Community Earth System Model

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Whole Atmosphere Working Group

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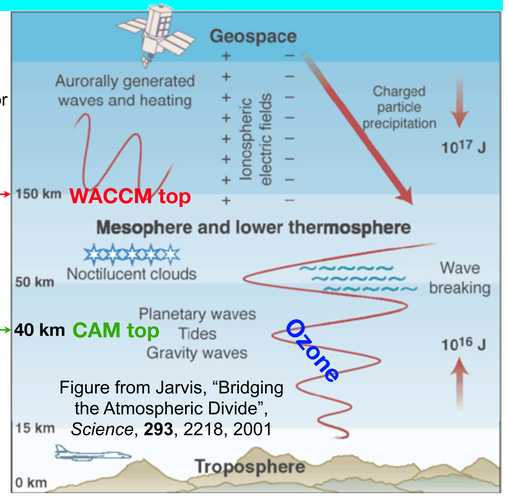
NCAR WACCM Whole Atmosphere Community Climate Model

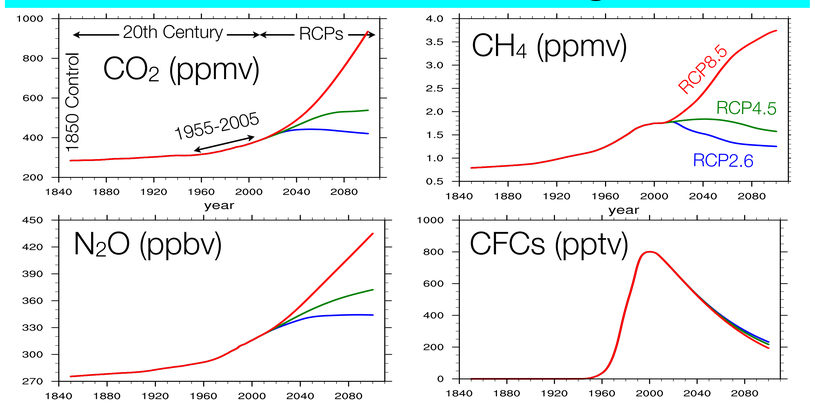
The Whole Atmosphere Working Group (WAWG) was formed to facilitate continued development of the Whole Atmosphere Community Climate Model (WACCM) as part of CCSM, and to use WACCM to understand the couplings between atmospheric layers, the role of chemical and physical processes in defining these couplings, and the interaction between the Earth's atmosphere and the Sun. The current version of WACCM spans the range of altitude from the Earth's surface to the lower thermosphere (~140 km) and is based on version 1 of the Community Earth System Model (CESM-1). WACCM is used to predict the evolution of ozone and other radiatively active species in the middle and upper atmosphere; to study effects of the stratosphere on tropospheric climate, including the response to increased greenhouse gases; and for independent investigations. We have used WACCM to simulate the Earth's climate from pre-industrial conditions to the end of the 21st Century in several experiments following the Coupled Model Intercomparison Project Phase 5 (CMIP5) protocols. We present preliminary analysis of these coupled experiments, highlighting the effects of chemistry and physics above the troposphere on climate.

CESM-WACCM Additions to CAM

- Extends from surface to 5.1x10^{-6} hPa (~150 km), with 66 vertical levels
- Detailed neutral chemistry model for the middle atmosphere,
  - catalytic cycles affecting ozone
  - heterogeneous chemistry on polar stratospheric clouds and sulfate aerosol
  - heating due to chemical reactions
- Model of ion chemistry in the mesosphere/lower thermosphere (MLT), ion drag, auroral processes, and solar proton events
- EUV and non-LTE longwave radiation parameterizations
- Imposed QBO, based on cyclic, fixed-phase, or observed winds
- Volcanic aerosol heating calculated explicitly
- Gravity wave drag deposition from vertically propagating GWs generated by orography, fronts, and convection
- Molecular diffusion and constituent separation



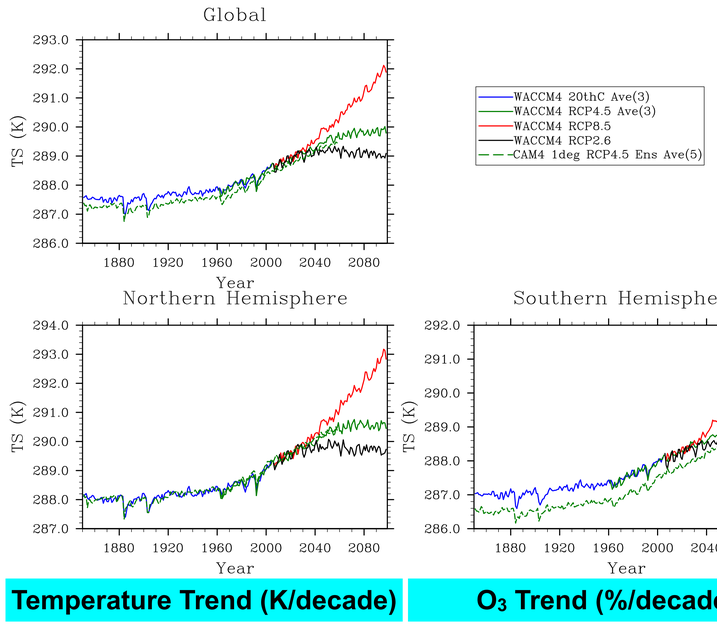
CMIP5 Transient Forcings



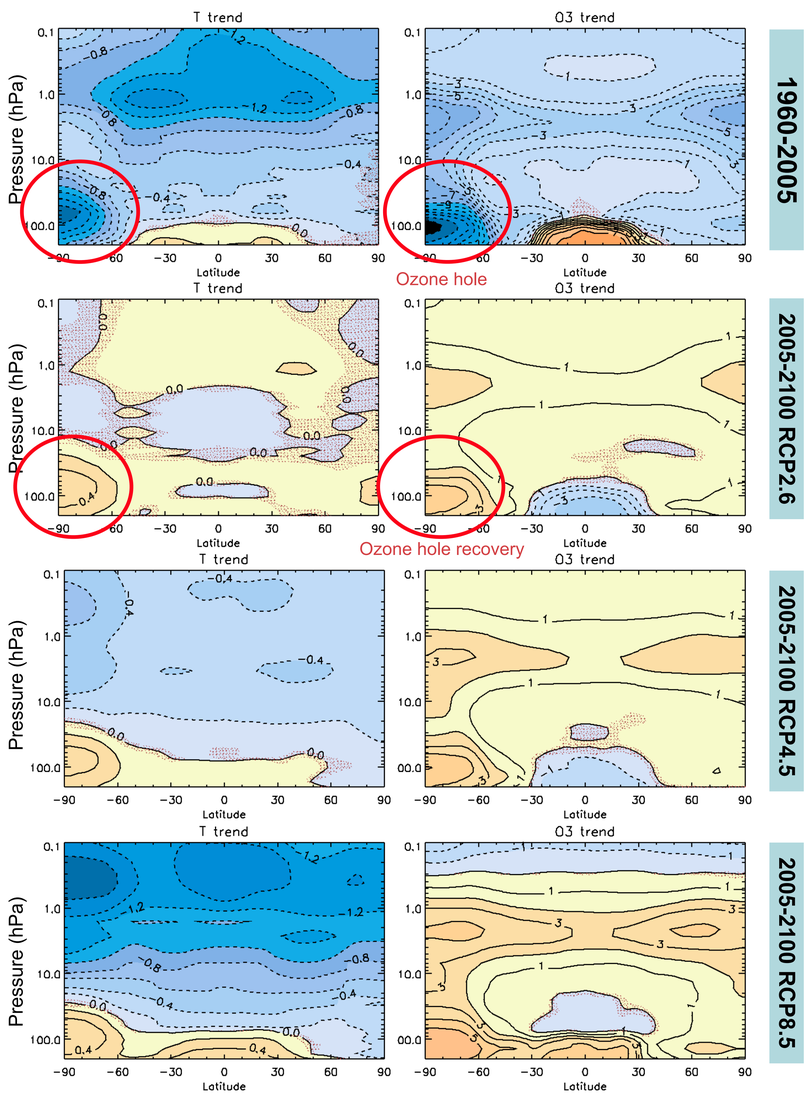
CESM-WACCM CMIP5 Runs Completed

Configuration	Runs	Solar variability	QBO
1850 Control	1 x 200 years	No	No
20th Century	3 x 1850-2005	Annual, no spectral	Yes
1955-2005	3 x 1955-2005	Daily with spectral	Yes
RCP2.6	2 x 2005-2050, 1 x 2005-2100	Daily with spectral	Yes
RCP4.5	2 x 2005-2065, 1 x 2005-2100	Daily with spectral	Yes
RCP8.5	2 x 2005-2050, 1 x 2005-2100	Daily with spectral	Yes

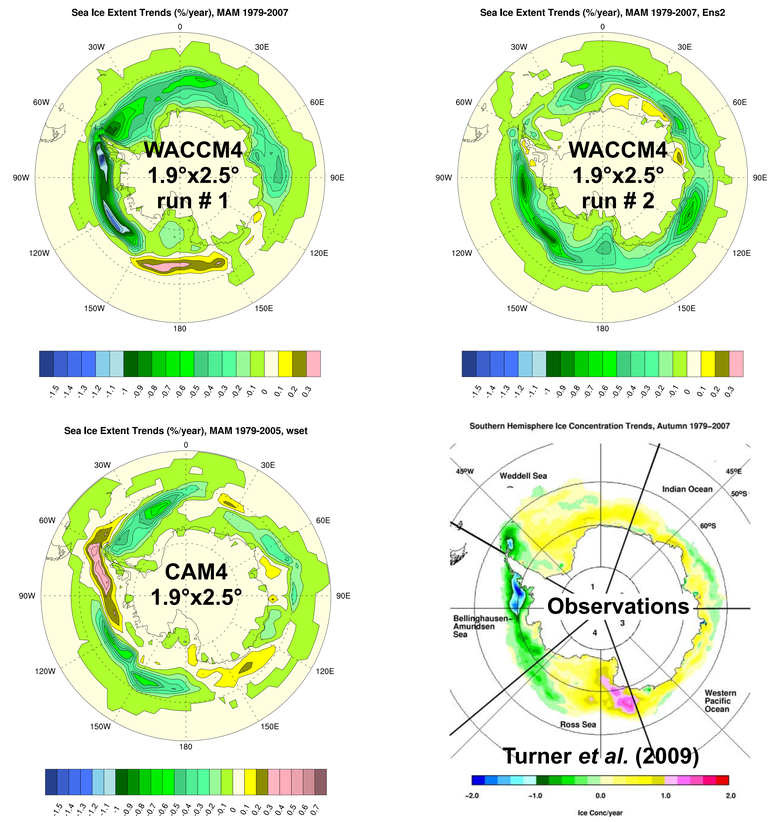
Surface Temperature



Temperature Trend (K/decade) and O_3 Trend (%/decade)

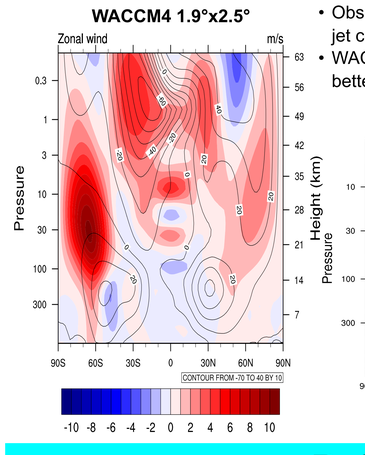


Sea Ice Extent Trends (%/year) MAM 1979-2007

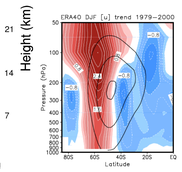


- Turner *et al.*(2009) suggested that observed autumn increase in Ross Sea ice extent might be produced by circulation changes driven by ozone loss, but found the gains to be within the range of natural climate variability.
- WACCM4 produces similar patterns of gain and loss in our first ensemble run, but the patterns are highly variable across our ensemble.
- In contrast, CAM4 predicts gains where losses are observed, and losses where gains are observed.

DJF Zonal Winds and 1979-2000 Change



- Observations reveal a poleward shift of the Antarctic vortex jet concurrent with the development of the ozone hole.
- WACCM4 reproduces the magnitude of this shift much better than CAM4, which lacks chemistry and a high top.



References

S.W. Son, L.M. Polvani, D.W. Waugh and CCMVal co-authors, The impact of stratospheric ozone recovery on the Southern Hemisphere westerly jet, *Science*, 320, 1486-1489, doi: 10.1126/science.1155939, 2008.

Turner, J., J. C. Comiso, G. J. Marshall, T. A. Lachlan-Cope, T. Bracegirdle, T. Maksym, M. P. Meredith, Z. Wang, and A. Orr, Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent, *Geophys. Res. Lett.*, 36, L08502, doi:10.1029/2009GL037524, 2009.