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

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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.

- Increased eastward wind/current
- Increased westward wind/current
- Heat fluxes
- Eddy response

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.

Swart and Fyfe, 2012
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

Full Chemistry minus Prescribed Ozone

Ozone 65-90S 50hPa 1990-2010

Pressure (hPa)

Month

0.00

1000

10

100

1

1000

1.0

1.5

2.0

2.5

3.0

3.5

(ppm)

Month

Full Chemistry

Prescribed Ozone
Prescribed ozone underestimates ozone depletion forcing

Full Chemistry minus Prescribed Ozone

Ozone 65-90S 50hPa 1990-2010

Zonal Standard Deviation Full Chemistry

Zonal Standard Deviation Prescribed Ozone
Prescribed ozone underestimates Antarctic climate change 1979-2010
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)
Southern Ocean Currents

Zonal Current Trends

Surface

Full Chemistry
Prescribed Ozone

Depth (m)

Latitude

(cm/s/decade)

-0.4 -0.2 0.0 0.2 0.4 0.6 0.8

-80 -70 -60 -50 -40 -30

Full Chemistry
Prescribed Ozone

Meridional Current Trends

Surface

Full Chemistry
Prescribed Ozone

Depth (m)

Latitude

(cm/s/decade)

-0.4 -0.2 0.0 0.2 0.4 0.6 0.8

-80 -70 -60 -50 -40 -30
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.