Simulating the effects of stratospheric ozone depletion on Antarctic climate

Nathan Gillett, School of Earth and Ocean Sciences, University of Victoria.

David Thompson, Colorado State University.

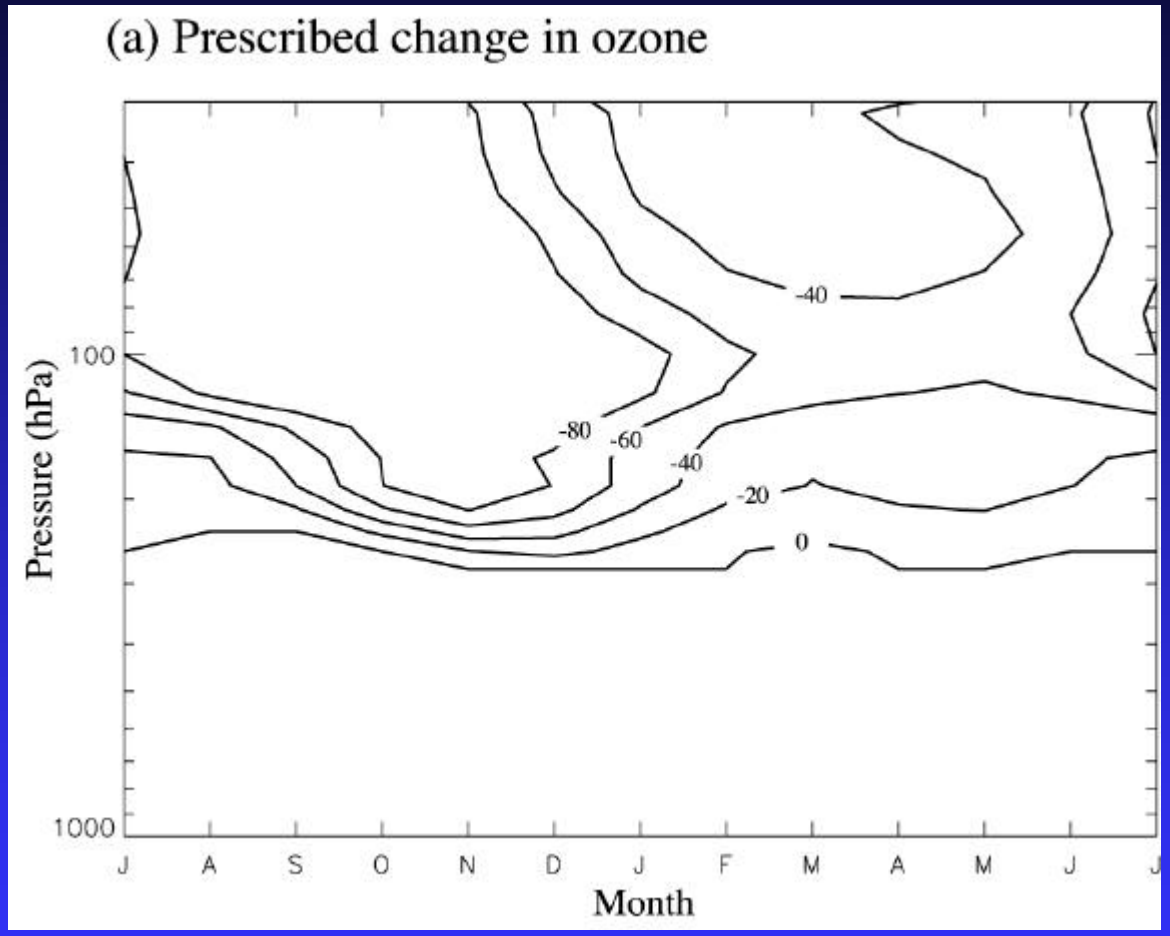
Introduction

- Thompson and Solomon (2002) show that recent climate change over the Antarctic has been dominated by a strengthening of the circumpolar westerly flow.
- Based on the structure and seasonality of the trend, they suggest that it has been caused by stratospheric ozone depletion.
- Here we prescribe stratospheric ozone depletion in a 64-level version of the Unified Model.
- We examine the stratospheric and tropospheric response.

Model

- 64-level version of HadSM3.
- Mixed-layer ocean, thermodynamic and dynamic sea ice, and an atmosphere extending to 0.01 hPa.
- Control ozone: Based on Li and Shine (1995).
- Perturbed ozone: Representative of ~1998, based on WMO (1995) trends.
- All other forcings held fixed.

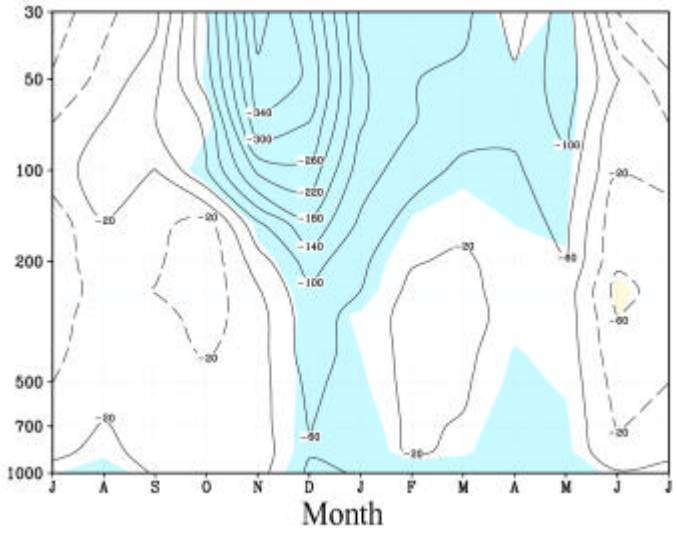
Prescribed ozone change



Prescribed change in ozone at 70°S based on WMO 1995. Ozone is held constant in the troposphere.

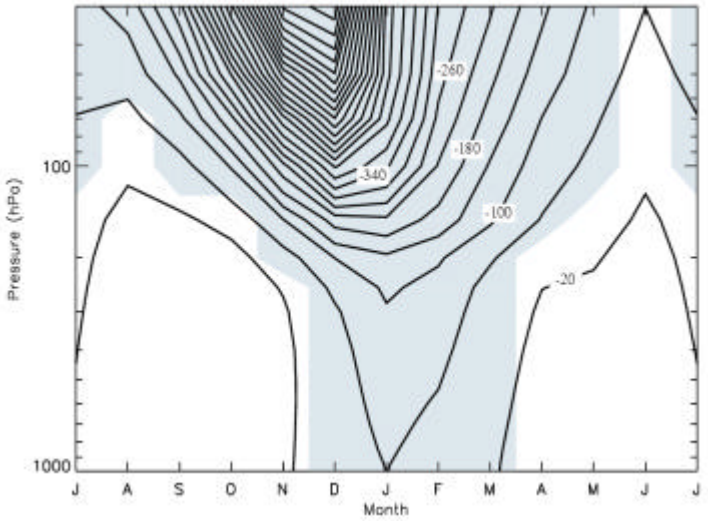
Simulated and observed geopotential height changes

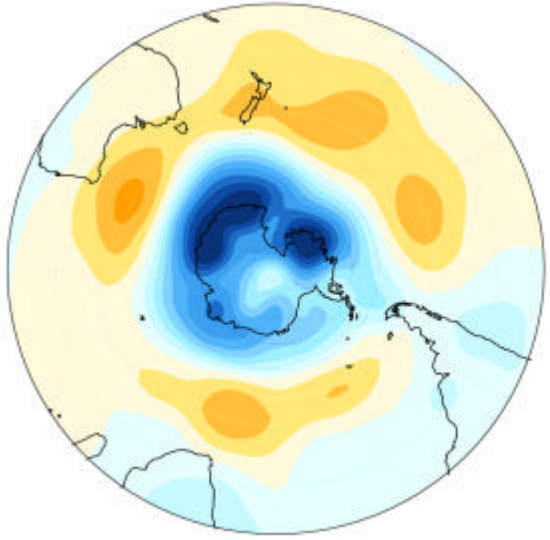
Obs (TS00)



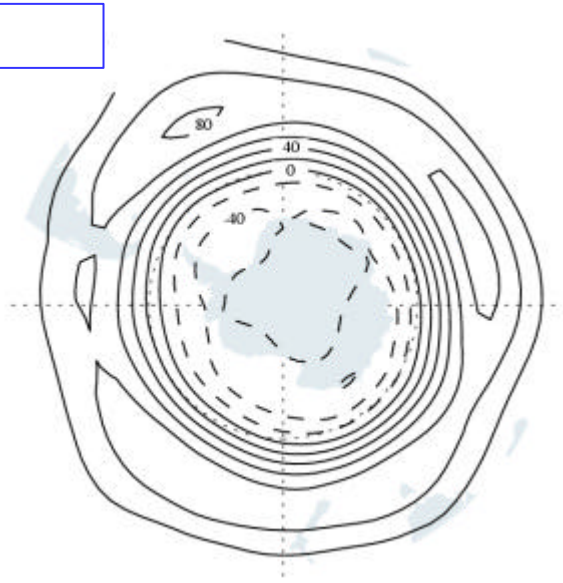
Model

$Z_{65S-90S}$



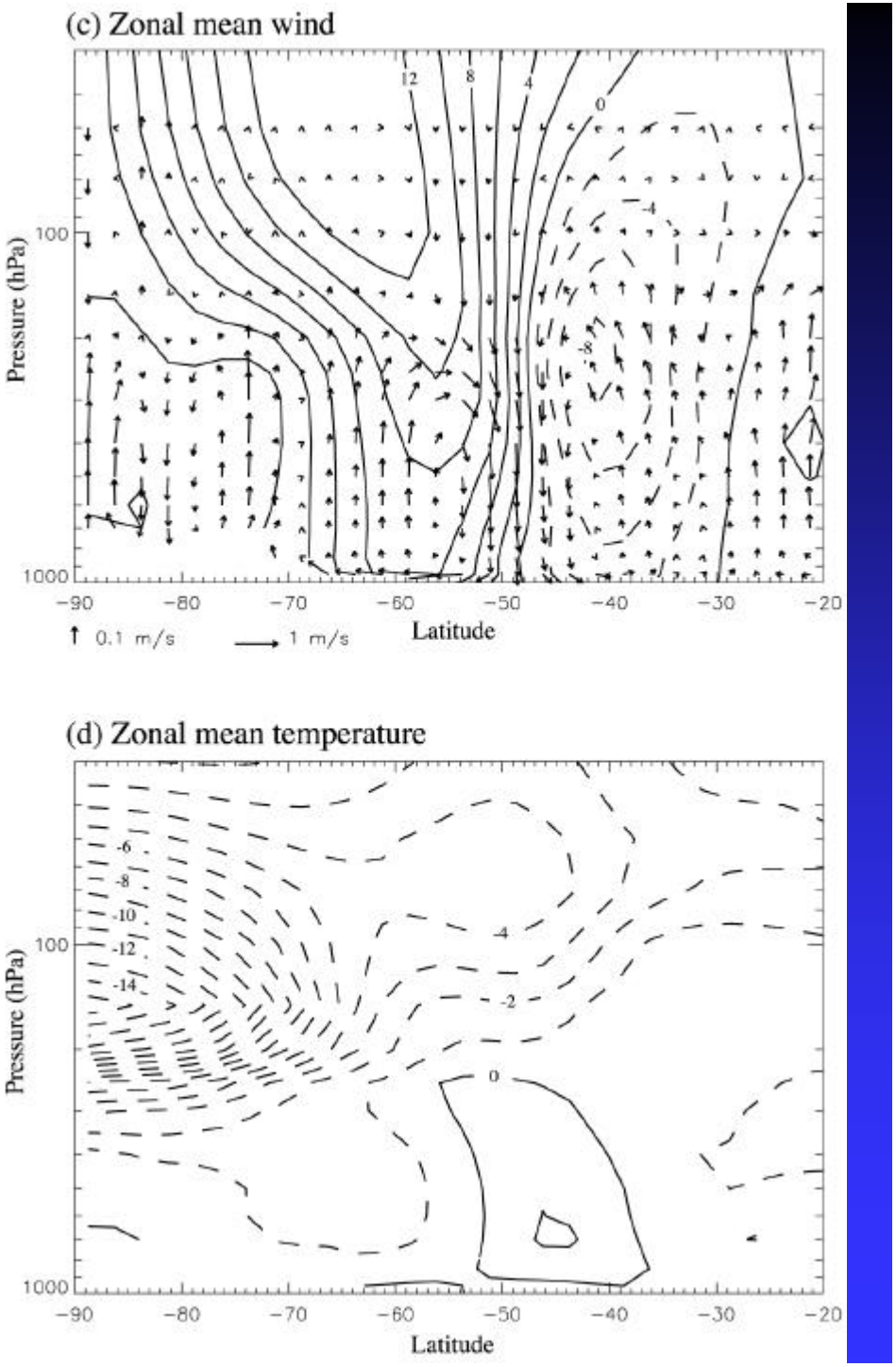


Z500



Dynamics of the response

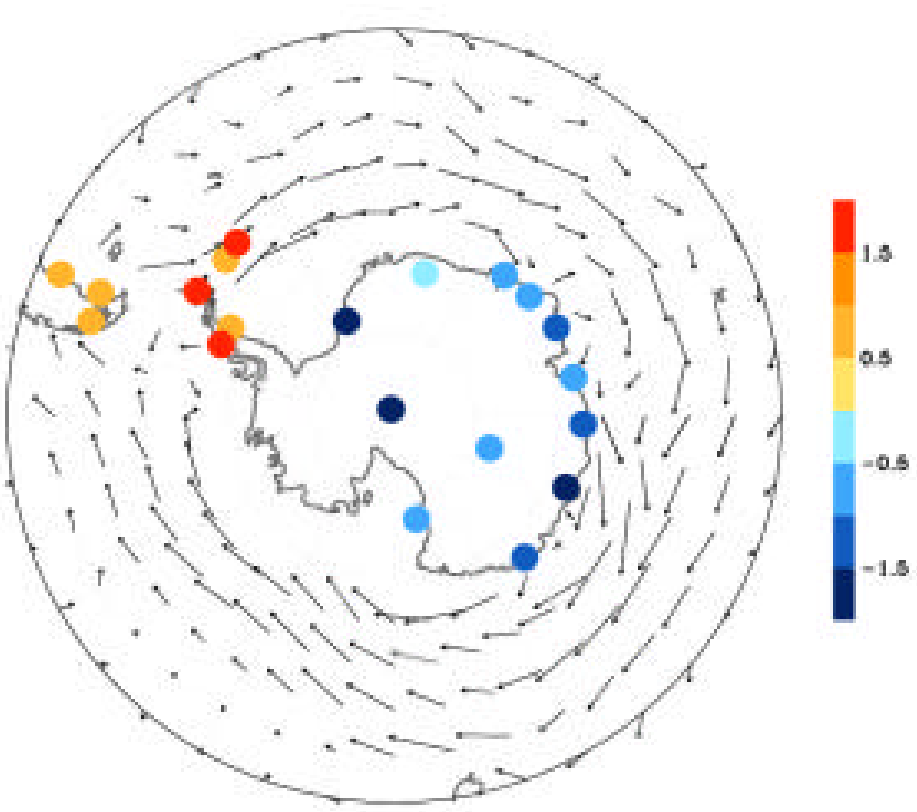
- Cooling of the stratospheric vortex and strengthening and poleward shift of stratospheric jet.
- Induced poleward flux of westerly momentum in the troposphere.
- Thermally-indirect rising motion over the pole causes cooling, and sinking at ~45°S causes warming.

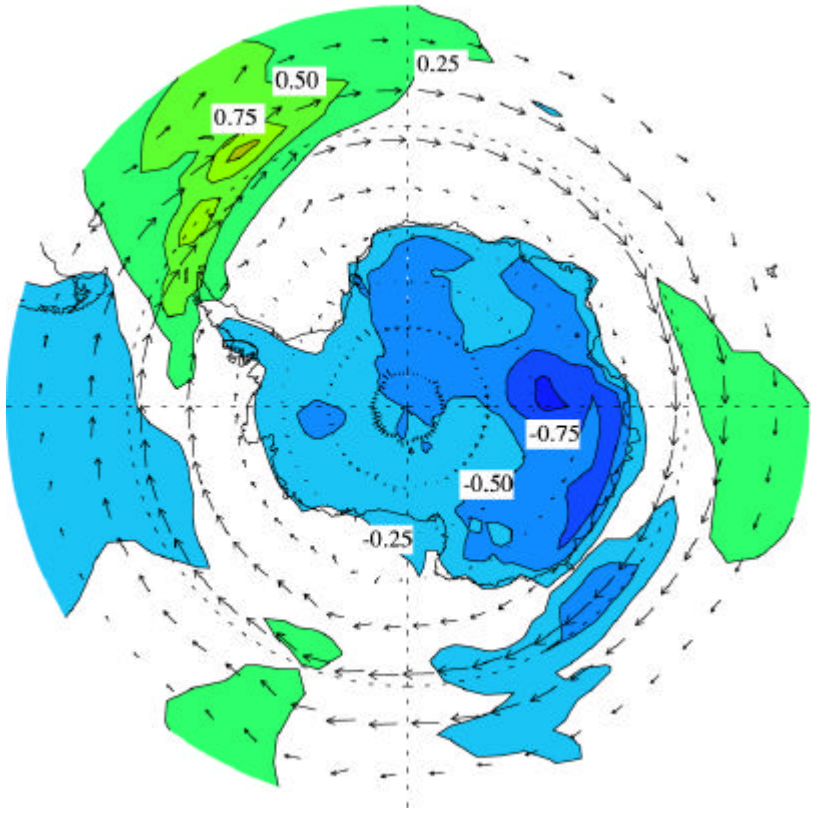


Simulated and observed surface changes

Observations (TS00)

Model

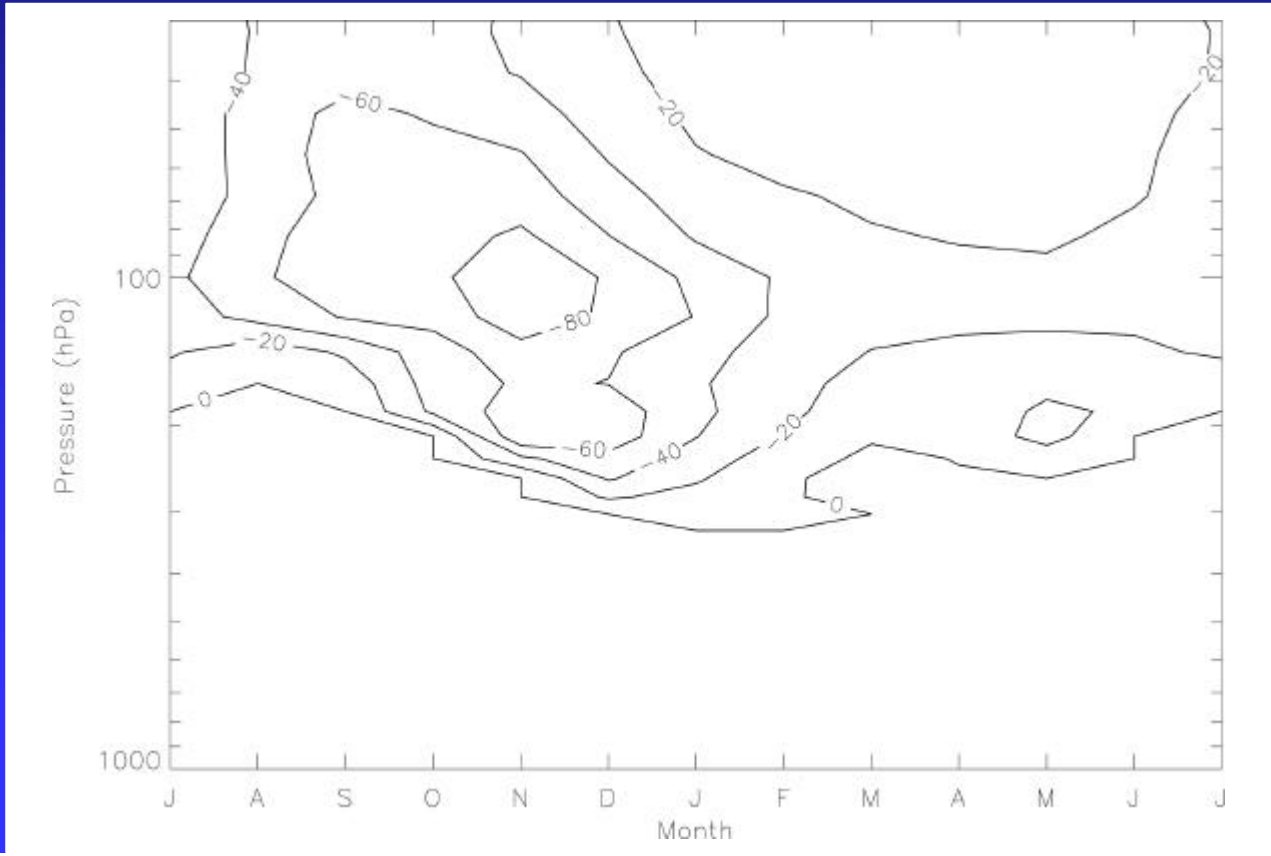




Observed and simulated summer surface temperature and wind changes.

Improved ozone forcing

- Previously prescribed ozone depletion is larger than other estimates (Randel and Wu, 1999), and leads to unrealistically strong stratospheric cooling.
- We are currently repeating the experiments using Randel and Wu (1999) ozone trends.



Conclusions

- By prescribing ozone changes only in the stratosphere we are able to simulate the structure and seasonality of geopotential height and temperature trends in the Antarctic troposphere.
- The tropospheric response is largely associated with the SAM.
- We simulate a pattern of DJF surface climate change consistent with that observed, including cooling in the Antarctic interior and warming over the Peninsula.
- The directly induced stratospheric circulation changes enhance eddy momentum transport in the troposphere, strengthening the tropospheric westerly flow.
- A response of this magnitude is not simulated in resopnse to realistic GHG changes, and requires high vertical resolution below 10 hPa.