A Pre-processing of Advanced Technology Microwave Sounder for Sea Ice Observations for Data Assimilation and its impact on Korean Integrated Model

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I. Introduction

❖ **Background**
➢ Microwave sea ice observations from the lower atmospheric channels (53.6, 54.4 GHz) have not been utilized in the Korean Integrated Model (KIM) due to underlined difficulties in estimating the sea ice surface radiation.
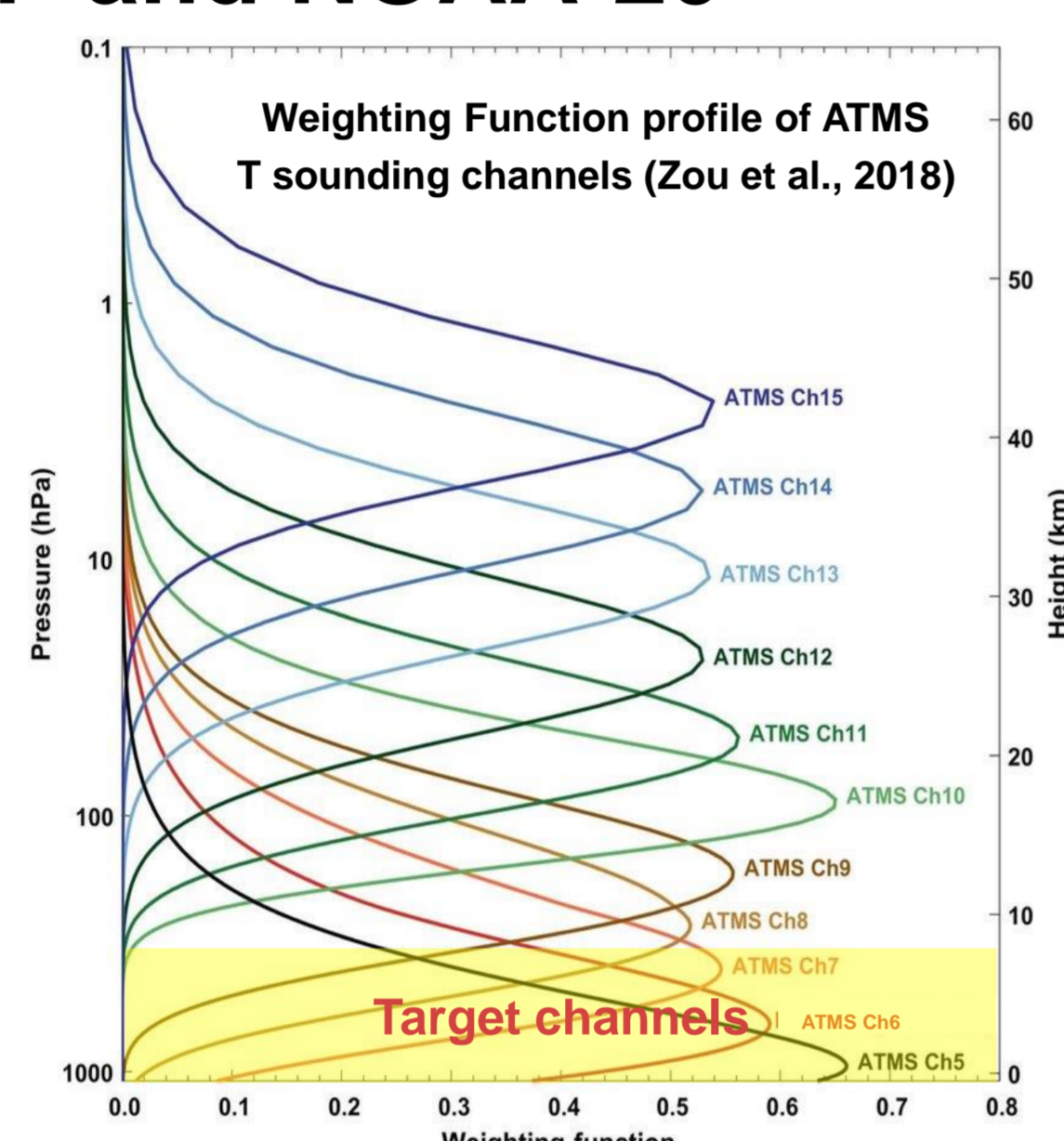
❖ **Objective**
➢ Develop a pre-processing algorithm for microwave sounder data over sea ice.

II. Data

❖ **ATMS**
➢ Onboard Suomi-NPP and NOAA-20
➢ 22 channels

CH	Frequency [GHz]
1	23.8
2	31.4
3	50.3
4	51.76
5	52.8
6	53.596±0.115
7	54.4
8-15	54.94~60
16	88.2
17	165.5
18-22	183.31

Weighting Function profile of ATMS T sounding channels (Zou et al., 2018)

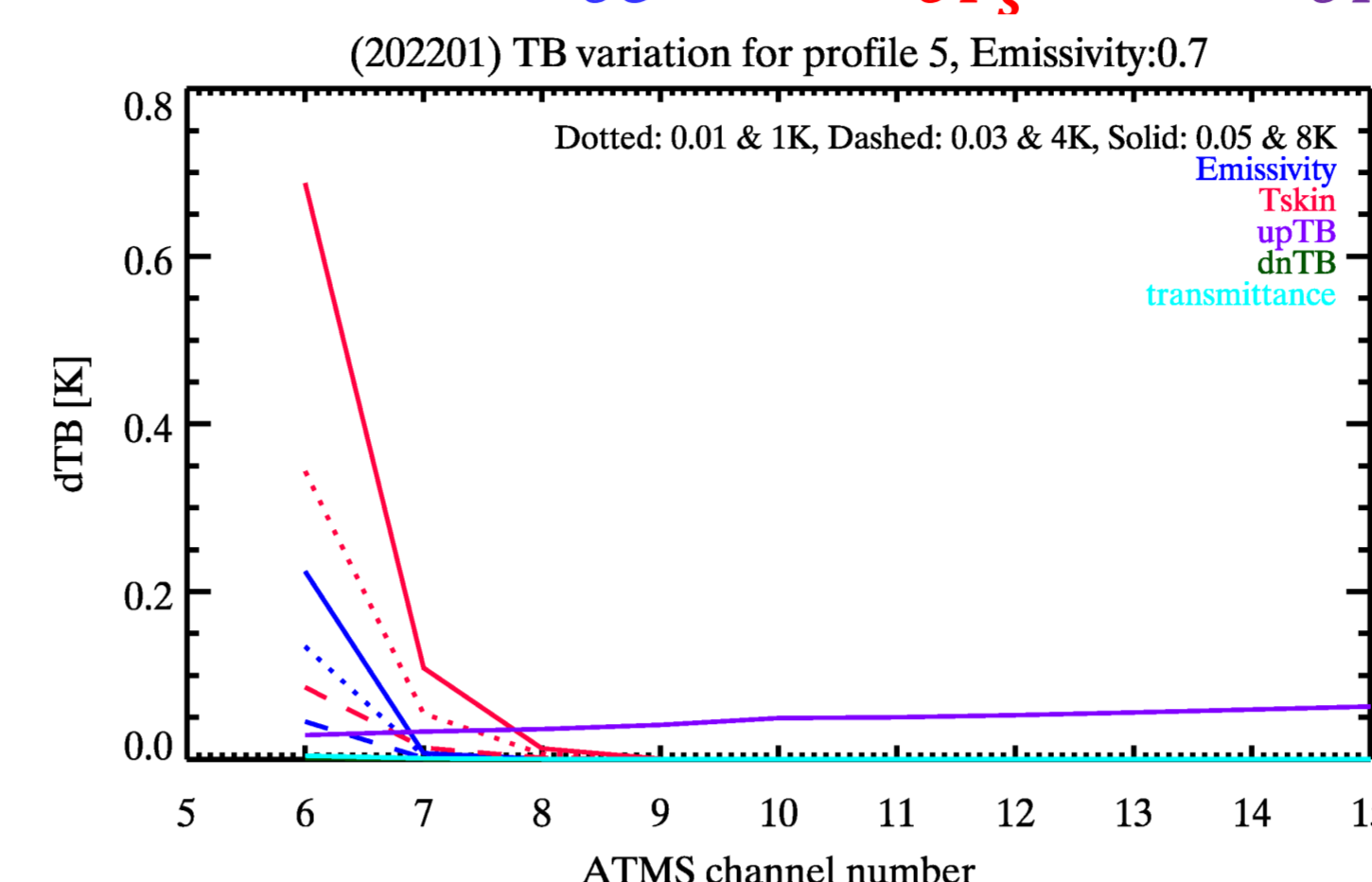❖ **Korean Integrated Model (Hong et al., 2018)**
➢ The KMA's operational NWP model
➢ Resolution: horizontal 12km, vertical 91 layers (~0.01 hPa)
➢ DA: Hybrid 4D-EnVar (Kwon et al., 2018)

III. TB variation to variables

❖ **Microwave RTE**

$$TB = \varepsilon T_s \widetilde{T} + TB^{\uparrow} + TB^{\downarrow}(1-\varepsilon)\widetilde{T} = \varepsilon(T_s - TB^{\downarrow})\widetilde{T} + TB^{\uparrow} + TB^{\downarrow}\widetilde{T} \quad (1)$$

Then, $\Delta TB = \frac{\partial TB}{\partial \varepsilon}\Delta\varepsilon + \frac{\partial TB}{\partial T_s}\Delta T_s + \frac{\partial TB}{\partial TB^{\uparrow}}\Delta TB^{\uparrow} + \frac{\partial TB}{\partial TB^{\downarrow}}\Delta TB^{\downarrow} + \frac{\partial TB}{\partial \widetilde{T}}\Delta\widetilde{T}$ (2)

(202201) TB variation for profile 5, Emissivity:0.7

TB: Upwelling radiance at TOA
$TB^{\uparrow}$: Atmospheric upwelling Radiance
$TB^{\downarrow}$: Atmospheric down-welling Radiance
$\widetilde{T}$: Atmospheric transmittance

➢ To assimilate microwave sounding channels, both underlined emissivity (ε) and skin temperature (T_s) errors should meet the requirements.

IV. A Pre-processing algorithm

❖ **Dynamic sea ice emissivity calculations** (Karbou et al., 2005)

$$\varepsilon_v = \frac{TB_v^{obs} - TB_v^{\uparrow} - TB_v^{\downarrow}\widetilde{T_v}}{(T_{skin} - TB_v^{\downarrow})\widetilde{T_v}} \quad (3)$$

➢ TB_v^{obs}: ATMS SDR data
➢ $TB_v^{\uparrow}$, $TB_v^{\downarrow}$, $\widetilde{T_v}$: calculated from the RTTOV
  ▪ RTTOV inputs: KIM's 6-hour forecasts
➢ T_{skin}: KIM's skin temperature
➢ T_{emit}: Emitting−layer temperature

❖ **Bias correction (BC)**
✓ From equation (1)
$$TB_{obs}(O) = \varepsilon(T_{emit} - TB^{\downarrow})\widetilde{T} + TB^{\uparrow} + TB^{\downarrow}\widetilde{T} \quad (4)$$
$$TB_{bgr}(B) = \varepsilon_a(T_{skin} - TB^{\downarrow})\widetilde{T} + TB^{\uparrow} + TB^{\downarrow}\widetilde{T} \quad (5)$$

✓ Δ TB to the contributing variables : $\varepsilon, T_s \gg TB_v^{\uparrow}$, $TB_v^{\downarrow}$, $\widetilde{T_v}$

$$O - B = \varepsilon(T_{emit} - TB^{\downarrow})\widetilde{T} - \varepsilon_a(T_{skin} - TB^{\downarrow})\widetilde{T} \quad (6)$$

✓ Let, $\Delta\varepsilon = \varepsilon - \varepsilon_a, and \Delta T_{skin} = T_{emit} - T_{skin}$

$$O - B = \widetilde{T}C_1 + \varepsilon_a\widetilde{T}C_2 + (T_{skin} - TB^{\downarrow})\widetilde{T}C_3 + C_4 \quad (7)$$

➢ The O-B bias can be corrected using multi-linear regression **coefficients(C)** with **the predictors**.
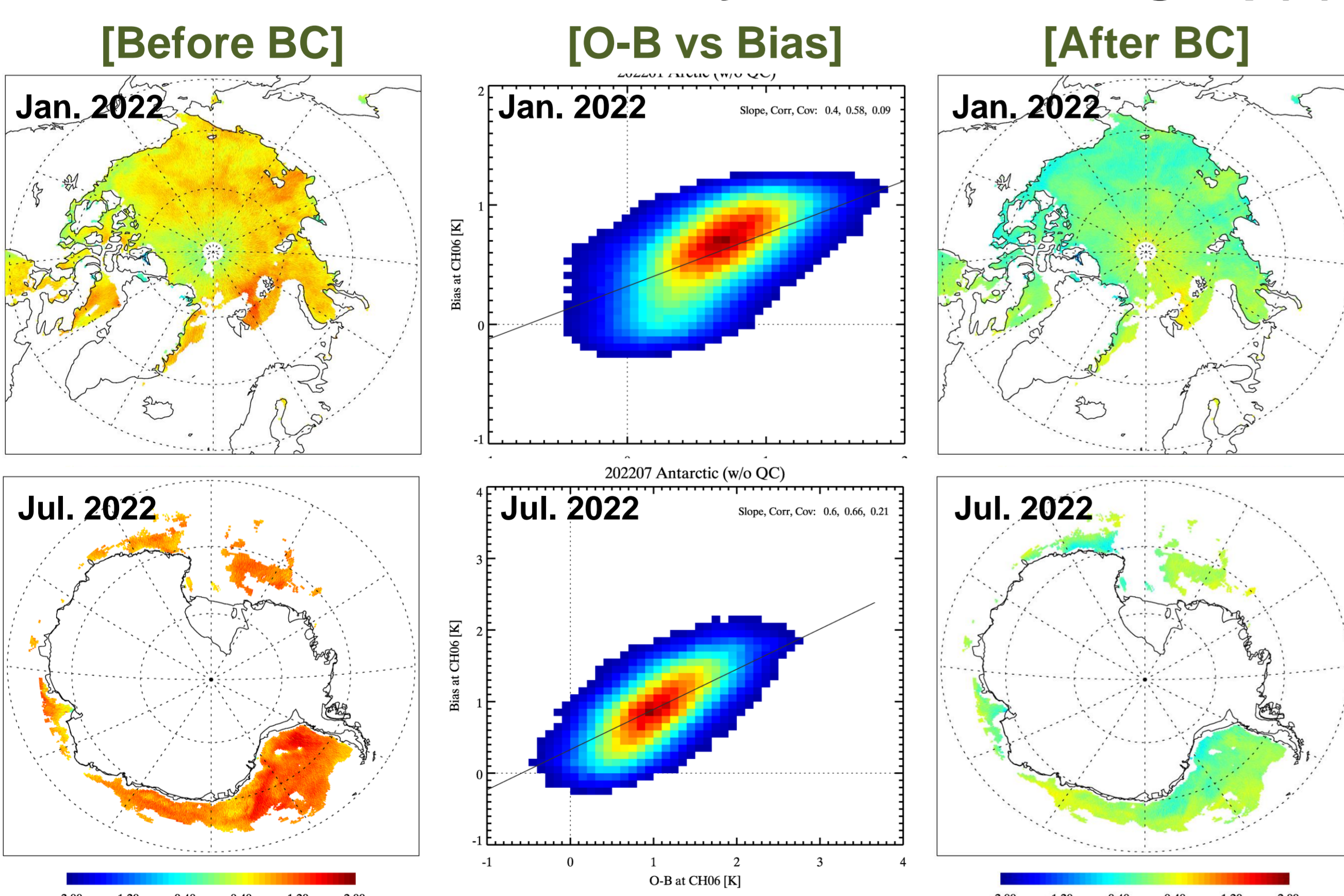
V. Results

❖ **TB simulation using the dynamic emissivity**
➢ Positive O-B bias in the winter sea ice.

❖ **Bias correction (BC)**
➢ BC coefficients are calculated using the 15 days data.

CH06	C1	C2	C3	C4
Jan. 2022	-0.45	13.	19.	-1.30
Jul. 2022	-0.62	17.	29.	-1.90

➢ Correlation coefficient between O-B and the predicted bias are about 0.6.
➢ The biases are effectively corrected using eq (7).

[Before BC]   [O-B vs Bias]   [After BC]

Jan. 2022

Jul. 2022

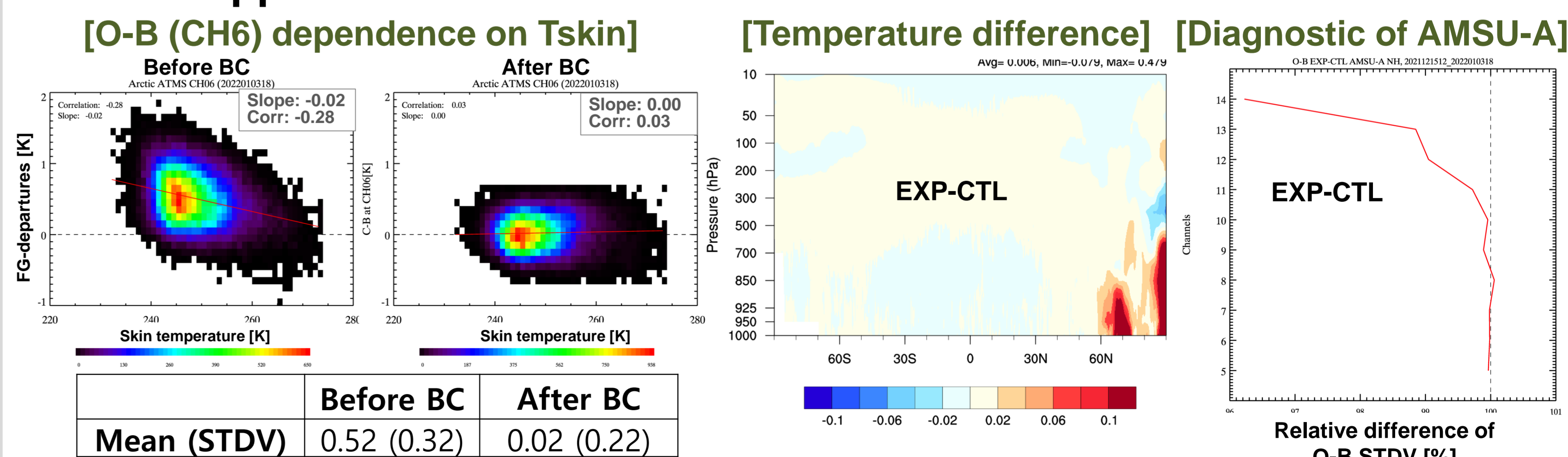| FG-departures [K] Mean (STDV)	Before BC	After BC
Jan. 2022	0.57 (0.26)	0.08 (0.22)
Jul. 2022	1.05 (0.22)	0.21 (0.21)

❖ **Assimilation experiment**
➢ Period: 2021.12.15-2022.01.03
➢ ATMS channel 6 and 7 are assimilated in the KIM system using the dynamic emissivity and the BC (eq (7)).

❖ **Results**
➢ The number of assimilated ATMS observations increased by **5%.**
➢ After the BC, the O-B dependence on the skin temperature disappeared.

[O-B (CH6) dependence on Tskin]   [Temperature difference]   [Diagnostic of AMSU-A]

	Before BC	After BC
Mean (STDV)	0.52 (0.32)	0.02 (0.22)

VI. Summary

✓ In winter sea ice, the O-Bs are biased due to the discrepancy between skin temperature and emitting layer temperature.
✓ A new BC scheme for microwave winter sea ice observations is proposed and it reduced the surface radiance bias.
✓ As a result of the assimilation of ATMS sea ice observations using the pre-processing algorithm, the model temperature from the surface to 500 hPa increased and the STDV of O-B of AMSU-A are decreased by up to 4%.