SPARC Activities in Relation to Anthropogenic Climate Change (ACC)
July 2009

Quantifying the effects of ozone depletion and recovery arising from anthropogenic halogens, together with those of changes in other greenhouse gases, is of great importance for human welfare. Achieving this goal requires evaluation of the impact of stratospheric ozone depletion and recovery on tropospheric climate as well as elucidating the effects of climate change on the evolution of ozone itself. This in turn requires understanding and quantification of the long-term sensitivity of the climate system to significant perturbations of the radiative and chemical balance of the atmosphere associated with human activities. Detecting and quantifying such effects also requires a quantitative understanding of the role of natural forcings such as volcanoes and solar variability on the composition and evolution of the atmosphere and ultimately of the effects of such forcings on the climate change signal throughout the active atmosphere and at the surface. The SPARC program has activities that address aspects of all of these issues. Those that are most directly relevant to the WCRP Anthropogenic Climate Change (ACC) cross-cutting theme are highlighted here.

A) Modelling of the interaction of ACC and ozone depletion and recovery

The depletion of stratospheric ozone during the latter half of the 20th century is the result of long lived chemicals that have been produced at the surface of the earth due to human activities. Recovery of stratospheric ozone in the 21st century is an expected outcome of the decline of the atmospheric burden of these ozone depleting substances resulting from the control on emissions mandated by the Montreal Protocol and its Amendments and Adjustments. However it has become increasingly clear that the future evolution of the ozone layer and its eventual recovery is part of the broader story of climate change associated with increasing concentrations of radiatively and chemically active substances in the atmosphere as a result of human activities. The critical role of such substances in the chemistry of ozone in the Antarctic stratospheric winter polar vortex, remote from their source regions, is in itself indicative of the importance of transport and exchange between the troposphere and stratosphere on time scales ranging from weeks to years. However it is now understood that stratosphere-troposphere dynamical coupling influences the troposphere as well.

Chemistry-climate models have become key tools for understanding and predicting the evolution of ozone and its interaction with the rest of the climate system. In the CCMVal Activity, SPARC has taken on a leadership role in quantifying the evolution of stratospheric ozone and its interaction with the climate system. The chemistry-climate modelling that is coordinated within CCMVal, with an associated comprehensive process-oriented diagnostic evaluation and validation program, provides a basic underpinning for the WMO/UNEP Ozone Assessments as well as key input to IPCC Assessments. In this activity, SPARC is enabling the scientific activities that link policy with impacts (***Fig. 1***).

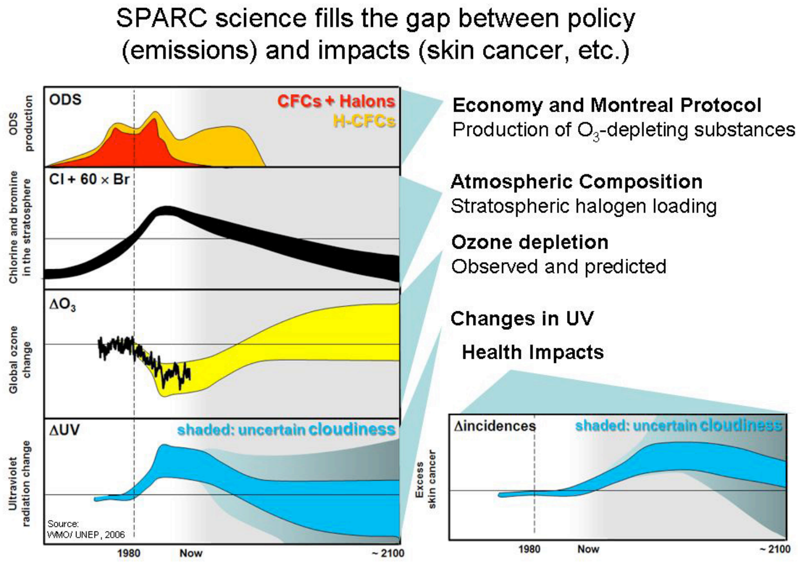

Figure 1 : Ozone depletion and recovery: the role of science in filling the gap between policy and impacts. From WMO (2007).

Recent research has established that the dynamical and thermal response to ozone depletion in the Antarctic is manifest in both the stratosphere and the troposphere (Thompson and Solomon, 2002). Analyses of climate change simulations made with models that include the effects of ozone depletion and recovery in the 21st century show that accounting for the recovery has a significant impact on predicted mean zonal wind and temperature trends in the southern hemisphere (***Fig 2***).

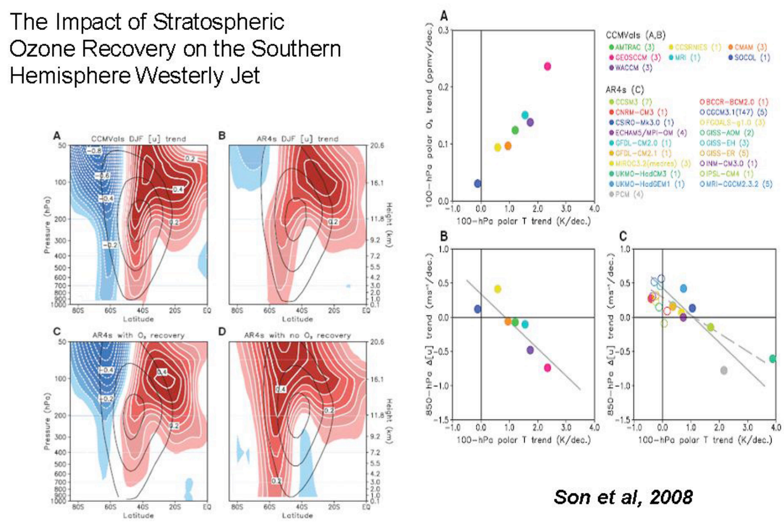

Figure 2: Left: Trends in December-to-February (DJF) zonal-mean zonal wind. Multimodel mean trends between 2001 and 2050. CCMVal models (A), AR4 models (B), AR4 models with prescribed ozone recovery (C), AR4 models with no ozone recovery (D). Black solid lines: DJF zonal-mean zonal wind averaged from 2001 to 2010 .Right: Relationships among SH polar-cap ozone trend at 100 hPa, polar-cap temperature trend at 100 hPa, and extratropical zonal wind trend at 850 hPa: ozone and temperature trends simulated by CCMVal models (A), zonal wind and temperature trends simulated by CCMVal models (B), and zonal wind and temperature trends as simulated by AR4 models (C)

B) Measuring the performance of Chemistry-Climate Models

A major current focus within the CCMVal activity is on production of a comprehensive report that will attempt to provide evaluations of the performance of chemistry-climate models (CCMs) through the use of quantitative metrics (Eyring and Waugh, 2008, see ***Fig. 3***). This report will also include results from new simulations of ozone recovery in combination with climate change.

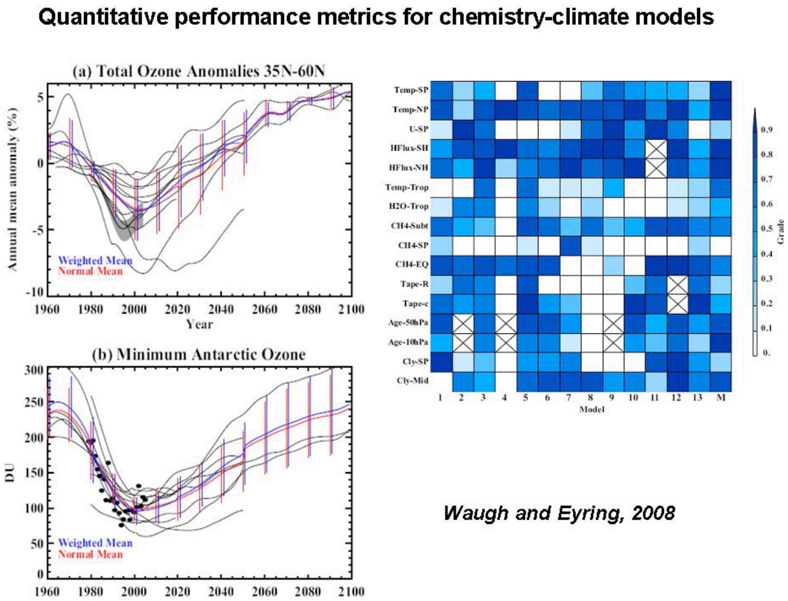

Figure 3: Left: Temporal variation of (a) annual mean anomalies for total ozone averaged over northern mid-latitudes (35? N to 60? N) and (b) minimum Antarctic ozone for individual models (black curves), unweighted mean (red) and weighted mean using performance indices based on the average grade (blue) of all models. The thick black curve and shaded region in (a) shows the mean and range of observed ozone anomalies, while the black dots in (b) show the observed minimum total ozone.

Right: Matrix displaying grades for application of each diagnostic test to each CCM. Each row shows a different test, and each column a CCM. The right most column is the "mean model". A cross indicates that this test could not be applied, because the required output was not available from that model.

C) Quantifying Stratospheric Temperature Trends

In addition to being key features of climate change, temperature trends in the stratosphere are also critically linked to stratospheric ozone variability and change. Because of their importance in this context, stratospheric temperature trends have been examined as part of the WMO/UNEP Scientific Assessments of Ozone Depletion (WMO, 2007) and previous assessments. Attempts to evaluate the causes of the stratospheric cooling in the recent past using models and observations (e.g. Shine et al., 2003) have suggested that the upper stratospheric trends are , in almost equal share, associated with ozone depletion and increases in carbon dioxide. While lower stratospheric cooling is associated with ozone depletion, there may also be a contribution from changes in stratospheric water vapor.

Quantifying observed temperature trends and uncertainty in them is a major focus of the SPARC Temperature Trends Working Group (Randel *et al*., 2009) (***Fig. 4 and 5***).

(SPARC Temperature Trends Group)

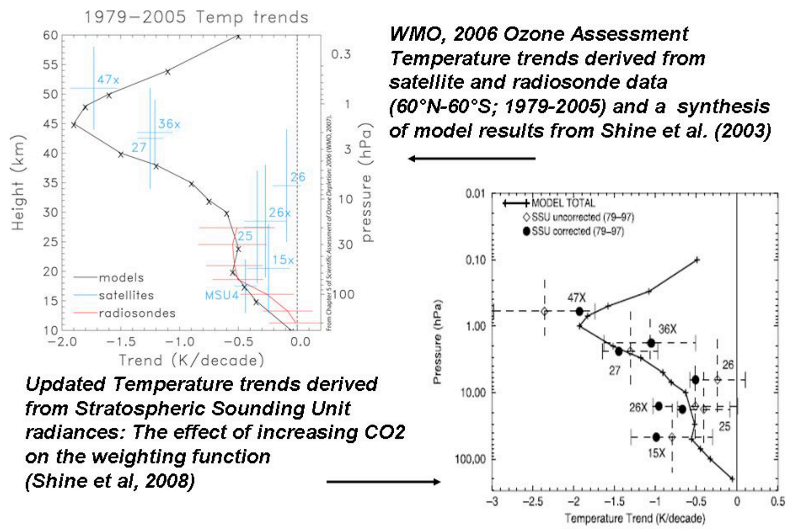

Figure 4: Left: WMO (2007) , Figure 5-6. Vertical profile of temperature trends derived from satellite and radiosonde data over 60°N-60°S for the period 1979-2005, together with a synthesis of model results taken from Shine et al. (2003). The satellite results are shown for each individual SSU channel (as noted) and MSU Channel 4. For each channel the vertical bar denotes the approximate altitude range sampled by that channel, and the horizontal bar denotes the (two sigma) statistical trend uncertainty. Radiosonde results are shown for individual pressure levels (200-20 hPa), and are derived from a subset of stations described in Lanzante et al. (2003a), updated as described in Randel and Wu (2006). The subset of stations is chosen to omit stations with large artificial cooling biases, in particular stations where MSU4 minus radiosonde trends are greater than 0.3 K/decade (taken from Table 1 of Randel and Wu, 2006). Note that the Shine et al. (2003) results refer to model calculations and observations for the period 1979-1997, whereas the observed trends in the figure are for the longer period 1979-2005. Right: Update from Shine et al. [2008] : Global mean stratospheric temperature trend (in K/decade) for the period 1979–1997. The solid line shows the ''consensus'' model-derived total trend from a group of models [Shine et al., 2003]. The open diamonds show the trends derived from SSU, as used by Shine et al. [2003], which are uncorrected for the effect of changes in CO2 on the weighting function. The solid circles show the trends corrected for the change in weighting function. The horizontal lines on the open diamonds on the uncorrected trends show the 2-sigma error bars in the observed trends; the vertical lines are intended to give an approximate altitude range sensed by each channel.

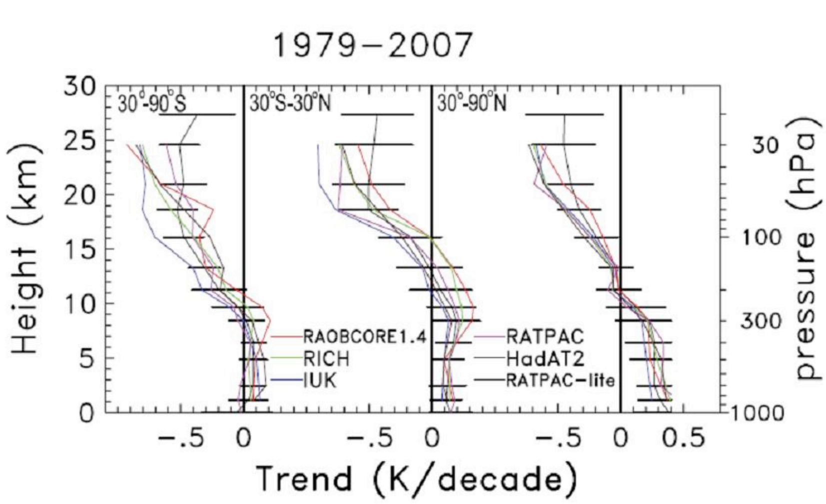

Figure 5: Vertical profiles of annual mean temperature trends for 1979–2007 from radiosonde data sets. Error bars show the two-sigma statistical uncertainty levels for the RATPAC-lite data. (From Randel et al, 2009)

Modelling recent stratospheric temperature trends and projections of future temperature trends in the stratosphere have been key contributions of the CCMVal Activity to recent Ozone A ssessments (***Fig. 6***).

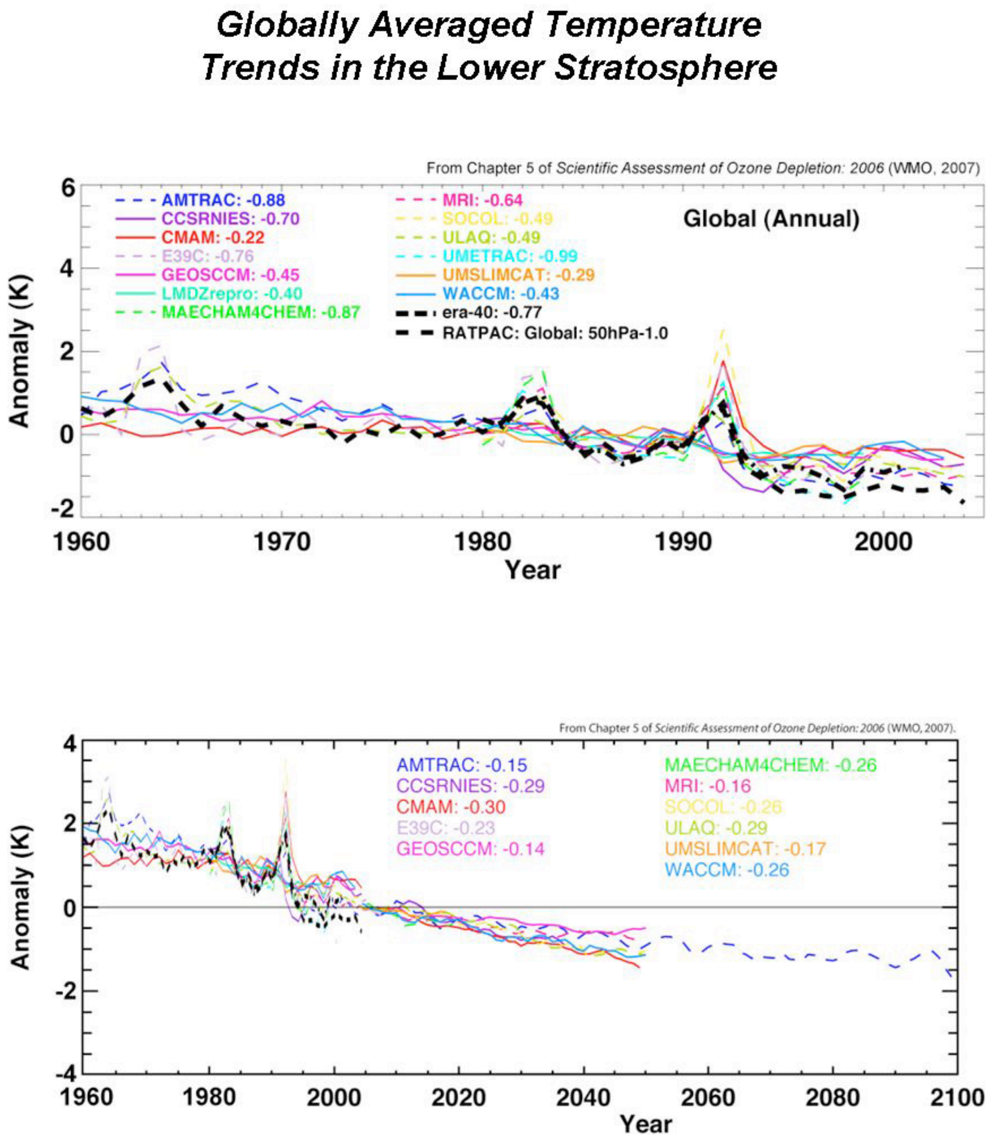

Figure 6

6a)Globally and annually averaged time series of temperature anomalies at 50hPa simulated by the CCMVal models for the past. Black dash-dotted line: ERA-40. Black dashed line: RATPAC. Anomalies for the 20th century are calculated with respect to the 1980-1980 mean. Numbers beside models are the linear trends calculated from the corresponding model output.

6b) Time series of the global and annual mean temperature anomalies at 50 hPa from CCMVal simulations. Although depicted here as extensions of the 20th century anomalies (shown in Fig. 7a), the 21st century anomalies are calculated with reference to the 2000-2010 mean from the model simulations. Numbers beside models are the linear trends calculated from the corresponding model output for the 21st century.