Background and Introduction

The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report gives rise to Earth’s surface air temperature increase from 1951-2012 as ~0.12 °K/decade and restated connection to increasing carbon dioxide (CO2) surface emissions. Many studies have ascertained the corresponding effects of this CO2 increase in the upper atmosphere including Roble and Dickinson [1989] where global mean model simulations indicate a cooling of the thermosphere related to increasing CO2; prompting subsequent research related to CO2 induced changes in thermospheric temperature and density. For the first time, a long-term transient simulation was done with the Community Earth System Model (CESM) Whole Atmosphere Community Climate Model eXtended (WACCM-X) (Liu et al., 2010). Here, we evaluate upper atmosphere changes in temperature and density for the period of this simulation, 1955-2010.

Model Simulation and Analysis Description

WACCM-X is a comprehensive numerical model of the Earth's atmosphere spanning a range of altitudes from the surface to the upper thermosphere. Electrodynamics and full ionosphere are under development.

- Simulation period: 1955-2010, with time varying CO2, data ocean and land at the lower boundary and realistic solar forcing at upper boundary
- Analysis procedure:
  - Area weighted yearly global mean: spherical cap method
  - Data on two vertical coordinates: pressure, geometric altitude (interpolated)
  - Multi-linear regression analysis: remove solar cycle effects for CO2, temperature, and density using independent variables F10.7 solar flux and ap index of solar related geophysical activity
  - Linear fit to residuals of regression: gives changes for entire period and one subset period

Analysis Results

- Comparison of trends on different vertical coordinates:
  - Temperature: negative on pressure, positive when interpolated to altitude. (see Akmaev and Fomichev, 1998 for a discussion)
  - Comparison of trends for the two time periods: temperature: similar in lower thermosphere but larger than expected in mid-upper thermosphere, even having an opposite sign
  - Density: Similar to temperature but trend does not change sign

Comparison To Previous Results

- For a more complete evaluation of WACCM-X thermospheric trends, it is reasonable to perform a qualitative, if not quantitative, comparison with results from previous studies.

Summary

- WACCM-X 1955-2010 simulated surface air temperature trend very similar to IPCC (0.145 °K/decade vs. 0.12 °K/decade), giving initial confidence in the simulation results
- In the upper atmosphere, temperature and density trend differences when using different vertical coordinates (pressure vs. altitude) and trend differences when using different time periods (entire 1955-2010 vs. subset 1970-2000 period) both present a challenge when interpreting the results
- For early part of 1955-2010 period, lack of thermospheric observations prevents formulating a conclusive idea how realistically the model represents trends but comparisons with previous studies for 1970-2000 period are encouraging.
- Simulations from other models which include early part of 1955-2010 period, would be of great value in examining these WACCM-X results
- Further work will include investigation of differences between the two time periods, evaluation of analysis method and analysis statistical accuracy, and, down the road, examining these trends after adding electrodynamics and a full ionosphere to WACCM-X.