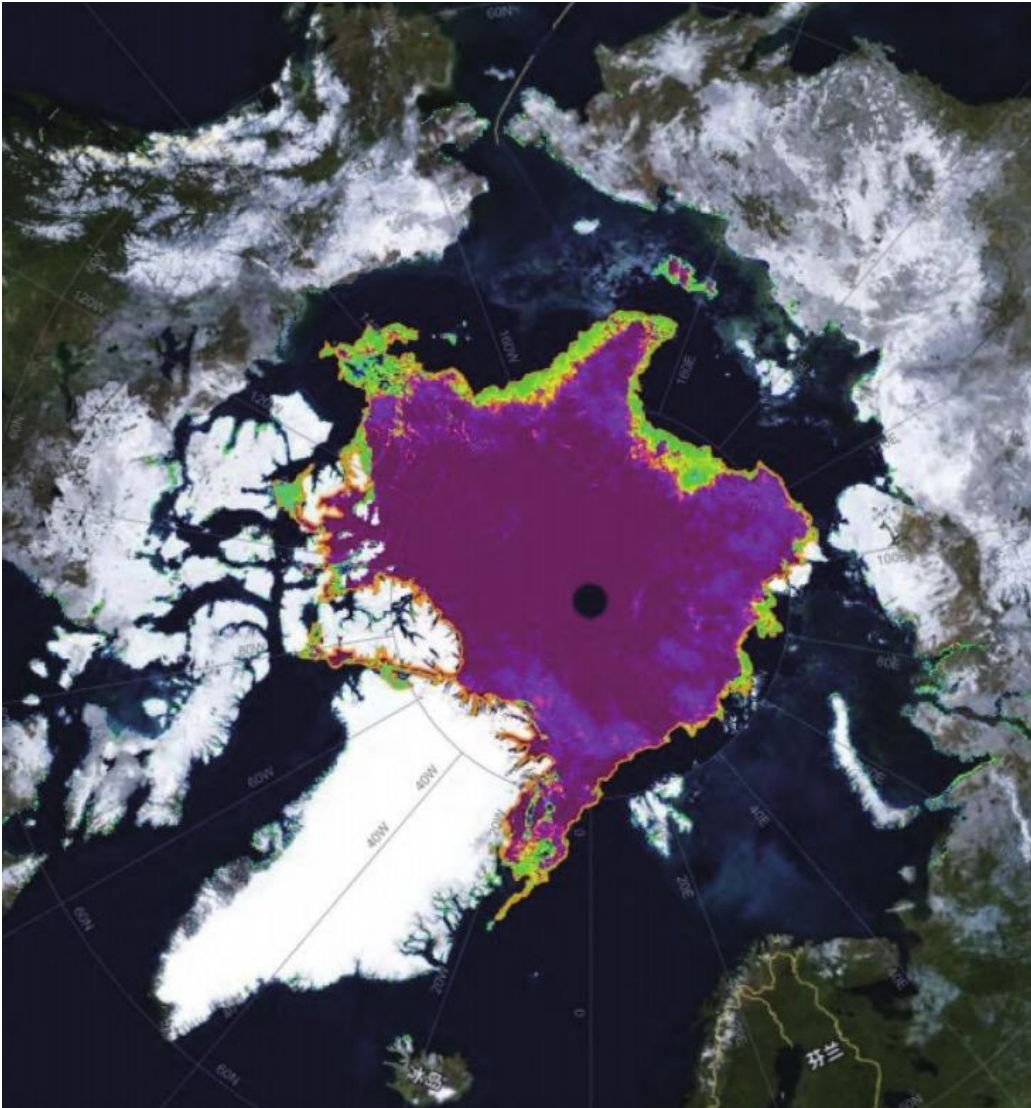# Surface emissivity characteristics of Arctic sea ice and their implication for a three-type ice classification

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* Seoul National University

Arctic Sea Ice

Average Monthly Arctic Sea Ice Extent
September 1979 - 2015

For decades, the extent and thickness of the Arctic sea ice have declined.

Observations show that the Arctic has been warming at about twice the global average rate, a phenomenon known as Arctic amplification.

The continuing decline of sea ice thus underscores the importance of accurate monitoring and improved understanding of its changes.
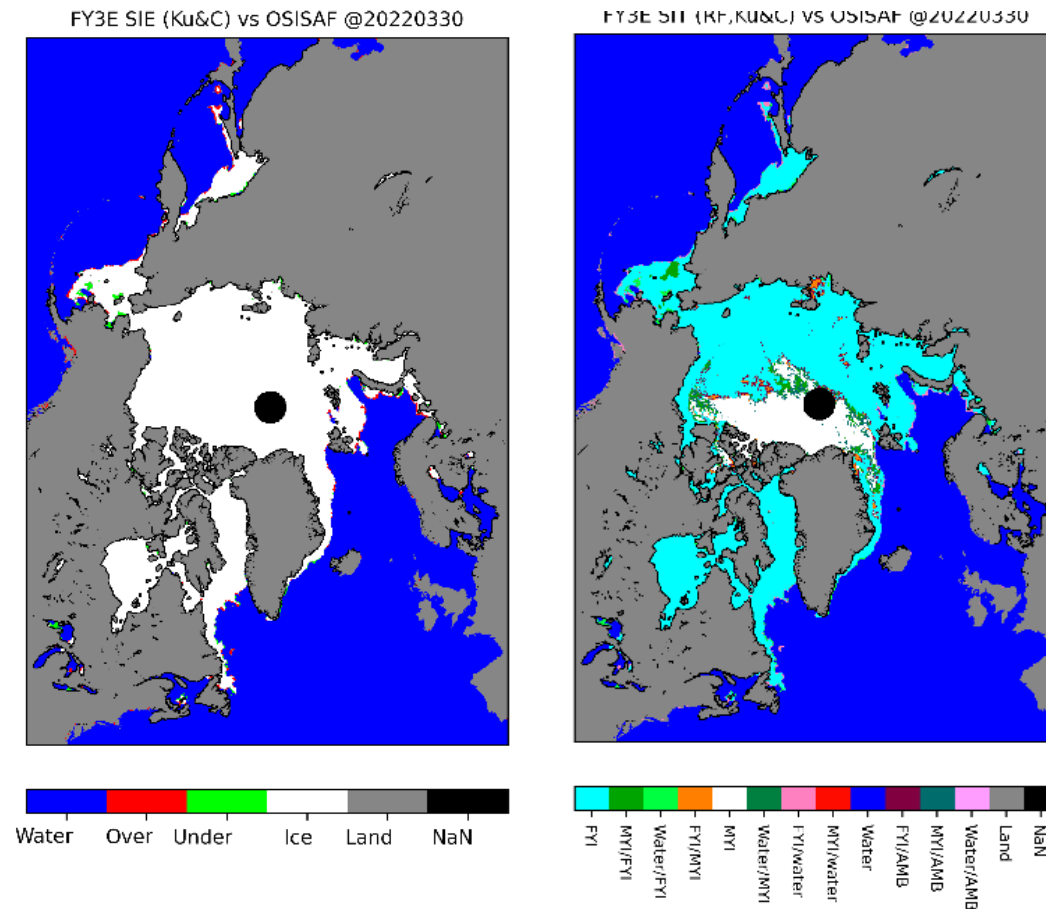
Sea ice types
Multi-year ice (MYI) > 2 years old
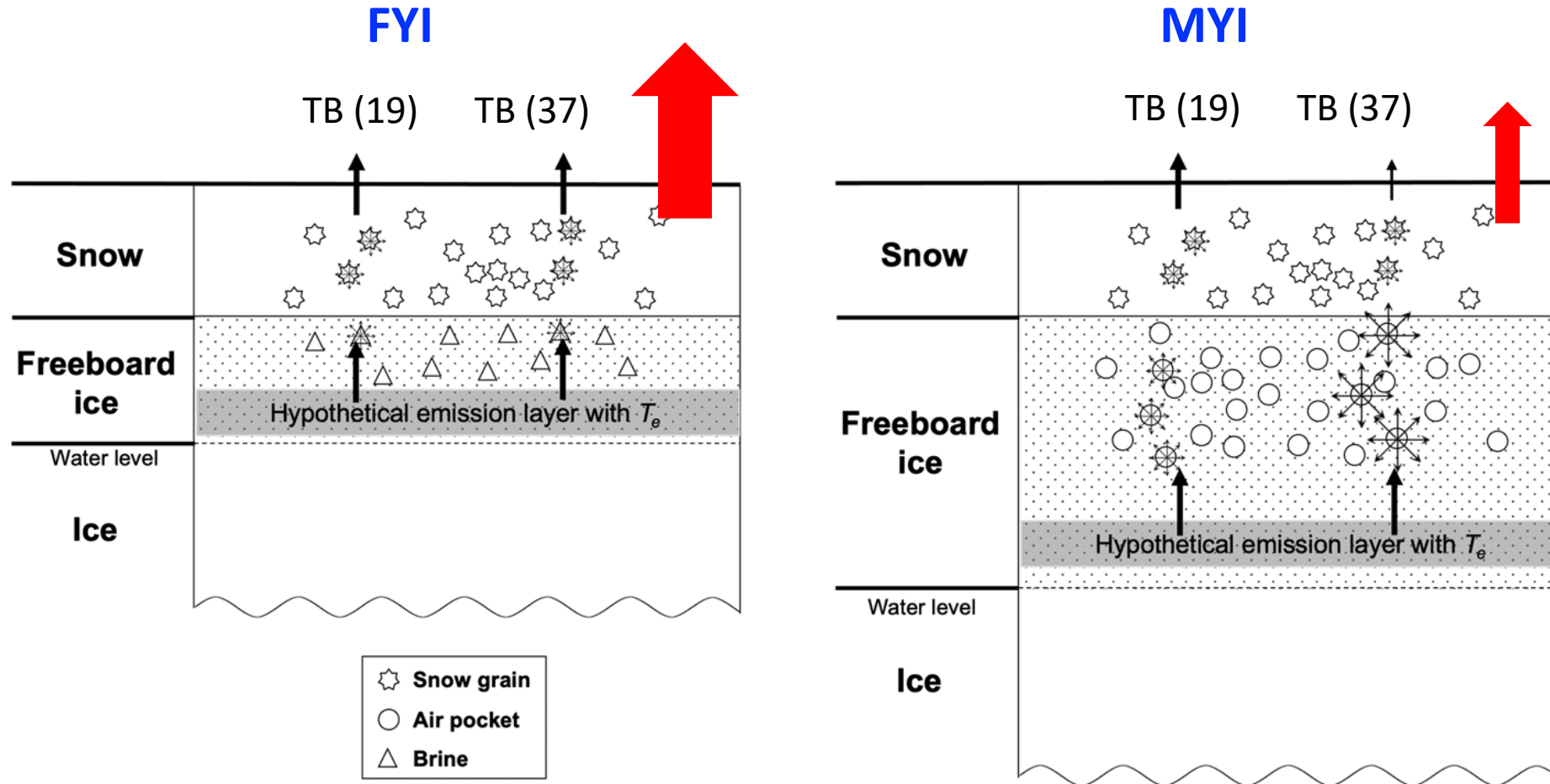## First-year ice (FYI): seasonal

FYI

MYI

Importance sea ice type monitoring

- Monitor Arctic changes by showing how much thick vs. thin ice exists
- Support climate, environment, and ecosystem monitoring
- Help ships and offshore projects avoid dangerous ice

FY3E SIE (Ku&C) vs OSISAF @20220330

FY3E SIT (RF,Ku&C) vs OSISAF @20220330

Water | Over | Under | Ice | Land | NaN

FYI | MYI/FYI | Water/FYI | FYI/MYI | MYI | Water/MYI | FYI/water | MYI/water | Water | FYI/AMB | MYI/AMB | Water/AMB | Land | NaN

Courtesy of Dr. Chen Lin (CMA)

Radiative properties of FYI and MYI

FYI

TB (19)   TB (37)

Snow

Freeboard ice

Hypothetical emission layer with T_e

Water level

Ice

Snow grain
Air pocket
Brine

MYI

TB (19)   TB (37)

Snow

Freeboard ice

Hypothetical emission layer with T_e

Water level

Ice

● **GR Index = TB(37) – TB(19) for sea ice type classification**

● **What about emissivity?**

GR Index vs. sea ice type
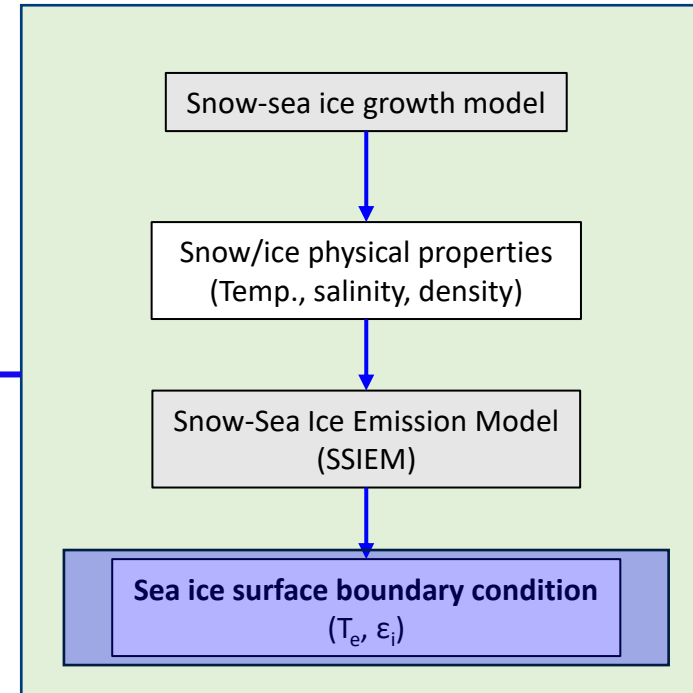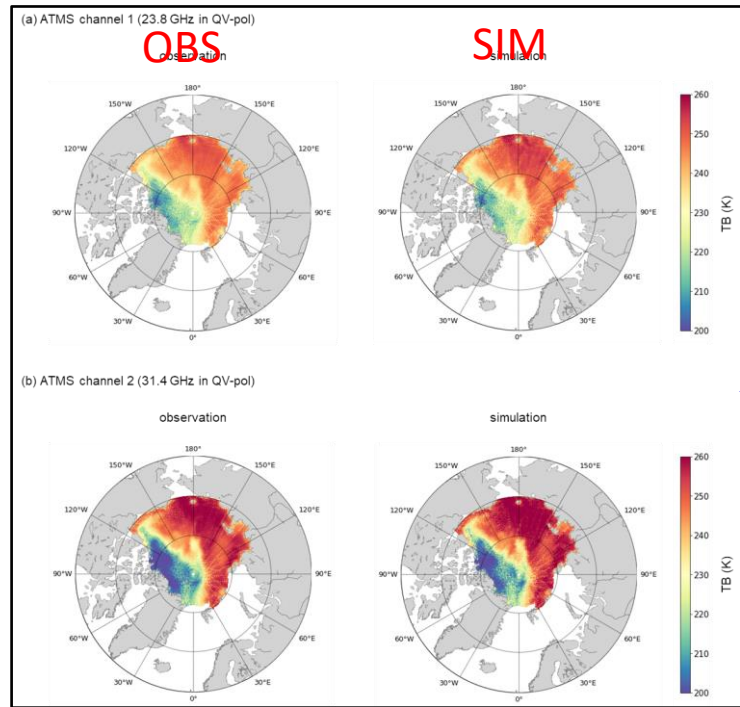
GR index [GR = (37V – 19V) / (37V + 19V)]
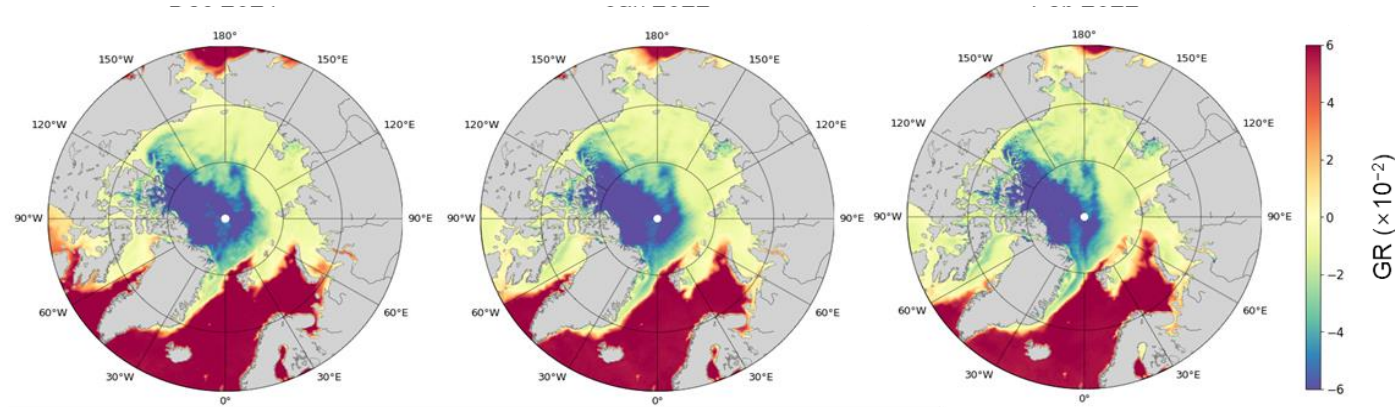
(d) Sea ice type

Sea ice type ■ MY sea ice ■ FY sea ice □ Mixing sea ice ■ Open water ■ Land

Dec 2021   Jan 2022   Feb 2022
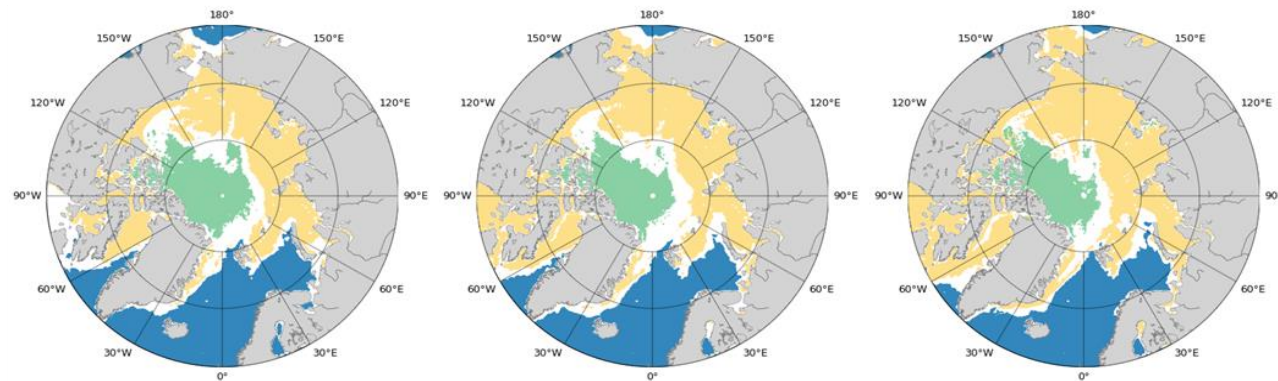
But, use of emissivity should be more direct and physically-based, if available.

Emissivity retrieval algorithm

OBS SIM

(a) ATMS channel 1 (23.8 GHz in QV-pol)

(b) ATMS channel 2 (31.4 GHz in QV-pol)

Model simulation approach
(Kang et al., 2021; 2023)

Snow-sea ice growth model

Snow/ice physical properties
(Temp., salinity, density)

Snow-Sea Ice Emission Model
(SSIEM)

Sea ice surface boundary condition
(T_e, ε_i)

ANN-based algorithm (Kang et al. 2025)

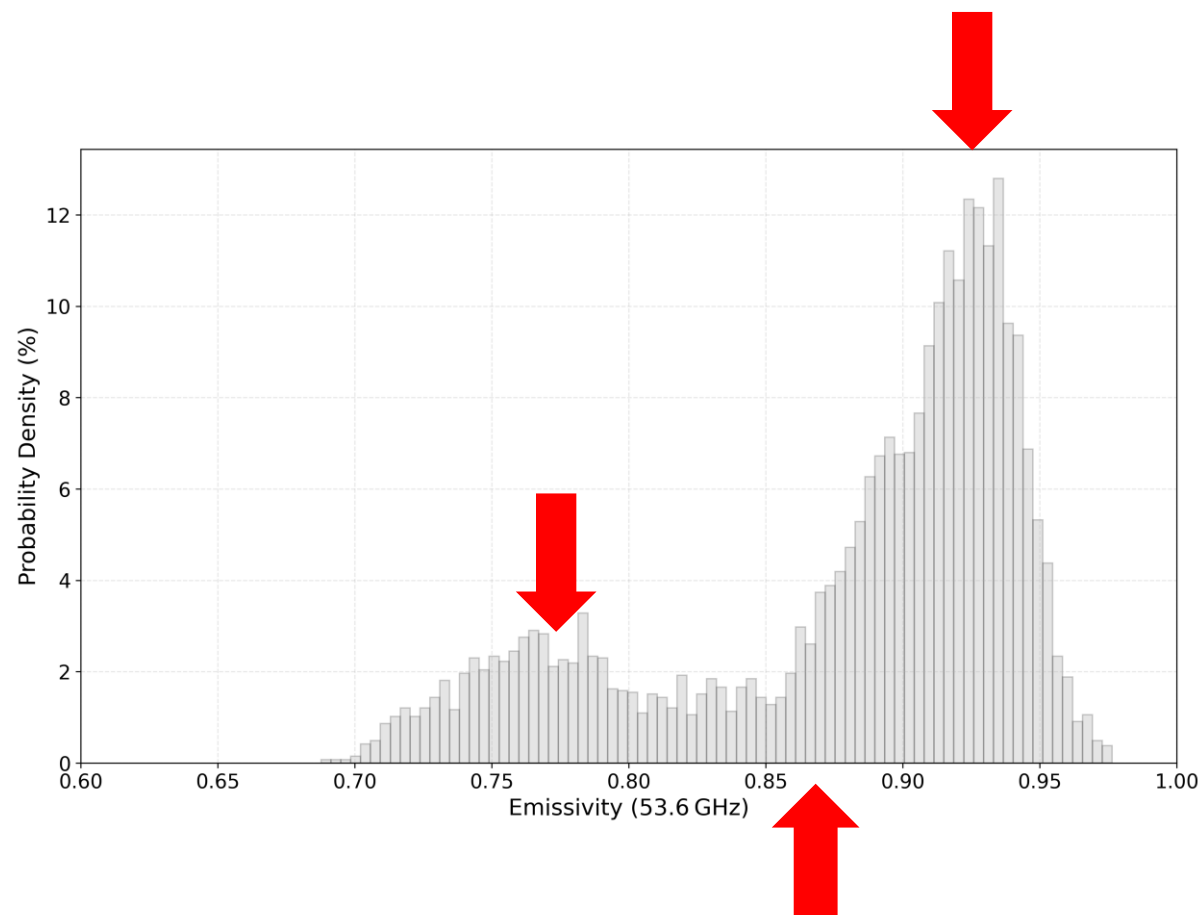Simulated ε, Te vs. Simulated TB

Observations
(ATMS TBs)

Satellite-derived
(T_e, ε_i)

6

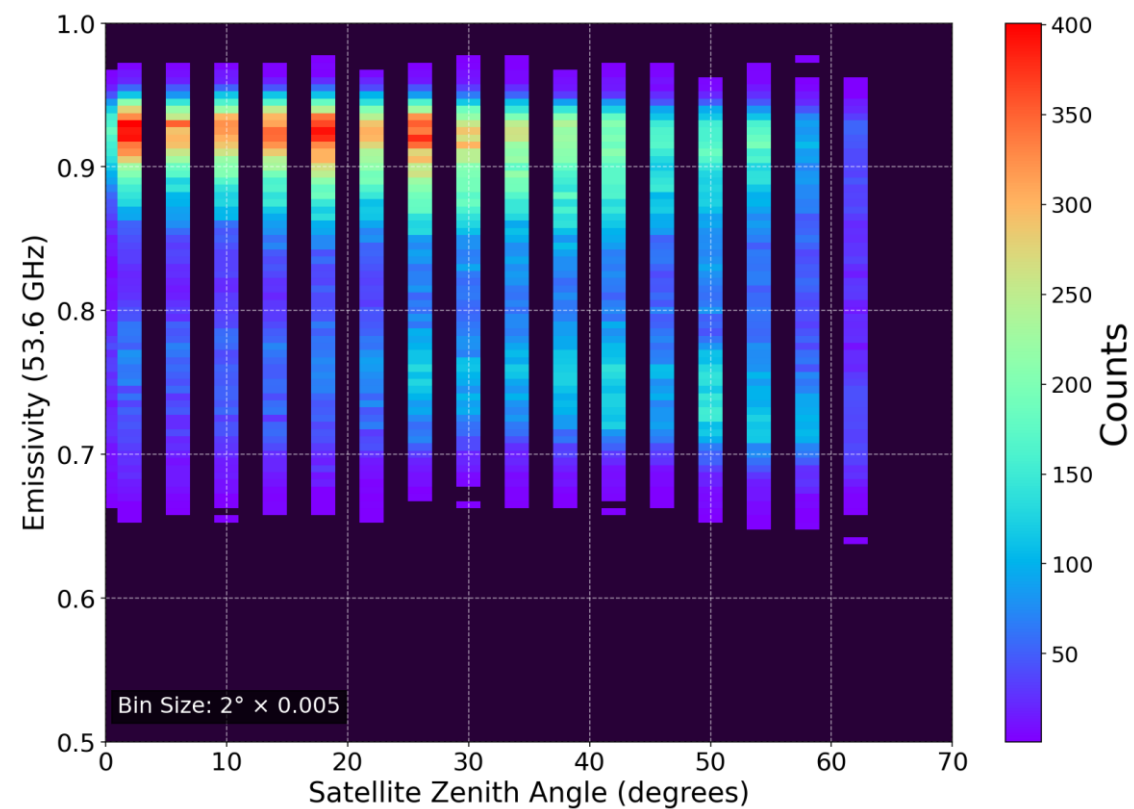# Distributions of Emissivity from ATMS 53.6 GHz Channel

1 January of (2013, 2017, 2021, and 2025).
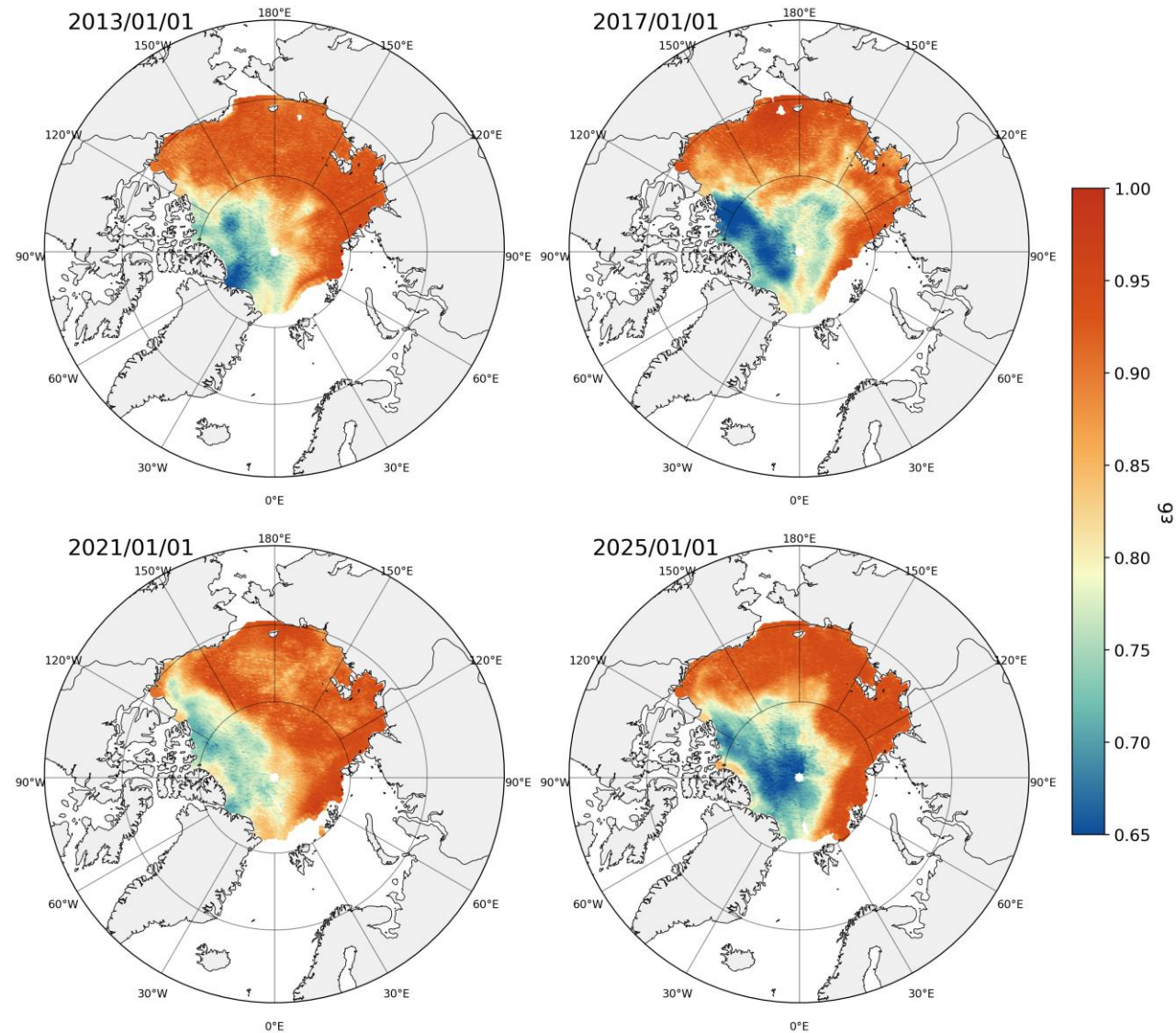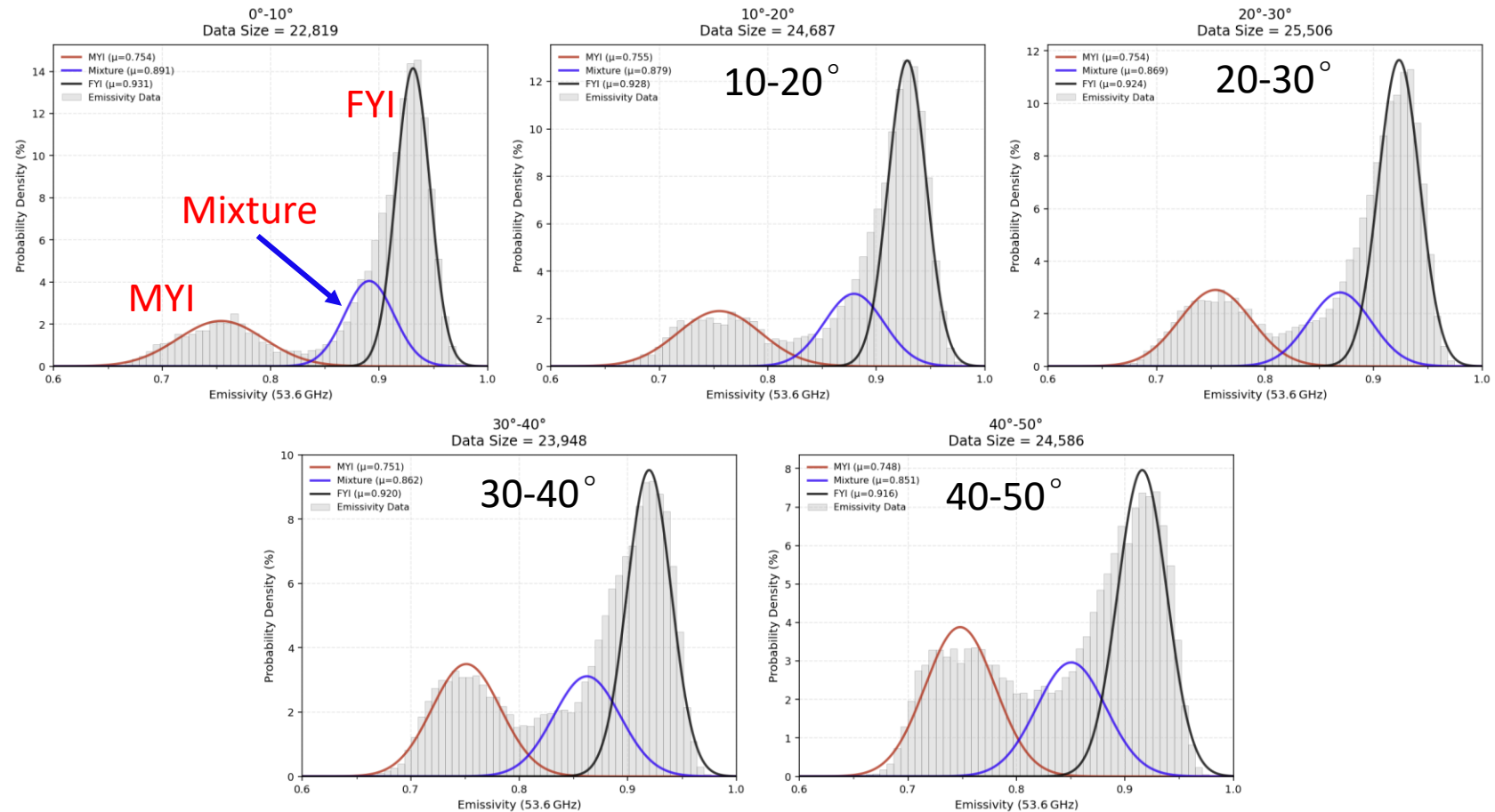
PDF distribution of emissivity (2021. 1. 1)

Scan angle vs. emissivity (2020. 12. 18 - 2020. 12. 21)

Three mode separation using Gaussian Mixture Model from 14-day cumulations

Assumption of mode separation: emissivity distribution of same type of ice (MYI or FYI) shows a Gaussian form of emissivity distribution.
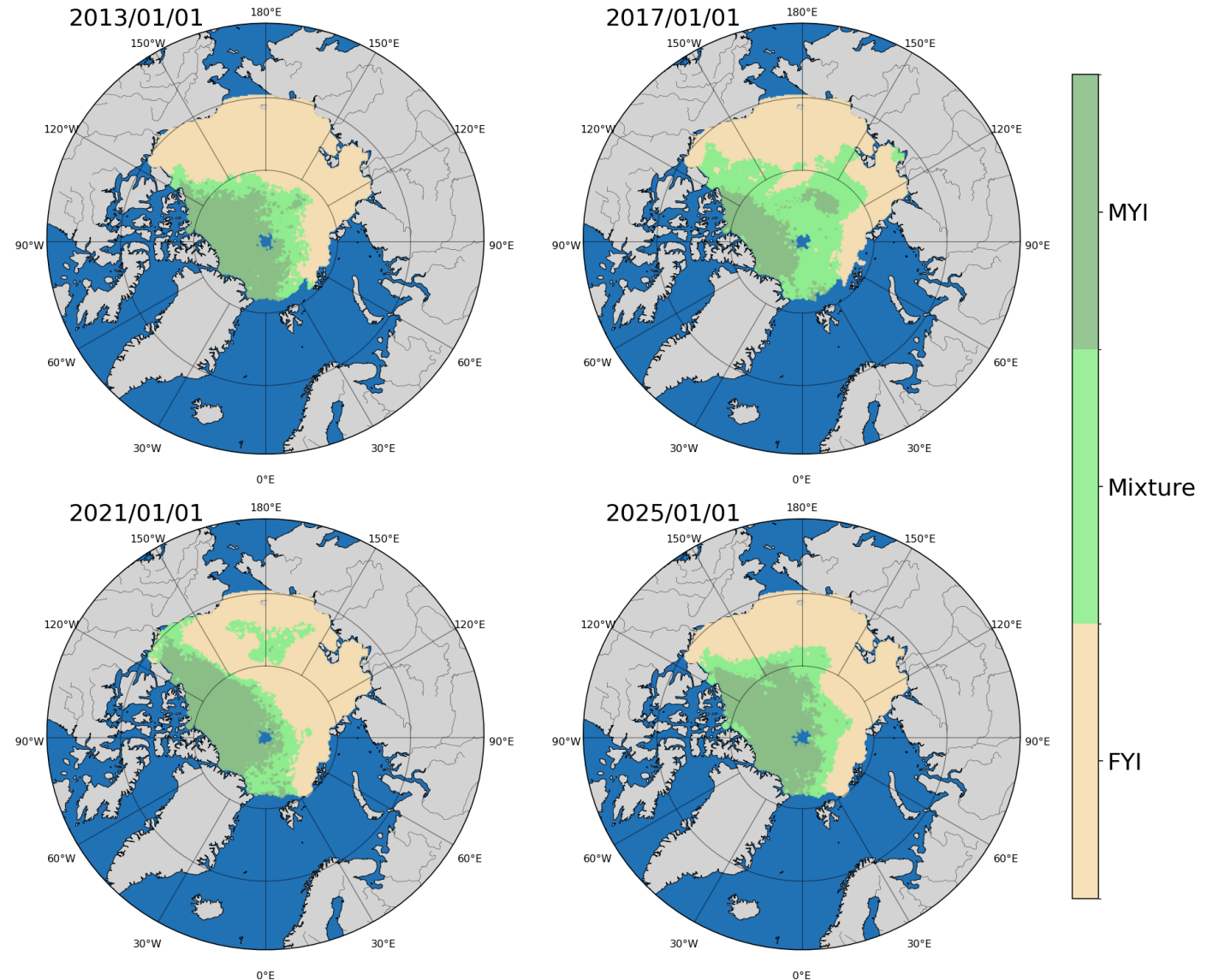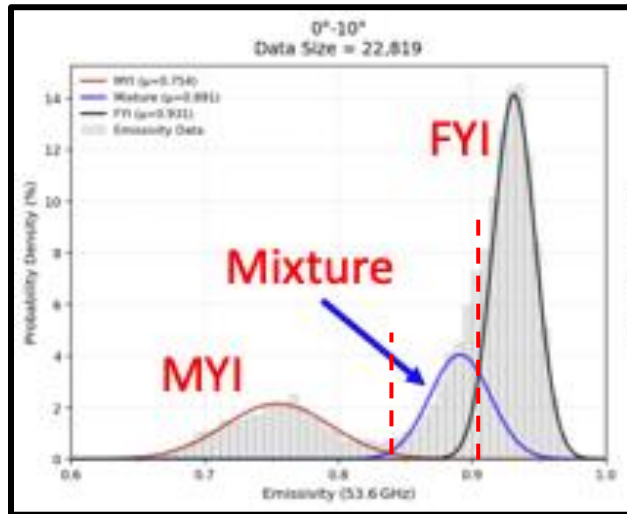

- **Well-separated MYI mode**
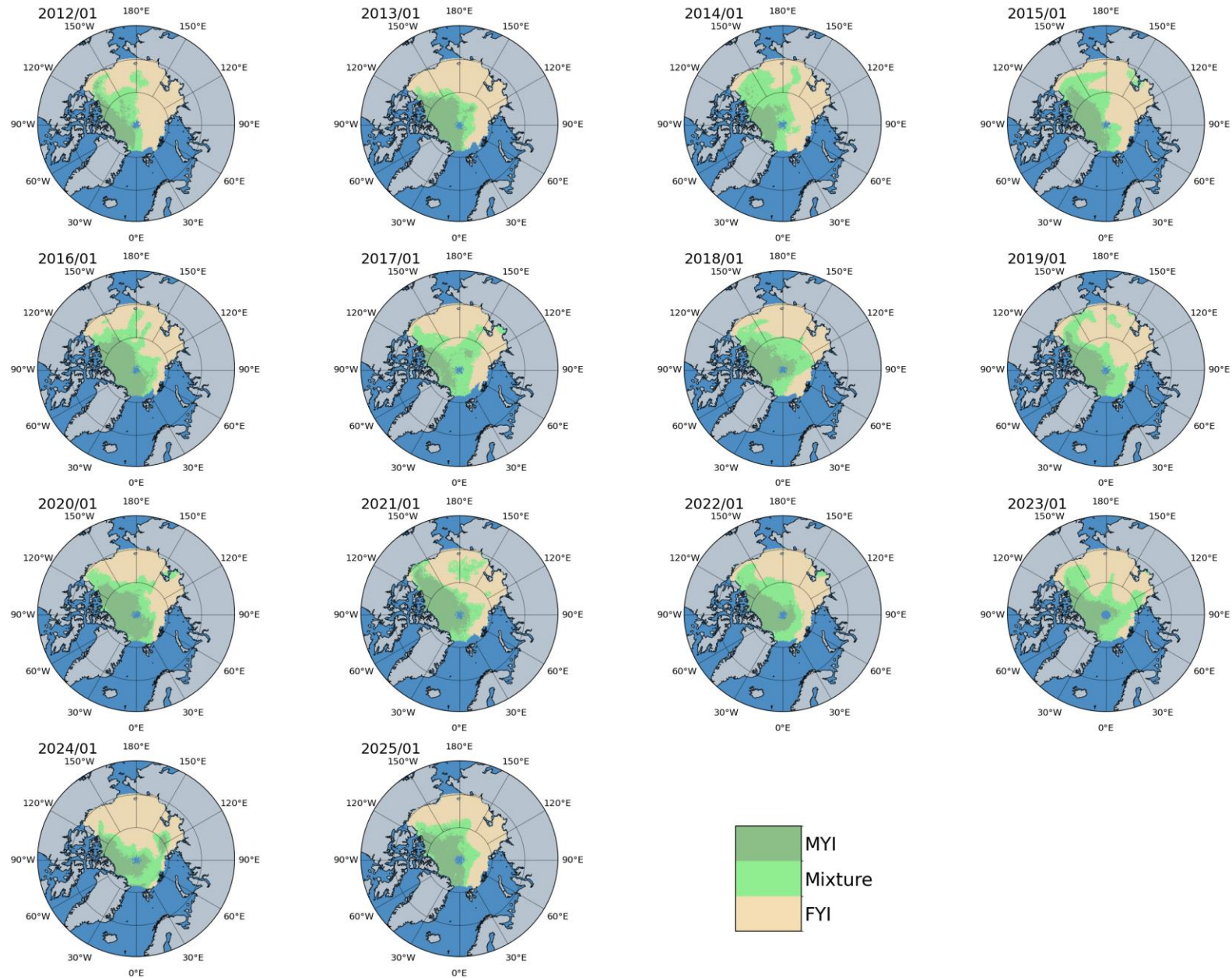- **FYI mode**
- **"transition" mode – Mixture**

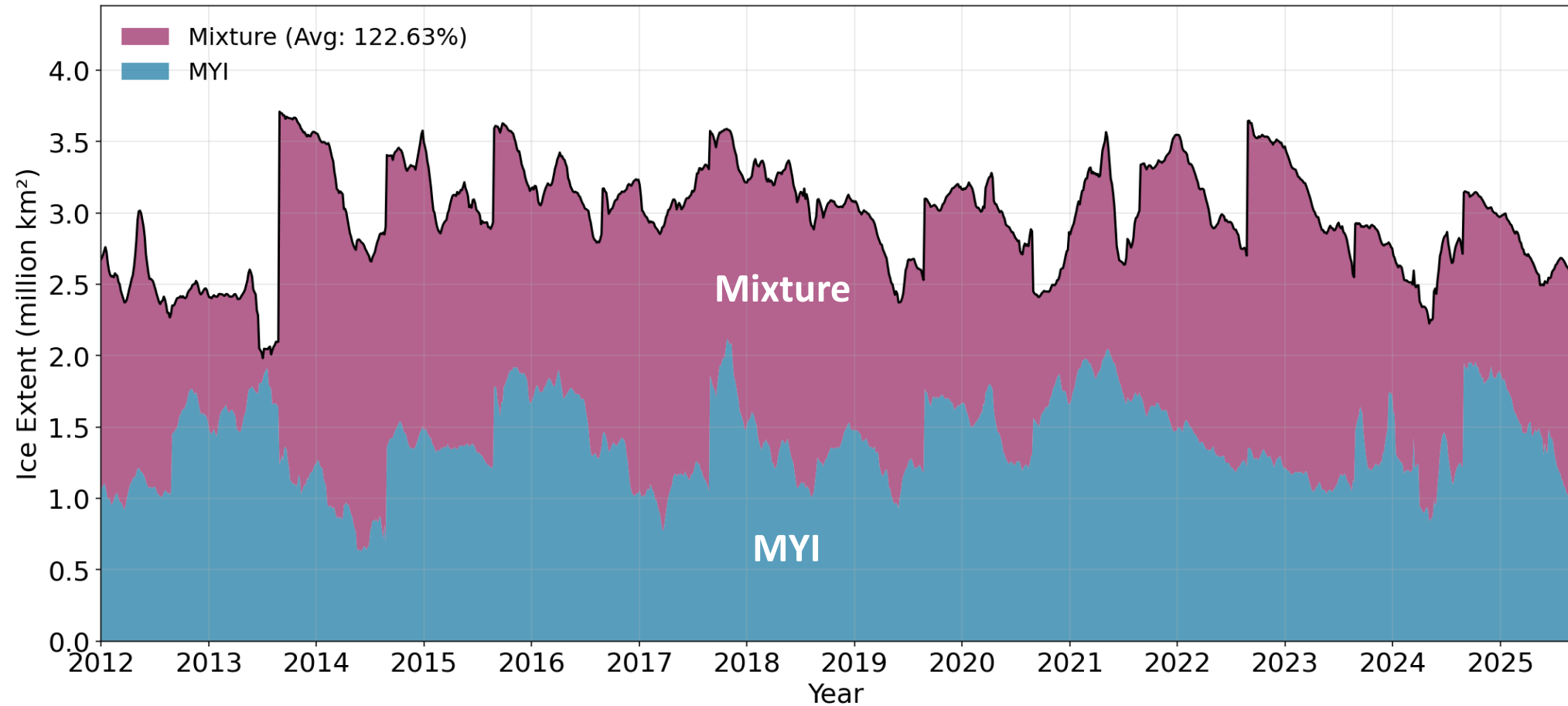The Mixture mode is clearly shifted toward the FYI mode.

(2020/12/18- 2021/1/1)

Moving Window: Use statistics obtained from previous 14 days for following day application [e.g., (2020. 12. 18 – 2020. 12. 31) → Jan 1].
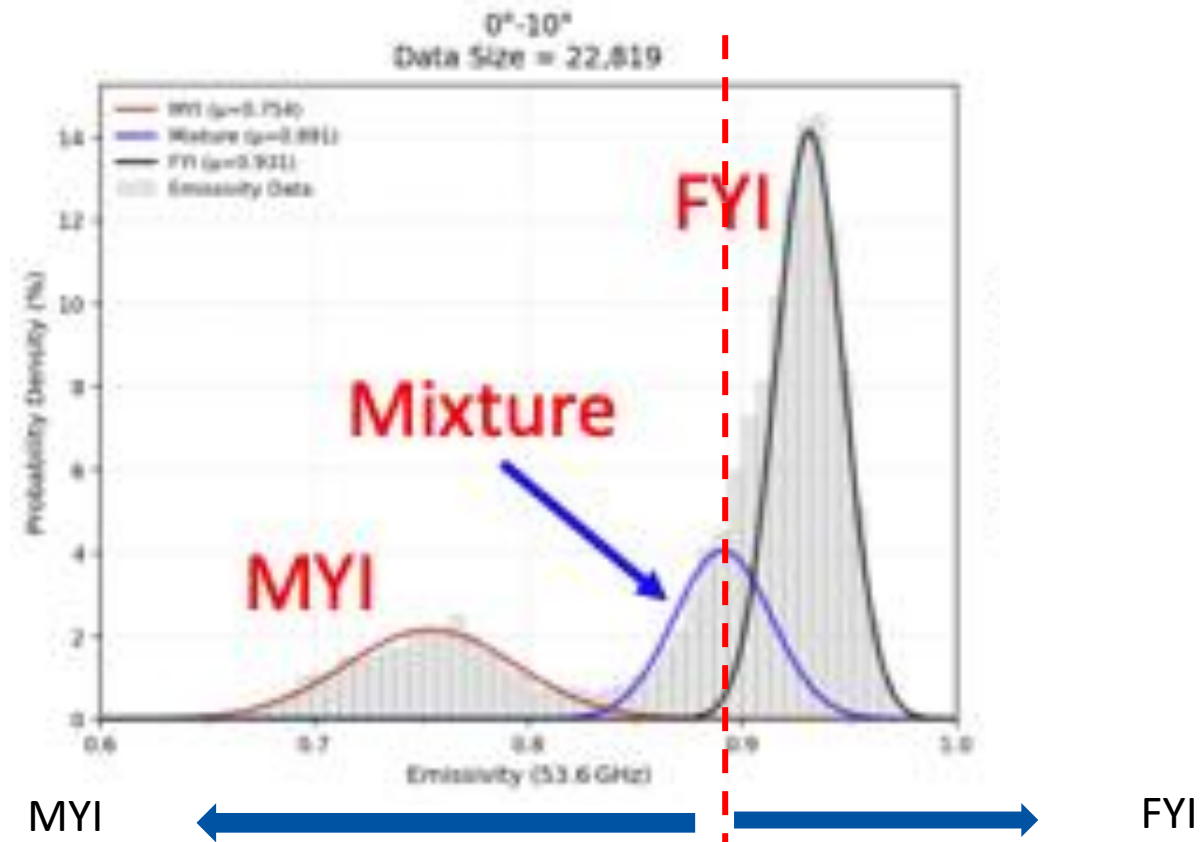
January mean distributions (2012 - 2025)

Time series of daily extent of winter time (DJF) MYI and Mixture type (2012-2025)
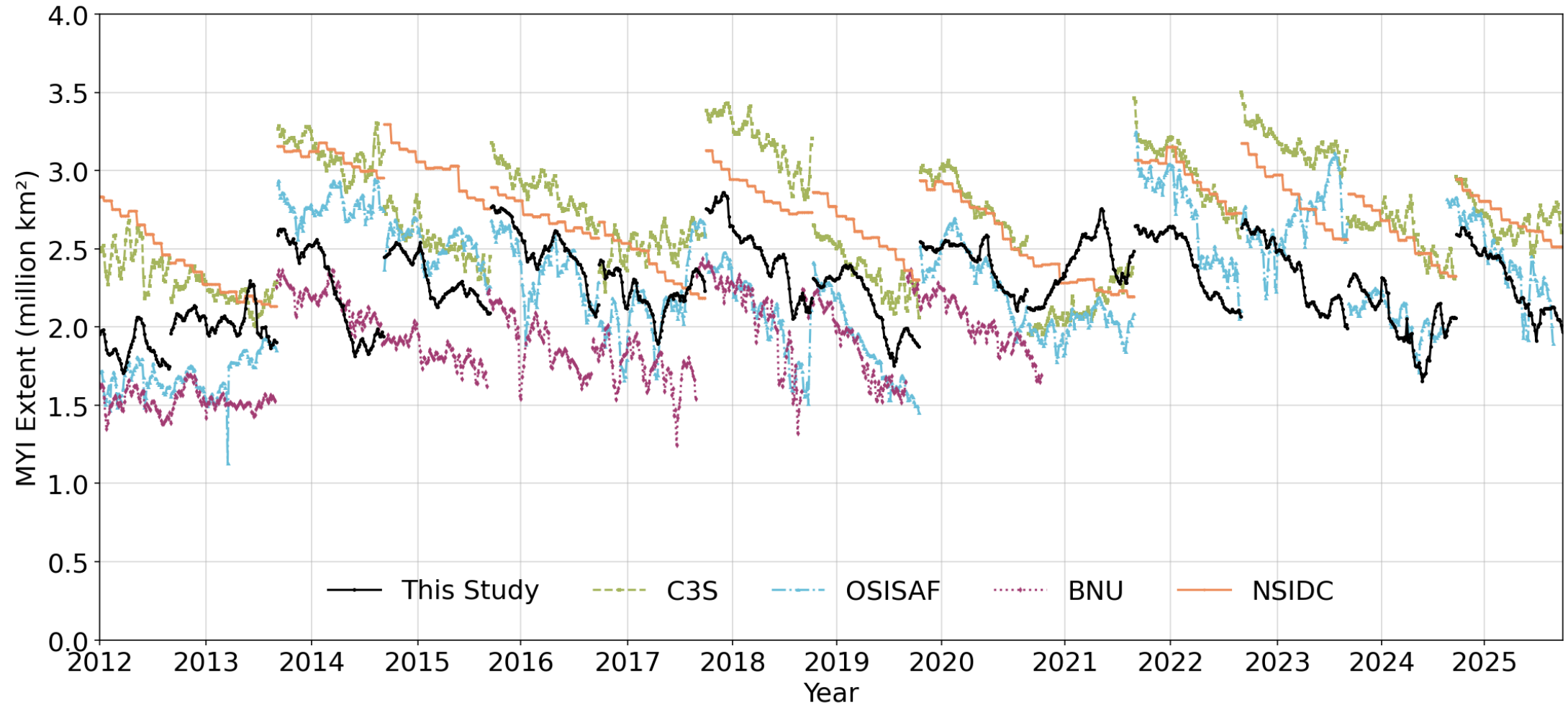

On average, Mixture is 1.2 times larger than MYI.

Comparison with conventional MYI vs. FYI ice type separation products (ECMWF C3S, Eumetsat OSISAF, BNU, NSIDC products)
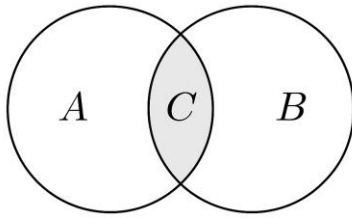
Separation of Mixture into MYI and FYI
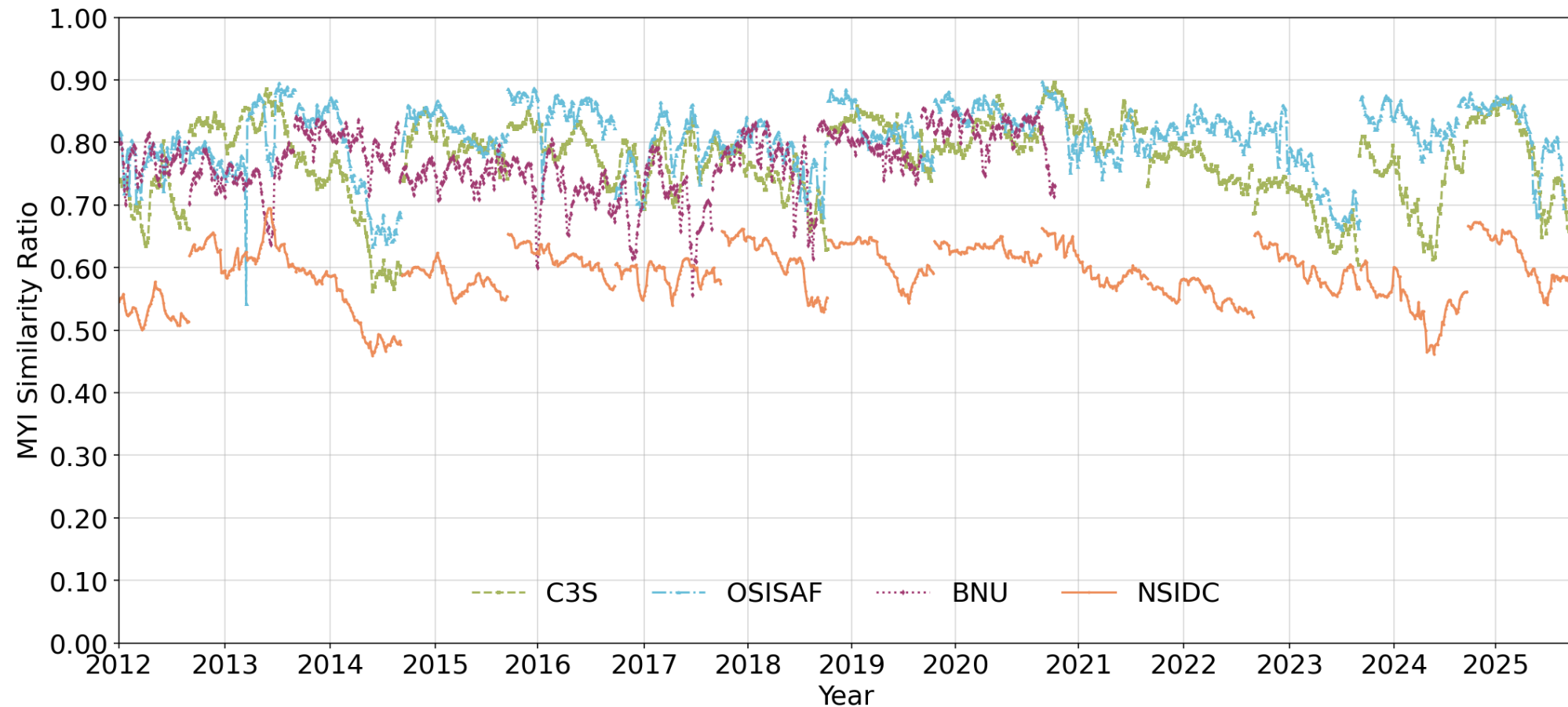
Time series of daily MYI area of five products

How similar is this product with others?

Similarity Ratio R

$R = C/(A+B-C)$, if R=1: perfect agreement, R=0: no overlap

Conclusions

- **In addition to MYI and FYI, a transition <u>Mixture</u> type was emerged from emissivity analysis.**

- **The Mixture type forms a ring around MYI and exceeds its area (on average <u>~1.2 times larger</u>).**

- **These transition zones represent areas of thinning and structural weakening, where the ice becomes more vulnerable to summer melt.**

- **As this thinner transitional Mixture ice fails to survive the melt season, the perennial ice reservoir may diminish further.**

- **Mapping the Mixture type thus provides an essential diagnostic of where and how the Arctic's long-lived ice cover is being eroded from within.**