Impact of Different Processes on Tropical Lower-Stratospheric Water Vapor as Simulated by Climate Models

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Motivation

Previous studies (e.g. Fueglistaler et al. 2009), show Tropical-Tropopause Layer (TTL) temperature to regulate water vapor ([H₂O]ₜₐₚ) entering the tropical stratosphere. Tropospheric warming (ΔT), Brewer-Dobson Strength (BDC), and the Quasi-Biennial Oscillation (QBO) directly influence TTL temperature, indirectly influencing [H₂O]ₜₐₚ. We show that a multiple linear regression can be used to test ΔT, BDC, and QBO influence on [H₂O]ₜₐₚ simulated by a set of chemistry-climate models (CCMs).

Data and Methodology

1. We analyze 21st century (2000-2097) CCM output from the CCMVal-2 and CCM1-1 Experiments
2. Similar to Dessler et al. (2013,2014), We use a linear regression (shown below) to reconstruct [H₂O]ₜₐₚ from models during the entire 21st century
3. To evaluate model reliability, we compare regressions of 10-year segments to observational-based regressions analyzed in Dessler et al. (2014)

Decadal Analysis

80-hPa Water Vapor

[H₂O]ₜₐₚ = β₀ + β₁ΔT + β₂BDC + β₃QBO + ϵ

500-hPa Temperature

Linear Regression

Sample Regression of MRI [H₂O]ₜₚ

21st Century Analysis

Coefficient Comparison

- We use a best-fit linear approximation to compare magnitude of the century and decadal regression coefficients and to approximate where ERAI (square) and MERRA (diamond) century coefficients would fall
- ΔT coefficients from the 21st century analysis are larger than those from the decadal analysis
- BDC coefficients from the 21st century analysis are larger than those from the decadal analysis
- QBO coefficients from the 21st century analysis are smaller than those from the decadal analysis

Decadal adjusted R² values generally overlap, or are larger than, observational-based regression adjusted R² values

Generally, CCM ΔT coefficients fall within confidence of the observational-based estimates
Most CCM BDC coefficients fall within confidence of the observational-based estimates
For all CCMs, QBO coefficients are smaller than the observational-based estimates

Summary

- In both the 21st century and decadal analyses, a linear regression model can be used to benchmark variability in [H₂O]ₜₐₚ by the TTL, as simulated by a set of CCMs
- For all CCMs, [H₂O]ₜₚ increases in response to a warming troposphere
- For most CCMs, [H₂O]ₜₚ decreases in response to a strengthening BDC
- For all CCMs, the QBO has little impact on [H₂O]ₜₚ
- In general CCM linear regression coefficients compare well to the observational-based regression coefficients, with the exception being the QBO

References:

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