Study on Extending the Use of Microwave Satellite Data over Land

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1 Background

The ATMS data have so far been assimilated over ocean in Korea Integrated Model (KIM), as shown in Table 1. The discontinuities in the spatial distribution of observation can degrade the quality of the initial condition in forecast model. In order to extend the ATMS coverage over land, we firstly assimilated the high-peaking channels that are relatively insensitive to surface conditions. And then to assimilate more surface-sensitive microwave observation, atmospheric contributions must be separated by removing surface impact. Compared to the ocean, the land skin temperature has higher uncertainties, and surface emissivity is larger at around 0.8-0.95 with higher heterogeneities due to the complex surface condition, making it harder to model the surface radiation. Among the key surface variables, land surface emissivity, including snow-covered regions, is directly retrieved from observation to improve the accuracy of simulated brightness temperature for surface sensitive channel. This emissivity includes errors from inaccuracies in surface information.

Table 1. The usage status of ATMS (2024. 9)

ATMS	Freq.[GHz]	53.6	54	55	56	57.3						183.31				
	Channel	6	7	8	9	10	11	12	13	14	15	18	19	20	21	22
	Sensitive Level[hPa]	750	400	250	150	85	50	25	10	5	2.5	700	600	500	400	350
ECMWF	Sea	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Seaice		+	+	+	+	+	+	+	+	+			+	+	+
	Land	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
MetOffice	Sea	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Seaice			+	+	+	+	+	+	+	+					
	Land		+	+	+	+	+	+	+	+	+		+	+	+	+
KIM	Sea	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
	Seaice			+	+	+	+	+	+	+	+					
	Land	Surface sensitive		Surface-insensitive channels								Surface sensitive				

2 Methods

ATMS land surface emissivity are estimated using an algorithm described in detail in Karbou et al(2006). This is under the assumption of specular reflection from surface and non-scattering plane parallel atmosphere. The window channels 3(50.3 GHz) and 16(88.2 GHz) provides the observed brightness temperature for the emissivity of temperature and water vapor channel respectively. The estimated emissivity is then used for assimilation of the other ATMS surface sensitive channels over land.

Karbou, F., E. G'erard, and F. Rabier, 2006: Microwave land emissivity and skin temperature for AMSUA and -B assimilation over land. Q. J. R. Meteorol. Soc., 132, 2333–2355.

Surface Emissivity

The emissivity can be directly calculated from satellite observation **in clear sky condition**, using the surface temperature(T_{skin}) and the radiative transfer model (RTTOV) along with the forecast model variables to estimate the atmospheric contribution(T_{up}, T_{down})(Karbou et al 2006).

$$T_b = T_{up} + \tau(1-\varepsilon)\,T_{down} + \tau\varepsilon\,T_{skin}$$

$$\varepsilon = \frac{T_b - (T_{up} + \tau T_{down})}{\tau(T_{skin} - T_{down})}$$

T_b: Tb measured by satellite, T_{up}, T_{down}: Upwelling and downwelling Tb, T_{skin}: skin temperature, ε: surface emissivity, τ: atmospheric transmissivity

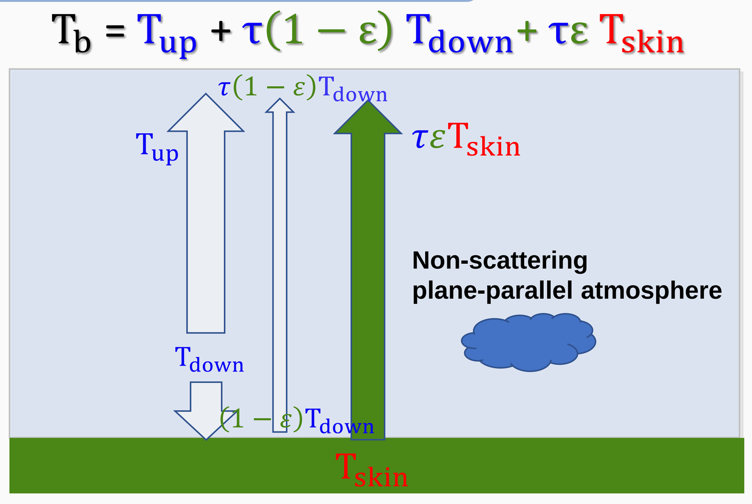


Figure 1. Diagram of brightness temperature measured by satellite in clear sky condition

Preprocessing

Remove the value that is contaminated by scattering ($Tb_{23GHz} \gg Tb_{89GHz}$, surface or precipitation) or shows large differences from climate emissivity (TELSEM2*).

* Tool to Estimate Land Surface Emissivity at Microwave2 [Aires et al., 2011]

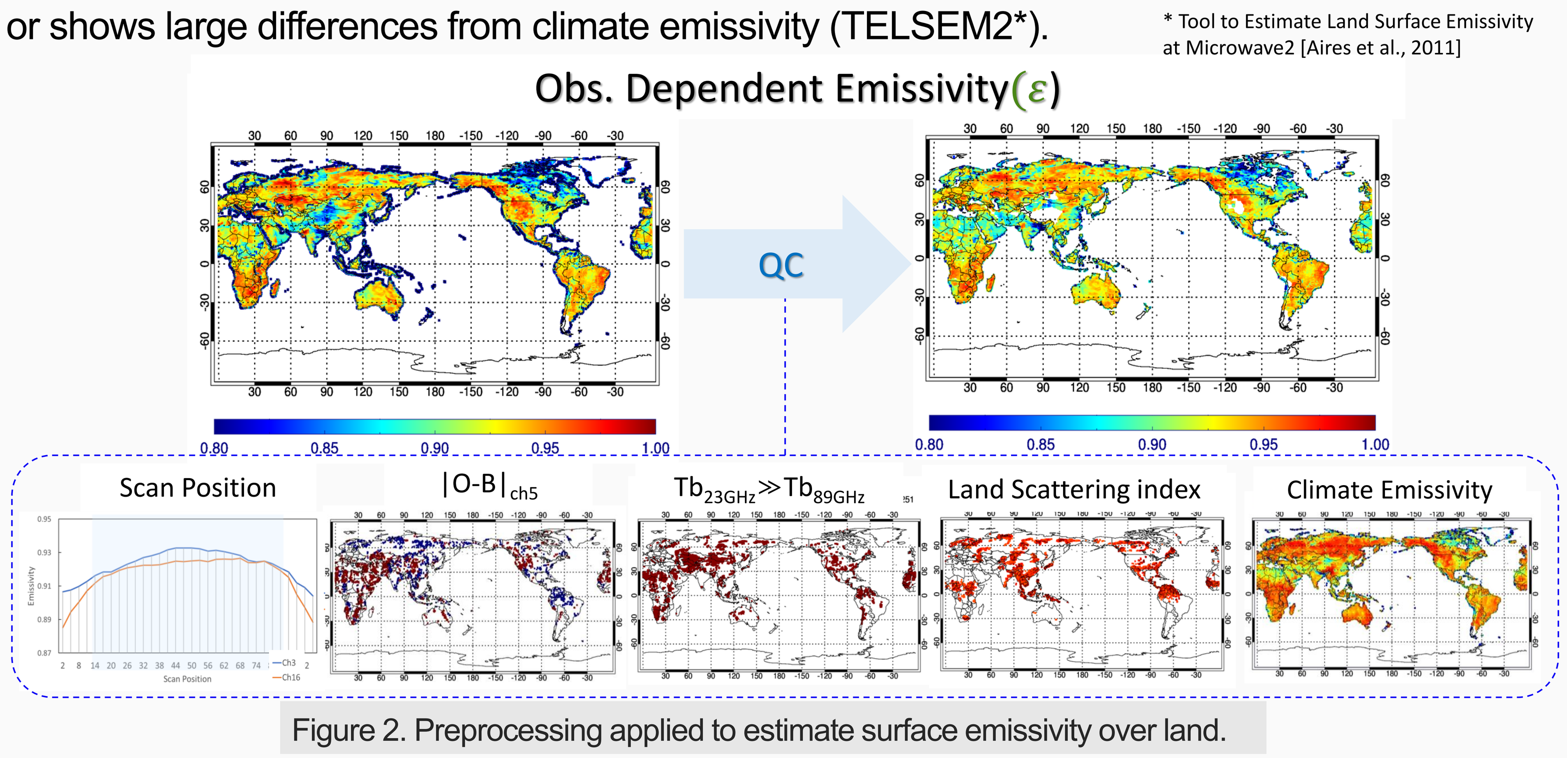


Figure 2. Preprocessing applied to estimate surface emissivity over land.

The observation at **scan edge** are removed as the increased atmospheric path leads to higher the retrieved emissivity error. The data contaminated by precipitation particles is removed using Land Scattering Index from cloud or precipitation–sensitive channels. (*Quin and Zou, 2016)

*Qin, Z. K., and X. L. Zou, 2016: Development and initial assessment of a new land index for microwave humidity sounder cloud detection. J. Meteor. Res., 30, 12-37.

Treatment of Snow Cover Area

The use of MW radiances in the Northern Hemisphere during winter significant decreased in snow-covered area. In these regions, the background estimation and observation difference are large, so a lot of data removed during the preprocessing process.

Assuming a **Lambertian surface** over snow-covered area, the simulation was closer to the observation (Figure 3). And the 166GHz channel used instead of 89 GHz to calculate the emissivity of the water vapor channel.

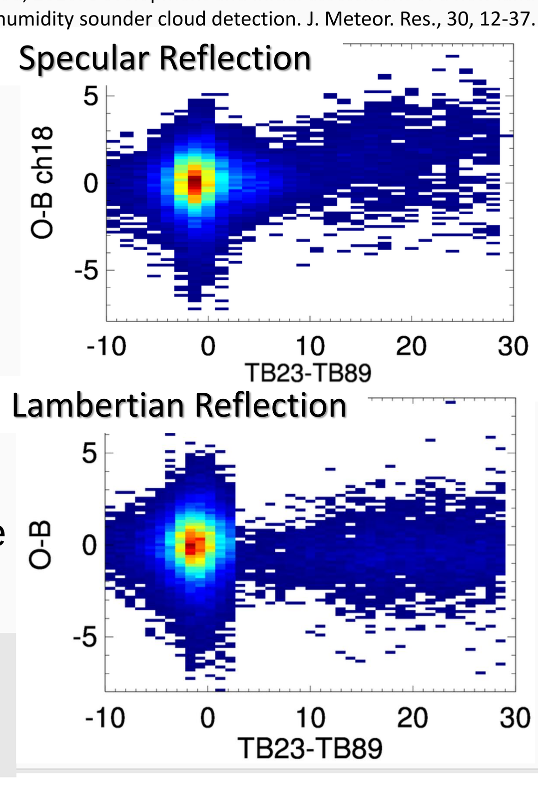
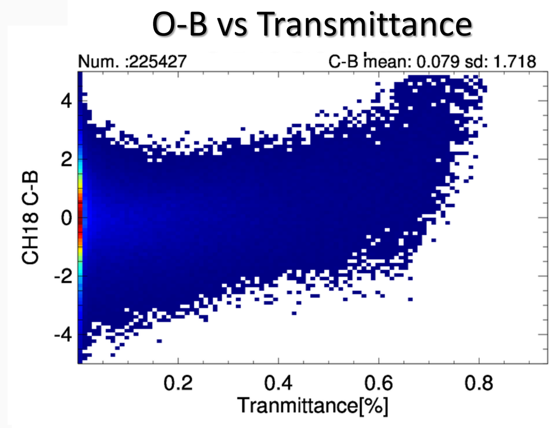


Figure 3. The scatter plots for observation increments and scattering index of water vapor channer (upper) with specular reflection and (bottom) Lambertian reflection.

Snow-covered areas have a dry atmosphere, resulting in high transparency of WV channels, making them highly influenced by surface radiation. And the WV Jacobian has a positive value in the lower troposphere, indicating significant influence from water vapor emission. This may lead to confusion in estimating water vapor information. Observations with significant surface influence were removed



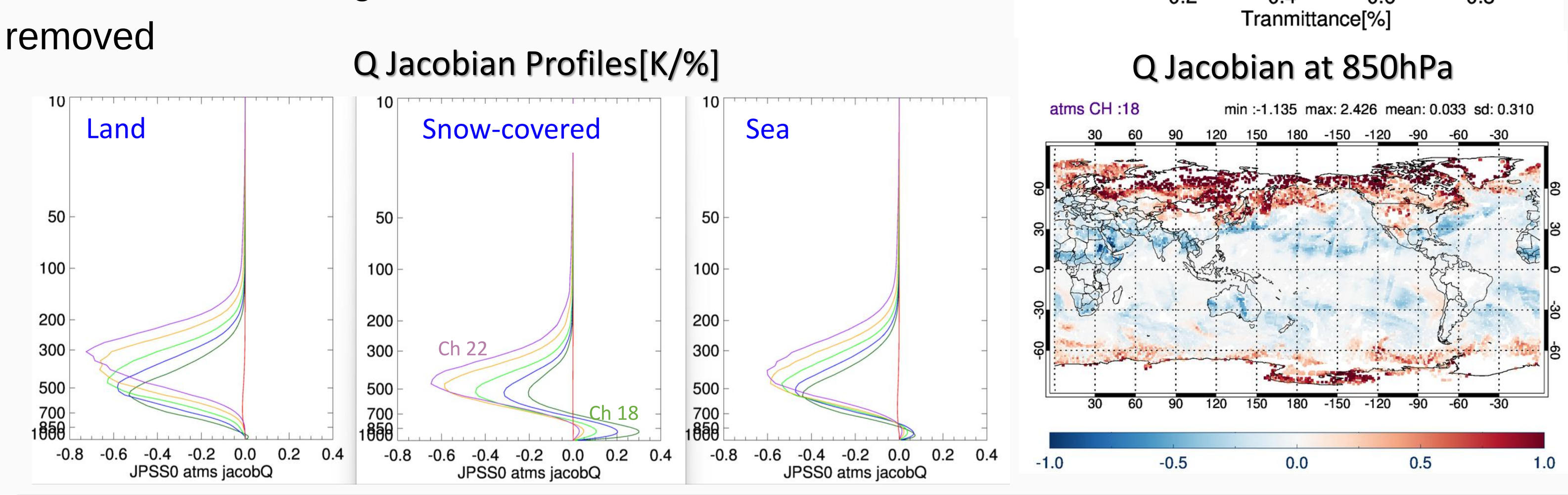
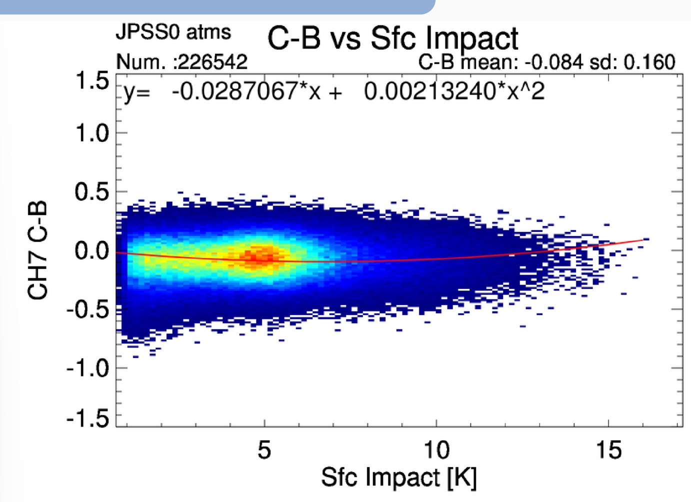


Figure 4. [upper] The scatter plot of observation increment and transmittance from surface. [bottom] The water vapor Jacobian profiles over land, snow-covered area and sea, and the spatial distribution of the Jacobian at 850 hPa. This value is calculated by multiplying q Jacobian with the specific humidity at that level.

Bias Correction w Surface Impact

- After the bias correction according to the current method, the bias caused by the surface remains.
- Calculate the bias correction formula using surface impact factor($\tau\varepsilon\ T_{skin}$) in the form of a quadratic equation using the data for July 2022 .
- Currently developed as static bias correction, surface impact term will be applied as predictor to variational bias correction in next step.
- Observation increment bias reduced and available **observation number increased** after the application of land bias correction.



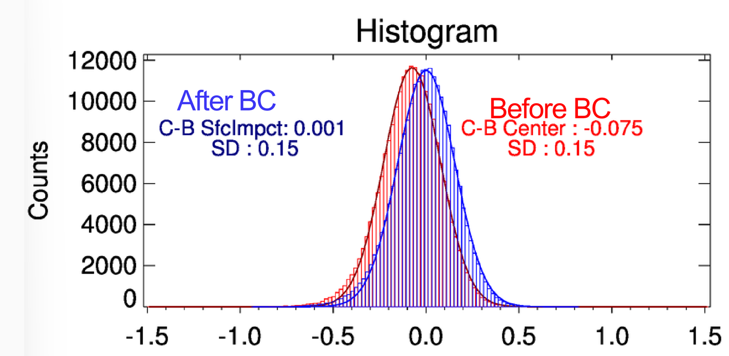


Figure 5. The scatter plot of observation increment and surface impact($\tau\varepsilon\ T_{skin}$) and the histograms of observation increment (ch7) before and after bias correction.

3 Conclusions and Plans

- ✓ The observation-dependent surface emissivity estimation method was introduced and tested to enhance the reliability of assimilating surface-sensitive channels over land.
  - Observation dependent emissivity retrieved using brightness temperature measured by satellite and surface temperature.
  - For snow-covered areas, a Lambertian reflection surface is assumed. Observations with significant surface influence are rejected.
  - In order to correct the bias caused by surface conditions, additional correction performed on the land with surface impact.
- ✓ The temperature field of the Northern Hemisphere has been improved by assimilation of surface-sensitive land observations.
  - Negative temperature biases over snow-covered regions are notably reduced, especially in Eurasia.
  - Temperature biases over North African desert are further amplified during summer.

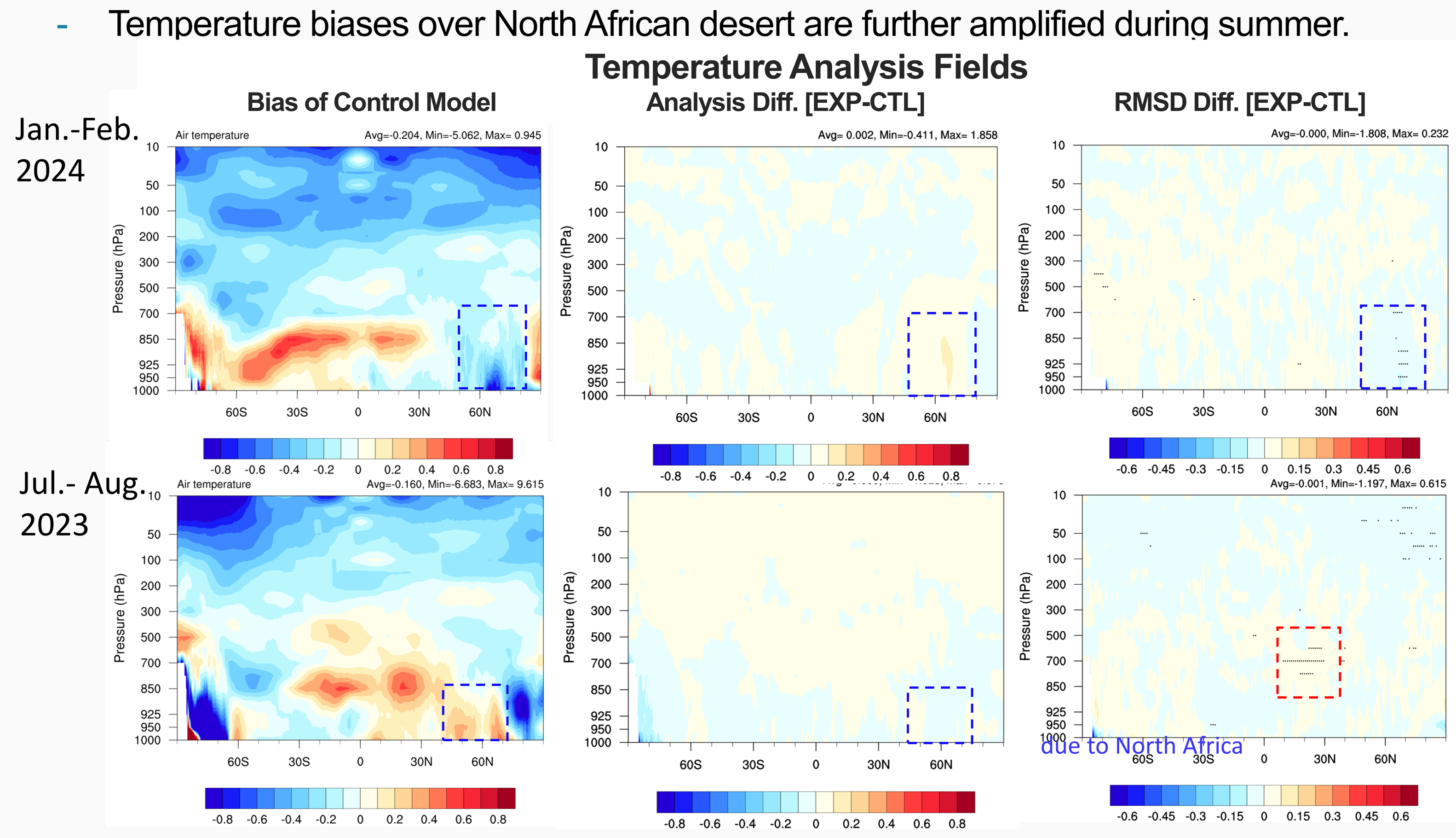


Figure 6. The zonal distributions of temperature bias for the control model compared to IFS, difference between the experiment and control model, and RMSD difference during winter and summer.

- ✓ The model prediction performance during summer and winter was found to be neutral.

Plans

- It need to consider the surface temperature suitable for estimation on microwave brightness temperature.
- Apply the predictor related with surface contributions to variational bias correction.