AMS 2020

# Comparison of the TAMU Vector Radiative Transfer Model (TAMU-VRTM) and Community Radiative Transfer Model (CRTM) in the Gas Absorption Calculation

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## 1. Introduction

Accurate and fast radiation transfer models are essential in satellite remote sensing and data assimilation. Different radiative transfer models may use different absorption schemes, single-scattering property databases, or radiation transfer solvers. To evaluate their performances and seek potential improvement in the future, we make comparison of different radiation transfer models using a variety of input fields.

We further improve the TAMU Vector Radiation Transfer Model (TAMU-VRTM). It can simulate the Stokes vector of radiance at various atmospheric levels and the top of the atmosphere in both hyperspectral and narrow sensor bands. The Community Radiative Transfer Model (CRTM) was developed by the US Joint Center for Satellite Data Assimilation (JCSDA).

In this study, we conduct the comparison of these two models in Moderate Resolution Imaging Spectroradiometer (MODIS) and Visible/Infrared Imaging/Radiometer Suite (VIIRS) bands. We use the results based on the line by line radiation transfer model (LBLRTM) as the reference benchmark for the comparison. We only focus on the gas absorption calculations of these two models in this study, so the bands radiances are simulated in clear sky conditions. We also compare the computational efficiencies of the absorption calculation algorithms.

## 2. Gas absorption algorithm in TAMU-VRTM

1. Use Line-by-Line Radiative Transfer Model (LBLRTM) to generate monochromatic optical thickness data, then calculate channel averaged optical thickness.

$$t_{i\sim j}=\frac{\sum_{m=1}^{N}S_m exp\left[-a\sum_{n=i}^{j}\tau_m^n\right]}{\sum_{m=1}^{N}S_m}$$

$$\bar{\tau}_{i\sim j}=-\ln t_{i\sim j}$$

2. Use the data in step 1 as training data and calculate the regression coefficient.

$$\bar{\tau}_{i\sim j,n}=\sum_{l=1}^{L}\sum_{m=0}^{M}c_{lm}\left(G_{i\sim j,n}^{\gamma}\right)^{l}\left(T_{i\sim j}\right)^{m}+G_{i\sim j,CO2}\sum_{m=0}^{M}c_{m,CO2}\left(T_{i\sim j}\right)^{m}$$

*G* and *T* are predictors which are related to layer temperature, pressure and gas concentration. Eight gases are considered: $H_2O$, $CO_2$, $O_3$, $N_2O$, CO, $CH_4$, $O_2$ and $N_2$.

$$T_{i\sim j,n}=\frac{\sum_{\mathrm{k}=1}^{j}T_kP_k}{\sum_{\mathrm{k}=1}^{j}T_{ref,k}P_k}$$

$$G_{i\sim j,n}^{0}=\frac{\sum_{\mathrm{k}=1}^{j}u_{k,n}}{\sum_{\mathrm{k}=1}^{j}u_{ref,k,n}}$$

$$G_{i\sim j,n}^{\mathrm{p}}=\frac{\sum_{\mathrm{k}=1}^{j}P_ku_{k,n}}{\sum_{\mathrm{k}=1}^{j}P_ku_{ref,k,n}}$$

$$G_{i\sim j,n}^{\mathrm{T}}=\frac{\sum_{\mathrm{k}=1}^{j}T_ku_{k,n}}{\sum_{\mathrm{k}=1}^{j}T_ku_{ref,k,n}}$$

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3. Organize the regression coefficients and use them to predict channel averaged thicknesses of independent atmospheric profiles.

## 3. Results of TAMU-VRTM

In sample training error of gas absorption algorithm in TAMU-VRTM. The training profiles are from Strow et al. (2003).

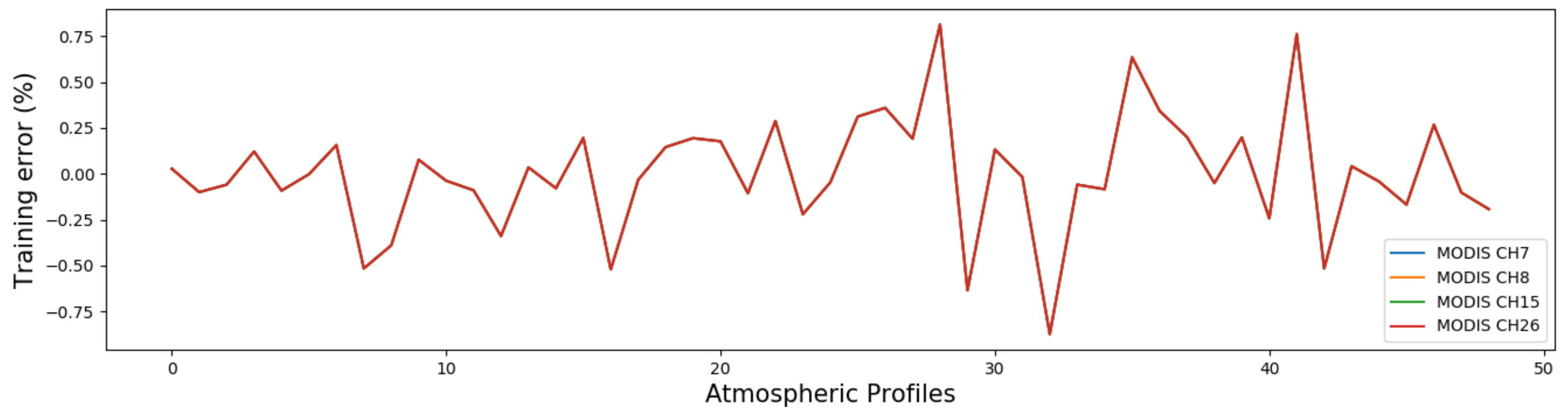

**Fig. 1** The training errors at MODIS channel 7 (2.1mm), channel 8 (0.41mm), channel 15 (0.76mm) and channel 26 (1.38mm) for different atmospheric profiles.

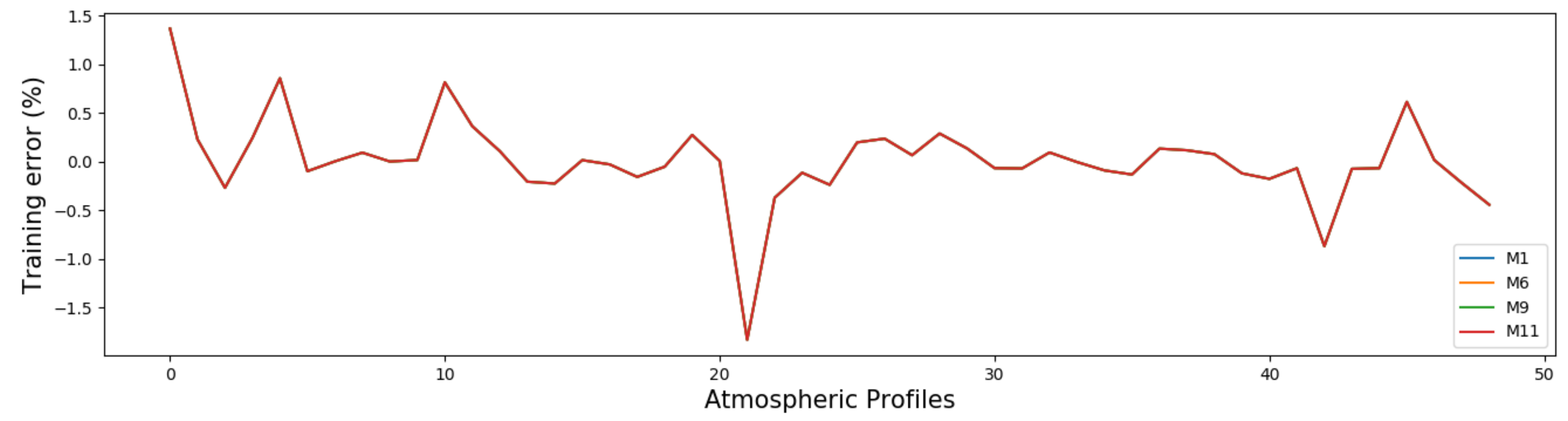

**Fig. 2** The training errors at VIIRS channel M1 (0.412mm), M6 (0.746mm), M9 (1.378mm) and M11 (2.25mm) for different atmospheric profiles.

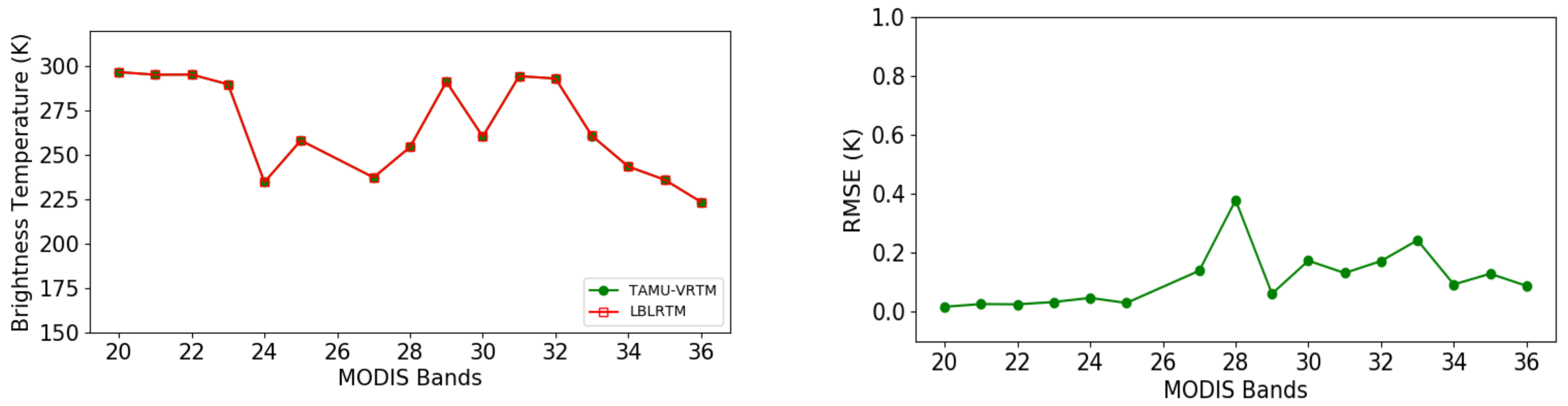

**Fig. 3** The simulated brightness temperature (left) and brightness temperature RMSE (right) from TAMU-VRTM (green) and LBLRTM (red) in the MODIS bands 20-25, 27-36 (thermal infrared bands) for 49 atmosphere profiles.

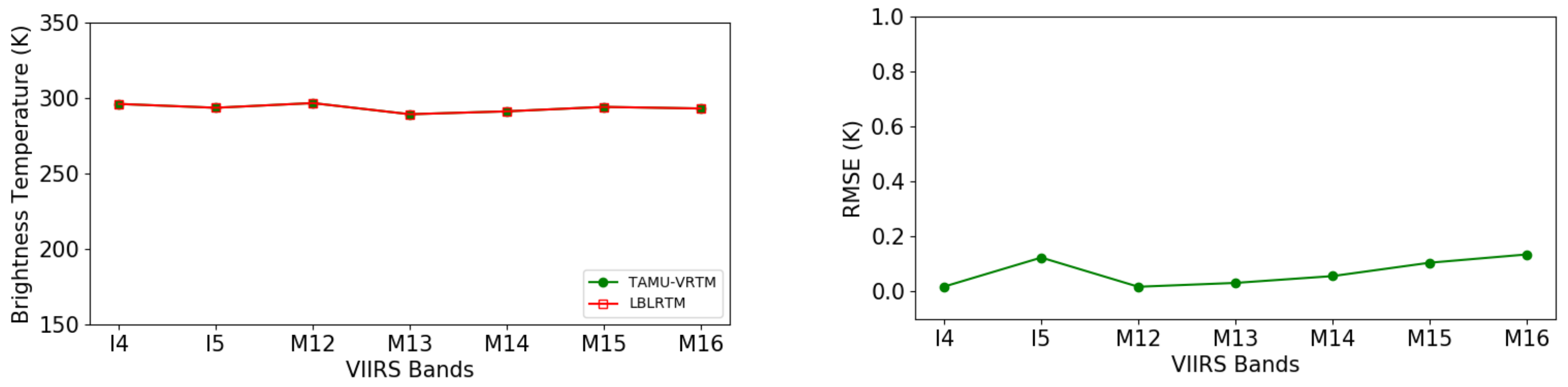

**Fig. 4** The simulated brightness temperature (left) and brightness temperature RMSE (right) from TAMU-VRTM (green) and LBLRTM (red) in the VIIRS bands I4-I5, M12-M15 (thermal infrared bands) for 49 atmosphere profiles.

## 4. Results of CRTM

We further use the atmosphere profiles that are used for TAMU-VRTM training as the inputs of CRTM and compare the outputs with LBLRTM.

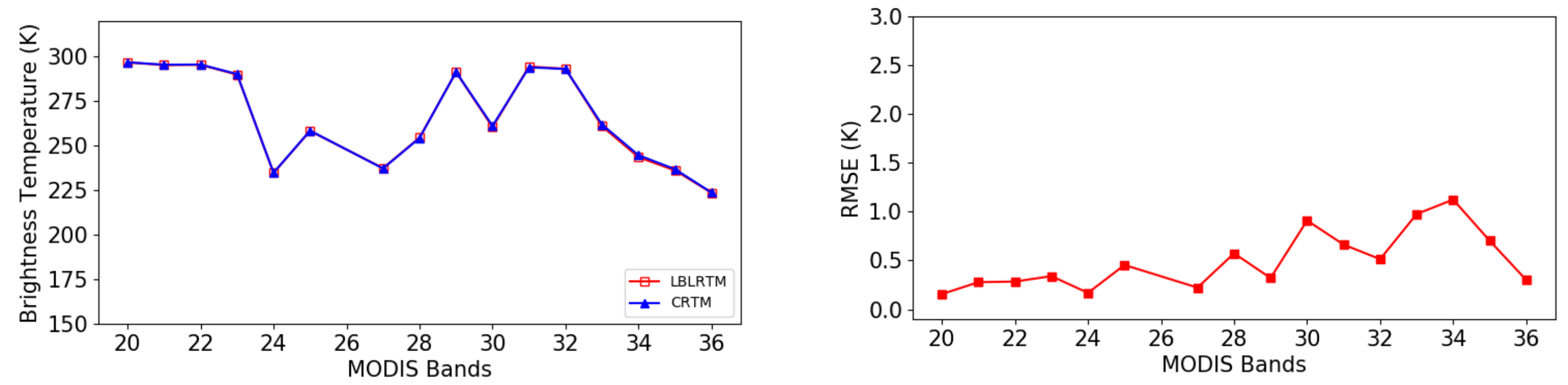

**Fig. 5** The simulated brightness temperature (left) and brightness temperature RMSE (right) from CRTM (blue) and LBLRTM (red) in the MODIS bands 20-25, 27-36 (thermal infrared bands) for 49 atmosphere profiles.

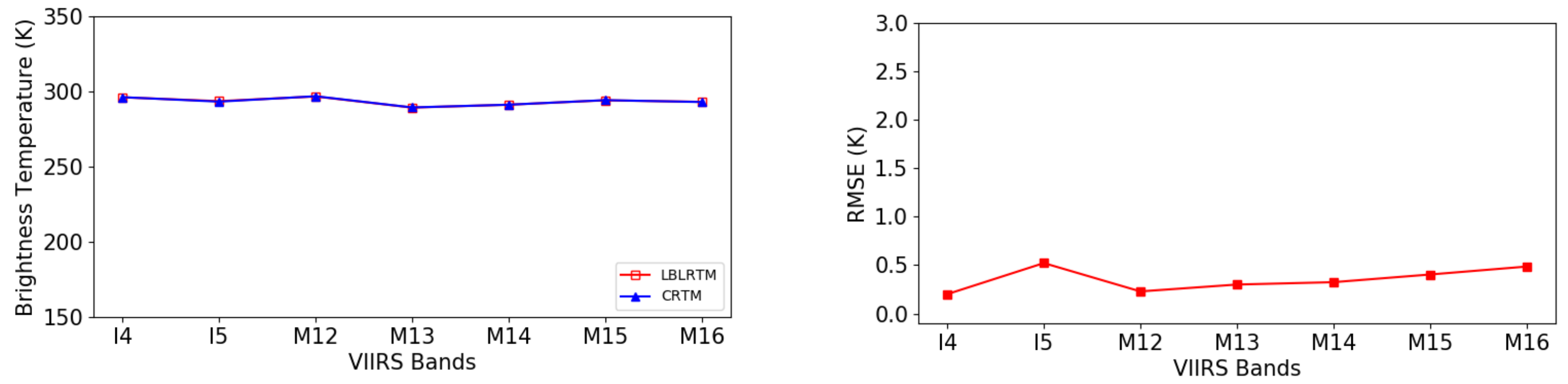

**Fig. 6** The simulated brightness temperature (left) and brightness temperature RMSE (right) from CRTM (blue) and LBLRTM (red) in the VIIRS bands I4-I5, M12-M15 (thermal infrared bands) for 49 atmosphere profiles.

## 5. Discussion and Summary

1. The training error of gas absorption algorithm of TAMU-VRTM is less than 0.75% when calculating the channel-averaged optical thickness in MODIS bands and the training error is less than 1.5% in VIIRS bands.
2. Compared with LBLRTM, the in sample root mean square error (RMSE) of TOA brightness temperature by TAMU-VRTM is less than 0.5K for MODIS bands. For the VIIRS bands, the RMSE is less than 0.2K.
3. Compared with LBLRTM, the RMSEs of TOA brightness temperature by CRTM are around 0.5K for most MODIS bands and VIIRS bands.
4. The gas absorption calculation speeds by TAMU-VRTM and CRTM are both fast, they are at least two orders of magnitude faster than LBLRTM.

## Acknowledgements and References

This work is supported by NASA Grant 80NSSC18K1516.

1. Strow et al., (2003), *IEEE Transactions on Geoscience and Remote Sensing*, **41**, 303-313