Exploring SST and sea-ice response to Antarctic ozone loss in the GISS coupled climate model

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1. Background
2. Present first results from ozone hole response function experiments with GISS Model E
3. Focus on seasonal cycle
4. Conclude

Thanks also to
Doug Kinnison, Yavor Kostov
& Bill McKenna
Predicted/Projected SST changes around Antarctica (50 to 70S) due to Ozone and GHG variations

Predictions depend, of course, on the form of the Climate Response Functions

\[
SST = \int_0^t G(t - t') \frac{dF}{dt}(t') dt'
\]

For discussions of the response of the SO (SST and sea-ice) to ozone forcing, see:

Sigmond and Fyfe, 2010,
Bitz and Polvani, 2012,
Smith, Polvani et al (2012)
Ferreira et al, (2015)
Purich, Cai, England and Cowan (2016)
Kostov et al (2016)
Holland et al (2016)
Inferred response of Southern Ocean SST to a step increase in SAM (from control runs)

Kostov et al, 2016

Seeking to engage modeling groups to map out Ozone response functions

MITgcm, CCSM, GFDL-JH

Will Seviour

Report on experiments with new GISS coupled model
GISS ModelE Configuration: beta-CMIP6-ish

CMIP5 resolution (144x90L40 Atm., 288x180L32 Ocn.) + updates to

Ocean (R)
- Mesoscales: 3D K, GM in thickness-diffusion form
- Diapycnal mixing: tidal dissipation contribution
- Advection: Prather scheme

Atmosphere
- Clouds: new moist convection, treatment of stratiform mixed-phase
- Radiation: improved LW at low WV amounts (high latitudes)
- Boundary Layer: stronger mixing for unstable case

Main impacts on Southern Ocean from
- Mesoscales: reduced ACC transport and reduced open-ocean deep convection. Much improved stratification and sea-ice cycle
- Clouds + ABL: reduced excessive SW absorption

Pre-industrial control is perturbed by a perpetual ozone hole, circa 2000
Pronounced seasonal cycle
Slower subsurface warming trend

Importance of seasonal cycle emphasized in:
Purich, Cai, England and Cowan
Nature Communications, 2016

Enhanced winds in summer
upwell cold water from below

Matt England’s presentation

10-ensemble members

Ensemble mean of anomalies relative to the control

Discuss role of enhanced vertical mixing due to SAM
Summertime

Anomaly in vertical mixing, driven by summertime SAM

300m

57°S

Vertical diffusive heat flux

Zonal-average T anomaly

T anomaly at 75m

3W m$^{-2}$ downwards
Mix vertically, carry warm fresh water to depth and cold salty water to the surface.

\[ k'_v \frac{\partial T}{\partial z}. \]

Anomalous vertical heat diffusion

\[ k'_v \frac{\partial S}{\partial z}. \]

Anomalous mixing acting on mean stratification
$T(z,t)$

$S(z,t)$

Numbers

300m

30 years

300m
Composite of cold SST events

Net surface heat flux

150m

SST

Sea ice declining

30 years

58S

SST

Sea ice cover

58S

month of year

30 years

Sea ice declining
Comparing several models

CCSM

MITgcm
Conclusions (provisional)

In response to a ‘step’ ozone hole

Observe two timescales

Anomalous vertical mixing plays a key role in the seasonal cycle

At the edge of the seasonal ice zone, heat sequestered to depth in the summer is brought to the surface in the wintertime, leading to the demise of sea-ice

On longer timescales, subsurface does not continue to warm but episodically vents to the atmosphere

Purich et al (2016)