The SPARC Workshop on Understanding Seasonal Temperature Trends in the Stratosphere

Silver Spring (MD), USA, November 5, 2003

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Previous SPARC activities organised under the Stratospheric Indicators of Climate Change initiative have included several highly successful projects, including assessments of the vertical distribution of ozone trends, stratospheric temperature trends, upper tropospheric and stratospheric water vapour, middle atmosphere climatologies, and stratospheric aerosols. These independent studies were aimed at assessing and consolidating our understanding of specific aspects of stratospheric climate change, with a focus on analyses and critical appraisal of existing observations and datasets. But it was also recognized that the topics are interrelated (such as ozone, water vapour and temperature changes), and as the SPARC programme matures, a natural evolution is to try to understand past and future stratospheric changes in a more coupled manner, combining a been labelled the **SPARC Initiative on Detection, Attribution and Prediction of Stratospheric Changes.**

To assess the state of the science and understand emerging research areas, a one-day workshop was held in Silver Spring, MD on November 5, 2003 (in conjunction with the Jim Angell 80th Birthday Symposium). This workshop focused on the outstanding scientific questions related to understanding stratospheric temperature trends, and discussing the community's plans for understanding past and future stratosphere climate change. The workshop was organised into three sessions focusing on: 1) observations, 2) model simulations, and 3) additional relevant topics, such as the effects of circulation changes and predictability of stratospheric climate. Each session had a set of invited presentations only, and time was allocated for extensive discussions among the 40 workshop participants, aimed at

Observations

The morning session focused on observational issues related to stratospheric climate change. **W. Randel** gave an overview of the current global temperature data sets used to assess stratospheric temperature changes, including meteorological analyses and reanalyses, and direct satellite measurements. There are substantial differences among the data sets, and there are often discontinuities associated with changes in analysis systems or changes between operational satellites (**Figure 1**). One important observational priority will be to produce long-term stratospheric temperature records where such artificial changes are minimised. **J. Miller** presented new analyses of Stratospheric Sounding Unit (SSU) and Advanced Microwave Sounding Unit (AMSU) satellite radiance data sets to understand long-term temperature

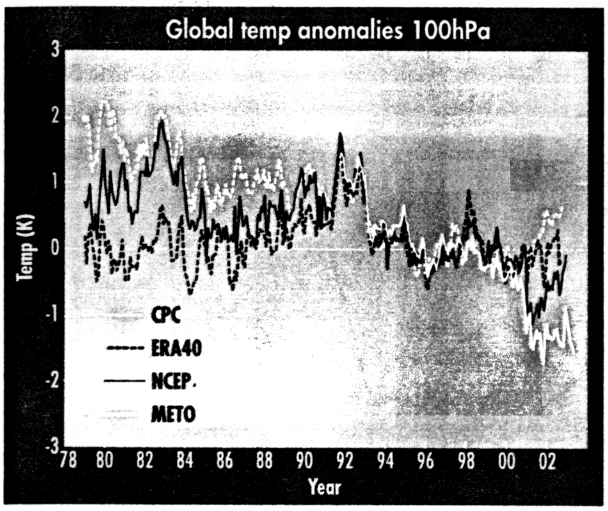


Figure 1. Time series of global mean 100 hPa temperature anomalies, derived from four different meteorological data sets (ERA40 reanalyses, NCEP reanalyses, METO stratospheric analyses, and NCEP CPC analyses). Each data set has been deseasonalized and the anomalies are normalized to zero for the period 1992-1999. Note the substantial differences in estimates of global temperature changes among the different data sets.

understanding of stratospheric temperature trends (especially in the middle and upper stratosphere) for this period; the AMSU data begin in 1998 and it will be incorporated on future operational satellites. While details of the SSU and AMSU instruments and weighting functions are very different, the substantial overlap period between the two instruments (1998-2002) allows continuous temperature data sets to be derived from regression analyses. This ongoing work will be of high value to the SPARC community.

J. Angell presented updated observations of lower stratospheric temperatures from radiosonde measurements, and highlighted the complexity of obtaining homogeneous time series from historical data (there are large disparities among different methods that are currently used). An unresolved point is the difference in trends in the lower stratosphere, and in the tropopause region, derived from radiosonde and satellite data since 1979, and among different radiosonde datasets since 1958, especially in the SH and Tropics. He also highlighted the non-linear nature of temperature changes, focusing on the abrupt changes associated with volcanic eruptions. **J. Haigh** presented a discussion of the effects of the 11-year solar cycle on global temperatures, zonal winds and ozone. Overall there is reasonable agreement between observations and model simulations for effects in temperature, whereas there are substantial uncertainties regarding the vertical structure of the ozone response. Mechanistic models are providing new insights into the mechanisms of solar influence. Improved characterization of the solar cycle is important for understanding temperature variability in stratospheric observational records that span only a few decades.

Modelling

The next session focused on model simulations of stratospheric temperature changes over the past two decades. **K. Shine** discussed a recent intercomparison of annual mean stratospheric temperature changes between several current models and observations. While there is reasonable agreement between the vertical profile of global mean observations and model results (**Figure 2**), there are uncertainties in some details, including the cause of observed northern midlatitude lower stratosphere cooling. There are also substantial differences in model results for identical imposed changes, suggesting that further model intercomparisons are needed. **D. Rind** discussed the effects of changing dynamical coupling between the stratosphere and troposphere, and chemical coupling effects, using results from the GISS model. He stressed the importance of temperature changes in the tropical upper-troposphere in influencing the residual circulation in the stratosphere and in determining the nature of the response of Arctic Oscillation to changes in well-mixed greenhouse gases, water vapour and ozone. **J. Austin** analysed stratospheric ozone and temperature trends simulated in coupled chemistry-climate models, presenting results from the EuroSPICE intercomparisons. Key points are that model temperature biases have an important leverage on polar ozone losses, and that dynamical variability and coupling with the troposphere are important contributors to decadal-scale changes. **R. Garcia** showed simulations of stratospheric temperature and water vapour trends using the NCAR Whole Atmosphere Community Climate Model (WACCM). The model results show water vapour increases of ~0.2-0.4 %/year for 1980-

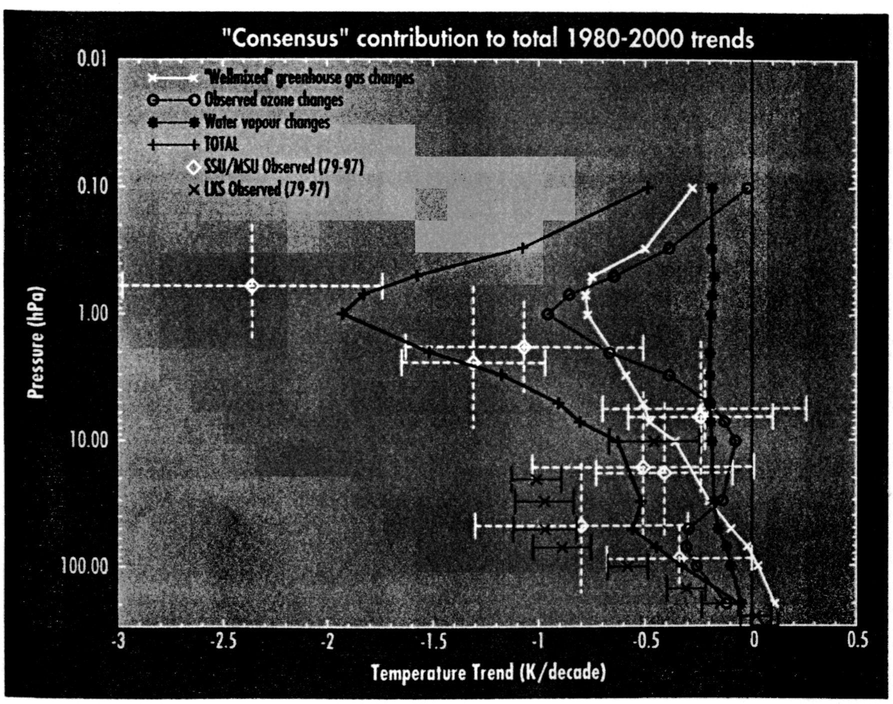
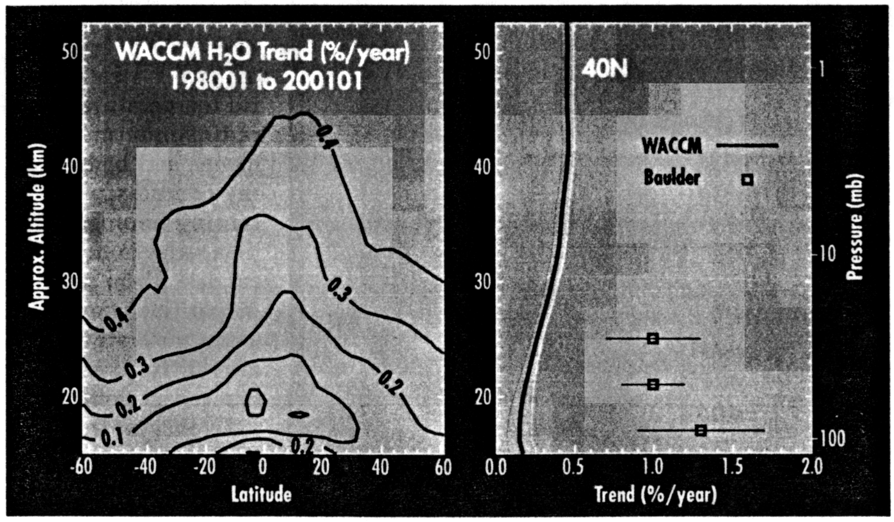


Figure 2. Global and annual mean temperature trends for the period approximately 1980-2000, from an average of model results using observed changes in ozone and greenhouse gases, and idealized water vapour trends. Observed temperature trends derived from satellite and radiosonde data sets are indicated by the symbols, and the error bars give the two-sigma trend uncertainties [from K. Shine et al., 2003].

Figure 3. Left panel shows linear trends in water vapour (in % per year) during 1980-2001 as simulated by the NCAR WACCM. Right panel compares the WACCM results at 40°N with water vapour trends derived from balloon measurements at Boulder, Colorado (40°N) during 1980-2000 (from S. Oltmans et al., 2000). [Courtesy of D. Marsh].



2000 (see **Figure 3**). There are also very different rates of increase for the two decades 1980-1990 and 1990-2000, illustrating substantial variability on decadal time scales.

Additional Relevant Topics

The afternoon session featured discussions on circulation effects, outstanding uncertainties in general circulation models, and prospects for stratospheric climate prediction. **U. Langematz** discussed the effects of changes in stratospheric circulation, including strengthened polar vortices and reductions in planetary wave forcing from the troposphere. The mechanisms that control tropospheric planetary wave forcing of the stratosphere, and how they will evolve under a changing climate, are key factors for understanding stratospheric climate change. The presence of significant internal dynamical variability also highlights the need to perform large ensembles of climate simulation experiments (to separate climate noise from forced signals). The important role of parameterized gravity wave forcing in middle atmosphere GCM's was highlighted by **T. Shepherd,** who showed that details of the schemes are very important for understanding dynamical feedbacks to radiative perturbations. **S. Pawson** presented an update of outstanding issues related to stratospheric climate models from the SPARC GRIPS programme. While, overall, models have substantially improved their climate simulations with time, there are still chronic problems in many models, including persistent temperature and zonal wind biases, and a lack of realistic tropical oscillations. These mean climate biases are probably associated with details of the resolved and parameterized wave forcings. The understanding of dynamical coupling between the stratosphere and troposphere and agreement with observations are especially challenging in light of such chronic model biases. **A. O'Neill** discussed a probabilistic approach to use of large ensemble simulations to properly distinguish signal and (climate) noise (illustrated in **Figure 4**). It also involves the use of multiple models, given current uncertainties in model formulations and dynamical feedbacks. Because large community resources are needed for such work, SPARC has an important role to play in planning effective research strategies.

Summary

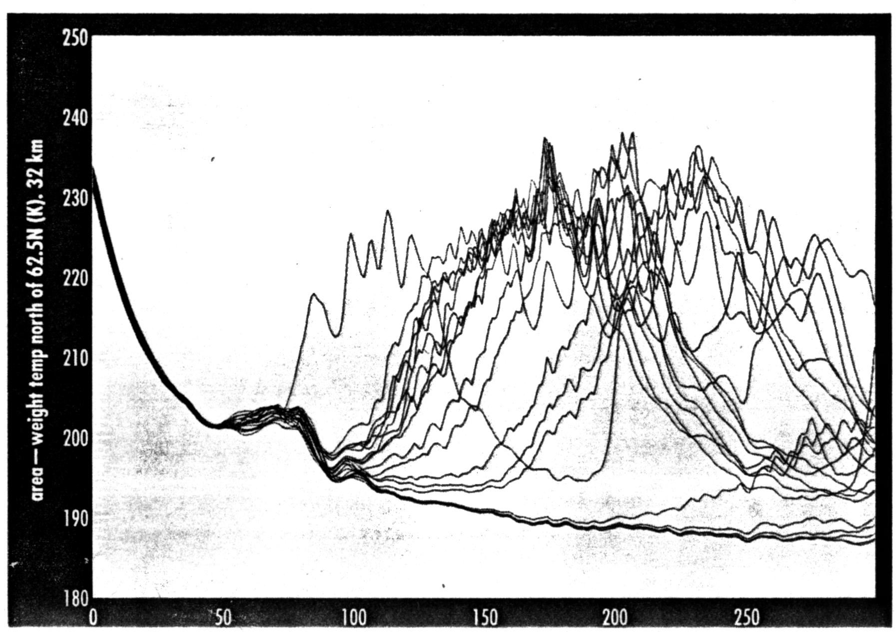
The workshop ended with a group discussion of some of the outstanding key issues raised during the day. The following is a list of topics and key points derived from that discussion (not in any particular order). Together with further community input, these topics can help SPARC in identifying future research priorities.

Observations

Operational and climate data sets

(1) Ensure the availability of long-term high quality 'climate' temperature data sets for the stratosphere and mesosphere; (2) Identify problems and quantify uncertainties in current satellite data and reanalyses; (3) Optimise continuity in data sets across the TOVS-ATOVS satellite boundary, and in future satellite datasets; (4) Include SPARC input into future reanalyses and 'climate network' designs.

Figure 4. An ensemble of time series of temperature in the middle stratosphere over the polar cap, as simulated by a numerical model of the stratosphere and mesosphere, starting from slightly different initial conditions in August. [Courtesy of L. Gray].



Process and experimental data sets

(1) Include multiple sources of data and specific UTLS measurements; (2) Ensure quality of radiative forcing data sets, including ozone, water vapour and aerosols.

Models

Consistency of model simulations

(1) Intercomparison of radiation codes; (2) Compare inter-model responses to specified forcings (GRIPS Level 3+4 activities - this includes both model vs. model and model vs. observations).

Model processes and parameterizations

(1) Evaluate the role of interactive chemistry in model variability; (2) Improved quantification of gravity wave parameterization effects, sensitivities and uncertainties; (3) Better understanding of dynamical coupling of the troposphere and stratosphere, especially EP flux coupling and annular modes; (4) Evaluate model uncertainties in the face of interannual variability, especially in winter polar regions; (5) Improve UTLS physics, especially aerosol and cloud microphysics; (6) Identify robust indicators for model sensitivity studies.

Detection, Attribution and Prediction

(1) Estimate signal vs. noise using ensemble runs and long control simulations; need to use a probabilistic approach for attribution and prediction. (2) Understand sensitivity of past and future predictions to uncertainties in forcings. (3) Test consistency across different indicators (*e.g.* temperature and radiative gases). (4) Develop and use fingerprint techniques based on space-time patterns of signal responses and noise. (5) Understand the differences between equilibrium runs (time slices) vs. transient response experiments. (6) Quantify the role of tropospheric forcing of the stratosphere, including the impact of observed vs. climatological vs. simulated SST's. (7) Develop improved diagnostics to distinguish radiative vs. dynamical responses.

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