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 ($[H_2O]_{entry}$) entering the tropical stratosphere. Tropospheric warming (ΔT), Brewer-Dobson Strength (BDC), and the Quasi- Biennial Oscillation (QBO) directly influence TTL temperature, indirectly influencing $[H_2O]_{entry}$. We show that a multiple linear regression can be used to test ΔT, BDC, and QBO influence on $[H_2O]_{entry}$ 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 CCMI-1 Experiments
2. Similar to Dessler et al. (2013,2014), We use a linear regression (shown below) to reconstruct $[H_2O]_{entry}$ 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)

80-hPa Water Vapor ↑ ($[H_2O]_{entry}$)

80-hPa Net-Radiative Heating ↑ (BDC)

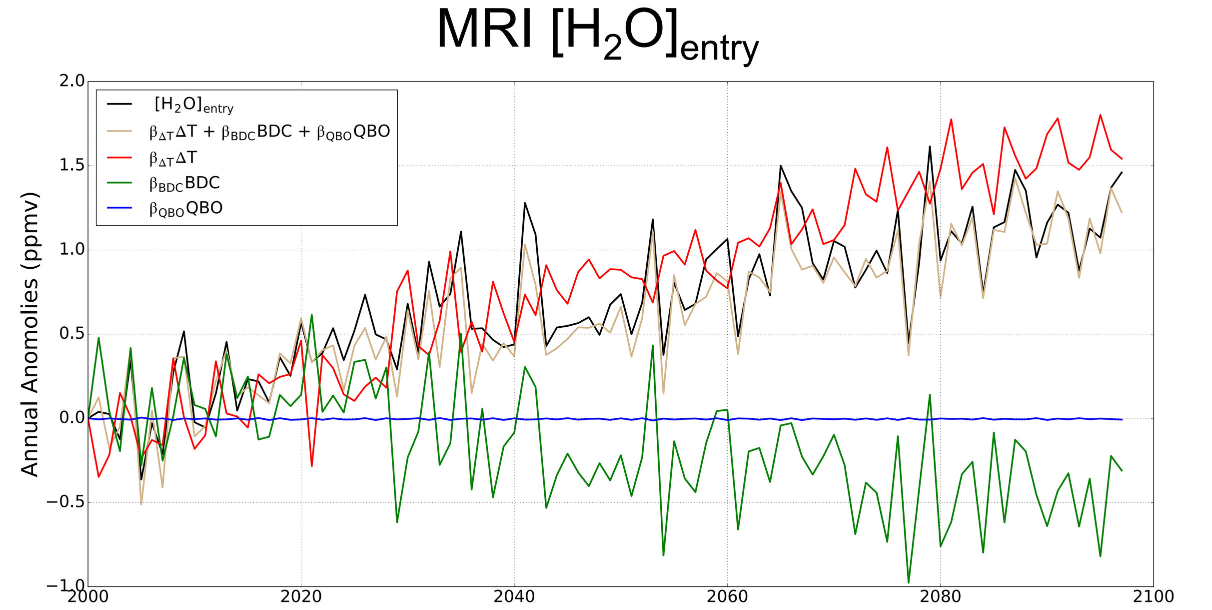
$$[H_2O]_{entry} = \beta_0 + \beta_{\Delta T}\Delta T + \beta_{BDC}BDC + \beta_{QBO}QBO + \epsilon$$

↓ 500-hPa Temperature (ΔT)

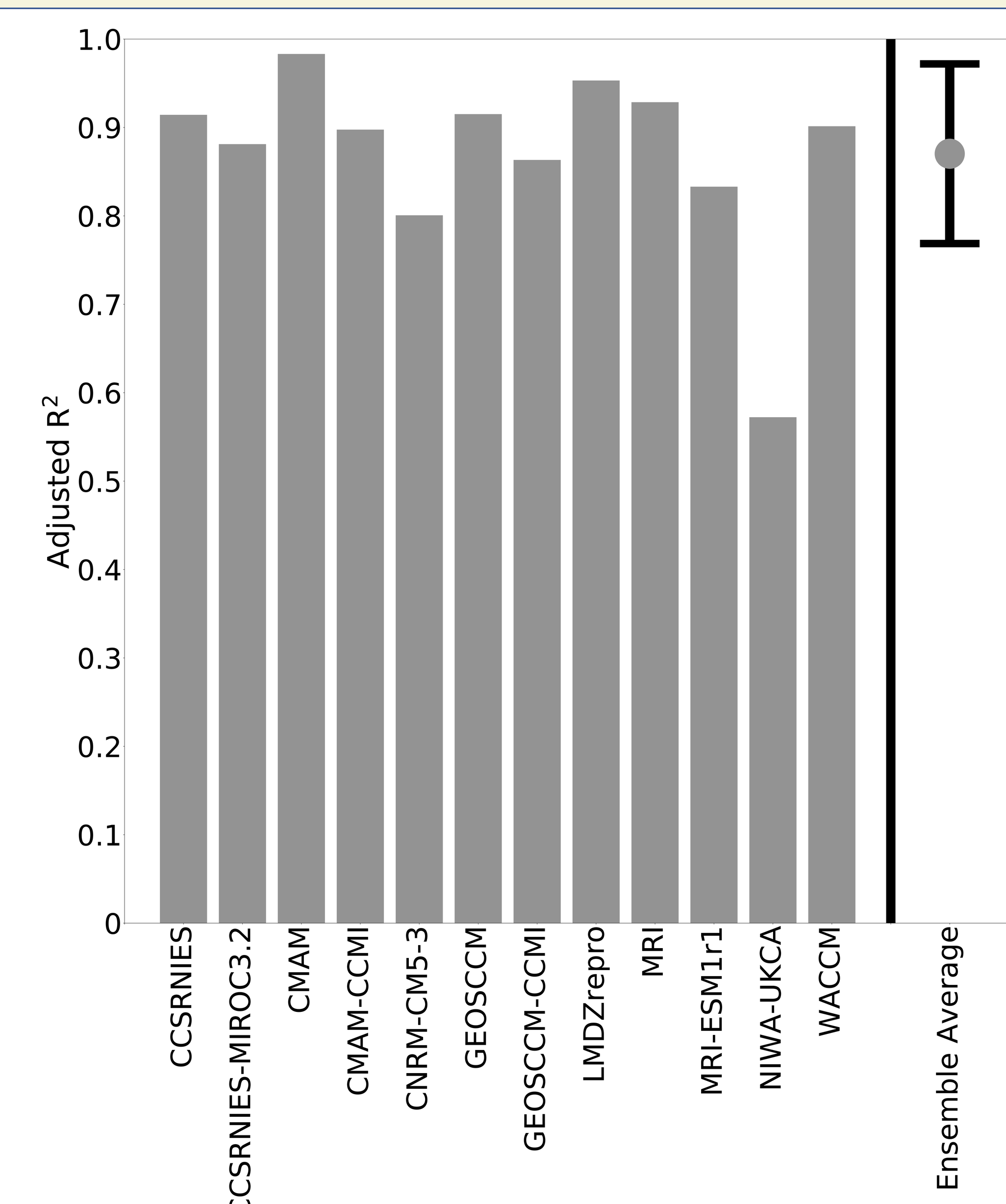
↓ 50-hPa Zonal Wind (QBO)

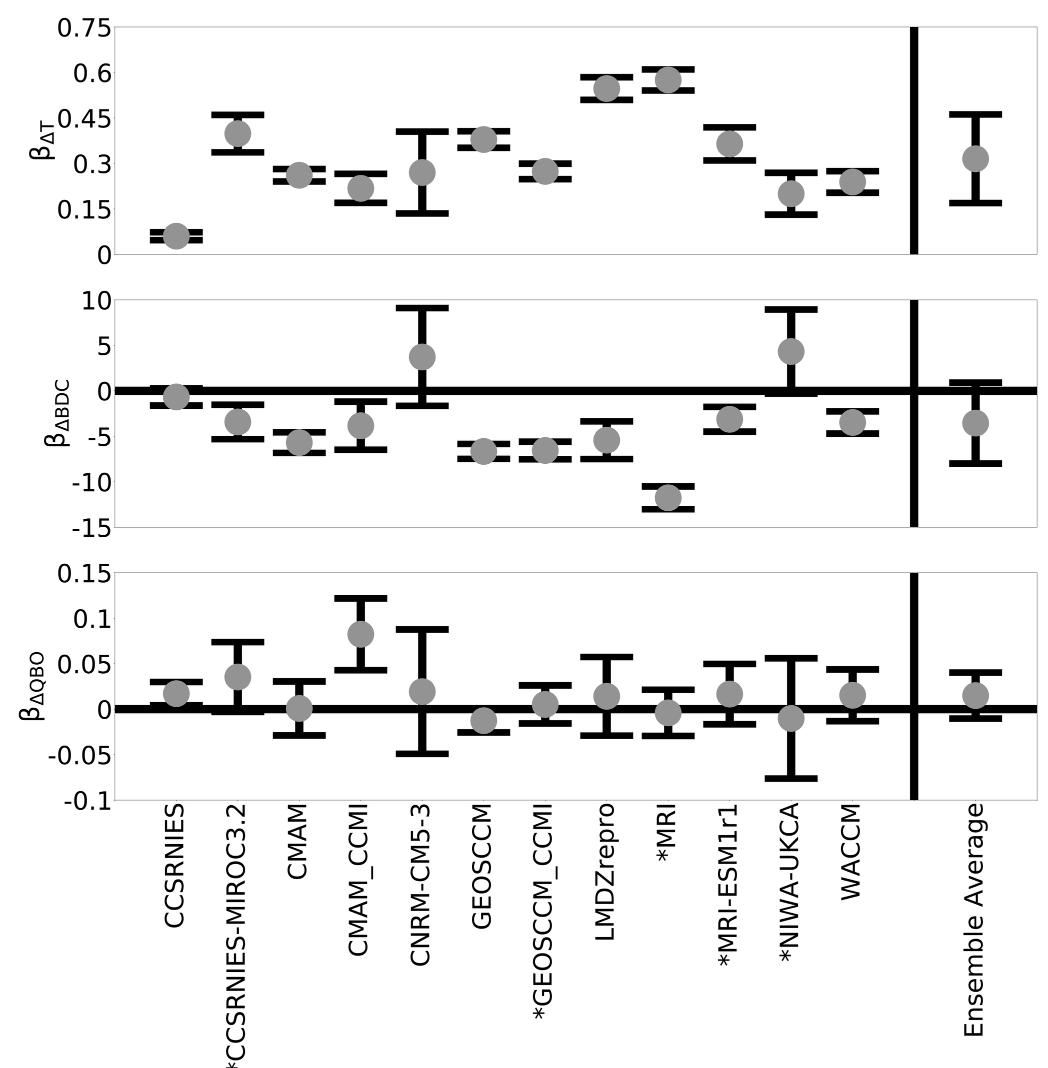
Linear Regression

Sample Regression of MRI $[H_2O]_{entry}$



21st Century Analysis

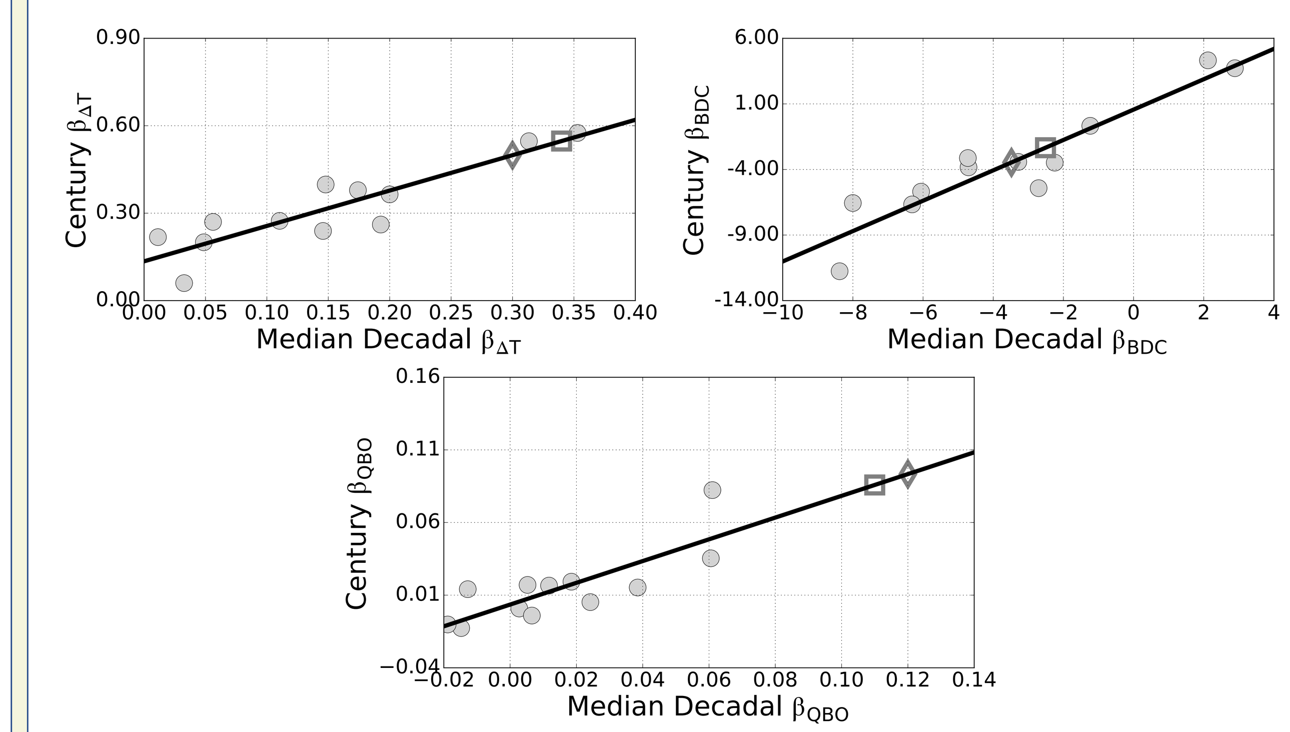




- For most CCMs, adjusted R^2 are larger than 0.8, suggesting a linear regression can effectively reproduce $[H_2O]_{entry}$
- In all models, $[H_2O]_{entry}$ increases with increasing ΔT
- For most CCMs, $[H_2O]_{entry}$ decreases with a strengthening BDC
- Among CCMs simulating a QBO, there is not much of a response in $[H_2O]_{entry}$ to changes in the QBO

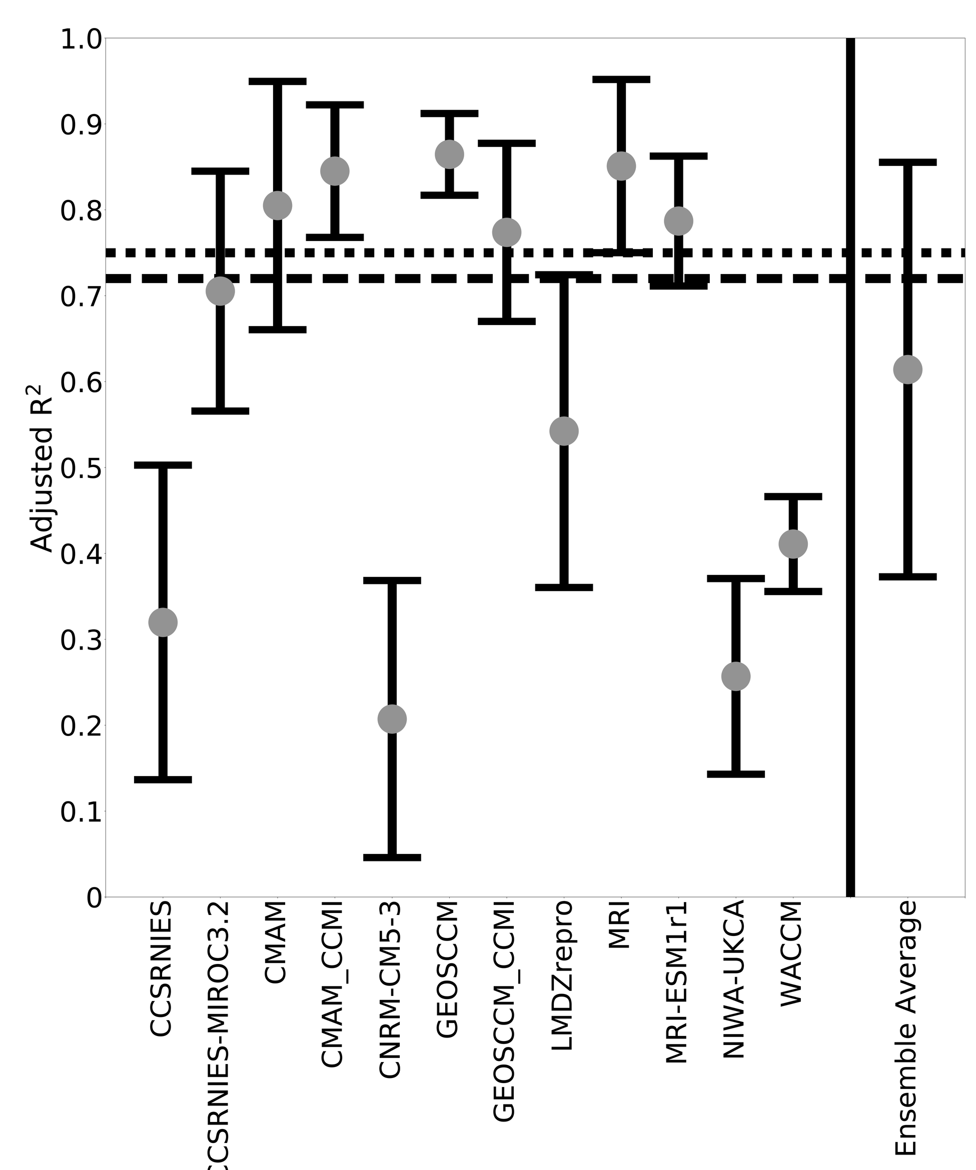
Coefficient Comparison

- 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



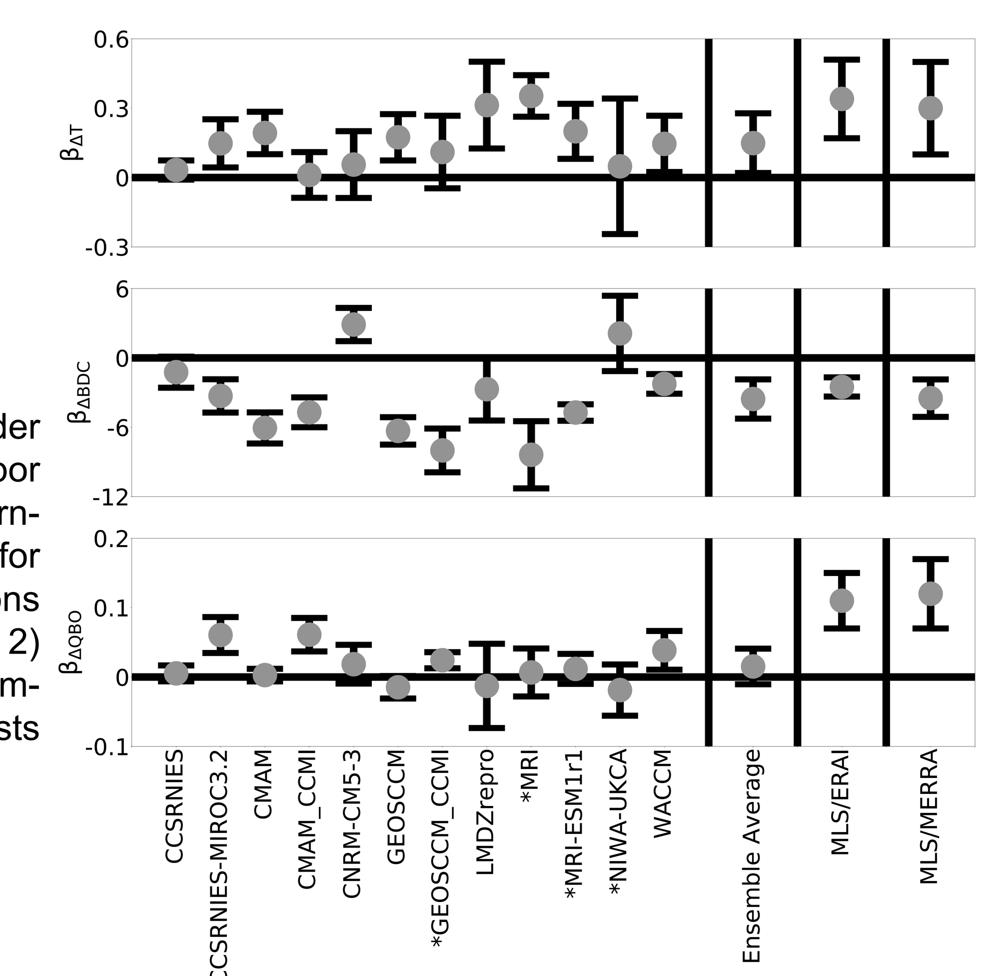
- ΔT coefficients from the 21st century analysis are larger than those from the decadal analysis
- BDC coefficients from the 21st century analysis are larger than those from the decadal analysis
- QBO coefficients from the 21st century analysis are smaller than those from the decadal analysis

Decadal Analysis



Observational-Based Regressions

Aura Microwave Limb Sounder (MLS) 82-hPa water vapor regressed against: 1) Modern-Era Retrospective Analysis for Research and Applications reanalysis (MERRA) and 2) European Centre for Medium-Range Weather Forecasts interim (ERAI) processes



- Decadal adjusted R^2 values generally overlap, or are larger than, observational-based regression adjusted R^2 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 then the observational-based estimates

Summary

- In both the 21st century and decadal analyses, a linear regression model can be used to benchmark variability in $[H_2O]_{entry}$ by the TTL, as simulated by a set of CCMs
- For all CCMs, $[H_2O]_{entry}$ increases in response to a warming troposphere
- For most CCMs, $[H_2O]_{entry}$ decreases in response to a strengthening BDC
- For all CCMs, the QBO has little impact on $[H_2O]_{entry}$
- In general CCM linear regression coefficients compare well to the observational-based regression coefficients, with the exception being the QBO

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