Poster W29B DynVar cluster:
Stratosphere-trosposphere Coupling: Future trends related to Ozone Recovery in the Southern Hemisphere in WACCM4 simulations

Natalia Calvo[1*,2], Daniel R Marsh[1], Rolando R. Garcia[1], Michael Mills[1], Douglas E. Kinnison[1], Anne K. Smith[1]

(contact: calvo@ucar.edu)

[1] Atmospheric Chemistry Divison, NCAR, Boulder CO USA * Advanced Study Program, NCAR, Boulder, CO, USA [2] Universidad Complutense, Madrid, Spain

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Motivation:

Observations over the last decades : a significant cooling over the SH UTLS polar cap together with significant acceleration of the tropospheric SH westerly jet (e.g. Thompson and Solomon 2002)
Attribution from GCMs: due to the increase in polar ozone depletion (major) and greenhouse gases (minor) (e.g. Polvani et al. 2010).

Future simulations:

a) IPCC-AR4 (CMIP3) models: acceleration of the SH jet although at a weaker rate than in the past.
b) CCMVal2 models: deceleration of the tropospheric westerly jet on the poleward side during the SH summer, attributed to the strong warming induced by the recovery of the ozone hole in the Antartic lower stratosphere (e.g. Son et al. (2008), Perlwitz et al. (2008)).

	CMIP3	CCMVal2	WACCM4
Coupled ocean	✓	✗ [1]	✓
Coupled chemistry	✗ [2]	✓	✓
Well resolved stratosphere	✗	✓	✓

(1) Prescribed SSTs typically taken from the AR4 upon which the high-top model is based
(2) Specified chemistry and not always ozone depletion or recovery is prescribed

Main Questions: What are WACCM4 predictions for future trends in the SH, where ozone recovery is the largest?
How do these trends vary in different GHG scenarios?

Model Runs:

The Whole Atmosphere Community Climate Model (WACCM4) is one of the atmospheric components of the NCAR Community Earth System Model (CESM).

- 'High-top' model: from the surface to about 140km.
- Horizontal Resolution: 1.9x2.5
- It includes interactive chemistry, radiation and dynamics
- It is coupled to a deep ocean model.

Length of simulation: 2006 to 2100
CMIP5 scenarios: RCP2.6 , RCP4.5 and RCP8.5
Three ensembles of 3 realizations for each scenario.

Method: Trends are determined by linear-square fits to the monthly-mean time series.
Significance of the trend has been computed as the two standard deviation uncertainty level in the trend coefficients.

Ozone Column (DU) Temporal Evolution:

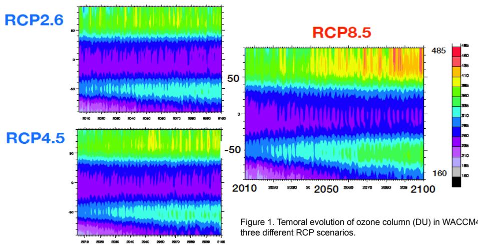


Figure 1. Temoral evolution of ozone column (DU) in WACCM4 in three different RCP scenarios.

Trends in O_3 over the SH polar cap :

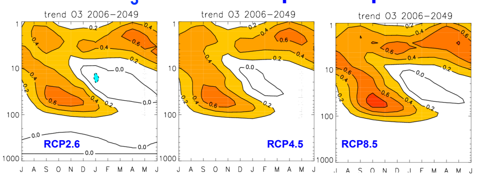
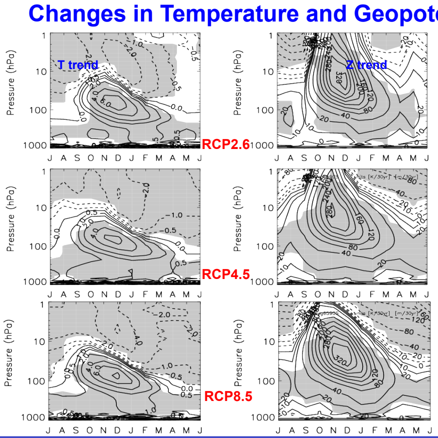


Figure 2. Time pressure cross section of ozone trends for the 3 members ensemble mean for the 2006-2049 period and 65-90S average. Units are ppmv/30yrs. Contours are every 0.2 ppmv/30yrs.

- The largest values on ozone recovery are observed under RCP8.5 conditions while RCP2.6 and RCP4.5 show more similar results: slightly weaker trends in RCP4.5.
- This is related to three simultaneous effects:
  i) the increase in O_3 due to the lack of ODS in the future (independent of RCPs)
  ii) the decrease in O_3 due to the decrease in stratospheric temperature related to the increase in GHGs.
  ii) the increase in O_3 coming from the tropics. Lower temperatures in the tropics due to the increase in GHGs reduce O_3 loss in this area, increasing net O_3 (production – loss). The Brewer Dobson circulation transports it from the source region in the tropics towards high latitudes.

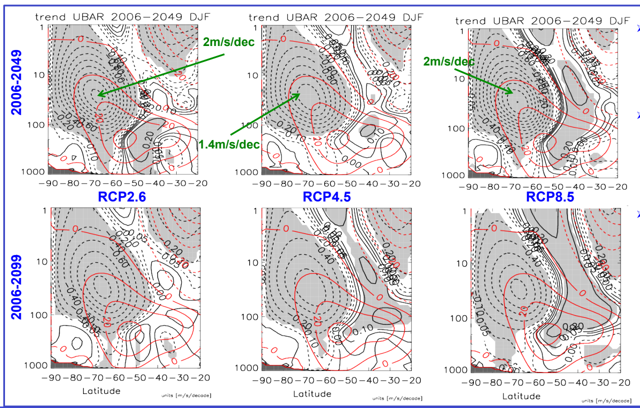
Changes in Temperature and Geopotential Height over the SH polar cap:



- Positive trend in T and Z predicted over the SH polar cap, in agreement with the positive trend in O_3 (more absorption of UV and IR radiation in the upper troposphere lower stratosphere). Trends peak in November and December following the largest change of ozone in October.
- As in ozone trends, the largest trends occur in RCP8.5.Temperature trends are about 2K warmer than in the other two RCPs. Interestingly, differences in temperature trends between RCP2.6 and RCP4.5 are small, slightly weaker in the medium RCP4.5 scenario
- Hypothesis:
  RCP2.6: increase in T mainly related to the direct increase in ozone (more absorption of both UV and IR radiation).
  RCP4.5: net increase in T, not larger than in RCP2.6, due to both direct increase in ozone and in GHGs (counteract effects), slightly smaller T trend.
  RCP8.5: large increase in GHGs, large increase in ozone in the tropics, large temperature trends.
- Downward propagation: Significant 0.5K anomalies reach the surface in RCP2.6 and RCP4.5 while larger anomalies up to 1K reach the surface in RCP8.5.
- The pattern of the tropospheric anomalies is similar in RCP2.6 and RCP8.5, the signal reaches the surface in austral summer. In RCP4.5, significant 0.5K anomalies reach the surface during an extended austral summer season, from September to March.

Figure 3. Time-pressure cross section of trends in zonal mean temperature (left panels) and geopotential height (right panels), latitudinally average by the cosine of latitude from 65S to 90S. Trends are computed over the 2006-2049 period for the 3 member ensemble mean for each RCP scenario. Units are K/30yrs and m/30yrs. Contours are solid for positive trends and dashed for negative trends. Grey areas denote areas over 2σ

Changes in zonal mean zonal wind (DJF):



- Results: Weakening of the zonal mean U in the poleward side of the jet. Strengthening of the winds on the equatorward side of the jet. Opposite trends as a the result of the competing effects from increase in O_3 and GHGs (specially well seen in RCP8.5).
- Downward propagation: The largest weakening of the jet occurs during the lowest and highest RCP scenarios (RCP2.6 and RCP8.5). Only in these cases the trends reach the troposphere and even the surface in agreement with temperature and ozone trend patterns. The weakening of the jet is not as strong during RCP4.5.
- Comparison of periods: The 2006-2099 period show lower trends in the poleward side than 2006-2049 because of the slower recovery of ozone in the second half of the 21st century. In the longer term trend, the strengthening of the equatorward side of the jet is larger because of the larger effect of GHG concentrations.

Figure 4. Latitude-pressure cross section of zonal mean zonal wind trends (black contours) and climatology (red contours) averaged for December-January-February months. Trends are calculated over the periods 2006-2049 (above) and 2006-2099 (below) for the three RCP scenarios. Units are m/s/decade and m/s. Solid (dashed) contours for positive (negative) values.

Conclusions:

- ✓ Future ozone recovery under different RCP scenarios over the SH polar cap.
- ✓ Positive trend in temperature and geopotential height in the UTLS region over the SH pole, which propagates downwards into the troposphere.
- ✓ Weakening of the zonal mean zonal winds on the poleward side of the jet and strengthening on the equatorward side, during austral summer season. Significant changes are predicted in the stratosphere under the 3 RCP scenarios but only reach the troposphere and the surface under RCP2.6 and RCP8.5.
- ✓ All trends are larger under RCP8.5 scenario due to the combined effect of a)direct increase of ozone at polar latitudes and b) the larger transport of ozone from the tropics, because of more tropical stratospheric ozone at lower temperatures generated by climate change (increase in GHGs).
- ✓ Trends under RCP4.5 are the weakest, probably related to competing O_3 and GHGs direct effects.

References:

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