

## SA52A CC: 518 C Friday 1030h

## Global Change in the Upper Atmosphere and Ionosphere I (joint with SM)

**Presiding:** R A Akmaev, University of Colorado; G M Keating, George Washington University

## SA52A-01 1030h INVITED

## Trends in Polar Mesospheric Clouds: What do Satellites Tell Us?

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Polar mesospheric clouds (PMC) have been observed at altitudes of 80 to 85 km from the ground since 1885 and from satellites since 1969. They occur at high latitudes during a three month period starting about one month before the summer solstice. PMC are composed of small ice particles, which form during the polar summer when the upper mesosphere reaches temperatures of less than 130 K, so that even the few parts per million of water vapor available at those altitudes becomes highly supersaturated. There are now several sets of satellite measurements of PMC, each of which cover a decade or longer with the same instrument or multiple copies of the same instrument on different satellites. We will focus on two of these datasets. The first from the Solar Backscatter UltraViolet [SBUV and SBUV/2] instruments on the NOAA polar-orbiting meteorological satellites, which provide over a quarter century of measurements beginning in 1978. The second from the Stratospheric Aerosol and Gas Experiment [SAGE II], which began operation in 1984. These measurements show that the number of PMC observed each season exhibit a strong anti-correlation with the solar Lyman-alpha flux. While there is no clear long-term trend in the frequency of occurrence of all PMC, there is evidence that the frequency of brightest PMC are increasing. There is also clear evidence that the average brightness or albedo of the PMC observed by the SBUV instruments has increased over the past quarter century. Recent modeling results by Thomas et al. have shown that this increasing brightness is consistent with the increase in mesospheric water vapor over the same period. We will discuss the implications of these findings in terms of our understanding of global change.

## SA52A-02 1050h INVITED

## Long-Term Mesopause Temperatures Over Fort Collins, CO (41N, 105W)

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Temperature measurements from 1991 through 2003 using the sodium lidar at altitudes of 80 to 105 km have been analyzed in terms of annual, semiannual, and episodic (Pinatubo volcano) variations as well as an 11 year solar cycle response and a trend. Trends lie between about -1 K/yr and +1 K/yr and during the summer show a local minimum between 90 and 95km whereas trends during the winter have a local minimum above 100km. Inclusion of an episodic variation trends by roughly +0.5 K/yr and makes the trends about the same during periods of positive and negative QBO winds at the equator. Disregarding the episodic variation, the trend for periods of negative QBO winds

is about +0.5K/yr larger than that for periods of positive QBO winds. The solar response is relatively insensitive to inclusion of the episodic variation but is generally smaller for periods of negative QBO winds compared to positive QBO winds.

## SA52A-03 1110h

## The Temperature Trend near the Mesopause as Measured Using the Hydroxyl Airglow

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Measurement of the relative intensities of lines in the rotational structure of the vibration-rotation bands of the hydroxyl airglow emission provides a ready means to obtain the temperature in the region from which the emission arises. Following a discussion of the limitations of the method, we present a time series of such measurements extending over 35 years. The time series is sparse over the first two decades, but includes a period of systematic frequent measurements extending over one full solar cycle. The analysis of the time series leads to the conclusion that there has been no measurable change in the temperature over the period covered. This result is in agreement with several modeled results that predict a change of less than 1 K/decade, and with some observational results, but is in contrast with some other sets of observations, including some obtained using the same method.

## SA52A-04 1125h

Near-IR CO<sub>2</sub> Bands in the Mesosphere and Their Effect for Doubled CO<sub>2</sub> Conditions

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Absorption of solar energy by the near-infrared (NIR) CO<sub>2</sub> bands provides an essential source of heating in the mesosphere. Between 65 and 85 km, this source can exceed 1 K/day and contribute up to 30 % to the total solar heating. Calculation of the solar heating in the NIR CO<sub>2</sub> bands requires consideration of complex non-local thermodynamic equilibrium (NLTE) processes in the CO<sub>2</sub> molecule. The relatively small energy effect and narrow altitudinal region of importance, as well as the necessity to consider complicated NLTE processes, have accounted for the absence of an adequate parameterization for the NIR CO<sub>2</sub> bands up to now. Recently such a parameterization has been developed and implemented into the Canadian Middle Atmosphere Model (CMAM). To examine the role of the NIR CO<sub>2</sub> bands in the mesospheric energetics, this model has been used in a series of multi-year experiments for conditions of perpetual July. Numerical experiments have shown that inclusion of the NIR CO<sub>2</sub> heating results in a significant thermal response of up to 8 K in the mesosphere for the current CO<sub>2</sub> amount but does not significantly change the model thermal response induced by doubling of CO<sub>2</sub>.

## SA52A-05 1140h

## The Response of the Mesopause Region to Natural and Anthropogenic Climate Forcing Simulated in a 3D Chemistry Climate Model

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The HAMMONIA general circulation and chemistry model resolves the atmosphere from the Earth's surface up to about 250 km. This newly developed model combines the 3d dynamics from the ECHAM5 model with the MOZART3 chemistry scheme and some extensions to account for important processes in the upper atmosphere. It is designed to study interactions between chemistry, dynamics and radiation in the whole

atmosphere, but in particular in the mesosphere and lower thermosphere (MLT) region. This study concentrates on the response of dynamics and trace gases, in particular ozone and water vapor, in the MLT region to solar and anthropogenic climate forcing. Results of different simulations with HAMMONIA for low and high solar activity on the one hand and for present day and doubled CO<sub>2</sub> concentration on the other hand are presented. The magnitudes of these natural and anthropogenic changes are compared and their statistical significance is analysed. Finally, we address the effect of the different types of forcing on the energy budget.

## SA53A CC: 518 C Friday 1330h

## Global Change in the Upper Atmosphere and Ionosphere II (joint with SM)

**Presiding:** E C Weatherhead, Cooperative Institute for Research in Environmental Sciences (CIRES); M J Jarvis, British Antarctic Survey

## SA53A-01 1330h

Updated Laboratory Studies of CO<sub>2</sub>( $\nu_2$ )-O Vibrational Energy Transfer

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We will present the latest results from our laboratory measurements of the CO<sub>2</sub>( $\nu_2$ )-O vibrational relaxation rate constant. The O + CO<sub>2</sub> vibrational excitation process is a key contributor to both the CO<sub>2</sub> 15- $\mu$ m emission intensity and to the upper atmospheric energy budget in the 75-120 km altitude range. Through collisions with the ambient O atoms, the ground vibrational state of CO<sub>2</sub> is efficiently excited to its lowest excited vibrational state, with one quantum of energy in the  $\nu_2$  bending mode. In the near-space environment, a sizable fraction of this population relaxes via 15- $\mu$ m spontaneous IR emission, which effectively converts ambient kinetic energy into radiative energy that passes into space. The vibrational relaxation measurements on the CO<sub>2</sub>( $\nu_2$ )-O system performed to date using our transient diode laser absorption spectroscopy apparatus will be summarized, including the latest information on temperature dependence in the relevant 150-500 K range. Possible extensions to the experiment will also be discussed, including the possibility of measuring energy transfer rates involving higher-energy CO<sub>2</sub> levels pumped through absorption of solar radiation.

## SA53A-02 1345h

## Effect of Middle-Atmospheric Greenhouse Cooling on Global Change in the Upper Atmosphere

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Carbon dioxide and water vapor are the primary greenhouse warming gases in the troposphere but they mainly act as cooling agents in the middle and upper atmosphere. The "greenhouse cooling" in the 15- $\mu$ m CO<sub>2</sub> band has been evaluated in several modeling

studies. Carbon dioxide also absorbs solar radiation in the near-infrared bands resulting in noticeable heating in the mesosphere and providing a correction to the cooling. Long-term observations reveal strong upward trends of the water vapor content in the stratosphere and possibly in the mesosphere over the last four decades. Additional H<sub>2</sub>O cooling in the infrared rotational and 6.3- $\mu$ m bands as well as solar heating in the near-infrared bands have not been previously accounted for in simulations of long-term changes in the mesosphere and thermosphere. These additional radiative processes have recently been incorporated into the Spectral Mesosphere/Lower Thermosphere Model (SMLTM). Their possible effects on long-term trends in the thermal and density structure of the mesosphere and thermosphere over the recent decades will be discussed.

#### SA53A-03 1400h INVITED

##### Apparent Detection of Global Anthropogenic Effects Extending Into the Thermosphere

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From a study of long-term orbital decay of Earth satellites, it has been discovered that thermospheric densities have declined substantially since at least 1976. Detection of this decline was first published by Keating et al (2000) in Geophysical Research Letters. They performed an analysis of 5 Earth satellites with periastron altitudes near 380 km. The study was conducted for conditions near solar minimum to remove the effect of the 11-year solar cycle. Comparisons were made with a standard empirical density model to remove the effects of variations in solar and geomagnetic activity, altitude, season, latitude, time of day, etc. In that article, it was proposed that the cooling trend was caused by anthropogenic effects. Now the data set has been expanded to 14 satellites near 380 km to obtain an improved estimate of the trend and to establish possible variations in the trend. In the new study, the average trend from 1976-1996 is found to be minus 10.3 plus or minus 1.2 percent. This is in accord with the 2000 paper, which gave an average trend of minus 9.8 plus or minus 2.5 percent. The new results show statistically insignificant differences between the trend at low and high latitudes indicating a global response with no significant correlation to geomagnetic activity variations. The results appear to be in accord with theoretical model estimates for the response of the thermosphere to increases in CO<sub>2</sub> and CH<sub>4</sub> predicted by Roble and Dickinson (1989), Rishbeth and Roble (1992), and Akmaev and Formichev (2000). A paper by Emmert et al (2004) using a similar approach of studying the orbital decay from 27 satellites qualitatively confirms the downward trend originally discovered in the 2000 paper. All 27 of the satellites they studied indicated a downward trend. Twenty of the 27 satellites experienced a decrease in thermospheric density at somewhat higher altitudes, between 500 and 700 km. It is estimated that CO<sub>2</sub> will double before the end of this century. Exponential extrapolation of the observed trend indicates densities near 400 km may decrease over this time interval by approximately 50 percent due to the strong anthropogenic cooling of the thermosphere.

#### SA53A-04 1420h

##### Long-Term Thermospheric Trends Based on Satellite Drag Analysis

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A new database of thermospheric densities has been derived for the period 1970 - 2000 from satellite orbital decay analysis. The data are generated from actual radar tracking observations, rather than from the

less accurate historical element sets, to form precise orbit and drag/density data with improved accuracy and one-day resolution. Satellites with high eccentricities were used to achieve long lifetimes and relatively localized latitude and local time resolution. Data are compared to three empirical models (Jacchia, NRLM-SIS and NASA MET). The data were normalized to remove systematic model errors vs solar activity detected in all three models. A linear regression through the normalized data was obtained for each satellite. The weighted average of these fits show, at 400 km altitude, a downward trend of about 5% over 30 years with a 95% confidence interval of about 25%. The data are also analyzed as a function of altitude, solar flux and geomagnetic activity, and compared to theoretical predictions. Assuming a linear fit, these results tend to agree with other recent studies indicating a long-term cooling trend in the thermosphere.

#### SA53A-05 1435h

##### A Long-Term Decrease in Thermospheric Density During 1966-2001 Derived From Orbit Data

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The orbital decay rates of long-lived near-Earth space objects indicate a secular decrease in thermospheric density during the period 1966-2001. Over the 200-700 km height range, the trend varies from -6% per decade at solar minimum to -2% per decade at solar maximum. With all solar activity levels combined, the trend increases from -2% per decade at 200 km to -4% per decade at 700 km. The trends do not show a noticeable dependence on geomagnetic activity, local time, season, or latitude. Our results are consistent with the predicted effects of increasing greenhouse gas concentrations. We examine several potential sources of error in our analysis and assess the extent to which they could impact the results.

#### SA53A-06 1450h

##### Modeling of Thermospheric Density Variations using Solar EUV Measurements

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In order to interpret inferences of secular change in thermospheric density, an accurate theoretical understanding of solar rotational and solar cycle influences must be obtained. Since the launch of the TIMED satellite in late 2001 and the SORCE satellite in early 2003, improved quantification of solar EUV and X-ray irradiance and variability has become available. In this study, we compare these recent solar observations to measurements of thermospheric density obtained from changes in satellite orbits. Two approaches are adopted: correlation of the satellite drag data to various bands in the solar spectrum, and comparison with simulations using the NCAR Thermosphere-Ionosphere-Electrodynamics General Circulation Model (TIE-GCM) with measured solar inputs. Although the solar measurements are not yet of sufficient duration to fully characterize the solar cycle behavior, the model response to rotational and impulsive forcing can be validated with the satellite drag data.

#### SA54A CC: 518 C Friday 1530h

##### Global Change in the Upper Atmosphere and Ionosphere III (joint with SM)

Presiding: S Solomon, National Center for Atmospheric Research; E P Shettle, Naval Research Laboratory

#### SA54A-01 1530h

##### Long Term Trends in the Lower Ionosphere Below About 120 km

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The increasing concentration of greenhouse gases in the atmosphere cools the mesosphere and lower thermosphere region. The cooling affects various lower ionosphere parameters. A brief overview of long term trends in the ionized component in the lower ionosphere is presented. Below about 87-90 km, the rocket measurements of electron density, the indirect phase reflection height measurements and the A3 radio wave absorption measurements reveal a trend of general increase of electron density at fixed heights corresponding to cooling and shrinking of the mesosphere and related changes in minor components (NO). Above 90 km, rather scarce rocket measurements display a negative trend in electron density, while ground based measurements support a positive trend. Global ionosonde network provides a slight increase of foE and a slight decrease of h'E, and the nighttime LF radio wave reflection height measurements indicate increasing electron density near 95 km. The discrepancy between rocket and ground based results is briefly discussed. This work was made for the IAGA/ICMA joint working group Long Term Trends in the Mesosphere, Thermosphere and Ionosphere.

#### SA54A-02 1545h

##### Optimally Estimated Mesospheric Ionization and Dynamical Structure From Medium Frequency Radar Measurements

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We describe the application of an optimal estimation inverse method to determine mesospheric electron densities from partially reflected medium frequency polarimeter radar pulses. The method allows us to retrieve both an electron density profile and an electronic structure profile. As well as accounting for the absorption of the two magnetoionic modes formed by ionospheric birefringence of each radar pulse, the forward model of the retrieval parameterises possible Fresnel scatter of each mode by fine electronic structure, phase changes of each mode due to Faraday rotation and the dependence of the amplitudes of the backscattered modes upon pulse width. Monthly mean retrievals from a six year data set (1994-1999) have been processed. Retrieved electron densities are consistent with accepted ideas about seasonal variability of electron densities and their dependence upon nitric oxide production and transport. Retrieved electronic structure values show seasonal variability of ionospheric discontinuity which confirms the predicted seasonal variability of gravity wave breaking height regimes.

#### SA54A-03 1600h INVITED

##### Long-term Change in the Ionosphere - Achievements and Challenges

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It is now twelve years since the first results were published showing a trend in the height of the F-region ionosphere. A large number of data sets have since been