Evaluation of the In-Orbit Performance of the FY-3D MWTS Using GPS Radio Occultation Data

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Abstract: The Microwave Temperature Sounder (MWTS) onboard the Fengyun-3D (FY-3D) satellite can profile the vertical structure of the atmospheric temperature from the surface to 1 hPa under nearly all-weather conditions. It is important to assess its in- orbit performance and calibration accuracy prior to the data applications. In this study, the atmospheric profiles obtained from Global Positioning System (GPS) radio occultation (RO) data, which are both stable and accurate, are used for assessing the performance of microwave sounders in orbit, as demonstrated by many previous studies. In addition, ERA-Interim analysis data was also used to assess the performance of the MWTS. To understand the sources of error, three fast models including Advanced Radiative Transfer modeling System (ARMS), Community Radiative Transfer Model (CRTM) and the Radiative Transfer for the Television Infrared Observation Satellite (TIROS) Operational Vertical Sounder (RTTOV) model were used to simulate the brightness temperature of MWTS. The radio-occultation data are quality controlled and the collocation criterion between the radio-occultation data and the MWTS measurements is defined such that the spatial and temporal difference is <50 km and <3 h, respectively. The results show that the biases of MWTS channels 5–10 produced by three models agree well over the oceans under clear sky conditions between 60° S and 60° N from July to December 2018. The mean biases simulated by the radio-occultation and ERA-Interim data are negative and the absolute values of the biases are <0.9 and <1.3 K for channels 5–10 of the MWTS, respectively. The biases at channels 4 and 11 between the CRTM and RTTOV simulations are inconsistent and require further investigation. The standard deviation of the biases from the radio-occultation and ERA-Interim data are <1.5 and <0.5 K for channels 4–11 of the MWTS. Asymmetrical patterns are detected for the MWTS through the scan angle-dependent bias. The long-term mean bias shows only a weak dependence on latitude, which suggests that biases of MWTS do not vary systematically with latitudes.

Results 1: Biases estimation using radio-occultation data

- **Biases estimation using GPS RO data**

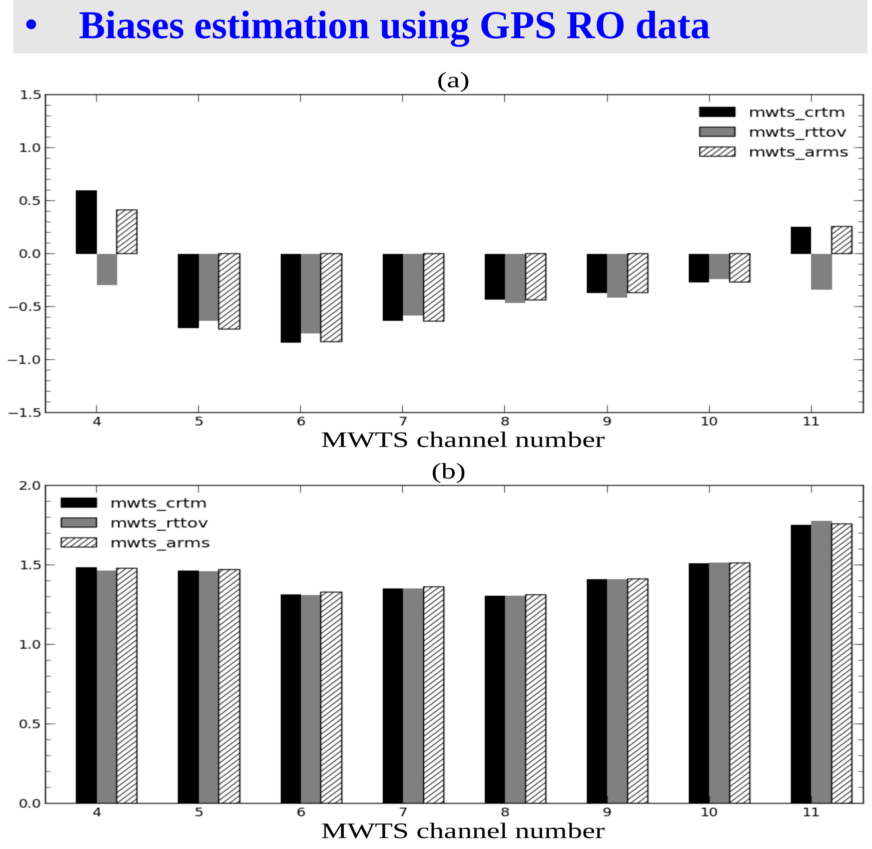


Fig. 1 (a) Mean bias and (b) standard deviation of FY-3D MWTS channels 4–11 observations and the simulations using radio-occultation profiles as inputs to the three fast models from July to December in 2018.

- **Spatial distribution of the O-B**

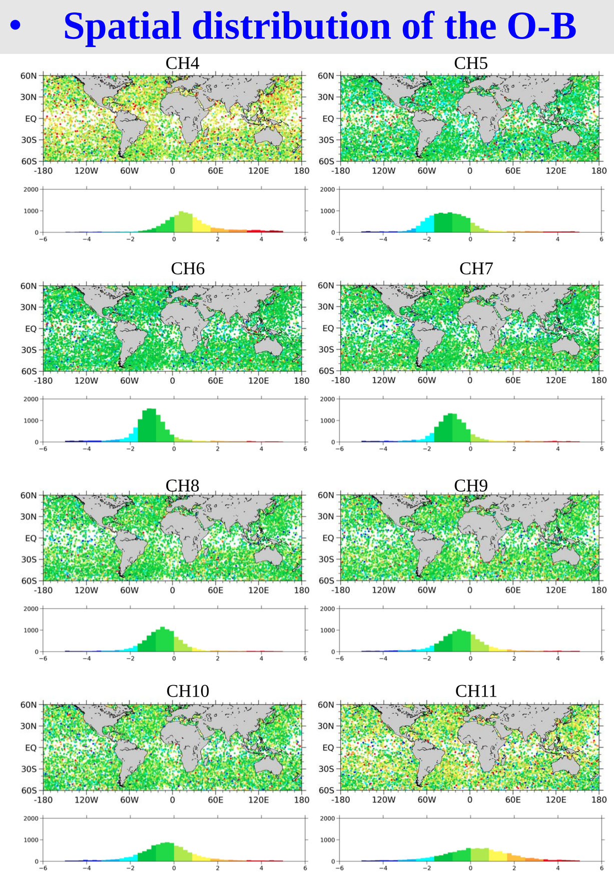


Fig. 2 Spatial distribution and histograms of the bias between FY-3D MWTS channels 4–11 observations and the CRTM simulations with radio-occultation data under clear conditions over the ocean between 60 °S and 60 °N from July to December 2018.

- **Scatterplots of observation and simulation**

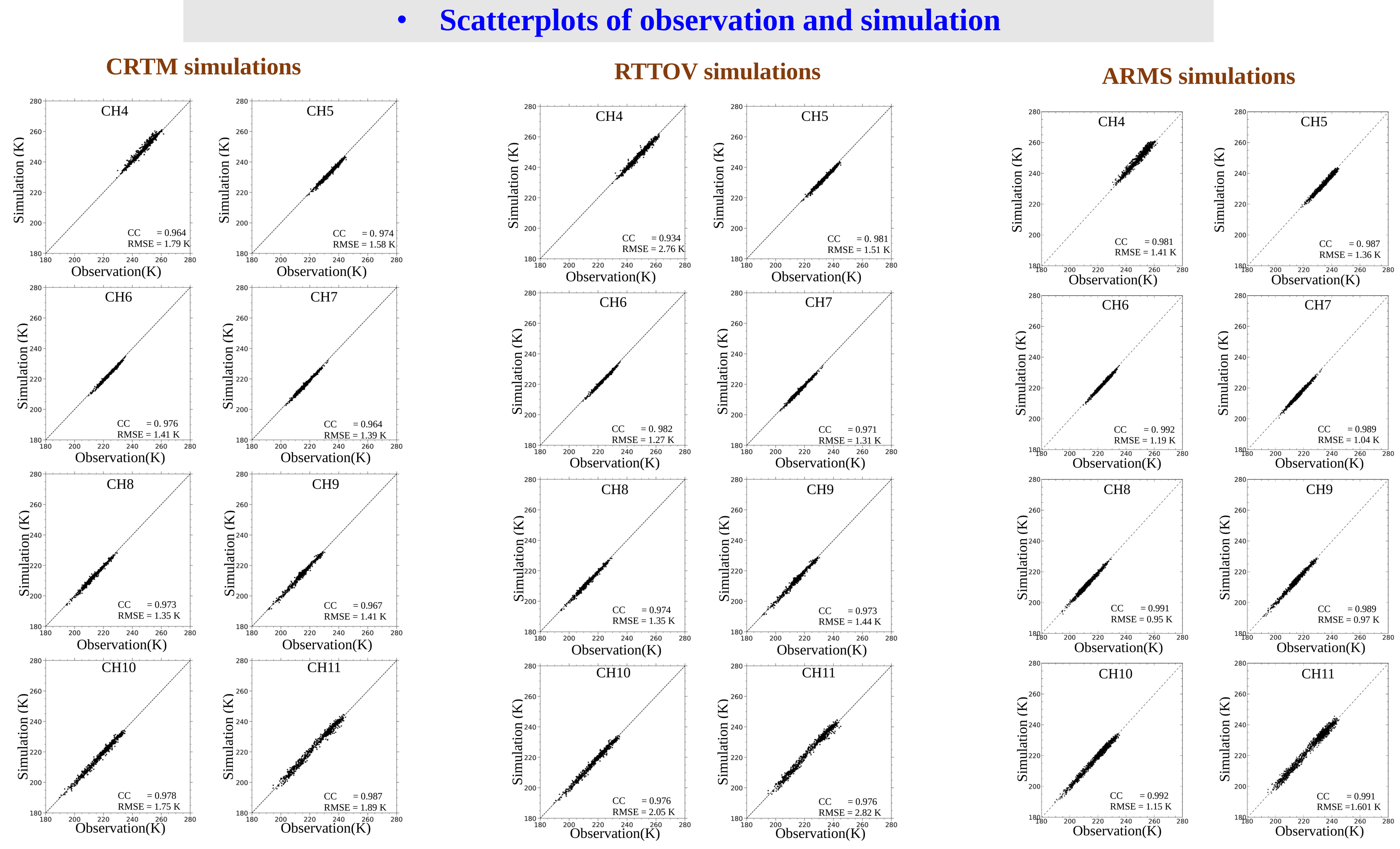
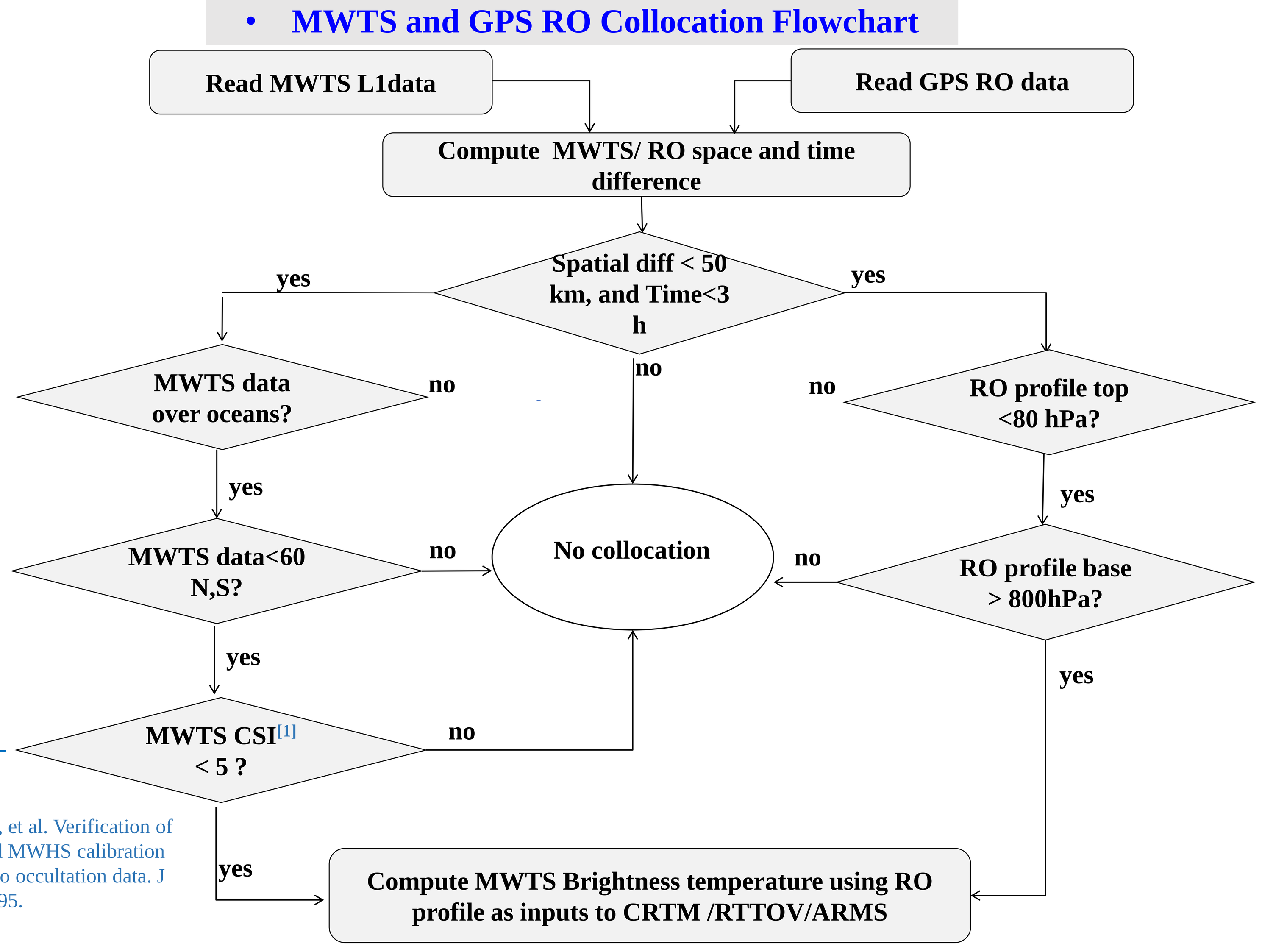


Fig. 3 Scatterplots of the brightness temperature from the FY-3D MWTS observations and the simulations with input from collocated radio-occultation profiles for channels 4–11 under clear sky conditions over the ocean between 60° S and 60° N from July to December in 2018.

Data and Methods

- **MWTS and GPS RO Collocation Flowchart**



[1] Hou X, Han Y, Hu X, et al. Verification of *Fengyun-3D* MWTS and MWHS calibration accuracy using GPS radio occultation data. J Meteorol Res 2019;33:695.

Results 2: Biases estimation using ERA-Interim data

- **Biases estimation using ERA-Interim data**

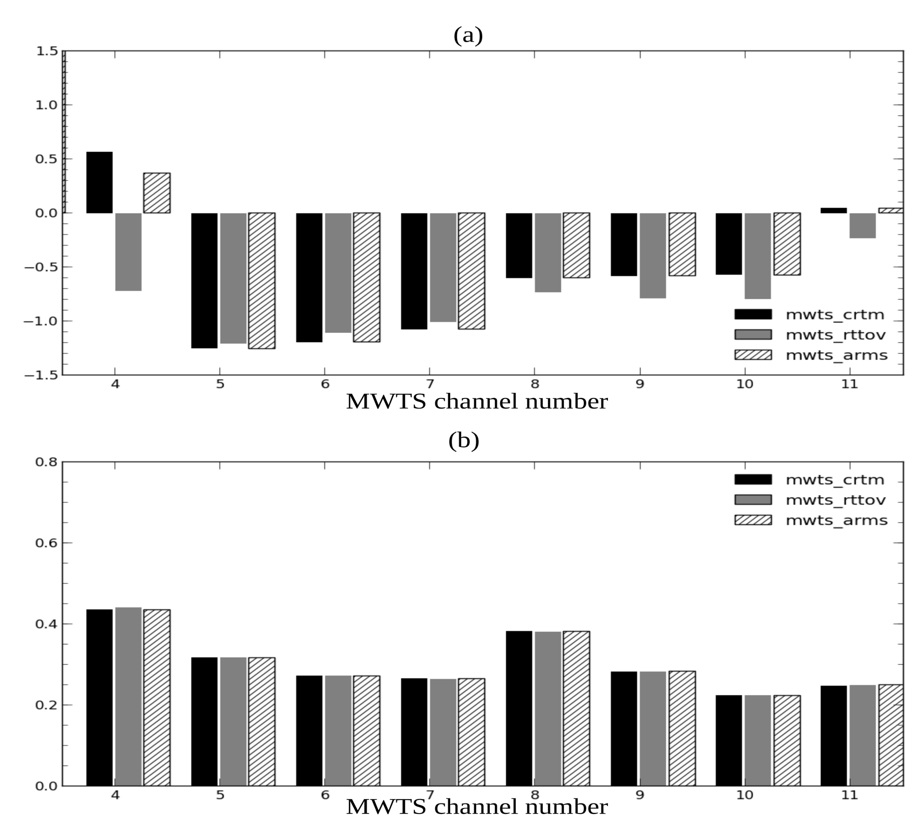


Fig. 4 (a) Mean bias and (b) standard deviation of FY-3D MWTS channel 4–11 observations and the simulations using the ERA-Interim data as inputs to the three fast models in July 2018.

- **Scan-dependent biases**

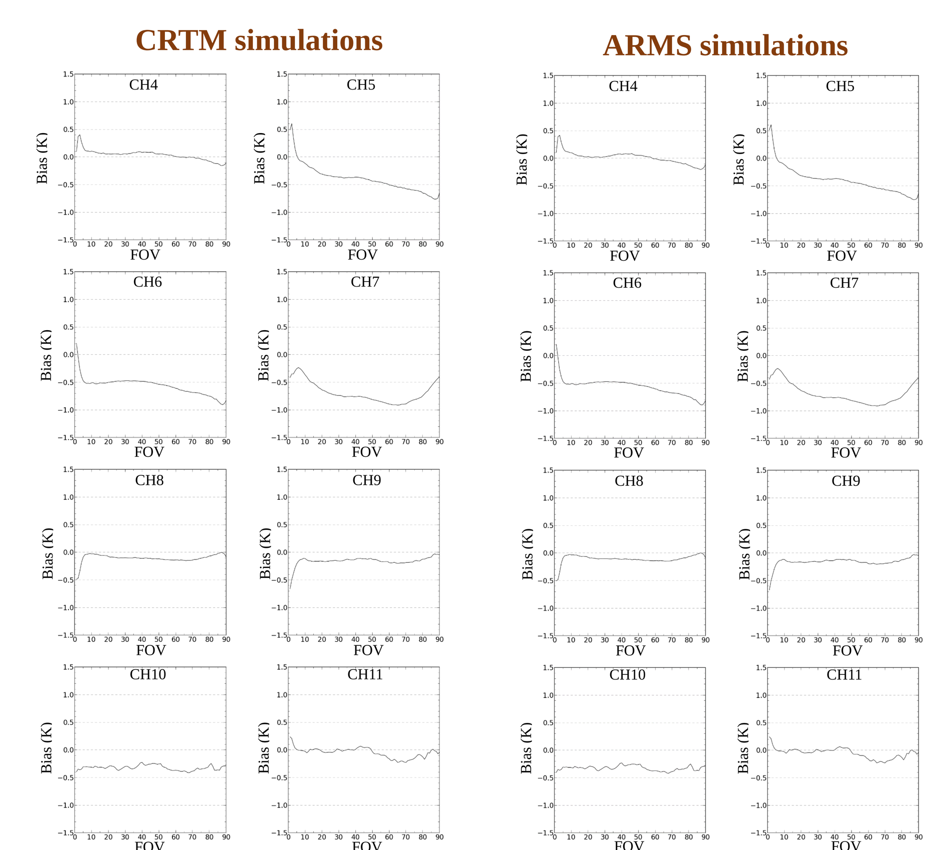


Fig. 5 Scan bias of FY-3D MWTS channels 4–11 calculated by the MWTS observations and the CRTM/ARMS simulations with input from the collocated ERA-Interim profiles under clear sky conditions over the ocean between 60 °S and 60 °N in July 2018.

- **Latitudinal dependency of bias**

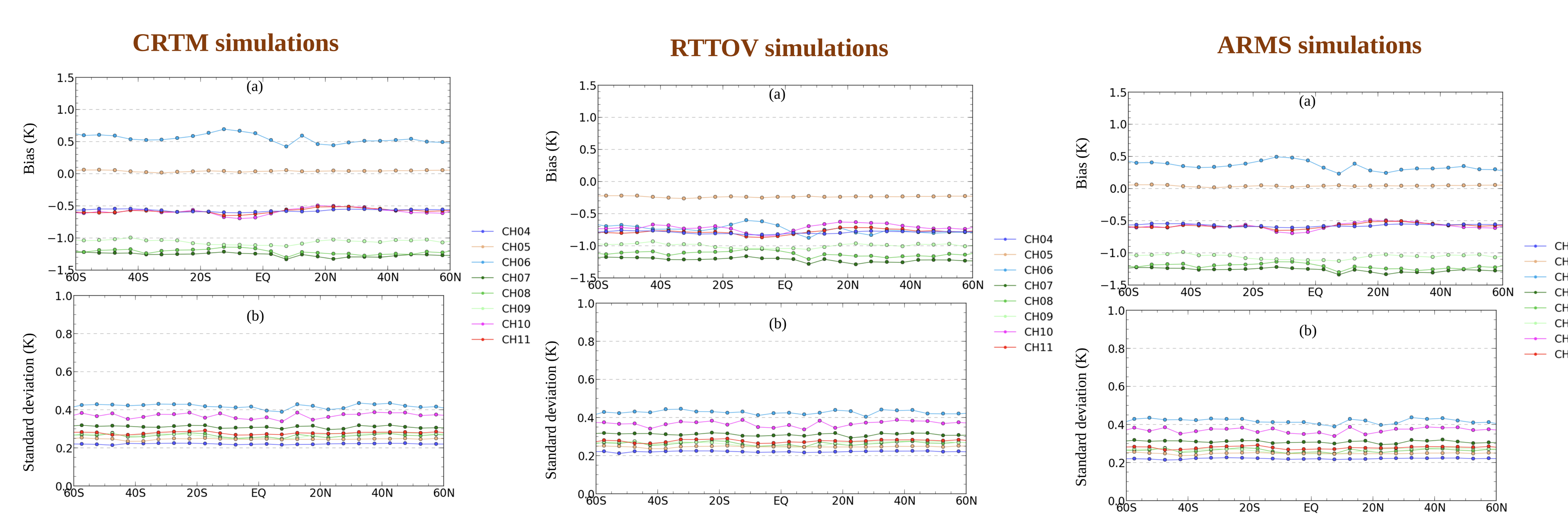


Fig. 6 Latitudinal dependency of (a) bias and (b) standard deviation for channels 4–11 of the FY-3D MWTS obtained within 5 ° latitudinal bands using the ERA-Interim data as the inputs the three fast models in July 2018.

Discussion and conclusions

- There fast radiative transfer models (CRTM, RTTOV and ARMS) are used to evaluate the in-orbit performance of the MWTS onboard FY-3D. The calibration coefficients of FY-3D MWTS were updated in late June 2018 and thus the biases from July to December 2018 are evaluated. Radio-occultation data (including COSMIC and GRAS) from July to December 2018 are used as the inputs for the three models because these profiles are accurate from the mid-troposphere to lower stratosphere. ERA-Interim data, widely used in the meteorological and climate research community, is also used to simulate the brightness temperature.
- The mean biases for the MWTS channels 5–10 estimated by the three models simulations using radio-occultation data as the model inputs are generally consistent, indicating that the results are reasonably reliable under clear sky conditions over the ocean between 60 °S and 60 °N. The mean biases of channels 5–10 simulated by the radio-occultation data are negative and the absolute values of the biases are <0.9 K. However, there is a disagreement about the bias from channels 4 and 11 between the CRTM and the RTTOV simulations in terms of the systematic errors of the models. The spatial distribution and histograms of bias between the observations and the CRTM simulations show that channel 4 and 11 mostly have positive biases, whereas the other channels have negative biases.
- The ERA-Interim data simulations confirm the disagreement between the models for channels 4 and 11. The mean biases simulated by the ERA-Interim data are also negative and the absolute values of the biases are <1.3 K for channels 5–10. The standard deviations of the mean biases for channels 5–10 simulated by the radio-occultation and ERA-Interim data are < 1.5 K and < 0.5 K, respectively .
- The scan biases of the FY-3D MWTS show an asymmetrical pattern and there are some zigzags in the fluctuations attributed to the design and configuration of the instrument. The long-term mean bias shows only a weak dependence on latitude, which suggests that biases of the MWTS do not vary systematically with latitudes.
- This study will serve as a reference for the assimilation of satellite data and other applications. It will also contribute to the establishment of climate data records for microwave instruments using advanced technologies.