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Vertical profiles of tropical temperature trends: comparing satellite-based radio occultation data with CMIP6 climate models

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In the tropics, the upper troposphere warms faster than the lower troposphere and the surface in response to increased greenhouse gas concentrations. This differential warming is a robust feature in climate models. High-quality observational datasets confirm the stronger warming at higher altitudes, but limitations in the observing systems have made it difficult to accurately characterize the vertical structure of observed temperature trends in the tropics. Additionally, the low vertical resolution of most satellite-based data records with a global coverage further complicate the comparison of climate models and observations.

We have analyzed the vertical structure of tropical temperature trends using satellite-based Radio Occultation (RO) data from EUMETSAT's RO Meteorology Satellite Application Facility (ROM SAF) for the period from 2002 to 2024. These data are compared with the CMIP6 ensemble of about 250 members from more than 30 models using combined historical and scenario runs under SSP2-4.5. The RO data provides a stable climate reference, combining global coverage with high vertical resolution, and has only recently reached the length necessary for trend analysis. Our comparison confirms the warming biases in the CMIP6 models previously reported in the literature – the models warm faster than the observations in the upper troposphere. In contrast, they cool faster in the stratosphere than the RO data. Furthermore, we demonstrate that there are substantial differences in the vertical trend structure between the CMIP6 models and the RO data: the models show peak trends in the middle to upper troposphere around 250-300 hPa, while the RO data have maximum trends in the lower stratosphere, around 50-100 hPa. In this presentation, we describe the characteristics of the RO climate data records and discuss the significance of the RO-CMIP6 differences, considering the uncertainties of the observations and the spread amongst the CMIP6 models.