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Determining regional fluxes from CO_2 measurements over land is rendered difficult due to high-frequency variability associated with synoptic events and changes in turbulent mixing, as well as convective redistribution and inhomogeneous fluxes in the near-field of the observations. Assimilated meteorological products at high resolution are thereby necessary to capture variations associated with weather systems and to adequately resolve atmospheric transport. To assess the requirements for assimilated meteorological data products necessary to derive surface fluxes from atmospheric measurements, we present the use of these products in a receptor-oriented framework that quantitatively links concentration changes in CO and CO_2 at the locations of observations (receptors) to surface fluxes in upwind regions. The framework consists of (1) regional Lagrangian transport model, (2) parameterized surface boundary conditions for fossil fuel and biospheric fluxes, and (3) lateral boundary conditions. The transport model - the Stochastic Time-Inverted Lagrangian Transport (STILT) model interpolates assimilated winds and incorporates realistic turbulent winds in the boundary layer - is run backward in time, extracting the adjoint solution from assimilated winds to map out the source-receptor relationship (footprint) at high temporal and spatial resolution. Issues like violation of mass conservation in the assimilated meteorological fields, and preservation of well-mixed distributions will be discussed in the light of requirements for time-reversibility. Comparison of simulated concentrations of CO and CO_2 with aircraft-borne data collected during the 2000 COBRA mission highlights the current shortcomings and future requirements for assimilated meteorological data products in carbon science.

A71G-09 1050h INVITED

A Comparison of the Lower Stratospheric Age-Spectra Derived from a General Circulation Model and Two Data Assimilation Systems

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We use kinematic and diabatic back trajectory calculations, driven by winds from a general circulation model (GCM) and two different data assimilation systems (DAS), to compute the age spectrum at three latitudes in the lower stratosphere. The age-spectra are compared to chemical transport model (CTM) calculations, and the mean ages from all of these studies are compared to observations. The age spectra computed using the GCM winds show a reasonably well-isolated tropics in good agreement with observations; however, the age spectra determined from the DAS differ from the GCM spectra. For the diabatic trajectory calculations, the age spectrum is too broad as a result of too much exchange between the tropics and mid-latitudes. The age spectrum determined using the kinematic trajectory calculation is less broad and lacks an age offset; both of these features are due to excessive vertical dispersion of parcels as can be seen in the simulations. The tropical and mid-latitude mean age difference between the diabatically and kinematically determined age-spectra is about one year, the diabatic being older. The CTM calculation of the age spectrum using the DAS winds shows the same dispersive characteristics of the kinematic trajectory calculation. These results suggest that the current DAS products will not give realistic trace gas distributions for long integrations; they also help explain why the mean ages determined in a number of previous DAS-driven CTMs are too young compared with observations.

A71G-10 1105h INVITED

Evaluation of Transort in the Lower Tropical Stratosphere in a Global Chemistry and Transport Model

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In order to compare the transport characteristics of an assimilated dataset with those of the parent general circulation model (GCM), a set of off-line transport experiments has been performed. The tracer-estimated age of air inferred from observations of SF6 and CO2 is compared to the values determined from the GCM and the data assimilation system (DAS). Distributions of ozone, total reactive nitrogen, and methane from the two simulations are also compared with observations. These comparisons show that DAS fields produce too rapid ascent in the Tropics and excessive mixing between the Tropics and middle latitudes; these features are much better represented in the GCM. The unrealistic transport produced by the DAS fields may be due to implicit forcing that is required by the assimilation process when there is bias between the GCM forecast and observations that are combined to produce the analyzed fields.

A71G-11 1120h INVITED

On the Issue of Excess Lower Stratospheric Subtropical Transport in GEOS-DAS

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In recent years, data assimilation has become an indispensable tool for our understanding of the global features of meteorological variables. However, assessments of transport characteristics using trajectory related methods as well as chemical transport models (CTMs) show that results derived from assimilated (or analyzed) winds exhibit significantly larger mixing and entrainment rates compared to results derived from GCM winds, which are closer to results derived from observations (e.g., Douglass et al., 2002; Schoeberl et al., 2002). This discrepancy presents a serious challenge to our ability to understand and model global trace gas transport and distribution. We use the GEOS-DAS to explore this issue by examining how the process of data assimilation alters the dynamics of the underlying GCM and how this leads to the excess of lower stratospheric mixing and transport in the subtropics. In particular, we show that significant model biases in tropical winds necessitate large analysis increments. These increments directly force large subtropical regions of instability with negative PV gradient on the one hand, and generate excessive noise in the tropical wind fields on the other. The result is an excess of transport in the lower stratospheric subtropics.

A71G-12 1135h

Seasonal Variations in UTLS Ozone as Determined by Measurements From the TOPSE Campaign, Satellite Observations, and Model Output

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A goal of the Tropospheric Ozone Production about the Spring Equinox (TOPSE) experiment is to determine the causes of observed springtime increases in mid-tropospheric ozone concentrations at remote mid- and high-latitude locations of the Northern Hemisphere. Observed seasonal variations in stratosphere-to-troposphere exchange (STE) may explain a portion of the increases. In this study, seasonal variations in CTM-calculated, assimilation-calculated, and measured lower stratosphere/upper troposphere (UTLS) ozone concentrations are compared in the mid- and high-latitudes of the northern hemisphere for the year 2000. CTM-calculated mixing ratios are taken from calculations with the Goddard CTM driven by meteorological data from versions 3 and 4 of the Goddard Earth Observing System Data Assimilation System (GEOS DAS). Assimilation-calculated mixing ratios are produced by assimilation of ozone observations from the Solar Backscatter Ultraviolet/2 (SBUV/2) instrument and/or the Total Ozone Mapping Spectrometer (TOMS). Ozone measurements include HALOE data from UARS and DIAL data from TOPSE. Questions to be addressed include: How similar are model-calculated and assimilation-calculated seasonal cycles? Is the seasonal cycle affected by the choice of assimilation system (version-3 or version-4)? Are seasonal changes in STE of ozone reflected in model and/or assimilation ozone distributions? Are seasonal changes in 2000 typical of other years?

A71G-13 1150h

Investigation of 2D-Trace Gas Field Reconstruction Techniques From Tomographic AMAX-DOAS Measurements

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Tomographic-Differential-Optical-Absorption-Spectroscopy (Tom-DOAS) is a new application of the DOAS method designed to measure 2-3-dimensional concentration fields of different trace gases (e.g. NO2, HCHO, Ozone) in the troposphere. Numerical reconstruction techniques are used to obtain spatially resolved data from the slant column densities provided by DOAS instruments.

We discuss the detection of emission plumes by AMAX (Airborne Multi AXis) DOAS Systems which measure sunlight by telescopes pointing in different directions. 2D distributions are reconstructed from slant columns by using airmass factor matrices and inversion techniques.

We discuss possibilities and limitations of this technique gained with the use of simulated test fields. Therefore the effect of the parameter choice (e.g. flight track, algorithm changes) and measurement errors is investigated. Further, first results from the Partenavia aircraft measurements over Milano (Italy) during the European FORMAT campaign will be presented.

A71H MCC: 125 Sunday 1020h

Recent Advances in Global Climate Modeling II *(joint with NG, B, H, OS, GC)*

Presiding: **E Bierly,** American Geophysical Union**; D Stephenson-Hawk,** The Stephenson Group

A71H-01 1020h INVITED

A Brief History of Climate Modeling

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A brief review of the development and application of climate models is presented, ranging from the early quasi-geostrophic atmospheric models used to study the general circulation to the current sophisticated coupled models of the climate system. The development of coupled models at NCAR and their application to the simulation of the climatic effects of increased atmospheric CO2 are seen as highlights of the contributions of Warren Washington.

This work was performed under the auspices of the U.S. Department of Energy by the University of California at Lawrence Livermore National Laboratory under Contract No. W-7405-Eng-48.

A71H-02 1035h INVITED

Simulation of Past Climates: Studies using NCAR Climate Models and Computers

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While climate models are being developed and improved to address questions of present and future climates, they are also being used to explain the causes of past climates and climate change. The use of climate models to study and understand the mechanisms of past climate changes began at NCAR, and elsewhere, in the 1970s, and continues in expanding fashion today. Warren Washington has played a key role in NCARs work in this fascinating area through his leadership in recognizing the importance and relevance of studies of past climate, through his direct involvement in this research, through his encouragement of NCAR scientists and visiting scientists in pursuing this work, and through his support of university scientists in using NCAR climate models and computers. This paper reviews some of these studies.

In the 1970s, the NCAR general circulation model was used in initial studies of ice age climates, of the warm climates of the Cretaceous with changed positions of the continents, of the response of climate to changes in the height of mountains and plateaus, and of the response of climate to changes in greenhouse gas concentrations. Warren Washington was a coauthor in all of these studies and thereby helped launch NCARs involvement in this area of interdisciplinary research involving geology and ecology as well as climatology. In the 1980s, and especially with the development of the NCAR Community Climate Model, version 0 (CCM0), the study of the causes of climate change expanded to include other climate forcing mechanisms (including the role of orbital changes). In the 1980s, and continuing into the 2000s, improved versions of the CCM, and other climate models, have incorporated more interactive components - soil moisture, sea ice, mixed-layer ocean, dynamic ocean, dynamic vegetation. These multi-component climate models are being used to greatly extend the early studies of past climates by simulating both the initial response of climate to changes in external forcing and the subsequent internal adjustments and feedbacks within the atmosphere-ocean-cryosphere-biosphere system. Some of the achievements of the past 25 years will be illustrated by comparing results from early studies and recent studies.

A71H-03 1050h INVITED

Using climate models to unraveling past conditions during Earth's history and its relevance to Climate Change

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During the mid 1970s global climate models were used to examine climate conditions of the past. Initially these early studies considered how external changes would influence the climate system and the ocean was considered as a fixed boundary condition. By the early 1980s the ocean evolved from a fixed boundary condition, to one acting solely as a moisture source and finally to considering the thermodynamic and dynamic states of the ocean. At the same time, the role of internal boundary condition (greenhouse gas concentrations, continental configuration, rotation rate, ice-sheets) as a means for understanding past climate were being taken into account. Many of the early studies used the National Center for Atmospheric Research (NCAR) community climate model (CCM) as the model of choice for studying paleoclimates. Today climate models are capable of examining the full climate system (atmosphere, ocean, cryosphere, biosphere, ocean) with paleoclimate modelers examining past climates and also attempting to simulate the last 500 years. If these simulations agree with the observed proxy record, then it may be possible to bracket the natural climate variability prior to the industrial revolution in climate models. Moreover, these types of simulation allow for the analysis of interannual to centennial variability. Consequently, the ability to correctly simulate past climates can only increase our confidence in simulating future climate change caused by anthropogenic greenhouse forcing.

A71H-04 1105h

Ocean and Sea Ice Components of NCAR Climate Models, 1975-2000

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This talk covers the evolution of the ocean and sea-ice components in climate models developed at the National Center for Atmospheric Research under the leadership of Warren Washington over the years 1975-2000. The oceanic component has always been a dynamic/thermodynamic model as formulated originally by Bryan and Cox at NOAA's Geophysical Fluid Dynamics Laboratory. It was brought from UCLA in newly vectorized form by Semtner in 1976, adapted for parallel vector processing by Chervin in 1988, and improved on massively parallel machines by Los Alamos investigators in the early 1990s. The ice model started as Semtner's streamlined thermodynamics, based on Maykut/Untersteiner's formulation and tested for Arctic and Antarctic by Washington et al. (1976); but in the 1990s, ice-dynamics formulations were added based on Hibler's viscous-plastic formulation and a more parallel Los Alamos version with elastic waves. NCAR's first climate model experiments with active ice and ocean were published by Washington et al. (1980). Over the next 20 years, model physics were improved and model resolution significantly refined in order to more realistically represent climatic states. By adopting the latest atmospheric component of the separately developing Community Climate System Model (CCSM), Washington's resulting Parallel Climate Model was able to reproduce historical climate records and project climate changes resulting from anthropogenic and natural causes, including the effects of unforced variability. This was a result of carefully planned and executed ensemble experiments conducted by Dr. Washington's research team and collaborators, using the most advanced computers available for the effort. That effort continues today as part of the CCSM.

A71H-05 1120h

Solar and Greenhouse Gas Forcing and Climate Response in the 20th Century

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Ensemble experiments with a global coupled climate model are performed for the 20th century with time evolving observed solar, greenhouse gas, sulfate aerosol (direct effect), and ozone (tropospheric and stratospheric) forcing. Observed global warming in the 20th century occurred in two distinct periods, one in the early 20th century from about 1900 until the mid-1940s, and one later in the century from the 1960s to 2000. Of interest here is the transient climate system response in these two periods when the nature of the forcing was fundamentally different. This difference is manifested by the fact that solar forcing is more spatially heterogeneous (i.e. acting most strongly in areas where sunlight reaches the surface) while greenhouse gas forcing is more spatially uniform. Consequently, solar forcing is subject to feedbacks involving temperature gradient-driven circulation regimes that can alter clouds. Over relatively cloud-free oceanic regions in the subtropics, the enhanced solar forcing produces greater evaporation. More moisture then converges into the precipitation convergence zones, intensifying the regional monsoon, Hadley, and Walker circulations, causing less clouds over the subtropical ocean regions, and even more solar input. Since the greenhouse gases are more spatially uniform, such regional circulation feedbacks are not as strong. Coupled regional responses are most evident when the solar forcing occurs in concert with increased greenhouse gas forcing of about the same magnitude. Additionally, the increases in the tropical precipitation regimes for early century solar-residual are greater than the late 20th century GHG+sulfates (by a factor of two to nearly an order of magnitude) in the West African and Asian monsoon regions (the latter qualitatively consistent with observed trends in All-India rainfall), the tropical Pacific, and in the southern ocean tropical convergence zones.

A71H-06 1135h INVITED

The Asian Brown Cloud

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The Indian Ocean Experiment discovered a wide spread anthropogenic haze over the south Asian region and the northern Indian ocean. It is now recognized that this south Asian haze is really a part of a larger scale phenomenon involving most of the Asian continent. The affected region is densely populated with over 50% of the worlds population, monsoon climate, impressive industrialization and high levels of pollution. INDOEX data revealed that black carbon and dust in the haze enhances atmospheric solar heating by 50% to 100% in the lower troposphere and reduces the solar energy absorbed by the surface by as much as 10%. These changes are about an order of magnitude larger than the radiative changes due to the increase in greenhouse gases.

After describing the nature and extent of the haze as well as the sources that contribute to it, we will show coupled ocean-atmosphere model simulations of the impact of the Asian Brown Cloud on regional and global climate. The most important insights we get from the model simulations thus far is that the haze may be contributing significantly to the observed climate variability of the recent decades, including the monsoon, El Nino and extra-tropical climate variability.

A71H-07 1150h INVITED

Climate Change Doesn't Just Happen

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The simulation of climate change is based on the use of global circulation models of the ocean and atmosphere coupled with land, sea ice and chemistry models. The level of understanding of processes and forcing involved with observed climate changes, and the ability to project future evolution and impacts is reflected in the complexity and scope of models such as Warren Washington's Parallel Climate Model (PCM) and the Community Climate System Model (CCSM2). Through careful reconstruction of the historical climate forcing it is possible to separate signal from noise and simulate what has happened from 1870 to present as a result of increased atmospheric greenhouse and aerosol loading.

That scientifically grounded coupled climate model simulations are possible is a remarkable feat in itself, a feat that did not just happen. A sustained, coordinated effort of researchers from several institutions has addressed the delicate balances of non-flux adjusted coupled components, the parallel decompositions of modern computing platforms, the software engineering methodologies of model development, and the data analysis challenges of ensembles of climate simulations. The approaches taken to these challenges will be described in this talk in relation to one of the key figures in climate change.

A72A MCC: Hall D Sunday 1330h

Polar Air Chemistry: Past and Present I Posters *(joint with C, OS, GC, PP)*

Presiding: **J E Dibb,** University of New Hampshire**; N M Mahowald,** National Center for Atmospheric Research

A72A-0133 1330h POSTER

SNOW2002: NOx Production From Nitrate-In-Ice Photolysis at Two pHs and Comparison with NOx Levels From Nitrite-In-Ice Photolysis

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