The Effects of Interactive Stratospheric Chemistry on Antarctic and Southern Ocean Climate Change in an AOGCM

Feng Li$^1,2$, Paul Newman$^2$, Steven Pawson$^2$, Darryn Waugh$^3$

$^1$Universities Space Research Association  
$^2$NASA Goddard Space Flight Center  
$^3$Johns Hopkins University

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Antarctic Ozone Hole is the Main Driver of SH Climate Change

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Surface fluxes, Ekman transport and MLD changes act in concert to produce SST response. Eddy heat fluxes act in the opposite sense.

Thompson et al., Nature Geoscience, 2011
Known Issues of Simulations with Prescribed Ozone

- Prescribed ozone lacks zonal asymmetries.
- Prescribed ozone underestimates Antarctic ozone depletion.
- Prescribed ozone does not have the diurnal cycle of the mesospheric ozone.
CMIP Models Underestimate Poleward Shift and Intensification of SH Westerlies

- Poleward shift and intensification of the SH westerlies has important implications for the Southern Ocean circulation.

- CMIP models significantly underestimate the strengthening of the surface westerly wind-stress.
Motivations

1. Can we improve the modeled SH wind-stress change by using interactive stratospheric chemistry?

2. What are the impacts of interactive chemistry on simulations of Southern Ocean circulation change?
GEOS-5

• Goddard Earth Observing System, Version 5 (GEOS-5)
• Coupled ocean version, Modular Ocean Model (MOM4) and LANL CICE sea ice model
• Atmosphere model resolution: 2.5°×2°, 72 levels, 0.01hPa model top
• Ocean model resolution: 360X200, 50 levels
• Two methods to represent stratospheric ozone:
  (1) **AOCCM**: Interactive stratospheric chemistry
  (2) **AOGCM**: Prescribed monthly and zonal-mean ozone
Experiment Design

• A pair of ensemble transient simulations 1960-2010: one with interactive chemistry, and the other with prescribed ozone
• The prescribed ozone simulations use outputs from the interactive chemistry simulations
• 4 members for each ensemble
Prescribed ozone underestimates ozone depletion forcing.
Prescribed ozone underestimates ozone depletion forcing

Full Chemistry minus Prescribed Ozone

Zonal Standard Deviation Full Chemistry

Ozone 65-90S 50hPa 1990-2010

Zonal Standard Deviation Prescribed Ozone
Prescribed ozone underestimates Antarctic climate change 1979-2010

**Surface Zonal Wind Trend 55-70S**

- **Full Chemistry**
- **Prescribed Ozone**

Pressure (hPa) | Month |
---|---|
1000 | J A S O N D F M A M J |
100 | J A S O N D F M A M J |
10 | J A S O N D F M A M J |
1 | J A S O N D F M A M J |

T 65°-90°S (K/decade)

U 55°-70°S (ms/decade)
Prescribed ozone underestimates Antarctic climate change
Wind-Stress Trends and the Southern Annular Mode

Surface Zonal Wind-Stress Climatology & Trend

Zonal Wind-Stress Trend & SAM Regression

Trends in Max Strength (Pa/decade)

- Full Chemistry
- Prescribed Ozone
Southern Ocean Currents

Zonal Current Trends

Surface

Full Chemistry
Prescribed Ozone

Full Chemistry

Prescribed Ozone

Meridional Current Trends

Surface

Full Chemistry
Prescribed Ozone

Full Chemistry

Prescribed Ozone
Meridional Overturning Circulation: Nov-Jan

Full Chemistry

Prescribed Ozone
Conclusions

• Compared to the interactive ozone simulations, the prescribed ozone simulations underestimate the strengthening of the SH westerly jet and surface wind-stress.

• Due to weak wind-stress changes, the prescribed ozone simulations have smaller trends in Southern Ocean circulation than the interactive ozone simulations.