Thin Arctic sea ice thickness and small-scale roughness retrieval using SMOS and SMAP observations

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Motivation

Why are Sea ice roughness(SIR) & Sea ice thickness(SIT) information important?

- Essential climate variables
- Impacts on climate change, Earth's surface energy budget, atmospheric circulation , water budget, global temperature and commercial human activity

Sea ice roughness (SIR)

- Affects on the surface reflection
- A fundamental physical parameter for estimating SIC and SIT

Sea ice thickness (SIT)

- High sensitivity to heat flux and radiative balance
- Especially, <u>thin SIT</u> is important for understanding sea ice-atmosphere-ocean interaction and for operational and commercial purposes

Motivation

Monitoring SIR & SIT using satellite remote sensing

Advantage |

- Global observation
- Plenty of long-term observation data of sea ice
- Sufficient spectral, spatial, and temporal coverage

Problem | SIR & Thin SIT are difficult parameters to be retrieved from satellite remote sensors

- The SIT estimation using satellite radar altimeters (Laxon et al., 2003), is disadvantageous owing to the validation issue and large uncertainty for SIT < 1.0 m.

Thickness classsification	Ice thickness d [m]
Young ice	$0.1 < d \leq 0.3$
Thin first-year ice	$0.3 < d \leq 0.7$
Medium first-year ice	$0.7 < d \leq 1.2$
Thick first-year ice	$1.2 < d \leq 2.0$
Multiyear *ice*	$d \geq 2.0$

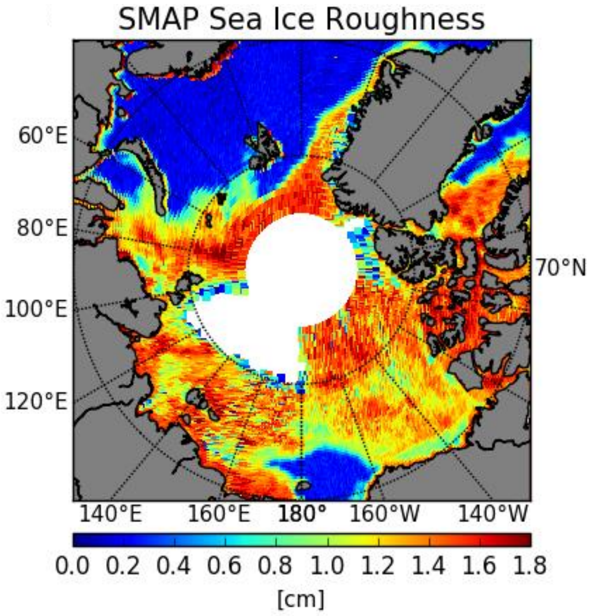
Motivation

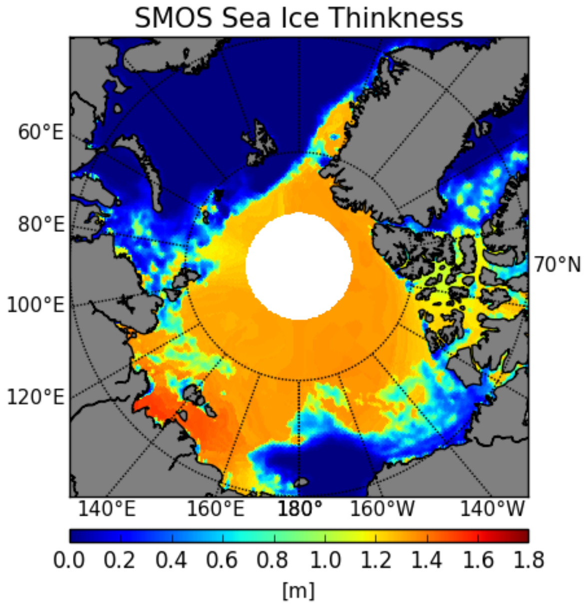
Key Idea |

✓ Availability of L-band radiometer satellites (SMAP &SMOS) data

- The L-band is sensitive to thin SIT variations and the large penetration depth (Mätzler, 2001).
- The SMOS with its Microwave Imaging Radiometer using Aperture Synthesis (MIRAS) sensor (L-band (frequency=1.4 GHz, wavelength=21 cm) radiometer) has a lower uncertainty in estimating thin SIT about 0.5 m under ideal cold conditions

✓ For thin SIT lower than 0.5m, there may be a correlation between SIT and SIR.





Data & Area

Period | December 2015~2018

Data | SMAP L3 polarized brightness temperatures ($T_{B,V}$, $T_{B,H}$ and Ts)

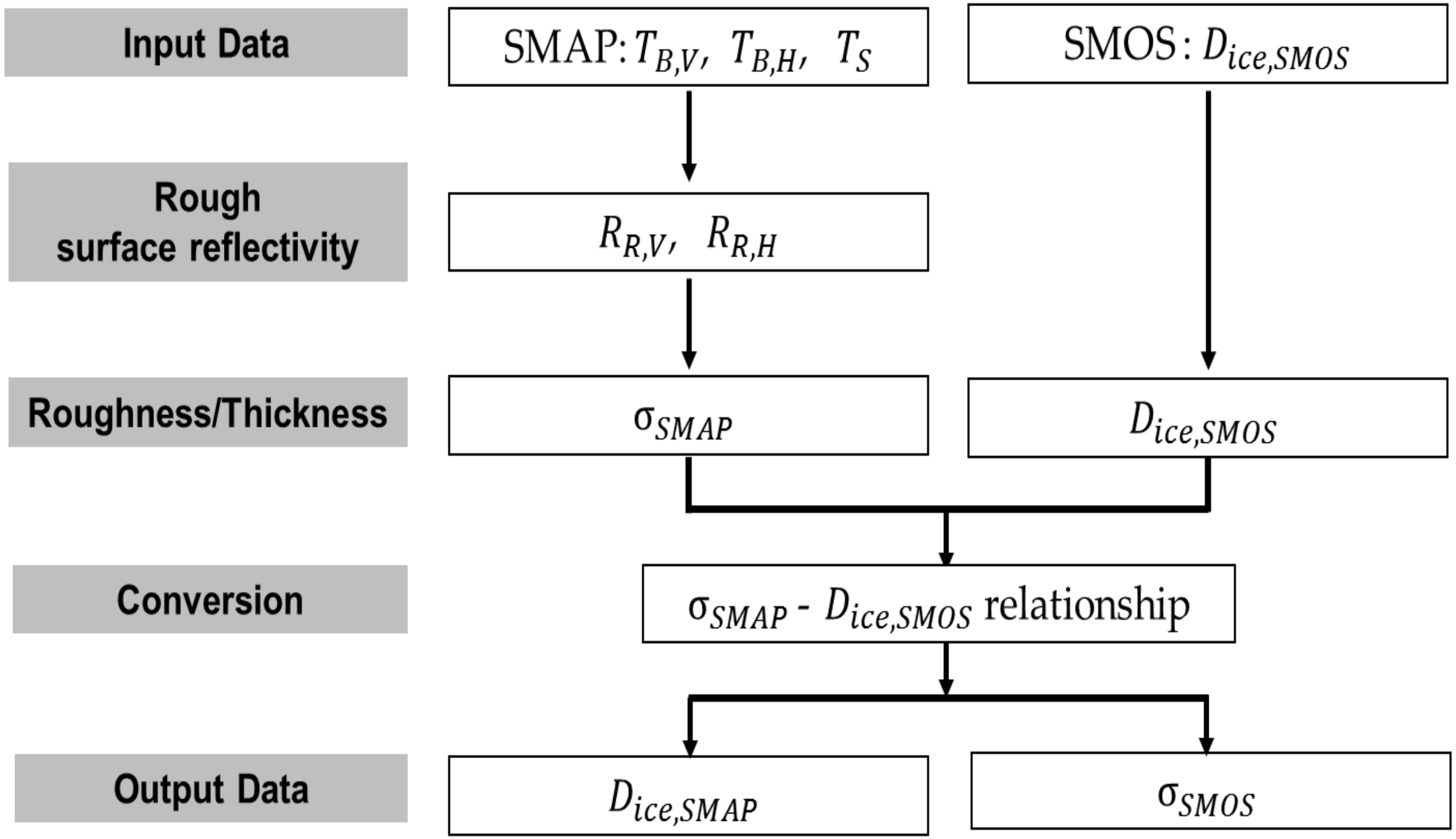
- Spatial coverage: global
- Spatial resolution: 9km x 9km
- Temporal resolution: 1day

SMOS L3C Sea Ice Thickness (SIT)

- Spatial coverage: latitude: 50 to 90° N , longitude: 0 to 360° E
- Spatial resolution: 12.5km x 12.5km
- Temporal resolution: 1day

Area | Arctic region within latitude 70° N to 90° N

Method & Procedure



Method :SMAP-retrieved small-scale SIR

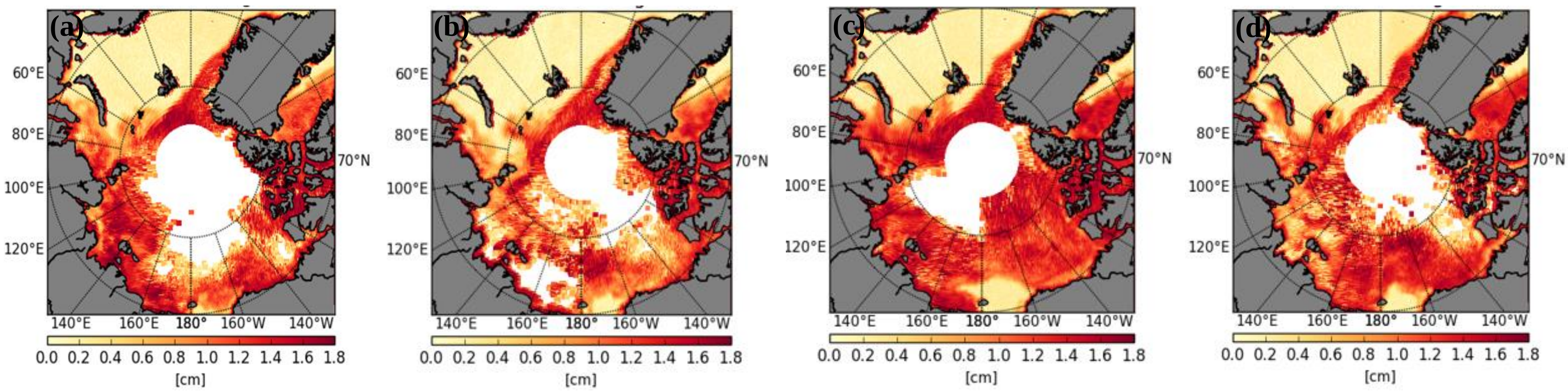
$$\sigma \approx \frac{\lambda}{4\pi \cos\theta} \cdot \sqrt{ln\left[\frac{\left(1-\frac{T_{B,H}}{T_S}\right)^{sec^2\theta}}{\left(1-\frac{T_{B,V}}{T_S}\right)}\right]}$$

$T_{B,P}$ = brightness temperatures (polarization P = V or H)
T_S = surface temperature
λ = SMAP wavelength; 21.43cm
θ = SMAP incidence angle;40°

(Hong et al. 2014)

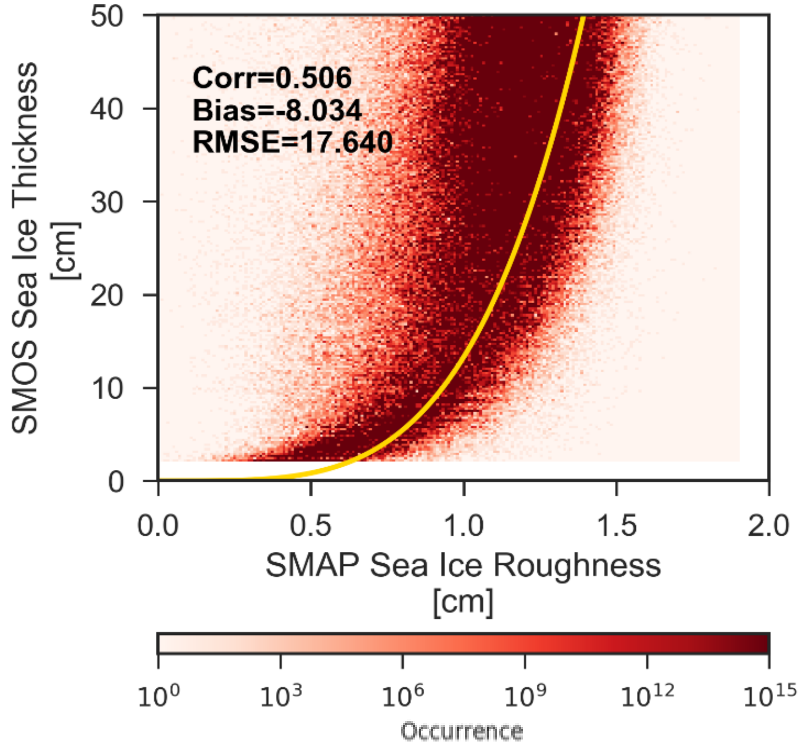
- e.g. SMAP-retrieved SIR on December 3 of (a) 2015, (b) 2016, (c) 2017, and (d) 2018

(Range: 0.01 to 1.81 cm)



Method :Conversion relationship between SIR & SIT

SMAP Surface Roughness VS. SMOS SIT (December 2017)



$$\mathbf{D_{ice,SMOS} = a \cdot \sigma_{SMAP}^{b}}$$

(a=13.27, b=4)

- **SMAP Sea Ice Thickness**

$$D_{ice,SMAP} = a \cdot \left[\frac{\lambda}{4\pi \cos\theta} \cdot \sqrt{ln \left[\frac{\left(1 - \frac{T_{B,H}}{T_S}\right)^{\sec^2\theta}}{\left(1 - \frac{T_{B,V}}{T_S}\right)} \right]} \right]^{b} + 8.034$$

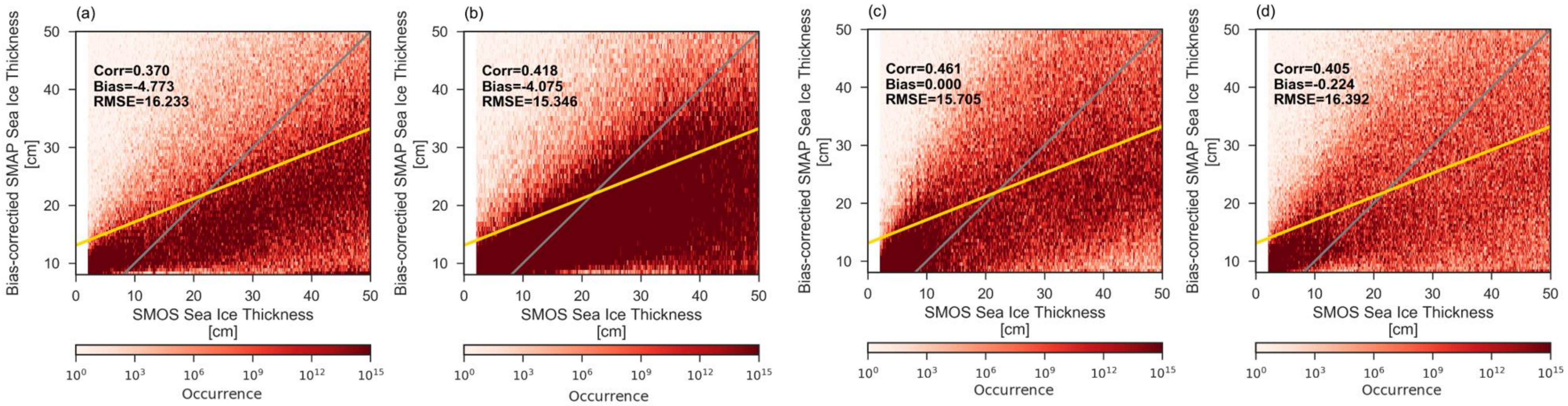
- **SMOS Sea Ice Surface Roughness**

$$\sigma_{SMOS} = \left(\frac{D_{ice,SMOS}}{a}\right)^{\frac{1}{b}} - 0.139$$

Results :SMAP-estimated SIT

SMOS SIT VS. SMAP SIT

(December (a) 2015, (b) 2016, (c) 2017, and (d) 2018)



Average of four month (2015-2018)

- Bias = -2.268 cm
- RMSE = 15.919 cm
- CC = 0.414

Kaleschke el al. (2009): using the aircraft equipped with the L-band Radiometer and coordinated with helicopter based electromagnetic induction (EM) ice thickness measurements vs. SMOS SIT

CC= 0.5, 0.82±0.4 m and 0.65±0.3 m

Paţilea et al. (2019) : SMOS–SMAP-derived SIT and the ship-observed SIT during the period October 5 to November 4, 2015 in the Beaufort and Chukchi seas

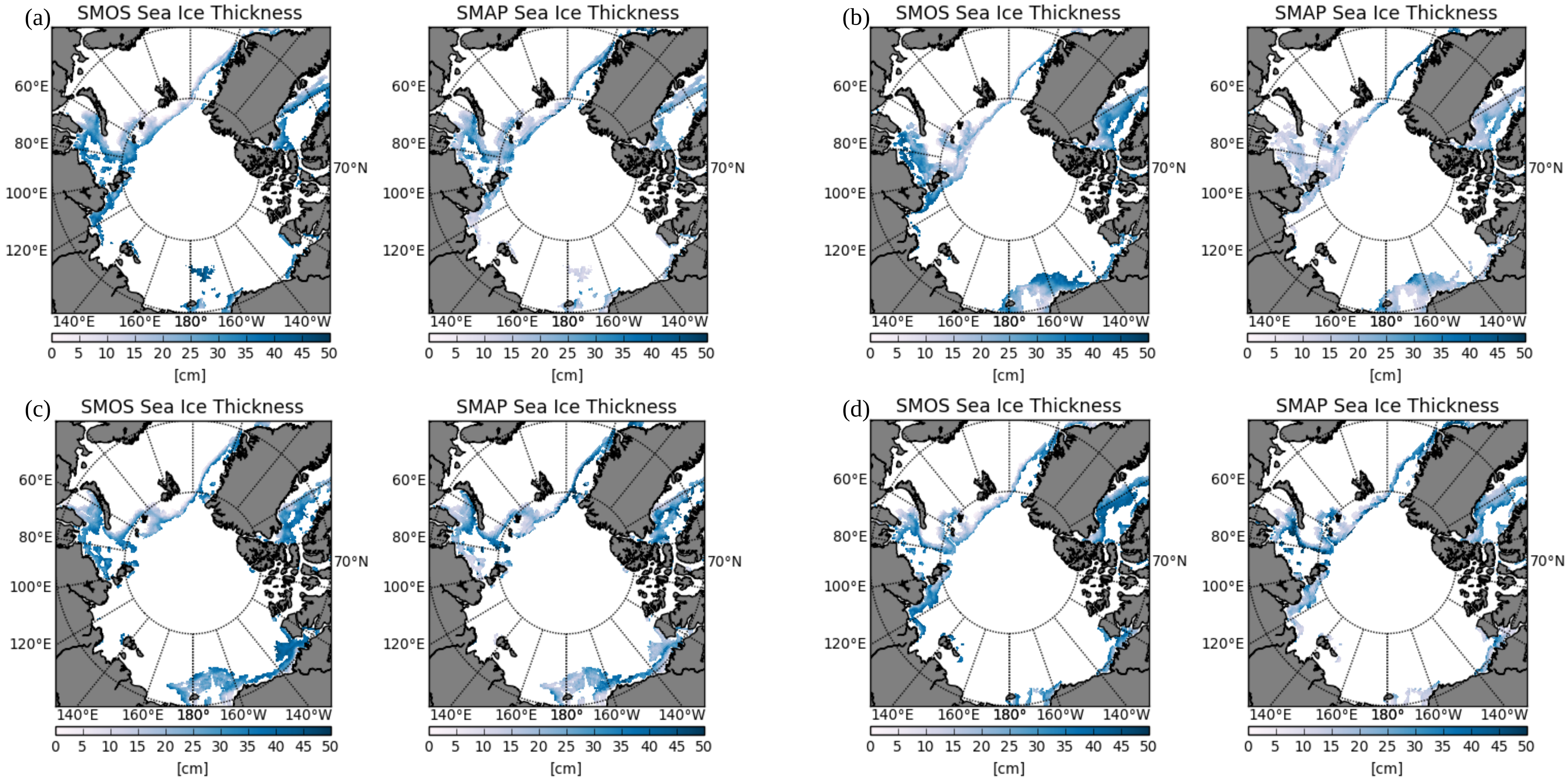
CC= 0.58

Williams et al. (2019) : comparison between the OSISAF and SMOS SIT during November to December 2018

Bias= -0.12m , RMSE=0.26 m

Results :SMOS SIT vs. SMAP-estimated SIT

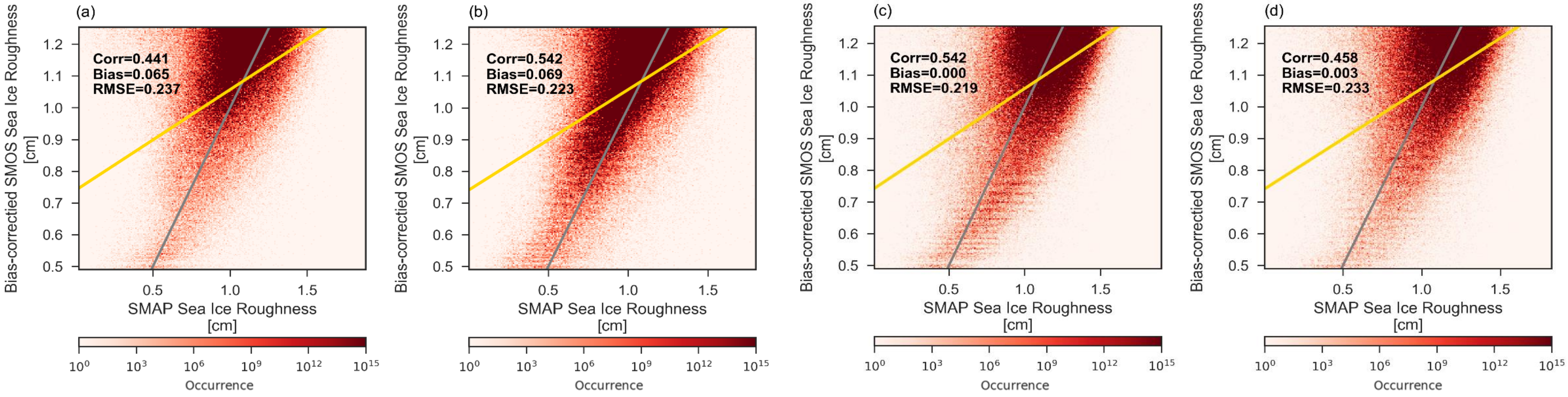
(December (a) 2015, (b) 2016, (c) 2017, and (d) 2018)



Results :SMOS-estimated SIR

SMAP SIR VS. SMOS SIR

(December (a) 2015, (b) 2016, (c) 2017, and (d) 2018)



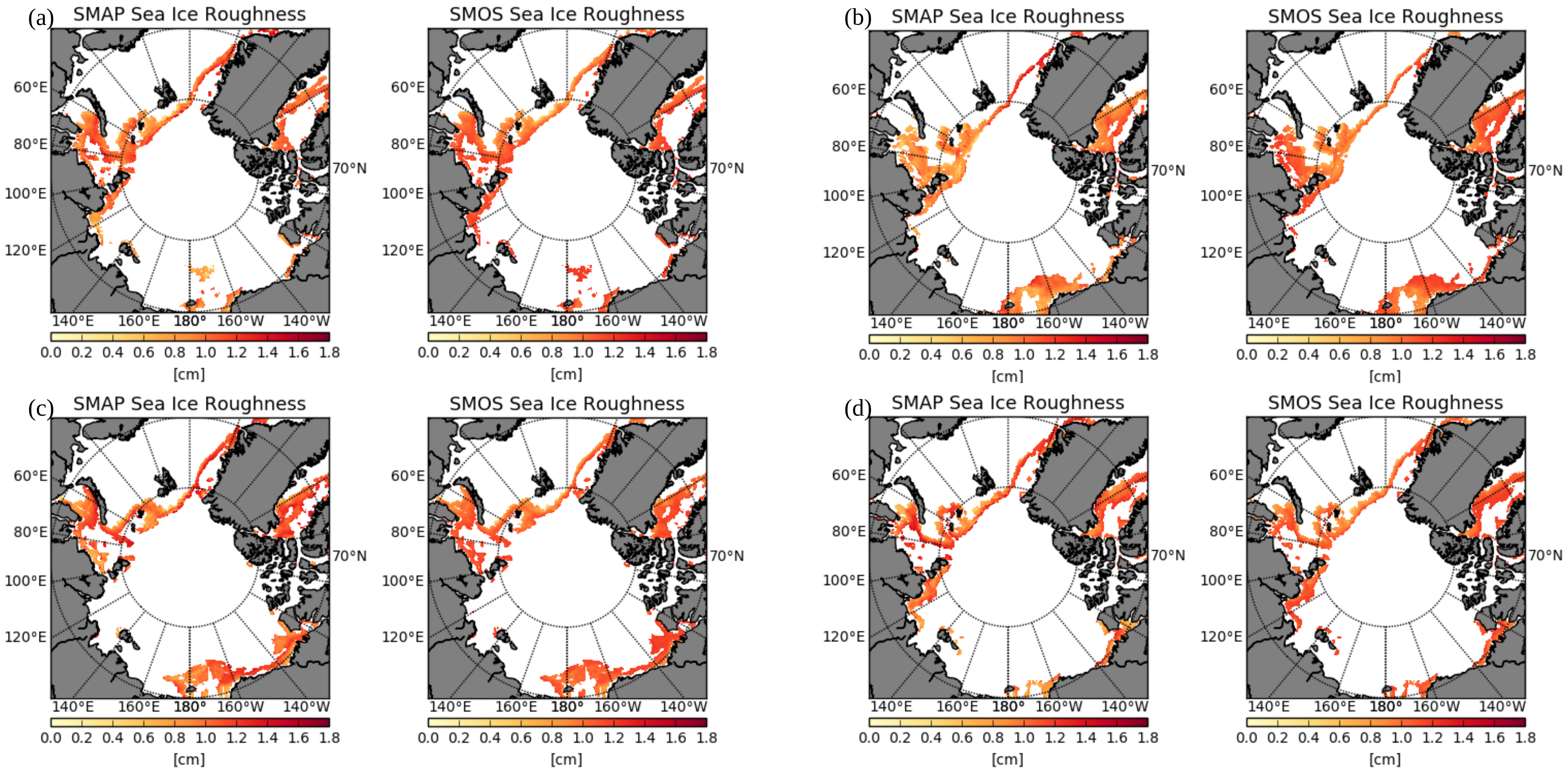
Average of four month (2015-2018)

- Bias = 0.03 cm
- RMSE = 0.228 cm
- CC = 0.496

Lack of observed data

Results :SMAP-derived SIR vs. SMOS-estimated SIR

(December (a) 2015, (b) 2016, (c) 2017, and (d) 2018)



Summary & Conclusions

- ✓ Assumption: a correlation between SIT and SIR derived from L-band radiometer, due to its high sensitivity to SIT variations and large penetration depth.

- ✓ We presented a novel method to estimate thin SIT and SIR using a conversion relationship between them, using the data of SMAP-retrieved SIR and SMOS-provided thin SIT.

- ✓ Advantage of this study:

  (1) provide the SMAP thin SIT and SMOS SIR, which are not available.

  (2) High accuracy (from the comparison results in the Arctic sea ice during winter)

  - SMAP-estimated SIT | bias = -2.268 cm, RMSE = 15.919 cm, and CC= 0.414
  - SMOS-estimated SIR | bias = 0.03 cm, RMSE = 0.228 cm, and CC = 0.496

  (Average of four month)

Thank you

• Special Session 8 : Research on analytical technique for satellite observation of Arctic sea ice - 1
Research on analytical technique for satellite observation of Arctic sea ice - 2

Date / Time	October 17(Thu), 13:30 ~ 17:00 / ThSS3, ThSS4
Room	SS (DCC 1F, #101+102)
Session Chairs	Hyun-cheol Kim (Korea Polar Research Institute, Korea)
Organization	Korea Polar Research Institute

Code	Time	Title	Author(s)
ThSS3-1	13:30-13:50	Digital surface model generation for Arctic sea-ice	Jae-In Kim, Chang-Uk Hyun, Hyangsun Han, and Hyun-cheol Kim (Korea Polar Research Institute, Korea)
ThSS3-2	13:50-14:10	Sentinel-1 SAR based sea ice classification for winter season	Jeong-Won Park[1], Anton A. Korosov[2], Mohamed Babiker[2], Morten W. Hansen[2], Joong-Sun Won[3], and Hyun-cheol Kim[1] ([1]Korea Polar Research Institute, Republic of Korea, [2]Nansen Environmental and Remote Sensing Center, Norway, [3]Yonsei University, Korea)
ThSS3-3	14:10-14:30	AI detection and tracking of sea ice using Sentinel-1 data	Hyungyun Jeon[1], Duk-jin Kim[1], Jungpyo Hong[1], and Seung-Hee Kim[2] ([1]Seoul National University, Korea, [2]Korea Polar Research Institute, Korea)
ThSS3-4	14:30-14:50	Flexural strength of Arctic sea ice using spaceborne polarimetric SAR data	Seung Hee Kim, Hyangsun Han, Jeong-Won Park, Chang-Uk Hyun, Sungjae Lee, Eun-Jin Yang, and Hyun-cheol Kim (Korea Polar Research Institute, Korea)
ThSS3-5	14:50-15:10	SAR destructive multiplicative noise effects analysis based on raw data evaluation and de-speckling filter application	Iman Heidarpour Shahrezaei and Hyun-cheol Kim (Korea Polar Research Institute, Korea)
		Break	
ThSS4-1	15:40-16:00	Tracing the sea ice motion in the Arctic Ocean using satellite and model data	Young Baek Son and Gwang Seob Park (Korea Institute of Ocean Science and Technology, Korea)
ThSS4-2	16:00-16:20	Estimation of daily Arctic sea ice thickness using passive microwave	Young Jun Kim[1], Hyun-cheol Kim[2], Daehyeon Han[1], Jungho Im[1], and Sanggyun Lee[3] ([1]Ulsan National Institute of Science and Technology, Korea, [2]Korea Polar Research Institute, Korea, [3]University College London, UK)
ThSS4-3	16:20-16:40	Thin sea ice thickness and small-scale roughness retrieval using SMAP and SMOS observations	Suna Jo[1], Hyun-cheol Kim[2], and Sungwook Hong[1] ([1]Sejong University, Korea, [2]Korea Polar Research Institute, Korea)
ThSS4-4	16:40-17:00	Evaluation of net radiation data over Arctic region	Minji Seo, Sungwon Choi, Daeseong Jung, Donghyun Jin, and Kyung-soo Han (Pukyong National University, Korea)