

## A13A-03 1410h INVITED

## Coupled Chemistry Climate Simulations: Past and Future

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Results from an ad hoc intercomparison of chemistry-climate models, recently published in WMO (2002 Ozone Assessment, 2003) and in expanded form in Austin et al. (Atmos. Chem. Phys., 3, 1-27, 2003) will be presented and discussed. Key diagnostics will be presented showing how tropospheric dynamics play a role in high-latitude stratospheric model performance, firstly in determining the heat flux into the stratosphere and via transport the temperature of the high latitude lower stratosphere. In turn, the high latitude lower stratospheric temperature directly influences the amount of heterogeneous ozone destruction as demonstrated in observations of the Arctic (Rex et al., GRL, in press, 2004) as well as more clearly in the Antarctic. Ozone amounts also play an important role in the radiative balance of the lower stratospheric region, resulting in a highly coupled system. The need to understand this system in more detail follows from suggestions of Baldwin and Dunkerton (JGR, 104, 30937-30946, 1999) and others of a possible downward propagation of the stratospheric signal thus implying that it is necessary to treat the atmosphere as a more complete system by including a reasonably detailed stratosphere in climate model simulations of the future. Some future suggestions for coupled model experiments will be given with the aim of establishing a stronger link between individual model simulations than has hitherto been possible. This would establish more rigorously the strengths and weaknesses of individual models, and in due course, allow improved models to be developed.

## A13A-04 1430h

## Sensitivity of Tropospheric Forecasts to Stratospheric Initial Conditions in Both Hemispheres.

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Although there has been much recent interest in the dynamical impact of the stratosphere on the troposphere much of this attention has been focussed on climate timescales. Data analysis results suggest that the largest impact of the stratosphere on the troposphere occurs on 10-60 day timescales. In this study the impact of the stratosphere on the troposphere on these timescales is investigated by considering the sensitivity of tropospheric ensemble forecasts to their stratospheric initial conditions. Using the standard ECMWF ensemble numerical weather prediction model a number of case studies of downward propagation events in the northern and southern hemispheres are examined, including the unprecedented Southern Hemisphere major warming in September 2002. In each case two forecast ensembles are run, one with the correct stratospheric initial conditions and one in which stratospheric initial conditions are replaced by a separate stratospheric analysis which has the opposite sign in the stratospheric annular mode index. In both the northern and southern hemisphere stratospheric initial conditions have a small, but statistically significant impact on the tropospheric annular mode, on 15-20 day timescales. Comparison of individual ensemble member forecasts shows that differences in the tropospheric forecast are concentrated on synoptic scales. In the northern hemisphere, consistent changes to the tropospheric flow occur in the North Atlantic in three different case studies. In the North Pacific there is little consistency in the pattern of tropospheric differences. In the Southern Hemisphere consistent changes to the tropospheric flow are also significantly non-annular. Using incorrect stratospheric initial conditions results in a statistically significant reduction in the 500hPa anomaly correlation of tropospheric forecasts.

## A13A-05 1445h

## Tropospheric influences on winter-time stratospheric variability

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Tropospheric height anomalies in autumn are found to often precede the downward propagation of wintertime stratospheric height and wind anomalies to the surface. The precursor anomalous wave pattern forces a series of energy perturbations that propagate through the troposphere and stratosphere, which leads to hemispheric-scale anomalies most closely associated with Arctic Oscillation. Because the dominant lower tropospheric height anomaly is centered over northern Eurasia, autumn snow cover variability in this region is important in influencing winter atmospheric variability both in the stratosphere and in the troposphere. First, diabatic cooling (heating) associated with snow cover anomalies over Siberia perturb local stationary wave energy forced by the high topography of Eurasia. The increased (decreased) upward energy flux perturbs the local troposphere, is propagated into the stratosphere, and eventually affects the remote troposphere. This process is consistent with current understanding of troposphere-stratosphere coupling. The proposed mechanism by which autumn Eurasian snow cover influences the subsequent winter climate is demonstrated by both observational and numerical simulation analyses.

A14A CC: 520 D Monday 1530h  
Forcing of the High-Latitude Climate System by the Stratosphere II (joint with OS, GC)

**Presiding:** M P Baldwin, Northwest Research Associates; J Austin, Geophysical Fluid Dynamics Laboratory

## A14A-01 1530h

## Interpreting Observed Stratospheric ozone (1970-2000) - Chemistry, Dynamics, and Model Sensitivities

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The SPb-SB 2-D transport-chemistry model is used to investigate how interpretations of causes of past changes in stratospheric ozone (1970-2000) can depend on different model dynamics. The results from two different simulations of ozone are compared. Both use the same SPb-SB 2-D model framework, with the same chemistry treatment, the same solar UV variations, and the same stratospheric aerosol variability. The two simulations use different dynamics for transport, and different lower stratospheric temperatures. One uses dynamics based on the NCAR MACCM2, as we have used in previous published works, and the other uses dynamics based on the DNM model of the Department of Numerical Mathematics of the Russian Academy of Sciences. Both simulations compare reasonably well with TOMS and ground-based observations of total ozone during the period. We see that in these two simulations the relative role of dynamics is very different in giving rise to ozone variations. With DNM dynamics, Northern Hemisphere ozone decreases are much more a consequence of the year-to-year variability in the dynamics

and transport than is the case with MACCM2 dynamics. In the Southern Hemisphere, ozone decreases are larger with MACCM2 dynamics and are more in line with observations. These results seem to be largely a consequence of the different degree of polar vortex isolation in the two general circulation models.

## A14A-02 1545h

## Changes in tropospheric and lower stratospheric temperatures in the Arctic: model and measurement comparison

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Efforts to understand the connection between the stratosphere and the surface rely, fundamentally, on an understanding of what is happening in both the free troposphere and the boundary layer. For the Arctic, the available temperature measurements by radiosonde offer some of our best insight into understanding the past forty years of change. Analysis of the NOAA's Forecasting Systems Laboratory's temperature sonde data from the North American Arctic shows features which are robust from station to station in the Arctic and which are not represented when examining current global climate model projections. Some insight is offered into possible explanations for these differences between modeled and measured trends as well as possible future approaches to understanding emerging data.

## A14A-03 1600h

## Tropospheric Response to Stratospheric Cooling in a Simple AGCM: Impact of the Seasonal Cycle

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stratospheric cooling in a relatively simple AGCM that consists of a dry hydrostatic primitive-equation model with zonally symmetric boundary conditions and analytically specified physics. Using a time-independent thermal forcing in the stratosphere, it is found that, as the polar-winter stratosphere is cooled, the tropospheric jet shifts poleward to a remarkable degree. Surprisingly, the troposphere takes a long time to adjust to the stratospheric cooling in this simple model, typically over 300 days. Naturally, then, one is lead to ask whether the tropospheric jet response would be observed in the presence of seasonally varying, instead of time-independent, thermal forcing. We address this issue by repeating the forcing experiments with a seasonal cycle in the forcing: specifically, we impose a thermal forcing in the stratosphere that only occurs in the winter months. We find that, even when the stratospheric forcing is applied with a seasonal cycle, the tropospheric jets shift poleward. Although the magnitude of this response is somewhat smaller than in the time-independent forcing case, the ratio of the tropospheric response to the stratospheric forcing is the same as in the time-independent forcing case, in the annual mean. In this sense, the response appears to be linear in the strength of the stratospheric forcing.

## A14A-04 1615h

## SKYHI GCM Simulations of the Response to the 1991 Pinatubo Eruption to Test Arctic Oscillation Sensitivity and High-Latitude Climate Variability

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A number of recent studies have suggested an important role for stratospheric dynamics in the intraseasonal, interannual and longer-term variations of extratropical surface circulation and climate. A particular focus has been on how the stratosphere affects variations of the Arctic Oscillation (AO). To understand atmospheric processes that cause the AO variability we studied the impact of the 1991 Mount Pinatubo eruption, which produced the largest global volcanic aerosol cloud in the 20th Century and caused an anomalously positive AO index in the next two winters. A series of control and perturbation experiments were conducted with the GFDL SKYHI general circulation model to examine the evolution of the circulation in the two years following the Pinatubo eruption. Forced by volcanic aerosols, SKYHI produces a statistically significant positive phase of the AO in winter, as observed. Ozone depletion causes a positive phase of the AO in late winter and early spring by cooling the lower stratosphere in high latitudes, strengthening the polar night jet, and delaying the final warming. A positive phase of the AO was also produced in the experiment with only the tropospheric effect of aerosols showing that aerosol heating in the lower tropical stratosphere is not necessary to force positive AO response, as was previously assumed. We also used long-term stratospheric wind observations at Singapore station to implement a quasi-biennial oscillation (QBO) in our simulations. Using this setup we showed that the phase of the QBO modulates climate system sensitivity to an external forcing. The QBO in its westerly phase strengthens the Arctic Oscillation response. Because of nonlinear interactions, aerosols and the QBO together produce a stronger response than a linear superposition of responses to each of these forcings. Improved quantification of the aerosol, ozone, and QBO effect helps to better understand mechanisms of the stratospheric contribution to natural and externally forced climate variability.

#### A14A-05 1630h

##### The Influence of the QBO and Solar Variability on the North Annular Mode.

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The Quasi-Biennial Oscillations (QBO) and solar variability are two natural stratospheric forcings affecting atmospheric dynamics and possibly climate. We study how these forcings affect the major mode of the wintertime atmospheric variability in the Northern Hemisphere, the North Annular Mode (NAM). This mode extends from the top of the stratosphere through the troposphere to sea level accounting for 22% of the variance in geopotential heights at sea level and more in the stratosphere (Thompson and Wallace, 1998; Baldwin and Dunkerton, 1999). It has been found (Ruzmaikin and Feynman, 2002) that the NAM of the coupled troposphere-stratosphere is influenced by decadal solar variability. But the influence depends on the phase of the QBO and phase of the winter season. Thus, in early (late) winter for the West (East) QBO, the NAM is more positive for low UV than for high UV fluxes. The effect was shown to be statistically significant. Here we present the results of our search for a physical mechanism by which the QBO and solar variability combined with seasonality affect the NAM. Because the NAM is excited in the interplay between the planetary waves and mean zonal wind (see for example Limpasuvan and Hartmann, 2000), we investigate the latitudinal, vertical and time distributions of the wave (EP) fluxes employing the NCEP Reanalysis Data and the ECMWF Data. We also investigate the possible effect of the QBO associated circulation on the NAM. References: Baldwin, M. P. and T. J. Dunkerton, J. Geophys. Res. 104, 30,937, 1999; Limpasuvan, V., and D. L. Hartmann, J. of Climate, 4414, 2000; Ruzmaikin, A., J. Feynman, J. Geophys. Res., 107, D14, 10.1029/2001JD001239, 2002; Thompson, D. W. J. and J. M. Wallace, Geophys. Res. Lett., 25, 1297, 1998.

#### A14A-06 1645h

##### Influence of the Southern Annular Mode on the circumpolar ocean circulation on timescales from subseasonal to interannual

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The Southern Ocean surrounding Antarctica is unique in being zonally unbounded, and forms a link between the Atlantic, Pacific and Indian Oceans that is important to the global oceanic thermohaline circulation and hence climate. Consequently there is great interest in measuring and understanding changes in ocean transport around Antarctica, although conventional techniques such as hydrographic sections and current meter arrays have limitations due to the complexity of the current systems. We will demonstrate that data from coastal tide gauges and Bottom Pressure Recorders (BPRs) deployed around Antarctica have great utility in monitoring the genuine circumpolar transport variability. The primary driving mechanism for the transport changes is variability in circumpolar eastward winds associated with the Southern Annular Mode (SAM, also called the Antarctic Oscillation). High levels of coherence are observed in the sea level data from around Antarctica at subseasonal frequencies, testifying to the circumpolar response to the forcing. At these frequencies, the transport changes are highly barotropic (depth independent), thus the signal of the SAM is seen to extend completely to the deep ocean floor around Antarctica. The SAM has been observed to be undergoing significant changes in the past 30 years, manifested via changes in its seasonality. These changes to the seasonal signal are also present in BPR data collected near Antarctica, and suggest a possible mechanism whereby large-scale atmospheric climate variability can directly influence ocean circulation. At interannual timescales, significant correlation is observed between the SAM and Antarctic sea level measured at Faraday (Vernadsky), despite the transport variability presumably having a significant baroclinic (depth dependent) component at these frequencies. This further suggests sensitivity of the ocean circulation to large-scale high-latitude climate variability, and presents a possible low-cost method for monitoring interannual variability in circumpolar transport. It is essential that the Antarctic tide gauge network is maintained so that continued monitoring covering longer-period signals can be pursued.

#### A21A CC: 220 C-E Tuesday 0830h

##### Magnitude and Causes of Decreasing Surface Solar Radiation Posters (*joint with B, H, GC*)

*Presiding: V R Ramanathan, Scripps Institution of Oceanography; H C Power, University of South Carolina*

#### A21A-01 0830h POSTER

##### Global Dimming, Diffuse Light and Photosynthesis

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Global dimming means that the transmission of sunlight through the atmosphere is decreasing. What effect would this have on photosynthesis? The simplest assumption would be that if there is less light then there should be less photosynthesis. In this talk we show that this assumption is wrong because; (1) canopy scale photosynthesis is very sensitive to, and usually increases with, diffuse light, and because (2) global dimming means a higher proportion of diffuse light will be incident at the surface. These two conclusions follow

from two well established facts; (a) leaf scale photosynthesis saturates with light, and (b) that as the transmission of sunlight declines, the diffuse fraction of the incident sunlight increases. Both relations are remarkably invariant. Volcanic eruptions are an ideal global test of the hypothesised relations and we show why we expect that the decline in atmospheric CO<sub>2</sub> following the eruption of Mt Pinatubo (July 1991) was due to an increase in photosynthesis.

#### A21A-02 0830h POSTER

##### Seasonal and Climatic Correlations with Surface Solar Forcing at Bet Dagan, Israel

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This study targeted the correlations between global dimming and seasonal and diurnal climatic conditions. Global, diffuse, and direct radiation measured during the last 40 years at the Israel Meteorological Service observatory at Bet Dagan, on the eastern coast of the Mediterranean Sea, where large decreases in annual global radiation have been observed and extensive climate data is available, were examined in order to determine the climatic conditions most correlated with these changes. Israel's Mediterranean climate enables clear differentiation between the cool, wet, rainy season, occurring between November and March, and the hot dry summer season between June and September. Examination of the seasonality in trends of radiative forcing shows that the largest mid-day decreases in global radiation occurred at the height of the rainy season in February, while in June, the least cloudy time of the year with zero mean cloudiness, no change has occurred. However, diffuse and direct radiation at noon and early afternoon in June have decreased and increased, respectively, during the past 10 years. Decreases in global radiation are significant at low sun angles in the mornings and evenings during most of the year, reflecting increasing haziness at these times. The significant seasonal-diurnal changes are highly correlated with wind azimuth, with the largest decreases in global radiation occurring when westerly, off-sea winds prevail. Regression of monthly average global radiation on sunshine duration for five year periods shows that there has been a gradual decrease in the extrapolated value of global radiation when sunshine duration is zero. These and other changes will be discussed with relation to their implications for solar dimming climate interactions.

URL: <http://www.agri.gov.il/People/ShabtaiCohen.html>

#### A21A-03 0830h POSTER

##### Role of Dust and Black Carbon on Dimming of the Arabian Sea

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Satellite aerosol and cloud data (MODIS, AVHRR, ISCCP) have been integrated with a comprehensive 3D Monte Carlo radiative transfer model to quantify the aerosol impacts on the surface solar radiation over the Arabian Sea and to generate the regional maps of aerosol radiative forcing. During winter monsoon, the haze reduces the diurnal mean solar flux at the surface by 20 W/m<sup>2</sup> and increases all-sky solar absorption in the atmosphere by nearly the same amount. Black carbon (BC) accounts for about 60% of the aerosol induced solar absorption. During summer monsoon, the large particles (sea salt, dust) contribute up to 50% to the aerosol optical depth, but relatively low values of aerosol single scattering albedo (SSA) suggest a strong interaction between anthropogenic BC and mineral dust. While the magnitude of the surface forcing during summer monsoon is estimated to be in the range from 15 to 30 W/m<sup>2</sup>, it is a subject to a larger uncertainty due to the lack of comprehensive SSA measurements over the Arabian Sea in summer. Also the decrease in the surface solar radiation during summer monsoon is partly offset by the positive mineral dust radiative forcing in the long-wave domain. While the absorbing aerosols over the Northern Indian Ocean have been shown to affect the winter monsoon circulation in a substantial way, further research is needed to understand if the aerosol impacts during summer monsoon can be equally important for the regional climate and hydrological cycle.