An assessment of the consistency between satellite measurements of upper tropospheric water vapor

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1. Introduction

- Upper tropospheric water vapor (UTWV) accounts for a very small fraction of the column-integrated water vapor. However, the absorption of outgoing longwave radiation by water vapor increases logarithmically with the concentration of water vapor, suggesting that even small variations in water vapor in the upper troposphere can have significant implications for the magnitude of water vapor feedback. Therefore, accurate and stable observations of UTWV are crucial for monitoring its changes and assessing the credibility of model projections.
- While a substantial amount of effort has been made to construct intersatellite-calibrated data sets suitable for long-term climate monitoring, a comprehensive assessment on their reliability has not been conducted. In this study, we assess the consistency and robustness of climatological variations in satellite-observed UTWV by comparing brightness temperature measurements from three independent satellite data sets (i.e., HIRS channel 12, microwave 183.31±1 GHz channel, and AIRS). We also analyze the patterns of UTWV variability from reanalysis data sets and climate model simulations using the HIRS record as a benchmark in order to examine whether reanalysis-produced and model-simulated UTWV data sets are suitable for analyzing UTWV changes on multi-decadal time scales.

2. Short-term Variability

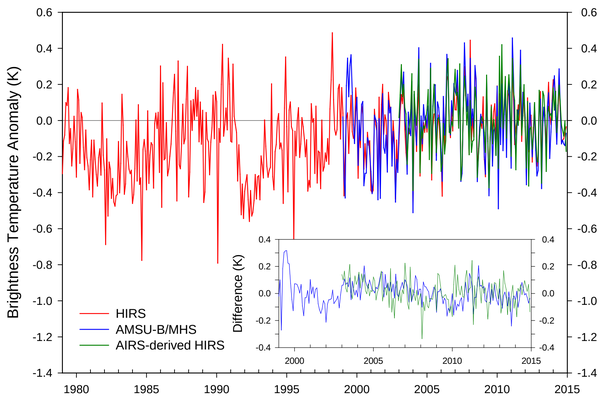

Figure 1: Time series of monthly mean brightness temperature anomalies averaged over 60ºS-60ºN for HIRS channel 12, AMSU-B/MHS 183.31±1 GHz channel and AIRS-derived HIRS channel 12. The inset displays difference time series (blue: AMSU-B/MHS minus HIRS, green: AIRS minus HIRS).

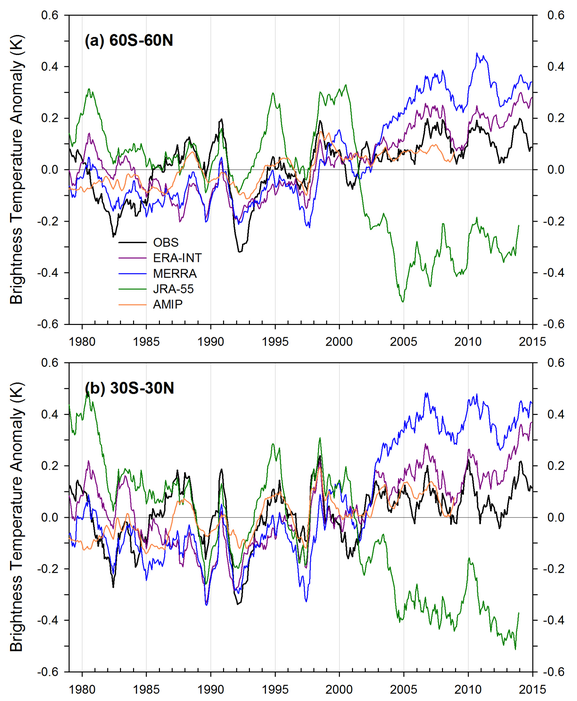

Figure 2: Time series of domain-averaged monthly mean HIRS channel 12 brightness temperature anomalies simulated from ERA-Interim, MERRA, JRA-55 and climate models for CMIP5 AMIP simulations for the period 1979-2008: (a) 60ºS-60ºN and (b) 30ºS-30ºN. The black lines denote the HIRS observations, and the orange lines represent the multi-model ensemble mean.

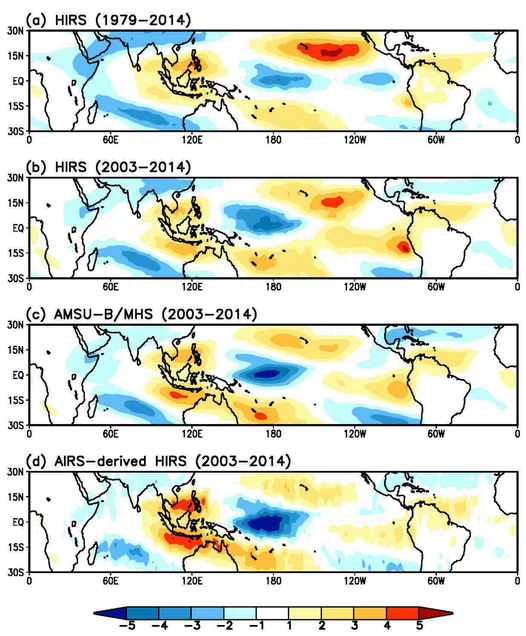

Figure 3: Spatial distribution of the leading EOF mode for brightness temperatures over the tropics: (a) HIRS channel 12 for the period 1979-2014, (b) HIRS channel 12 for the period 2003-2014, (c) AMSU-B/MHS 183.31±1 GHz channel for the period 2003-2014, and (d) AIRS-derived HIRS channel 12 for the period 2003-2014.

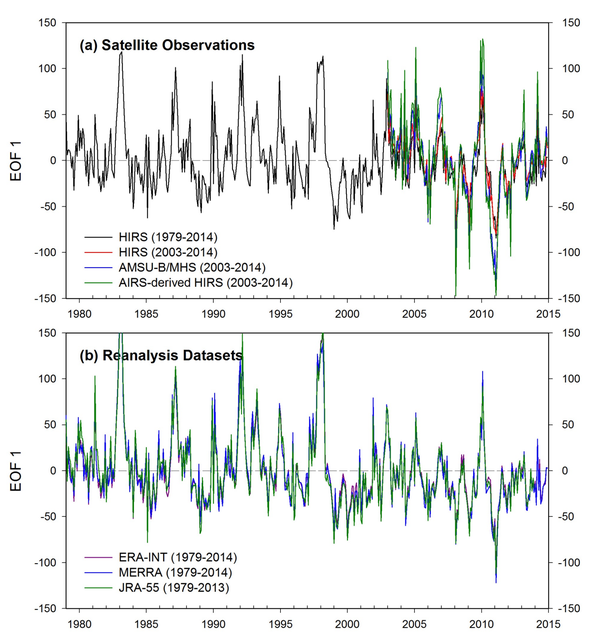

Figure 4: Principal component of the leading EOF mode over the tropics: (a) satellite observations and (b) simulated HIRS channel 12 brightness temperatures from reanalysis data sets.

3. Long-term Variability

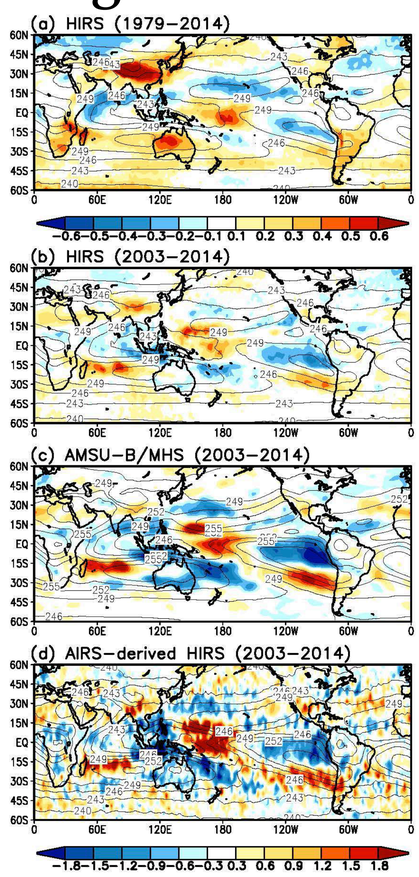

Figure 5: Trends of brightness temperatures: (a) HIRS channel 12 for the period 1979-2014, (b) HIRS channel 12 for the period 2003-2014, (c) AMSU-B/MHS 183.31±1 GHz channel for the period 2003-2014, and (d) AIRS-derived HIRS channel 12 for the period 2003-2014. The unit is in K decade^{-1}. Contours represent the annual mean brightness temperatures (unit: K).

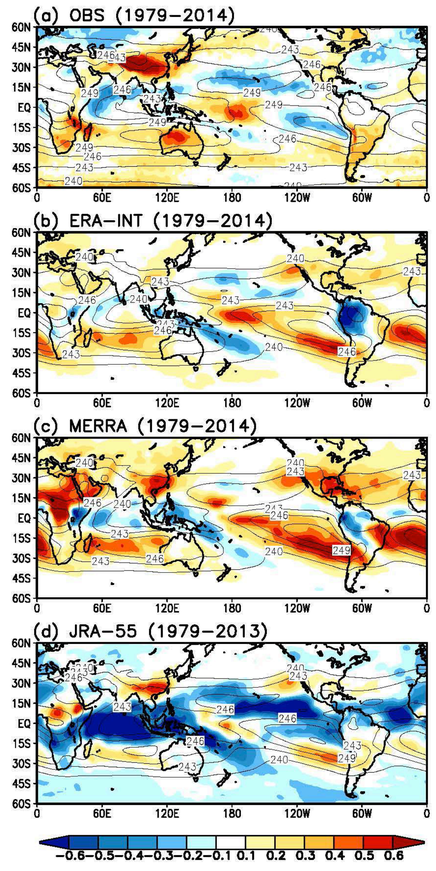

Figure 6: Trends of satellite-observed and reanalysis-simulated HIRS channel 12 brightness temperatures: (a) observations for the period 1979-2014, (b) ERA-Interim for the period 1979-2014, (c) MERRA for the period 1979-2014, and (d) JRA-55 for the period 1979-2013. The unit is in K decade^{-1}. Contours represent the annual mean brightness temperatures (unit: K).

Table 1: The linear least-squares trend (unit: K decade^{-1}) and ±2 standard errors of the linear trend for satellite-observed brightness temperatures.

	HIRS Channel 12		AMSU-B/MHS 183.31 ± 1 GHz	AIRS-derived HIRS Channel 12
Period	1979-2014	2003-2014	2003-2014	2003-2014
60ºS-60ºN	0.063 ± 0.022	0.038 ± 0.074	-0.055 ± 0.090	-0.020 ± 0.081
30ºS-30ºN	0.039 ± 0.029	0.006 ± 0.108	-0.089 ± 0.125	-0.076 ± 0.138

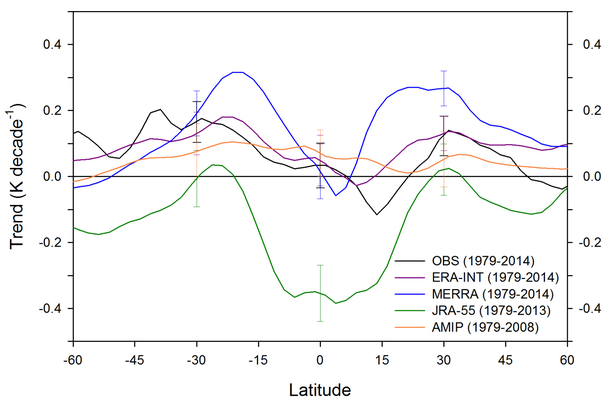

Figure 7: Zonal-mean trends of simulated HIRS channel 12 brightness temperatures from ERA-Interim (1979-2014), MERRA (1979-2014), JRA-55 (1979-2013) and climate models for CMIP5 AMIP simulations (1979-2008). The black line denotes the HIRS observations for the period 1979-2014, and the orange line represents the multi-model ensemble mean. In the case of the observations and the reanalysis data sets, the error bars denote ±2 standard errors of the linear trends. For the AMIP simulations, the error bars indicate ±2 intermodel standard deviation.

4. Summary

- In spite of consistent spatial and temporal patterns of interannual variability among the three products, noticeable discrepancies in the amplitude of regional trends are observed due to differences in cloud screening. The trends over tropical or near-global spatial scales are however found to be consistent among the three products, suggesting their credibility for documenting long-term changes in UTWV.
- On decadal time-scales, both reanalysis data sets and the multi-model mean have difficulty in capturing the observed moistening of climatologically dry regions of the subtropics, although the model-simulated trends are more consistent with the HIRS measurements than the reanalysis data.

Acknowledgments

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