Estimate and its application of new channel RTTOV coefficients for GK5 follow on GK2A

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Introduction

KMA is preparing to launch a follow on satellite to the GK2A in 2029. The satellite will be on boarded sensors more channels than 16 channels of GK2A. The added channels will be affected the accuracy of the meteorological products of GK5. So, KMA estimated new channels RTTOV coefficient to determine which channel would have the greatest effect on meteorological products.

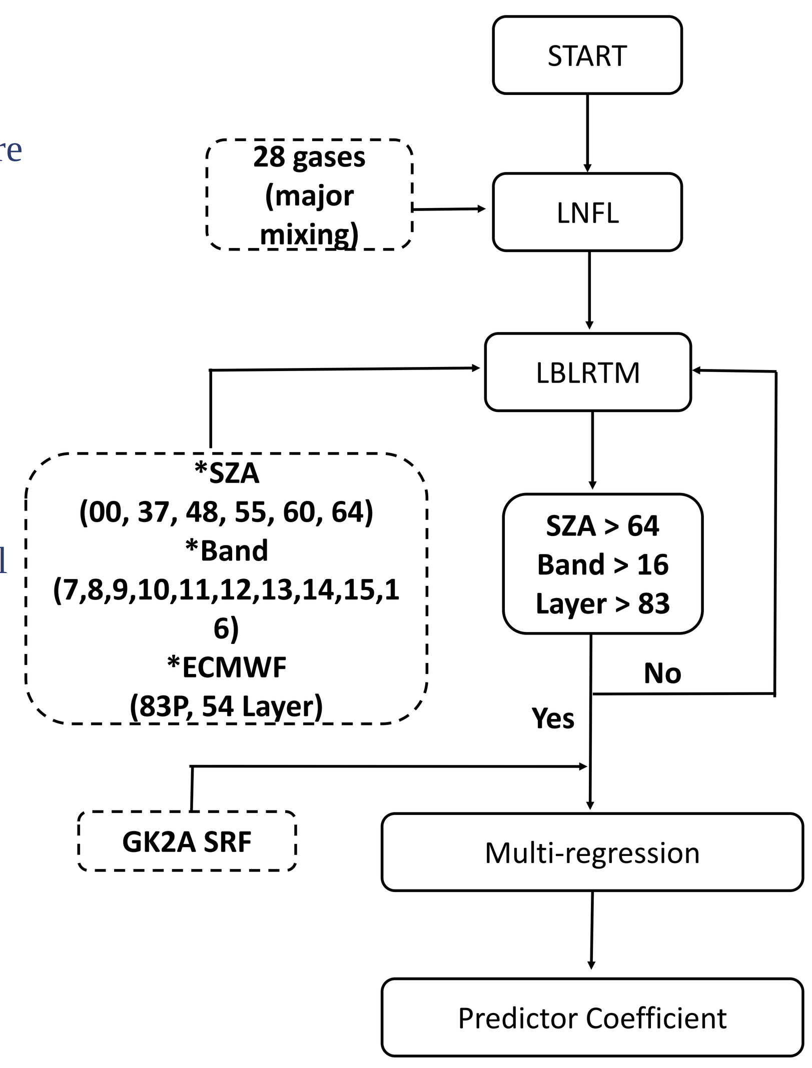
To verify the accuracy of the new RTTOV coefficient, GK2A coefficient was estimated by AER Line-By-Line Radiative Transfer Model (LBLRTM) and compared with the coefficient provided by NWPSAF. The differences of Brightness Temperature for two coefficients are shown less than 0.5K except for water vapor channel(6.3, 6.7, 7.8 um) and ozone channel(9.6) for 10 IR channels of GK2A/AMI. so, we are trying to estimate NMSC's coefficients using AER Line-By-Line Radiative Transfer Model (LBLRTM) and compared the results with the original coefficients.

Data & Method

❖ DATA

The ECMWF 83 profiles and 54Layers(101 layers interpolated into 54 layer). In addition, the number of absorber gases used(28gases are used), AMI Spectral Response Function, etc. are used as input for RTTOV and LBLRTM.

<Predictor Coefficient Flow chart>



❖ Method

✓ **Step 1**

RTTOV13(LBLRTM v12.8, HITRAN 2012) database is used to calculate gas absorption for each gas. And 6 solar zenith angle, mixed gas, ozone, and water vapor is consider to estimate optical depth in each layer for GK2A IR channels(band07(3.8 μm) to band16(13.3 μm).

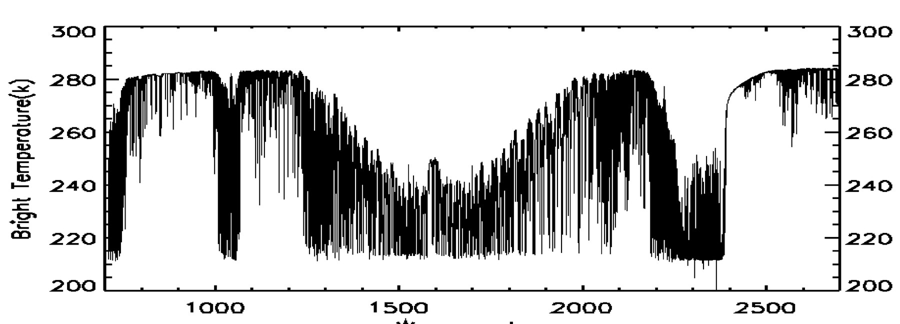


Fig.1 Distribution of bright temperature of GK2A Band7~16.

✓ **Step2**

The transmittance per function can be calculated from the calculated optical depth of each layer.(1)

$$T_{ch} = OD(\sigma_{i=1}^{54}\ Mixing\ gas + \sigma_{i=1}^{54}\ Ozone\ gas + \sigma_{i=1}^{54}\ Watervapor) \times SRF_{ch} \quad (1)$$

T - transmittance
ch - each GK2A channel(band07~16)
SRF – GK2A Spectral Response Function

The fast coefficient is calculated using the optical depth and predictor.(2)

$$d_{(ch,L)} = \sigma_{g=1}^{Ng}\ C_{(ch,L,g)} X_{(\lambda,L,g)} \quad (2)$$

X – predictor, g – gas, λ - wavelength
C – fast coefficient, L – layer

For calculate the fast coefficient, adapt linear least-squares calculation(Lai et al., 1978) using fig. 2 variation and LBLRTM optical depth.

Predictor	Fixed gases	Water vapour	Ozone
$X_{j,1}$	$sec(\theta)$	$sec^2(\theta)W_r^2(j)$	$sec(\theta)O_r(j)$
$X_{j,2}$	$sec^2(\theta)$	$(sec(\theta)W_w(j))^2$	$\sqrt{sec(\theta)O_r(j)}$
$X_{j,3}$	$sec(\theta)T_r(j)$	$(sec(\theta)W_w(j))^4$	$sec(\theta)O_r(j)\delta T(j)$
$X_{j,4}$	$sec(\theta)T_r^2(j)$	$sec(\theta)W_r(j)\delta T(j)$	$(sec(\theta)O_r(j))^2$
$X_{j,5}$	$T_r(j)$	$\sqrt{sec(\theta)W_r(j)}$	$\sqrt{sec(\theta)O_r(j)}\ \delta T(j)$
$X_{j,6}$	$T_r^2(j)$	$\sqrt[4]{sec(\theta)W_r(j)}$	$sec(\theta)O_r(j)^2 O_w(j)$
$X_{j,7}$	$sec(\theta)T_w(j)$	$sec(\theta)W_r(j)$	$\frac{O_r(j)}{O_w(j)}\sqrt{sec(\theta)O_r(j)}$
$X_{j,8}$	$sec(\theta)\frac{T_w(j)}{T_r(j)}$	$(sec(\theta)W_r(j))^3$	$sec(\theta)O_r(j)O_w(j)$
$X_{j,9}$	$\sqrt{sec(\theta)}$	$(sec(\theta)W_r(j))^4$	$O_r(j)sec(\theta)\sqrt{(O_w(j)sec(\theta)}$
$X_{j,10}$	$\sqrt{sec(\theta)}\ \sqrt[4]{T_w(j)}$	$sec(\theta)W_r(j)\delta T(j)\|\delta T(j)\|$	$sec(\theta)O_w(j)$
$X_{j,11}$	0	$(\sqrt{sec(\theta)W_r(j)})\delta T(j)$	$(sec(\theta)O_w(j))^2$
$X_{j,12}$	0	$\frac{sec(\theta)(W_r(j))^2}{W_w}$	0
$X_{j,13}$	0	$\frac{\sqrt{(sec(\theta)W_r(j)}W_r(j)}{W_w(j)}$	0
$X_{j,14}$	0	$sec(\theta)\frac{W_r^2(j)}{T_r(j)}$	0
$X_{j,15}$	0	$sec(\theta)\frac{W_r^2(j)}{T_r^4(j)}$	0

Fig.2 Function of each gas variation of RTTOV

New SRF and WF for GK5

❖ New Spectral Response Function

✓ AMI Spectral Response Function shifted from 7.3μm to new channels 5.1 , 7.5 μm.

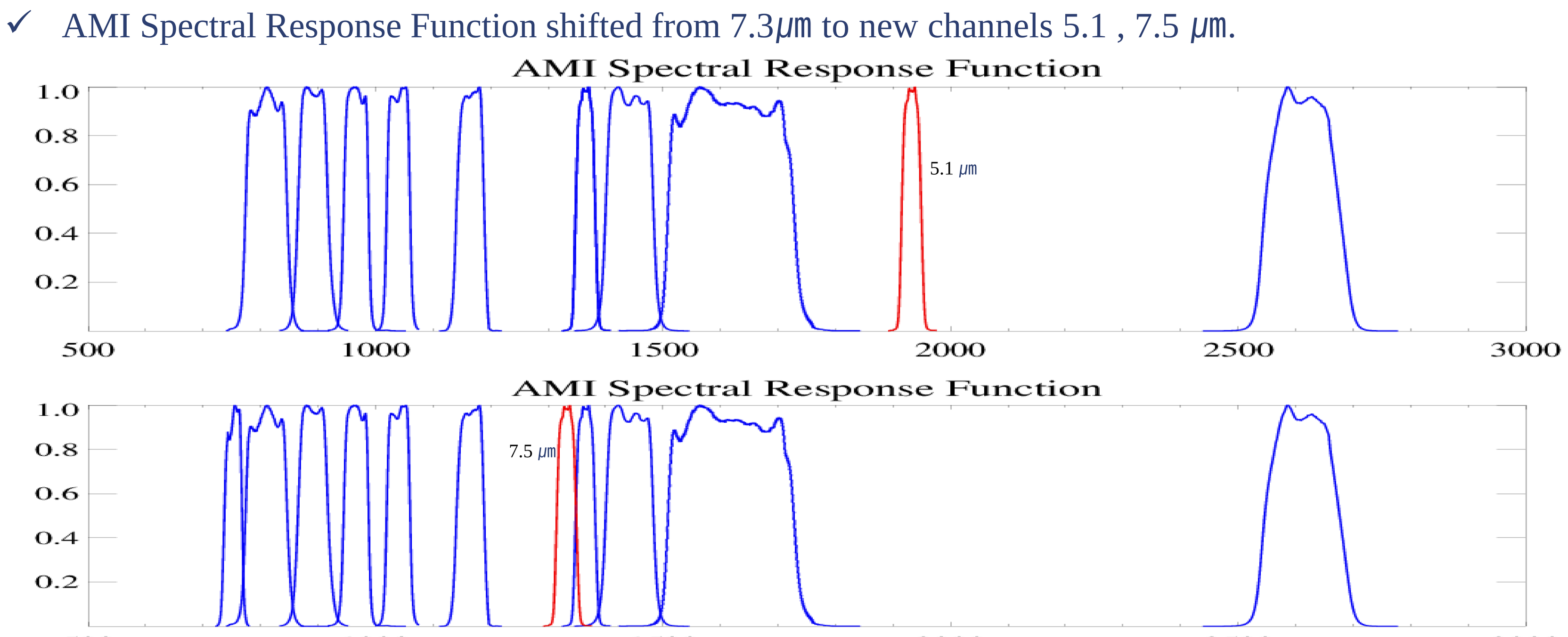


Fig.3 AMI Spectral Response Function Shifeted(5.1, 7.5um)

❖ New Weighting Function(5.1, 7.5μm)

$$\text{Weighting Function} = \frac{dT}{dp} = \frac{T(z) - T(1-1)}{P(z) - P(z-1)}$$

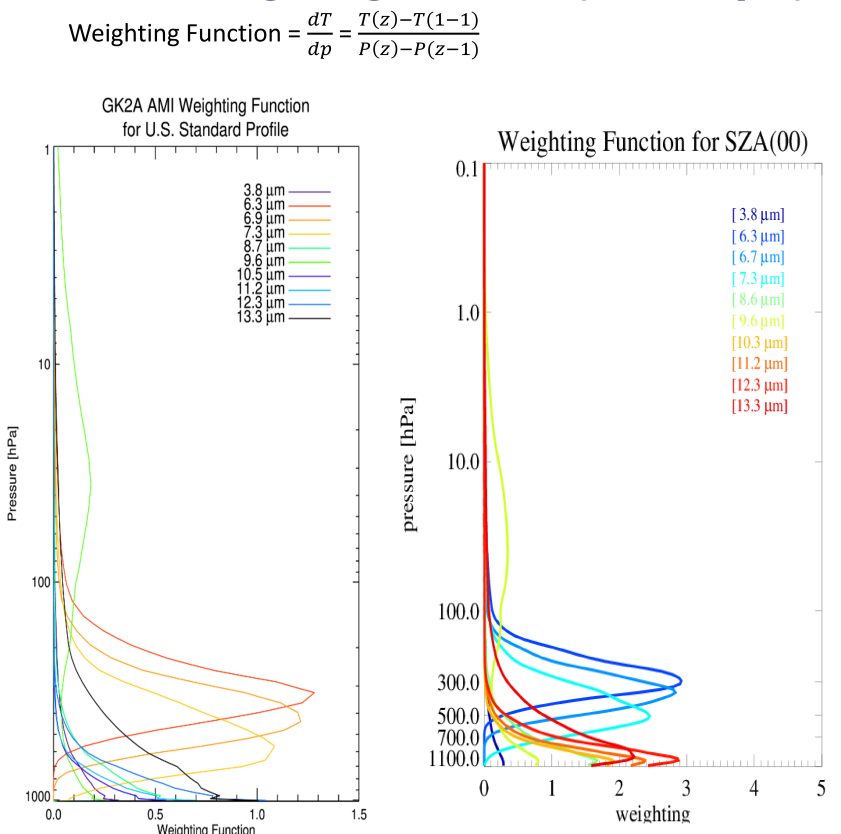


Fig. 4 Weighting Function of each band for the simulated LBLRTM(right) and GK2A AMI Weighting Function for U.S Standard Profile(left).

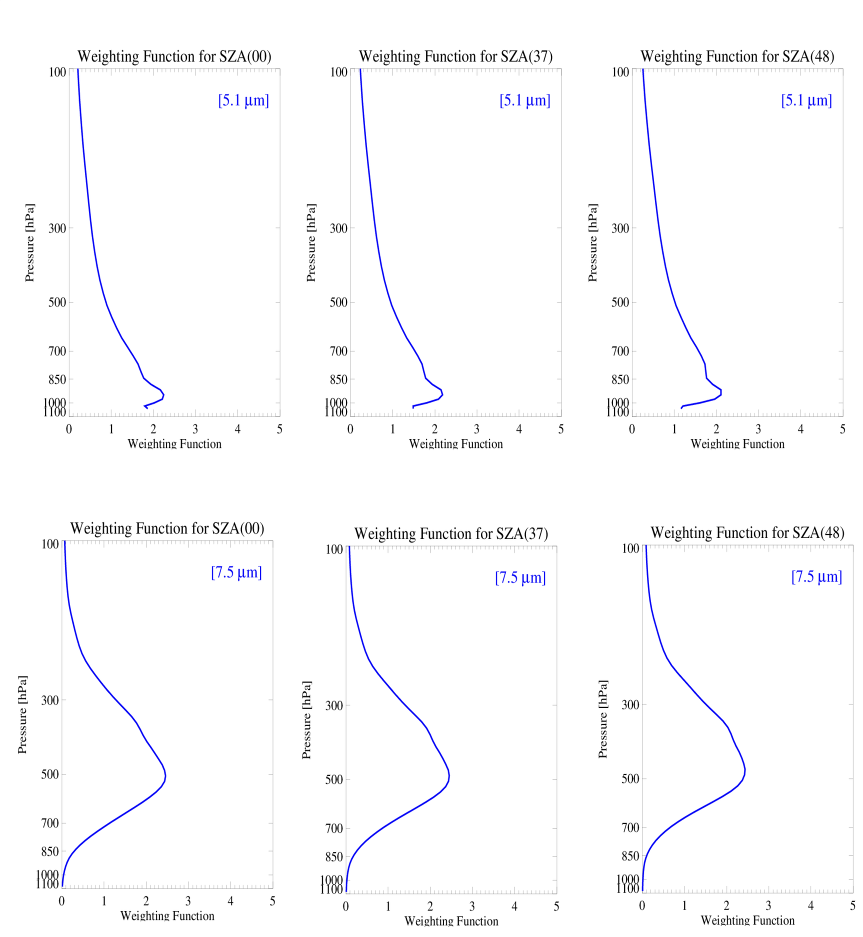


Fig. 5 The upper figure shows three satellite zenit angles of the 5.1μm weight function, and the lower figure shows the 7.5μm weight function.

Validation & Result

❖ Validation 1: Transmittance of LBLRTM vs RTTOV

- In order to compare the results of the fast coefficient calculated by the regression method, the difference between each layer was within about 0.01, showing good performance.

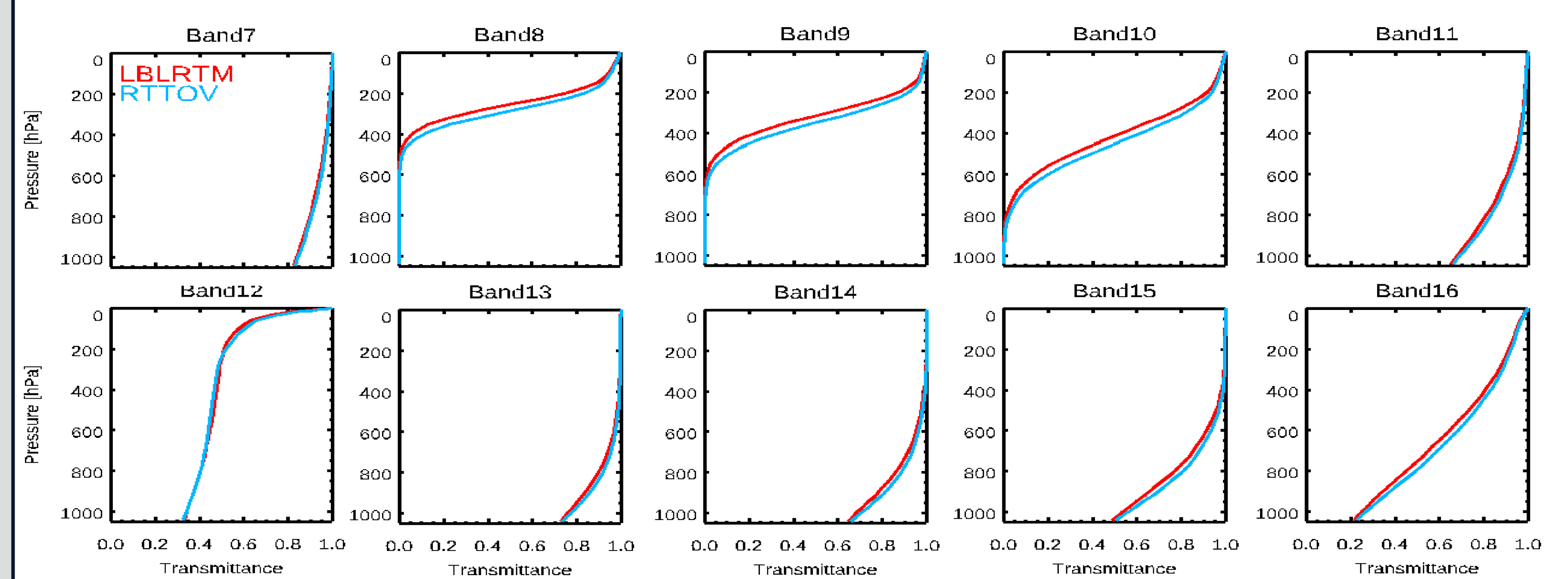


Fig. 6 Transmittance of each band for the simulated LBLRTM(red line) and RTTOV simulated using training fast coefficient(sky line).

❖ Validation 2: Bright Temperature of SAF vs training vs LBLRTM

- The comparison results of brightness temperature between two fast coefficients(NWP-SAF and trained in this study) for RTTOV and LBLRTM shows in Fig. 7.
- The difference of brightness temperature is less than 0.5K except for water vapor channel(6.3, 6.7, 7.8 um) and ozone channel(9.6).
- We analyzed the difference between the v7 training data with LBLRTM and the BT value provided by NWPSAF. We will check the difference between the water vapor channel and the ozone channel, and since GK2A uses RTTOV v9 data, it will be updated later.

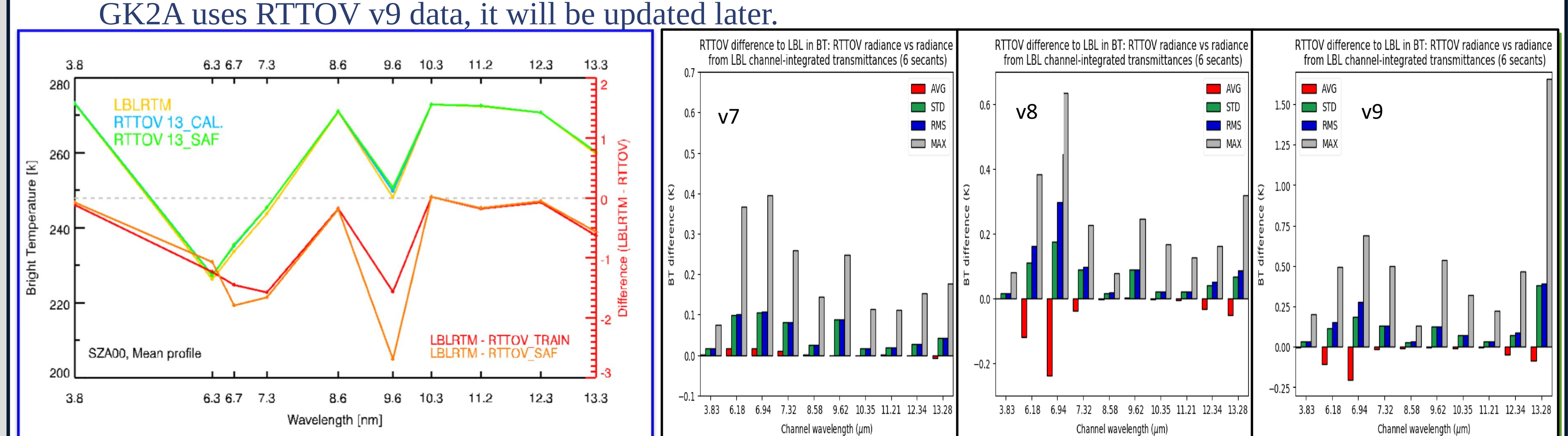
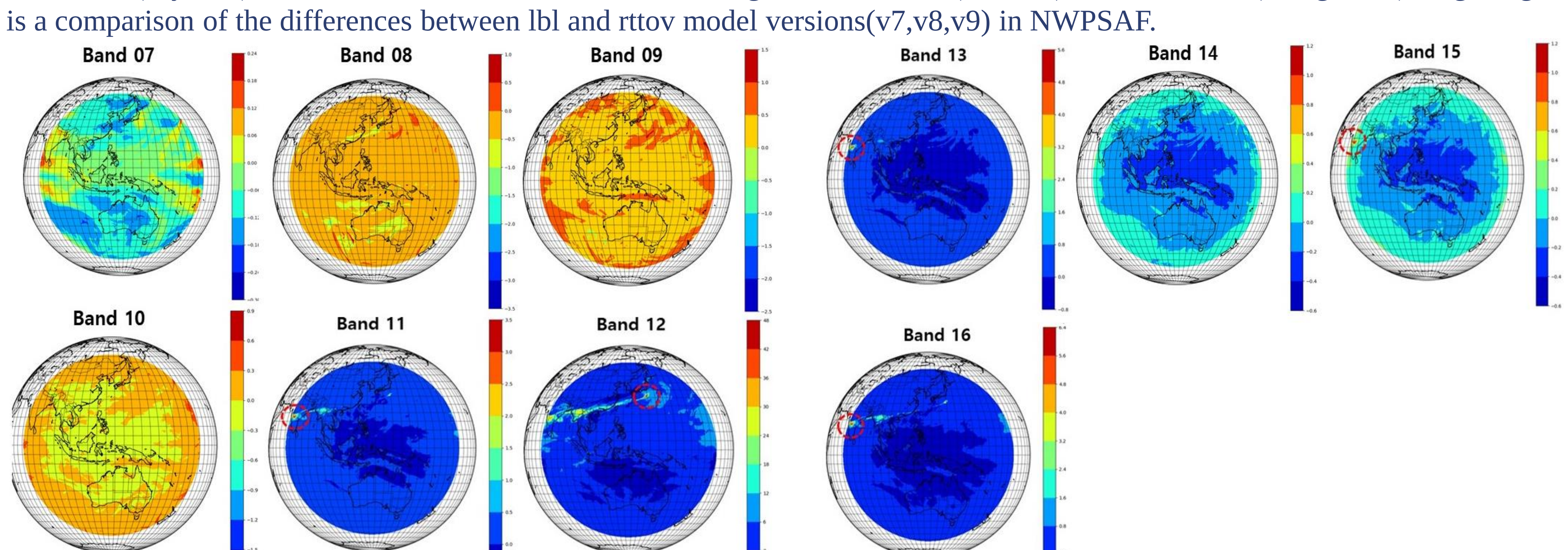


Fig. 7 Left figure Each channel BT of LBLRTM(yellow line), RTTOV BT of SAF fast coefficient(green line) and training fast coefficient(sky line) and difference of LBLRTM and training fast coefficient(red line), each RTTOV(orange line). Right figure is a comparison of the differences between lbl and rttov model versions(v7,v8,v9) in NWPSAF.



Wavelength (um)	Difference Max (T)	Difference Min (T)	Difference Mean (T)	RMSE (T)
3.8	0.20	-0.24	0.07	0.09
6.3	0.75	-3.13	0.28	0.32
6.7	1.32	-2.17	-0.38	0.41
7.3	0.61	-1.53	-0.05	0.12
8.6	3.19	-0.23	-0.15	0.20

Wavelength (um)	Difference Max (T)	Difference Min (T)	Difference Mean (T)	RMSE (T)
9.6	42.42	-3.49	-3.03	4.19
10.3	4.96	-0.30	-0.13	0.22
11.2	1.04	-0.49	0.07	0.12
12.3	1.08	-0.50	0.03	0.13
13.3	5.72	-0.36	-0.23	0.36

Fig. 8 RMSE and Difference Mean of brightness temperature between GK2A observation and simulated RTTOV in NWP-SAF panel is difference map GK2A observation and CSR simulated RTTOV.

Summery & Conclusion

- **To calculate the optical depth using AER-LBLRTM with SZA6(00, 37,48,55,60,64), 83 atmospheric profiles converted to 54 layer and then regression method is applied to estimate fast coefficient of RTTOV.**
- **Through the weighting function of the new channels(5.1, 7.5μm) of GK5, it was possible to detected the lower layer water vapor.**
- **In order to compare the results of the fast coefficient calculated by the regression method, the difference between each layer was within about 0.01, showing good performance.**
- **The brightness temperature difference between LBLRTM and RTTOV with new coefficient for each channel is less than 1.5K exception for water vapor channel(6.3, 6.7, 7.3 μm) and ozone channel(9.6), the difference might be due to gases and water vapor amount between two models.**
- **The difference between observed and simulated brightness temperature with NWP-SAF coefficients for GK2A have positive Conclusion.**
- **We will apply RTTOV v9 and GK5 new channel coefficient and compared with NWPSAF using the training coefficient CSR simulated by LBLRTM validation.**

Reference

✓ Prior research report on microwave satellite data impact assessment and observation operator development (2016, Seoul National University)

✓ 6th year report on the development of data processing technology for Cheonan Satellite 2A in the field of radiant aerosol (2019, Gangneung University)

✓ GK2A radiation model detailed design (2019, Korea Electronics and Telecommunications Research Institute)

✓ EUMETSAT NWP SAF Website (RTTOV)

✓ AER's Radiative Transfer Working Group (LBLRTM)