A21B-03 0830h POSTER

Measuring the Forcing Function of Global Warming

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The earth's climate system is warmed by 35 C due to the emission of downward infrared radiation by greenhouse gases in the atmosphere (surface radiative forcing) or by the absorption of upward infrared radiation (radiative trapping). Increases in this emission/absorption are the driving force behind global warming. Climate models predict that the release of greenhouse gases into the atmosphere has altered the radiative energy balance at the earth's surface by several percent by increasing the greenhouse radiation from the atmosphere. With measurements at high spectral resolution, this increase can be quantitatively attributed to each of several anthropogenic gases. Calibrated radiance spectra of the greenhouse radiation from the atmosphere have been measured at ground level from Peterborough and Mirabel using FTIR spectroscopy at high resolution. This long wave radiation consists of thermal emission from naturally occurring gases such as CO_2, H_2O and O_3 as well as from many trace gases such as CH_4, CFC11, CFC12, CFC22 and HNO_3. The forcing radiative fluxes from CFC11, CFC12, CCl_4, HNO_3, O_3, N_2O, CH_4, CO and CO_2 have been quantitatively measured over a range of seasons. The contributions from stratospheric ozone and tropospheric ozone are separated by our measurement techniques. A comparison between our measurements of surface forcing emission and measurements of radiative trapping absorption from the IMG satellite instrument shows reasonable agreement. The experimental fluxes are simulated well by the FASCOD3 radiation code. This code has been used to calculate the increase in surface radiative forcing since 1850 to be 2.55 W/m^2. An ensemble summary of our measurements indicates that an energy flux imbalance of 3.5 W/m^2 has been created by anthropogenic emissions of greenhouse gases since 1850. This should effectively end the argument by skeptics that no experimental evidence exists for the connection between greenhouse gas increases in the atmosphere and global warming.

A21B-04 0830h POSTER

Impact on Climate due to Changes in Radiative Forcing from Stratospheric Aircraft Emissions

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Aircraft emissions can affect climate both directly and indirectly. The 1999 Intergovernmental Panel on Climate Change report on Aviation and The Global Atmosphere estimated that emissions from a fleet of one thousand High Speed Civil Transport aircraft (flying at Mach 2.4) could produce a non-negligible impact on the radiative forcing driving changes in climate. In this study we reexamine the radiative forcing from fleets of aircraft flying at stratospheric altitudes and predominantly in the northern hemisphere mid-latitude regions. We use our narrowband radiative transfer model in these studies, along with model calculations of calculated changes in ozone and water vapor from our zonally-averaged model of atmospheric chemical and physical processes. The radiative transfer model has higher resolution in the tropopause and lower stratosphere region than the models used in the 1999 IPCC assessment. Our results suggest that the radiative forcing for the water vapor emissions from aircraft was overestimated previously.

A21B-05 0830h POSTER

Prognostic Greenhouse Tracers in the CCCma Atmospheric GCM

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Improvements to the Canadian Centre for Climate Modelling (CCCma) atmospheric GCM, as part of ongoing work within the Canadian Global Coupled Carbon Climate Modelling (CGC^3M) project, are described. Specifically, a prognostic tracer scheme has been introduced for methane and nitrous oxide, including parameterized chemical loss of both species and methane oxidation as a source of water vapour in the stratosphere. Results and sensitivity tests of ten-year climate simulations forced with climatological SSTs, sea ice, ozone, and specified surface concentration distributions of the tracers are presented. Zonally-averaged distributions are compared with UARS (HALOE/CLAES) climatology for the years 1992 to present. The model is able to reproduce the observed latitude-height distributions and seasonal variations of these radiatively important species with an accuracy sufficient for long-term transient climate simulations.

A21B-06 0830h POSTER

Climate Variability of Free Atmosphere in the Polar Regions

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Preliminary investigations of free atmosphere above the Arctic Ocean fulfilled with sounding data of the drifting stations "North Pole" show that in 70% of the soundings the inversion base was on the surface; boundary layer height did not exceed 200 m; mean air temperature gradient in the inversion layer was 0.5-1.0 C/100 m. Low-level jets were found in 30% of the soundings. During the investigated period (1955-1991) the boundary layer height and surface inversion depth tended to decrease, and the temperature change through the inversion tended to increase. Longest time series of soundings, executed at the polar station Dickson, shows the maximal inversion height in late 1940s - early 1950s, minimal - in 1980s- early 1990s, and graduate increase in the last years of 20th century. Long-term variations of the monthly mean air temperature and humidity in the free atmosphere above the North Polar Region (60-90 N) were investigated with the original database, created in the Arctic and Antarctic Institute, Russia by V. Maistrova. This database combines the results of soundings executed on 116 aerological stations, ship observations and observations on the drifting stations "North Pole". The analysis of temperature trends for 1959-2003 shows that the annual mean air temperature in the North Polar Region increased in the low and middle troposphere (850-400 hPa) and decreased in the upper troposphere and in the low stratosphere. The total energy of the Arctic atmosphere attributed to the so-called "mean energetic level" shows weak positive trend with strong long-term variations. Preliminary estimates of temporal variability of mean specific humidity at 850, 700, 500, 400 and 300 hPa show pronounced increase from surface to 850 hPa and decrease above 850 hPa. The spatial distributions of air temperature and humidity trends demonstrate strong inhomogenity of relevant meteorological fields. Comparison the trends of the annual mean air temperature and humidity for 1959-2003 in the North and South Polar Regions shows strong differences, especially in the low stratosphere, where negative trends in the Arctic much more pronounced. In total the data demonstrate the increase of local instability in the polar upper troposphere and low stratosphere, which could be explain as due to direct greenhouse effect, as well as due to changes in global circulation, originated by the increase of global or tropical ocean temperature.

A21C CC: 520 D Tuesday 0830h

Tropical Water Vapor: New Understanding and New Challenges I

(joint with H, OS, GC)

Presiding: **I Folkins,** Dalhousie University**; A Gettelman,** National Center for Atmospheric Research

A21C-01 0830h INVITED

Free-tropospheric Water Vapor in the Tropics

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In the deep Tropics, convective detrainment and evaporation of precipitation falling from convective clouds are the only sources of the free-tropospheric moisture. It is thus not surprising that the observed large-scale fluctuations of the free-tropospheric humidity are closely tied to convection, with large-scale regions featuring deep convection being more humid than regions void of deep convection. Tropical convection is organized on a large range of spatial and temporal scales, and involves individual convective clouds, mesoscale convective systems, convectively-coupled equatorially-trapped waves, and intraseasonal oscillations. Coping with this range of convective phenomena in the Tropics is challenging for temporary climate models. This has important implications not only from the point of view of climate variability in the tropics, but also for the stratospheric physics and chemistry. This paper will review the role of the water vapor in the tropical dynamics and climate. In particular, it will be argued that free-tropospheric humidity is not a passive constituent, but it has a significant role in organizing convection on intraseasonal time scales. A comparison between tropical climate simulations using a traditional climate model and a model featuring a novel representation of convective processes, the super-parameterization, will highlight key processes relevant to the tropical free-tropospheric water vapor.

A21C-02 0900h

Predicted and observed histograms of free-tropospheric water vapor

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The simplest conceptual model of free-tropospheric water vapor is that initial water vapor amounts are nearly saturated in air that is introduced from the boundary layer into the free troposphere, and are subsequently unchanged as air slowly descends to lower potential temperatures while circulating horizontally. This may be combined with stochastic models of convective lofting to predict water vapor histograms; a broad distribution of relative humidity is predicted. If cloud effects are qualitatively included, and if the sinking rate is sufficiently rapid, this distribution becomes bimodal. We present these results and test the idea using GPS and MLS (Microwave Limb Sounder) satellite observations.

A21C-03 0915h

Bimodality in Tropical Water Vapor

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Probability distribution functions of tropospheric water vapor in the tropics are shown to be commonly

bimodal. This bimodality implies sharp gradients between dry and moist regimes in space and time. A method of testing for and quantifying bimodality is introduced. Using this method, the bimodality of water vapor is surveyed in satellite and in situ observations, as well as global model reanalysis and simulations. The bimodality suggests that the radiative drying time after an injection of moisture by convection is short (1-2 days) compared to a homogenizing time, whether physical (mixing) or mathematical (averaging). It is shown that the local bimodality found in cloud-model simulations and in situ point measurements disappears with modest time averaging (18 h and 200km), but then reappears on the global scale, where dry and moist regions are separated so widely that synoptic and large-scale mixing times exceed the drying time scale. Large discrepancies exists in the ability of reproducing the global-scale bimodality by global model reanalysis and simulations.

URL: http://orca.rsmas.miami.edu/~czhang/publications/bimodal.pdf

A21C-04 0930h

Trimodal distribution of ozone and water vapor in the UT/LS during boreal summer

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The relation of ozone and water vapor in the upper troposphere and lower stratosphere (UT/LS) is strongly influenced by the off-equatorial Asian and North American monsoons in boreal summer. Both regions experience hydration, presumably as a result of deep convection. This behavior contrasts sharply with the apparent dehydrating influence of near-equatorial deep convection in boreal winter. There is also a striking difference in ozone between Asia and North America in boreal summer. Over Asia, ozone concentrations are low, evidently a result of ubiquitous deep convection and the vertical transport of ozone-poor air, while over North America, ozone concentrations are much higher. Since deep convection also occurs in the North American monsoon, it appears that the difference in ozone concentration between Asia and North America in boreal summer reflects a differing influence of the large-scale circulation in the two regions: specifically, (i) isolation of the Tibetan anticyclone versus (ii) the intrusion of filaments of ozone-rich air from the stratosphere over North America. During boreal summer, as in winter, near-equatorial concentrations of ozone and water vapor are low near the equator. The result of these geographical variations is a trimodal distribution of ozone and water-vapor correlation. Our talk reviews the observational evidence of this trimodal distribution and possible dynamical and microphysical causes, focusing primarily on the quality and possible sampling bias of satellite and aircraft measurements. A key issue is the ability of HALOE to sample areas of ubiquitous deep convection. Other issues include the vertical structure of tracer anomalies, isentropic stirring in the UT/LS, horizontal transport of biomass burning products lofted by deep convection, and connections to the moist phase of the tropical tape recorder' signal in water vapor.

A21C-05 0945h

Intraseasonal Variations of Water Vapor and Cirrus Clouds in the Tropical Upper Troposphere

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Space-time variations of tropical upper tropospheric water vapor and cirrus clouds associated with the intraseasonal oscillation (ISO) are investigated using data from the Microwave Limb Sounder (MLS) and the Cryogenic Limb Array Etalon Spectrometer (CLAES) on board the Upper Atmosphere Research Satellite (UARS). Composite moisture and meteorological fields based on five ISO events selected in two boreal winters (1991-1993) are analyzed using 20-80 day band-pass filtered data. At 215 and 146 hPa, wet anomalies with frequent appearance of cirrus clouds exist over the convective system and move eastward from the Indian Ocean to the central Pacific, suggesting a direct effect of convective activity up to this level. At 100 hPa, however, the moisture field seems to be indirectly affected by convective activity through the dynamical response to the convective heating. Dry anomalies are observed over the Indian Ocean around the developing stage and over the eastern Pacific around the mature-to-decaying stage of the ISO. Cirrus clouds are frequently found over the cold region located to the east of the convective system. These structures around the tropopause level are closely related to the eastward moving Kelvin and Rossby wave responses to the convective heating with the equatorial cold anomaly and with the subtropical anticyclonic gyres. Between the two gyres the easterly wind blowing through the equatorial cold region may cause dehydration through cirrus formation when the convective system develops over the Indian Ocean and the western Pacific. As the northern gyre intensifies, tropical dry air is transported to the subtropical Pacific and eventually to the equatorial eastern Pacific. It is suggested that the temperature and flow variations due to the coupled Kelvin-Rossby wave structure play an important role in dehydrating air in the tropical and subtropical tropopause region.

A21D CC: 520 F Tuesday 0830h

Atmospheric Chemistry and Aerosol Processes in West Africa: Saharan Dust, Biomass Burning, and Measured Tropospheric Ozone I *(joint with U)*

Presiding: **G S Jenkins,** Howard University**; V Morris,** Howard University**; R Martin,** Dalhousie University

A21D-01 0835h INVITED

An Investigation of Tropospheric Ozone Interannual Variability over Africa Determined from Satellite Measurements

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Using measurements from the Total Ozone Mapping Spectrometer (TOMS) and Solar Backscattered Ultraviolet (SBUV) satellite instruments, we have derived nearly 20 years of tropospheric ozone monthly distributions. Previous studies have shown that the interannual variability of the amount of ozone over western Europe can be related to the intensity of the North Atlantic Oscillation (NAO) and that the amount of ozone pollution over northern India is correlated with the indices defining the strength and phase of the El Niño/Southern Oscillation (ENSO). In addition, this dataset also displays significant interannual variability over several regions of Africa. This study will focus on the ozone abundance over these regions and investigate the extent to which such variability is related to either the NAO or ENSO as a means to determine which prevailing meteorological situation is most conducive to enhanced tropospheric ozone production.

A21D-02 0850h INVITED

Satellite Observations of African Biomass Burning Emissions and Their Impact on Tropospheric Air Quality

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Satellite remote sensing offers one of the best opportunities for making global measurements of tropospheric trace gases and aerosols over extended periods of time. It provides an integrating step between observations of emission sources and subsequent in-situ measurements taken some distance away, thus allowing the the examination of the impact of intense local pollution sources on continental scale air quality. Measurements from the Terra satellite launched in December of 1999 now provide a global record of the recent inter-annual variability of tropospheric air quality: carbon monoxide (CO) from the Measurement Of Pollution In The Troposphere (MOPITT) instrument, and of aerosol optical depth from the Moderate-resolution Imaging Spectroradiometer (MODIS). In this paper we use different sensor measurements to obtain a broader picture of the processes affecting tropical tropospheric chemistry and transport over Africa and the Atlantic and Indian Oceans at different times of the year. We use the signatures of large biomass burning events to trace the long-range transport of pollutant emissions and their effect on air quality in remote regions as revealed through comparisons with in-situ measurements and satellite estimates of tropospheric ozone. We also assess the role of large-scale convection in delivering biomass burning pollutants to the upper troposphere. When used in conjunction with satellite fire detection, the availability of global CO and aerosol data from the last 3 years also allows us to study variability in biomass burning and the corresponding influence that this has on seasonal and inter-annual variability of atmospheric pollutant burdens on the global scale.

A21D-03 0905h INVITED

African Equatorial and Subtropical Ozone Plumes: Recurrence Timescales of the Brown Cloud Trans-African Plume and Other Plumes

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We have found repeated illustrations in the maps of Total Tropospheric Ozone (TTO) of apparent transport of ozone from the Indian Ocean to the Equatorial Atlantic Ocean. Most interesting are examples that coincide with the INDOEX observations of late northern winter, 1999. Three soundings associated with the SHADOZ (Southern Hemisphere Additional Ozonesondes) network help confirm and quantify degree of influence of pollution, lightning, and stratospheric sources, suggesting that perhaps 40% of increased Atlantic ozone could be Asian pollution during periods of maximum identified in the TTO maps. We outline recurrent periods of apparent ozone transport from Indian to Atlantic Ocean regions both during and outside the late-winter period. These are placed in the context of some general observations about factors controlling recurrence timescales for the expression of both equatorial and subtropical plumes. Low-level subtropical plumes are often controlled by frontal systems approaching the Namib coast; these direct mid-level air into eithier easterly equatorial plumes or westerly mid-troposphere plumes. Equatorial plumes of ozone cross Africa on an easterly path due to the occasional coincidence of two phenomena: (1) lofting of ozone to mid and upper levels, often in the Western Indian Ocean, and (2) the eastward extension of an Equatorial African easterly jet.

URL: http://www.sonic.net/~chat

A21D-04 0920h

AEROSE 2004 - An Interdisciplinary Atmosphere-Ocean Saharan Dust Expedition

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The NOAA Center for Atmospheric Sciences (NCAS) is sponsoring a Trans-Atlantic Saharan Dust AERosol and Ocean Science Expedition (AEROSE) aboard the NOAA Ship Ronald H. Brown in March 2004. The fundamental purpose of this aerosol cruise is to study the impacts and microphysical evolution of Saharan dust aerosol as it is transported across the Atlantic Ocean. The mission encompasses both, atmospheric and oceanographic components. Participating institutions include Howard University, NCAS lead institution, the University of Puerto Rico at Mayagüez, the Canary Institute of Marine Sciences,