Evaluation of WACCM simulations of winter 2004-2005 Arctic ozone
Matthias Brakebusch¹, Cora E. Randall¹, Douglas E. Kinnison², Simone Tilmes², Michelle L. Santee³, Gloria L. Manney³,⁴
¹Laboratory for Atmospheric and Space Physics & Dept of Atmospheric and Oceanic Sciences, University of Colorado at Boulder, USA
²Atmospheric Chemistry Division, National Center for Atmospheric Research, Boulder, Colorado, USA
³Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, USA
⁴also at New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA

SUMMARY
The work presented here evaluates polar stratospheric ozone (O3) simulations of the Community Earth System Model (CESM) Whole Atmosphere Community Climate Model (WACCM) component set for the Arctic winter of 2004-2005 by comparing to the Earth Observing System Microwave Limb Sounder (MLS). We use the Specified Dynamics version of WACCM (SD-WACCM), in which temperatures and winds are nudged to meteorological assimilation analysis results.

Results:
- Modeled vortex-averaged O3 and related constituents for December 2004 through March 2005 generally compare well to observations [Fig. 2]
- We attribute the SD-WACCM O3 overestimate to too much simulated descent early in the winter, too much mixing across the vortex edge later in the winter, and too little heterogeneous processing of halogens [Fig. 2]
- Errors in transport and mixing result in excess transport of O3-rich air into the lower stratospheric polar vortex [Fig. 3]
- Errors in heterogeneous processing result in underestimate of activated chlorine, thus too little chemical ozone loss [Fig. 2]
- Too much depletion of nitric acid, suggesting overestimate in production of PSCs [Fig. 4]
- Even though the previous result would lead to excess availability of aerosol surface area for heterogeneous reactions, underprediction of ClONO2 limit such reactions [not shown]
- 1.1 ppmv of inferred ozone loss on average and up to 1.6 ppmv locally [Fig. 5 & 6]
- O3 loss based on the pseudo-passive ozone subtraction method similar to that based on tracer-tracer correlations [Fig. 7]
- O3 loss in good agreement with previous independent results for the Arctic winter of 2004-2005 [Fig. 8]

1. METHOD
- Initialization on 1 Dec (O3, N2O, HNO3, HCl, and H2O)
- Three model simulations (nudged with u, v, T, P_psc):
  - full-ozone chemistry
  - gas-phase-ozone chemistry only (pseudo-passive O3)
  - 1.5K T bias for Cl activation due to heterogen. chemistry
- Polar vortex averaging (SPV > 1.4-10^-5s^-1)

2. EVALUATION OF SD-WACCM
Fig. 2: Evolution of vortex averaged MLS (left), SD-WACCM (center) and their difference (right).
Difference = SD-WACCM - MLS, gray areas indicate no data inside the polar vortex or missing data, white lines are warming events, hatched areas are not statistically significant

3. COMPARISON OF MEASURED AND MODELED N2O
Fig. 3: Spatial distribution of N2O at 450 K for one day each month throughout the season with polar vortex edge line contour. The final warming began Mar ~10 [Manney et al., 2006].
Model overestimates mixing processes across vortex edge late in the winter.

4. COMPARISON OF MEASURED AND MODELED HNO3
Fig. 4: Partial columns (400 K – 700 K) of polar vortex averaged modeled and observed gas-phase HNO3.
Modeled condensed-phase HNO3 (~PSCs) and modeled total HNO3 MLS temperature at 550 K is superimposed.

CONCLUSIONS
- SD-WACCM is valid for inferring O3 loss from observations.
- More accurate simulation of O3 loss in WACCM requires further investigation of chlorine partitioning and PSC particle sizes.
- Equivalent analysis for Antarctic winter needed to better investigate mixing and descent.
- Future plans include O3 loss calculations for all Arctic and Antarctic winters since 2004.

References:

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Contact: brakebusch@lasp.colorado.edu