Stratosphere-Troposphere coupling and trends in the Southern Hemisphere tropospheric circulation in CMIP3 models

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Abstract

The recent intensification of the circumpolar circulation in the SH troposphere in summer and autumn has been attributed to external forcing such as stratospheric ozone depletion and greenhouse gas (GHG) increases. Several studies have shown that climate models are able to simulate observed changes when forced by observed ozone trends or combined ozone and GHG trends. However, as some of these studies suffered from erroneously specified forcing, the reason for the circulation intensification remains debatable. Here, we re-approach this issue using data from 21 CMIP3 models. We demonstrate that only models that include ozone depletion simulate downward propagation of the circulation changes from the stratosphere to the troposphere similar to that observed, with GHG increases causing significant Antarctic geopotential height trends only in the lower troposphere. These changes are simulated by the majority of the ozone-forced models except those with the lowest vertical resolution between 300 hPa and 10 hPa.

Model data

- **21 CMIP3 coupled climate models (61 simulations)** of which:
  - **8 models (20 simulations) without ozone depletion**:
    BCCR BCM2.0 (Norway); CCCMA CGCM3.1 T47 (Canada); CCCMA CGCM3.1 T63 (Canada); GISS-AOM (USA); FGOALS-g1.0 (China); INM-CM3.0 (Russia); IPSL-CM4 (France); MRI CGCM2.3.2 (Japan)
  - **13 models (41 simulations) with ozone depletion**:
    CSIRO MK3.0 (Australia); CSIRO MK3.5 (Australia); GFDL CM2.0 (USA); GFDL CM2.1 (USA); GISS-ER (USA); GISS-EH (USA); INGV-SXG (Italy); MIROC3.2 hires (Japan); MIROC3.2 medres (Japan); ECHAM5/MPI-OM (Germany); CCSM3.0 (USA); PCM (USA); UKMO-HadGEM1 (UK)

Trends: GHG vs ozone

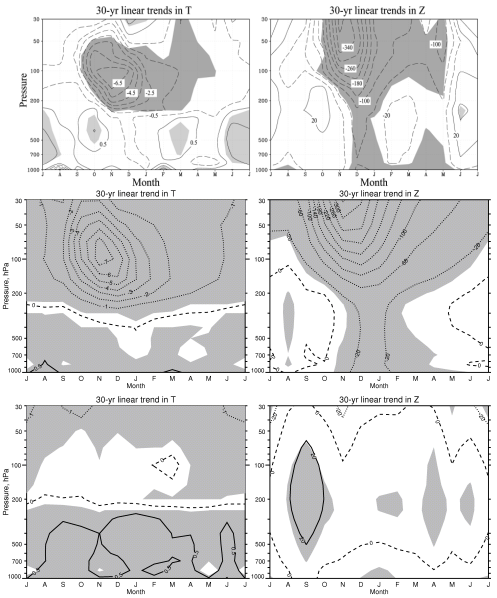

Figure 1: Linear trends (1969-1998) in T (left column, K per 30 years) and Z (right column, m per 30 years) over the Antarctic in observations (upper), GHG+ozone forcing models (middle) and GHG only forcing models (lower). Shading denotes trends that exceed 1SD of the respective monthly time series.

Trends: role of vertical resolution

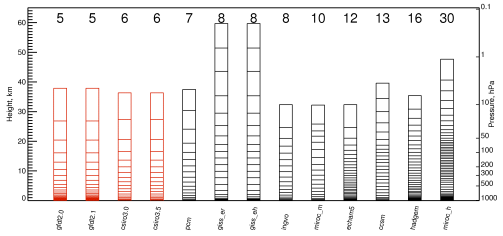

Figure 2: Structure of vertical levels in ozone ensemble models. Models which do not simulate the downward trend propagation are marked in red (low resolution group). Numbers above the bars indicate the number of levels between 300 hPa and 10 hPa.

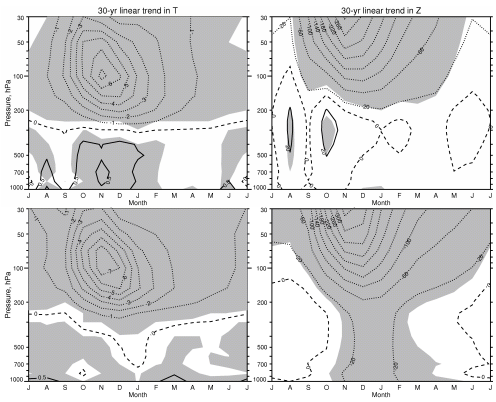

Figure 3: The same as Figure 1 except for ozone ensemble models with low (9 simul., upper plots) and high (32 simul. lower plots) vertical resolution in the lower stratosphere.

Downward propagation

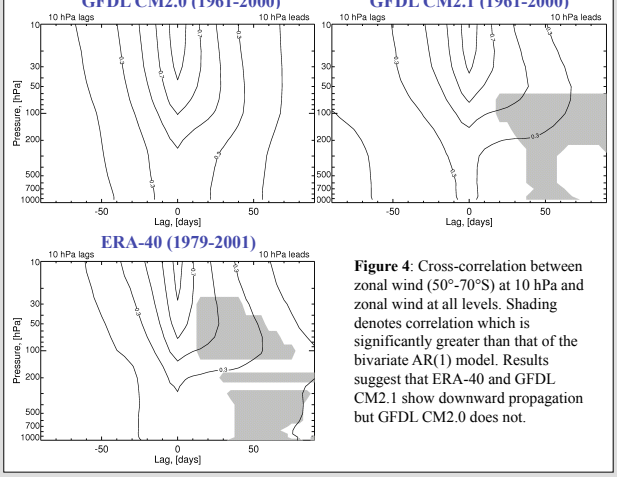

Figure 4: Cross-correlation between zonal wind (50°-70°S) at 10 hPa and zonal wind at all levels. Shading denotes correlation which is significantly greater than that of the bivariate AR(1) model. Results suggest that ERA-40 and GFDL CM2.1 show downward propagation but GFDL CM2.0 does not.

Acknowledgments:
This work is supported by NERC Project NE/E006787/1. We acknowledge the modeling groups, the Program for Climate Model Diagnosis and Intercomparison (PCMDI) and the WCRP's Working Group on Coupled Modelling (WGCM) for their roles in making available the WCRP CMIP3 multi-model dataset. Support of this dataset is provided by the Office of Science, U.S. Department of Energy. ECMWF is acknowledged for providing ERA-40 data. We thank the following people: Phil Rasch, Lawrence Boja, Gary Strand, Seok-Woo Son, Grigory Nikulin, Mark Baldwin.

Reference:
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