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M-I: Climate Change

Decadal to Interdecadal Climate Variability and the Climate Change Background

Chris Folland, Adam Scaife, Andrew Colman, Jeff Knight, David Fereday and Peter Baines

UK Met Office

Using the Met Office's sea surface temperature and night marine air temperature analyses and other diagnostics, we show that on quasi-global scales, three prominent modes of variability and change are observed. The first is a global warming signal that is very highly correlated with global mean SST and thus has the same shape. The second mode is an interhemispheric variation which, with the help of climate model experiments, can be assessed to be largely due to natural variations in the thermohaline circulation. We show some of the climatic impacts of this mode which also appear to be present in long model simulations. The third mode is a decadal to multidecadal modulation of ENSO which is associated with the Pacific Decadal Oscillation and whose quasi global manifestation has been termed the Interdecadal Pacific Oscillation (IPO). Night marine air temperature show similar modes, such as the same global warming signal, despite the fact that night marine air temperature is measured and analysed almost independently of sea surface temperature after 1893. There is currently disagreement as to whether the IPO mode is a genuine mode of variability or solely due to interdecadal modulation of the interannual ENSO phenomenon. We present some evidence which supports the idea of a real mode.

On smaller space scales, there are a number of other regional atmospheric phenomena affecting climate on decadal to interdecadal time scales e.g. the Arctic Oscillation, the Antarctic Oscillation and the Indian Monsoon amongst others. We concentrate here on one such regional mode, the winter North Atlantic Oscillation. This shows strong decadal to interdecadal variability in the twentieth century and a correspondingly strong influence on surface climate variability which can be confused with regional anthropogenic climate change. We present evidence to indicate that the winter NAO is influenced by both SST forcing and stratospheric feedback. A full understanding of decadal changes in the NAO may require a detailed representation of the stratosphere that is hitherto missing in the major climate models used to study climate change.

Finally we note that the potential interaction of natural modes of decadal to inter-decadal climate variability and (mainly) anthropogenically induced climate change is an almost unexplored topic which could be of great practical importance.

Global Climate Change in the 20th Century: Forcing Mechanisms and their Impacts

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We discuss the natural and anthropogenic forcing mechanisms that have acted upon the Earth's climate system in the 20th century. We carry out simulations with the GFDL global climate model to discern the responses to the different forcing factors. Comparisons are carried out with unforced integrations to qualify the roles that variability, natural and anthropogenic factors have played. Observation are used to evaluate the model's simulation of present-day climate. Model simulations of climate change are compared with observations to ascertain the relative effects due to the diffrent factors upon the surface, troposphere and stratosphere. Gaps in knowledge and areas where further research is needed to reduce the uncertainties will also be discussed.

Sensitivity of Climate to Changes in CO_2

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One of the mysteries of climate change and climate modeling is the response of the global average temperature to a doubling of CO_2 and this has led to the wide range of climate scenarios projected for the next century. There have been a number of interesting studies along these lines over the last few decades. More recently it has been acknowledged that there are many poorly constrained parameters in climate models and that these contribute significantly to the uncertainty in climate sensitivity. This talk will review some of the previous studies and present some new results based on the simplest climate models that have only a few phenomenogical parameters. We introduce a Gaussian penalty function for the poorness of fit a particular parameter choice implies. The penalty function serves as a prior distribution for the probability density function of the sensitivity. This method tends to diminish the high sensitivity tail of the distribution that is found in some earlier studies.

The Virtual Butterfly Effect, Pseudo Errors in Initial Conditions, Symmetry Breaking and Long-Term Forecasting

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Because of sensitivity to initial conditions inherent in the governing dynamical equations, it is widely accepted that there exists a limit of about two weeks for operational forecasting of the weather. For long-term forecasting, averaging over a collection of computed values deduced from an ensemble of initial conditions seems to be a way through this barrier. But can small systematic errors survive this process and grow nonetheless? Plausible mechanisms that might produce such errors are difficult to envisage. They must entail errors initially small enough that they can be overlooked in the beginning. They cannot contradict known behaviors on middle time scales, but on long enough time scales they must be able to meaningfully affect average behaviors to matter. This talk reviews a physical scenario for such errors and it introduces another one that is computational in origin. The physical scenario concerns small corrections to the Navier Stokes equations used in studying shock waves (i.e. Burnett equations). The initial difference in solutions can function as if it were an error in initial conditions, creating a butterfly-like effect, but without the butterfly. On the other hand the computational scenario entails the loss of mathematical (e.g. Lie) symmetries in dynamical equations in the implementation of any computational scheme to model them. Thus computational schemes do not generally conserve (exactly) quantities conserved by the original dynamics. While this may not matter over short times, average behaviors over long enough times can be affected, as examples will show.

Characteristic Response Time of Global Mean Surface Temperature

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Earth's climate system responds to perturbations on numerous time scales from short -- diurnal, annual -- to long -- multiple centuries (warming of the deep oceans) to millions of years (Kelvin and "the age of the Earth"). Here I argue that the time scale pertinent to climate system response to forcings over decadal scales is that associated with change in global mean surface temperature GMST. On such time scales GMST is tightly coupled to the ocean mixed layer, which provides virtually all the heat capacity of the system, global mean areal heat capacity 9.4 W yr m-2 K-1 (100 m depth; fractional ocean area 0.71). Recent compilations of the rate of increase in the heat content of the oceans over 1960-2000 together with the observed rate of increase of GMST over this time period permit determination of the heat capacity pertinent to climate change as 9 W yr m-2 K-1, uncertain to 50%, comparable to that of the ocean mixed layer. From energy balance considerations such a global heat capacity yields for the time constant of climate system response (time for e-fold decay of a perturbation) a value of 2.5 years in the absence of feedbacks; inclusion of a feedback factor of up to several fold yields a time constant of up to a decade or so. Similarly short values of the time constant are obtained from analysis of autocorrelation of time series of GMST and ocean heat content. Such a short time constant implies that most of the change in GMST due to radiative forcing on the decadal time scale has been realized and hence that climate sensitivity might in principle be inferred from observed change in GMST if forcing were known with sufficient accuracy, but the present uncertainty in aerosol forcing does not usefully bound that sensitivity. For reasonable estimates of aerosol forcing (corresponding to aerosol forcing over the industrial period of -0.5 to -1.5 W m-2) climate sensitivity is estimated as 0.63 to 1.4 K/(W m^{-2}), equivalent to a temperature increase for doubled CO_2 of 2.5 to 5.8 K. The corresponding range of present temperature increase due to increased CO_2 alone is 1.0 to 2.3 K, the difference relative to the observed temperature increase (~0.6 K) being due mainly to cooling by anthropogenic aerosols. Relaxation of the perturbation to GMST due to enhanced greenhouse gases requires a much longer time, being governed mainly by the decay of excess CO_2, which occurs on the time scale of centuries.

M-II: Remote Sensing: In Memory of Yoram Kaufman (Part 1)

Using MODIS aerosol products the way Yoram and Didier intended: Calculating the aerosol direct radiative effect.

Lorraine A. Remer

NASA/GSFC

When Yoram Kaufman and Didier Tanré began developing the operational MODIS aerosol algorthims, the only precedent they had to follow was the ocean only AVHRR retrievals. The TOMS people had not discovered aerosol in their ozone data yet, and all other satellite retrievals were done for local and regional situations where assumptions about aerosol and surface properties could be verified by local data. The AVHRR instrument was never meant for aerosol retrieval and nobody had dared try an operational global product over land. Yoram and Didier were daring. Daring and smart. They coaxed as much information out of the MODIS channels as they could, and they knew when they had reached the limit of what MODIS could do. All the time the algorithms were in development, they never lost track of the goal, and the goal was to use the MODIS aerosol results to answer climate questions. One of the first questions to answer was the simple one, what is the aerosol direct radiative effect? The original MODIS products included a parameter that was the aerosol radiative backscattered flux at the top of the atmosphere. In a paper that Yoram and Didier wrote, but never published, they showed how MODIS's calculation of reflected flux should be more accurate than the retrieval of aerosol optical thickness. This was because assumptions of aerosol properties introduced error into the retrieval of AOT, but the errors associated with assumptions of aerosol model would cancel out in the calculation of outgoing flux. The "Flux" parameter in the original data sets was never well-defined, and it went through at least 4 revisions as we struggled to understand the conditions in which it was calculated and to maintain consistency between land and ocean. Finally, we eliminated the parameter altogether.

Instead, Yoram and I made the flux calculation outside of the retrieval algorithm using the retrieved products in a consistent manner. By doing so we could produce an estimate for the aerosol radiative effect with a high degree of accuracy and confidence. I would like to briefly step through an insider's view of the development of the MODIS aerosol algorithms and end with how we used the data to make this radiative calculation.

Can Remote Sensing Unravel the Duality of Aerosol Effect on Clouds and Climate?

Yoram J. Kaufman, J. V. Martins, and L. Remer

NASA/GSFC

The aerosol effect on cloud formation, properties and precipitation is very intriguing. Aerosols can increase or decrease the cloud cover, having regional cooling or warming effects on climate. Aerosol increase of the cloud droplet concentration can interfere with precipitation processes, thus increasing the cloud lifetime and cover. However, aerosol absorption of sunlight heats the atmosphere and cools the surface, usually making the conditions for cloud formation less hospitable, thus decreasing the cloud cover. By "usually" I mean if the aerosol is mixed with the clouds in the same layer. Absorbing aerosol above stratiform clouds were shown to increase the cloud cover by increasing the strength of inversion that forms the clouds. These different faces of the aerosol effects form one of the largest uncertainties in climate research.

Satellites and ground based instruments measure both clouds and aerosol and therefore can report the correlation among them. However correlation of clouds and aerosol can result not only from aerosol impact on clouds, but also from cloud processing of trace gases to increase the aerosol mass concentration and due to variation of the humidity field in the vicinity of the clouds and the aerosol response. Coincidental variations of clouds and aerosol can also generate a correlation among them. I shall review several studies that by observing the aerosol-cloud interaction using different techniques, looking both on hygroscopic air pollution aerosol and less hygroscopic smoke and dust, attempt to resolve experimentally these effects.

Polarimetric Remote Sensing and the NASA Glory Mission

Brian Cairns(a), Jacek Chowdhary(a), Makoto Sato(b), Larry D. Travis(c), Kirk Knobelspiesse(a), Michael Mishchenko(c)

(a) Columbia University, (b) SGT Inc., (c) NASA Goddard Institute for Space Studies

Abstract: The polarimetric remote sensing measurements in the solar spectral range that are currently available come from the satellite-borne POLDER series of instruments, the airborne Research Scanning Polarimeter (RSP), the airborne HyperSpectral Polarimeter for Aerosol Retrievals (HySPAR) and some ground-based CIMEL sunphotometers. These capabilities will be supplemented and extended in late 2008 by the launch of the NASA Glory mission which includes in its payload the Aerosol Polarimetry Sensor (APS) which builds on the legacy of the RSP measurements. In this paper we summarize the capabilities of the various instruments and outline how the APS will improve and expand the capabilities of polarimetric remote sensing. We describe the aerosol and cloud parameters that can be retrieved using polarimetric remote sensing and what the accuracies and limitations of the various retrievals are. Two areas are emphasized: The retrieval of aerosols over land since this is currently the most difficult area for satellite based passive remote sensing of aerosols. The determination of cloud base and top heights and the vertical profiles of particle size within clouds since these are key ingredients in being able to differentiate between the effects of atmospheric dynamics and pollution on clouds. We end with some preliminary analyses of the capabilities provided by combining polarimetric remote sensing with high spectral resolution lidar measurements.

Evidence for Recent Climate Change on Mars

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Mid latitudes of Mars, ±(30^o to 60^o), show extensive evidence for recent changes in the water-ice content of subsurface soils. These changes can be explained primarily, by relatively recent cyclic variations in the obliquity of the rotation axis of Mars (over the past several million to 10 million years). Such variations affect latitudinal-dependent average surface temperatures, which should then drive cycles of relatively high diffusive deposition of atmospheric water vapor into, or sublimation from, subsurface water ice deposits.

Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar

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The Parasol (Polarization and Anisotropy of Reflectances for Atmospheric Science coupled with Observations from a Lidar) mission launched in Dec. 2004 by CNES is carrying a wide-field imaging radiometer/polarimeter designed to improve the knowledge of the radiative and microphysical properties of clouds and aerosols.

The advantage of measuring the directionality and polarization of light reflected by the Earth-atmosphere system will be illustrated for some key cloud and aerosol parameters.

Since PARASOL is flying in formation with Aqua and Aura, as part of the so-called A-Train, comparison of products will be provided

Aerosol Optical Depth Retrieval Over Central Europe Using Meteosat-8 Seviri Data and Accuracy Assessment with Ground-Based Aeronet Measurements

Christoph Popp, Adrian Hauser, Nando Foppa, Stefan Wunderle

Remote Sensing Research Group, Institute of Geography, University of Bern

In this study, the potential of the geostationary Meteosat-8 Spinning Enhanced Visible and Infra-Red Imager (SEVIRI) for the retrieval of aerosol optical depth (AOD) over land is demonstrated. The proposed method is based on the analysis of a time series of SEVIRI's 0.6 micrometer channel images. Top-of-atmosphere reflectance is pre-corrected for the effect of atmospheric gases and an assumed background aerosol amount. Subsequently, surface reflectance for each pixel is estimated by determine its lowest pre-corrected reflectance within the observed time period for each satellite observation time of the day. The resulting diurnal surface reflectance curve in combination with the radiative transfer code SMAC is finally used to derive AOD. This approach is applied to SEVIRI sub-scenes of Central Europe (40.8N-51.3N, 0.3W-19.9E) which span the entire month of August 2004, daily acquired between 06:12 and 17:12 [UTC] in intervals of 15 minutes. SEVIRI AODs are related to Aerosol Robotic Network (AERONET) measurements from nine stations located within the study area. Almost 3400 instantaneous SEVIRI retrievals and AERONET measurements are compared. An overall correlation of 0.81 and a root mean square error of 0.12 is obtained which is in the range of operationally retrieved AODs from polar orbiting satellites. Further, the spatial distribution of SEVIRI AOD maps for August 2004 represent expectable features like higher concentrations in industrialized regions or the lower loading in higher altitudes. It is concluded that the described method enables the retrieval of AODs over land from Meteosat-8 SEVIRI data. Such aerosol maps of high temporal frequency could be of interest to atmospheric related sciences, e.g. to track large scale aerosol particles transport.

M-III: Remote Sensing: In Memory of Yoram Kaufman (Part 2)

Pushing the Envelope of Aerosol Research: on a Few of Yoram Kaufman's Latest Studies

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Yoram Kaufman was a true earth saver. He dedicated his career to answer questions related to manmade effects on the delicate balance of the natural system. In particular those related to the aerosol effects on climate.

Some of the many intriguing questions Yoram enjoyed dealing with were on the border between aerosols and clouds, including:

What is the effect of aerosols on cloud coverage and how significant this effect is compared to the effect on cloud reflection?
How do aerosols affect convective clouds?
How does aerosol absorption affect clouds?
How to distinguish between aerosol effects to coincidental correlations driven by meteorology?
How do clouds affect aerosols and how to measure it?
What is the overall climate forcing of these effects?

Such questions were the source of “adrenalin” in Yoram’s science. He was fascinated by the beauty of nature and looked for answers with curiosity and passion that never blurred over the years.

In this talk I will try to illustrate some of his latest studies on cloud aerosol interaction.

Global Dimming Or Local Dimming?: The Large Cities' Contribution

Alpert, P.[1], Kishcha, P.[1], Kaufman, Y.J.[2], Y. Barkan[1] and Schwarzbard, R.[1]

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During the last 50 years, a significant decrease of surface solar radiation was observed at different locations throughout the world. We relate this phenomenon, now widely termed global dimming, with anthropogenic air pollution. A new quality-tested global database Global Energy Balance Archive (GEBA) of surface radiation time series for the 25-year period 1964-1989 was used in this study. Circumstantial evidence that human activity does determine global dimming was obtained with the aid of a comparison between surface radiation changes in highly populated sites and ones in sparsely populated sites. The comparison of year-to-year variations of annual radiation fluxes shows a decline of about 0.41 $W/m^2/yr$ for highly populated sites, which is 2.6 times as large as the surface radiation decline for sparsely populated sites (0.16 $W/m^2/yr$). Moreover, for highly populated sites the sharpest decline (1.25 $W/m^2/yr$) in the Northern hemisphere corresponds to the latitudinal zone from 10°N to 40°N surrounded by zones with less pronounced declines. Finally, for sparsely populated sites, year-to-year variations of annual radiation fluxes reveal a pronounced increase in the equatorial zone from 15 °S to 15°N, which, in a northward direction, gradually changes into decline at latitudes higher than 40°N.

There are interesting mutual interactions between son insolation and aerosols. In the first part we show that urban aerosols decrease local son insolation. Next, we show that the son insolation is the one most dominant factor correlated with total mineral dust. It is shown that the daily course of the total amount of dust in the atmosphere based on the TOMS aerosol index (AI), is highly correlated (0.98) with the integrated daily solar insolation over the Sahara region for spatially and temporally averaged data. Other factors like cloudiness, rainfall soil moisture, and wind probably play a more dominant role in smaller areas. The fact that on a very large scale like the whole of the Sahara, the solar insolation becomes the one single forcing directly correlated with the total amount of dust in the atmosphere is suggesting a simple climatic index for the total dust loading in the atmosphere. This index is shown for the Saharan region only, while more studies are needed for other regions.

Aerosol Effects on Climate System Simulated by Aerosol Climate Model

Toshihiko Takemura1, Yoram J. Kaufman2, Lorraine A. Remer2, Teruyuki Nakajima3, Yoko Tsushima4, Tokuta Yokohata5, Toru Nozawa5, and Tatsuya Nagashima5

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4: Frontier Research Center for Global Change, Japan
5: National Institute for Environmental Studies, Japan

A global aerosol transport-radiation model, SPRINTARS, simulates effects of anthropogenic aerosols on the climate system in this study, especially changes in the cloud water and precipitation. The SPRINTARS is based on a general circulation model, MIROC, and treats not only the aerosol transport processes but also the aerosol direct, semi-direct, and indirect effects of main tropospheric aerosols, i.e., black carbon, organic carbon, sulfate, soil dust, and sea salt. Two climate simulations are made with SPRINTARS. The first uses prescribed meteorological fields. The second allows changes in the meteorological field due to the aerosol effects with a mixed-layer ocean model. The first experiment shows that anthropogenic aerosols increase the cloud water path and decrease the precipitationthrough the microphysical effect, that is, the second indirect effect. This operates on the time scale of individual clouds and can be analyzed in recent satellite data created from a seasonal ensemble of individual cloud observations. On the other hand, the second experiment indicates that the aerosol-induced changes in the meteorological field such as surface insolation, evaporation, and hydrological cycle can reduce forming clouds. This will not be obvious from the time scale of satellite observations. The microphysical effect, however, can counteract the aerosol-induced effects in the North and tropical Atlantic and East Asia where a huge amount of anthropogenic aerosols exist. This study also suggests that time series of the radiative forcings at the surface as well as the tropopause for all of main climate forcing agents from 1850 to 2000 can be appropriate index to explain changes in the surface air temperature in the 20th century. A rapid increase in the negative radiative forcing at the surface by the aerosol effects can explain the cooling of the surface air temperature in the mid-20th century. This presentation is dedicated to Yoram Kaufman who passed away on May 31, 2006 by traffic accident.

An Overview of Atmospheric Retrievals Performed by the Multispectral Thermal Imager (MTI)

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The Multispectral Thermal Imager (MTI) is a 15-band spaceborne pushbroom imager with 5- and 20-meter ground sample distance and channels spanning the visible to the thermal-infrared regions of the spectrum. It is a research and development project sponsored by Department of Energy and was launched in March 2000 into a sun-synchronous orbit. A number of the bands were selected specifically for atmospheric retrievals, including atmospheric water vapor, aerosols, and clouds. In this presentation, we will give an overview of MTI atmospheric retrievals, including retrievals uniquely suited to MTI's observation geometry and spatial resolution.

Using Satellite Passive Remote-Sensing Aerosol Data for Large-Scale and Long-Term Climate Studies

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The current generation of satellite-derived global aerosol products, especially those from MISR and MODIS, are increasingly being used in large-scale and long-term climate studies. These data sets have enormous advantages over previous satellite aerosol products, but many researchers have discovered some systematic differences among MISR, MODIS, and ground-based-AERONET-retrieved aerosol optical thickness (AOT) and aerosol properties, even over water. We examine in detail dark-water cases where such discrepancies occur, and trace the differences to algorithm spectral water-leaving reflectance assumptions, ocean near-surface wind speeds adopted, particle property constraints, and cloud masking procedures. Overall, the discrepancies map to mid-visible AOT differences on order 0.025 to 0.05, and depend heavily on environmental circumstances. We conclude with recommendations about how the current products can be aggregated for larger-scale studies, and how, in future algorithms, these sources of errors might be reduced.

This work is performed at the Jet Propulsion Laboratory, California Institute of Technology, under contract with NASA.

Tuesday, July 18, 2006

T-I: Solar Variability and Cosmic Rays

New knowledge about the Sun and its impact on the Earth's climate

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Numerous attempts have been made over the years to link various aspects of solar variability to changes in the Earth's climate. Since the Sun's output of electromagnetic radiation and energetic particles varies, and since the Sun is the ultimate driver for the climate system, it seems natural to link the two together and look for the source of climate variability in the Sun itself. In recent years there has been a growing concern about the possible anthropogenic forcing of climate change through the increasing atmospheric content of greenhouse gases. As a result the connection between solar variability and global climate change is sometimes considered a very controversial area of research. Over the past 150 years the Earth has experienced a warming of about 0.6 degrees. In the same period both the concentrations of greenhouse gases in the atmosphere and the level of solar activity have increased. Thus, it is not a trivial task to detangle the two effects. To further complicate the picture there are several ways the Sun may impact the climate; through the electromagnetic radiation (Total Solar Irradiance) — or some component of it such as the ultra violet (UV), through the direct solar wind via magnetosphere/atmospheric coupling, and/or through the galactic cosmic radiation, which is modulated by solar shielding and possibly influences cloud formation. This presentation will summarize our current understanding of these mechanisms. Some recent results from the ESA/NASA SOHO mission will be disussed that allow us to forecast the strength of the next solar cycle.

Solar Radiation

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Contiguous, redundant, overlapping total solar irradiance (TSI) observations have been made by satellite experiments since late 1978. Composite time series have been constructed from this set of observations to investigate TSI variability of interest to solar physics and climate change. One of these, the ACRIM Composite, finds a TSI trend between the two adjacent solar minima during solar cycles 21 - 23 of +0.04 %/decade. This result is significant relative to measurement uncertainties and of definite interest as a climate change forcing, were it to be part of a trend lasting many solar cycles or longer. The next solar minimum will be reached soon, providing an opportunity for the on-going satellite observations to provide new insight into the duration and nature of the TSI trend.

Where on Earth can cosmic rays make a big difference in cloud cover?

Daniel Rosenfeld

Very small changes in absolute amounts of aerosols are observed to make a phase change in the marine stratocumulus between full cloud cover, open cellular convection, and a completely cloud free regime where clouds cannot form due to lack of sufficient concentrations of CCN. This huge sensitivity of cloud cover might hold the key to an outstanding question. The connection between cosmic rays and global temperature has been suggested to be related to the creation of CCN that enhance the cloud cover. However, the apparent negligible contribution of CCN does could not appear to have made such impact. New observations suggest a mechanism by which even the small added CCN concentrations from the cosmic rays might make a big difference in cloud cover at the locations where clouds cannot form due to CCN starvation.

Solar activity, cosmic rays and clouds: an update.

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In the past decades several possible links between solar activity and clouds have been proposed in the literature, but the underlying possible physical mechanisms are still vague. It is reasonable to expect that if any of these indirect mechanism(s) is acting on climate, its effects should be manifest in changes in cloud amount and albedo.
More recently some correlations between low cloud cover and solar activity have been reported. Here I will review the evidences for a solar influence on clouds at several altitudes especially that of a direct influence of galactic cosmic rays on cloud formation. I will show how the flux of GCR is found to correlate positively with the low clouds and negatively with higher clouds, supporting previous theoretical predictions linking atmospheric ionization by cosmic rays and cloud cover at different altitudes. All these correlations are however only marginally significant and the only strongly significant (negative) correlation is found between low and higher cloud layers. Thus, there is strong evidence that the solar-like variability in low cloud may be artificially induced by the satellite observing perspective. I will also briefly review how the existence of such mechanisms fits with the available long-term datasets of cloud amount and Earth's reflectance.

Phenomenological solar signature in 400 years of reconstructed Northern Hemisphere temperature record

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Herein we study the solar impact on 400 years of a global surface temperature record since 1600. This period includes the pre-industrial era, when no anthropogenic-added climate forcing was present, and the post-industrial era, when anthropogenic-added climate forcing has been present in some degree. We use a recent Northern Hemisphere temperature reconstruction obtained from low- and high-resolution proxy data and a scale-by-scale transfer climate sensitivity model to solar changes by using several total solar irradiance proxy reconstructions [Scafetta and West, 2005 and 2006]. Both methodologies explicitly take into account the nonlinearity and multi-scale frequency-dependence aspects of a complex system such as climate. We adopt two alternative phenomenological strategies: (a) we adopt our basic phenomenological model [Scafetta and West, 2005 and 2006] applied to an average TSI proxy reconstruction to show that from 1600 to 1900 the sun likely drove almost 100% of the major climate changes, such as the cooling periods occurring during the Maunder Minimum (1645-1715) and during the Dalton Minimum (1795-1825); [b] we assume different TSI proxy reconstructions and hypothesize that the sun drove most of the pre-industrial climate change (when anthropogenically added greenhouse gases was not present) to calibrate our phenomenological model to the new situation. We find that both methodologies approximately yield to the same result, that is, that the sun might have on average contributed approximately 50\% of the observed global warming since 1900 [Scafetta and West, 2006]. However, during the last three decades, anthropogenic-added climate forcing might have played a more dominant role in determining global warming.

T-II: Climate Change: Observations

CLIMATE, WATER AND CARBON CYCLES: TERRESTRIAL RECORDS ACROSS A HIERARCHY OF TIME SCALES

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The observed temperature increase of ~ 0.6ºC over the last century has been attributed (IPCC) by ~ 2/3 to GHG and ~ 1/3 to an increase in solar irradiance (TSI). Such relative attribution reflected the general consensus that no credible amplifier to muted changes in TSI was known. Recently, however, a spate of empirical observations demonstrates that sun-climate connections are apparent in a plethora of high-fidelity climate indicators, suggesting that “solar influence on climate is greater than would be anticipated from radiative forcing estimates” (Hadley Centre technical note 62). The most likely amplification candidates are high-energy particles such as cosmic rays and solar protons, via their potential role in cloud formation. Juxtaposition of empirical records of paleoclimate with proxies for atmospheric CO_2 levels vs. celestial (solar and cosmic rays) intensities, across a $10^8 – 10^1$ hierarchy of time scales, indeed favours a reversal of the relative impact of the above climate “drivers”, the last few decades being the focal point of the ongoing controversy. In the above scenario, the celestially modulated planetary energy balance drives the hydrological cycle, with the carbon cycle “piggy-backing” on the water cycle “thermostat”.

Surface and Tropospheric Temperature Changes, Evidence of Greenhouse Warming?

John R. Christy

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Surface and tropospheric temperature changes are considered to be clear responses to forcing changes on the Earth's climate. We document the significant effort it takes to construct surface temperature measurements for climate purposes in three locations and find that the warming evident in two of these locations (Central California and East Africa) is inconsistent with the pattern of warming produced from models run with 20th century forcing, including greenhouse forcing.
Since 1979, tropospheric warming is evident in nearly all upper air datasets, but the rate of warming varies, most datasets being inconsistent with the rate of warming generated when climate models respond to enhanced greenhouse gas forcing. Efforts to determine the actual rate of tropospheric warming with some level of confidence will be presented.

Unresolved Issues with the Quantitative Assessment of Multi-decadal Surface Temperature Trends

Roger A. Pielke Sr.

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The U.S. Climate Change Science Program (CCSP) Report entitled "Temperature Trends in the Lower Atmosphere: Steps for Understanding and Reconciling Differences" claims that the zonally-averaged and global surface temperature trends are robust measurements of the surface temperature. However, several significant uncertainties remain including i) poor microclimate exposure of some of the observing sites; ii) the neglect of concurrent trends in absolute humidity; iii) the vertical variation of surface layer temperature trends even with the same boundary layer heat content trends; iv) the neglect of quantifying the uncertainty associated with the homogenization of the surface data for grid area analyses; and v) the lack of adequate data point for vast areas of the land surface of the Earth.

Examples of each issue with the surface temperature trend data will be presented. Since the surface temperature is the icon with respect to the monitoring of global warming, the issues raised in my presentation should be of concern to policymakers who use the global surface temperature trend for decision making. An alternative metric to assess global warming and cooling is presented in my talk which uses trends in ocean heat content. Using ocean heat content provides a metric to assess radiative forcing which avoids the pitfall of the surface temperature trends.

The talk concludes with the reasons that we need to move beyond global warming and discuss the much more inclusive and diverse issue of climate variability and change if we are going to properly communicate the complexity of human- and natural- climate change to policymakers.

Greenland Climate Change

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We provide an analysis of Greenland temperature records and compare the current (1995-2005) warming period with the previous (1920-1930) Greenland warming. We find that the temperature increases are of a similar magnitude, however, the rate of warming in 1920-1930 was about 50% higher than that in 1995-2005.

Although the last decade of 1995-2005 was relatively warm, all decades within 1915 to 1965 were warmer at both the southwestern (Godthab Nuuk) and the southeastern (Ammassalik) coasts of Greenland. The current Greenland warming is not unprecedented in recent Greenland history.

We find no evidence to support the claims that the Greenland ice sheet is melting due to increased temperature caused by increased atmospheric concentration of carbon dioxide. The rate of warming from 1995 to 2005 was in fact lower than the warming that occurred from 1920 to 1930. The temperature trend during the next ten years may be a decisive factor in a possible detection of an anthropogenic part of climate signal over area of the Greenland ice sheet.

Global Warming Seen from Satellites

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Climate researchers for years has been struggling with an apparent discrepancy in the data on global warming: Temperatures in the troposphere had apparently been rising far slower than models predicted, given how fast the Earth's surface is heating. In this talk I will present recent debate and progress to solve this paradox by analyzing the satellite microwave sounding unit (MSU) observations. The implications of tropospheric temperature trends and their spatial patterns to the climate feedback and changes in the atmospheric circulations will also be discussed.

T-III: The Next Ice Age

Interglacials were Marked by Global Cooling, Glacials by Global Warming

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Radiometrically dated paleoclimatic evidence shows that in the early Holocene and in the last interglacial the areally averaged global mean surface temperature was relatively low, whereas at the time of accelerated growth of land based ice around 110 thousand years ago, in the beginnings of the last glacial cycle, it was relatively high and increasing. Episodes of the fast sea level drop and land ice growth around 70 and 23 thousand years ago were probably also accompanied by global warming.

The Holocene and the last interglacial were times of extreme high obliquity producing diminished meridional insolation and temperature gradients, whereas the intervals of rapid Pleistocene ice growth were marked by low obliquity and high meridional temperature gradients.
During the obliquity minima the highest proportion of incoming solar radiation was channeled into the highly absorbing, predominantly oceanic low latitudes. It was at the expense of radiation reaching the seasonally snow and ice covered, reflective, mainly terrestrial sub-polar belts. Such configuration intensified water transfer from the warming oceans onto the cooling lands, where it accumulated as ice. The process was driven by geographically redistributed but undiminished incoming solar radiation.

Current insolation trends, while less than one half as intense as during the last 300 millennia, are qualitatively similar to those which accompanied the past intervals of rapid ice build-up. The expected natural climate shift due to the orbital change is considerably weaker than in the past. However it has to be marked by tropical warming, by the increasing occurence of El Nino and decrease of La Nina anomalies and, at least in its early stages, by the increase of the globally averaged mean annual temperature.

There is still unclear whether the ongoing changes of ice volume in Greenland and Antarctica are accelerating or slowing the ongoing global sea level rise, the bulk of which is attributed to the thermal expansion of warming oceans. In either case the separation of the man-made from the natural contribution to the observed global warming requires a more detailed analysis than that currently available. The observed increase of the globally averaged mean annual surface temperature, strongly expressed in the tropics, is not proving the man's impact on climate.

A Postponed Next Ice Age?

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Climate has been seen to vary at many timescales during the Earth's history. For example, the recent warming trend of the last century is superimposed on long-term variations related to glacial-interglacial cycles, which are explained, according to astronomical theory of paleoclimate, by the changes in the Earth's orbit and position against the Sun, and consequently by the changes in the distribution of the solar energy reaching the Earth. Climate models, such as the LLN 2-D NH model developed in Louvain-la-Neuve, have been used to test that hypothesis. Sensitivity experiments showed that insolation plays indeed a major role to explain the succession of glacial-interglacial cycle over the last million years but the variations in atmospheric CO_2 concentration alone are unable to do it. However, they amplify the response to the solar forcing. Several important feedbacks were also identified, e.g. snow-albedo-temperature feedback, water vapour-temperature feedback and vegetation-albedo-temperature feedback.

A few decades ago, according to studies of the length of the previous interglacials, it was suggested that our interglacial would end very soon. Other projections of future climate were based on the climate evolution during the previous interglacial, some 125 000 years in the past. However, a close analysis of the climate forcings and the EPICA ice core show that a better analogue to the present-day climate forcing occurred some 400 000 year ago. At that time, it is only if high latitudes summer insolation decrease is simultaneous with the atmospheric CO_2 concentration decrease that the length of the interglacial is short. The same situation applies at present. However, we know that CO_2 concentration remains high while insolation is decreasing, leading to a long interglacial (50 000 yr) in the future. Moreover the human activities over the next centuries can impact significantly on the climate of the next 50 000 year.

PEALIAH – the Peatland/Ice Age Hypothesis

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In 1994-97 I presented the idea that peatlands might be responsible for the regular shifts of glacials and interglacials during the whole of the Pleistocene. The, so called, Peatland/Ice Age Hypothesis postulates that an ice age cycle is divided into five distinctive phases or stages, all of which could be interconnected to the development of the atmospheric concentration of carbon dioxide, as it has been described from the Antarctic and Arctic Ice core investigations.

1/ Deglaciation phase 2/ Vegetation reestablishment phase 3/ Mire phase
4/ Glaciation initiation phase 5/ Glacial phase

The Peatland/Ice Age Hypothesis – a schematic overview.

The main point in the hypothesis is that peatlands do not only grow vertically but also horizontally. After a certain period of interglacial, peatland growth reaches a point (CO_2 BP) where this CO_2 sink exceeds the bottle-neck value of deep ocean/surface ocean compensation i.e. more carbon dioxide is retracted from the atmosphere into the peatland carbon sink than what could be compensated by flows from the deep ocean reservoir. At this point atmospheric carbon dioxide sinks rapidly towards values which are critically low to maintain a high enough greenhouse effect. Peatland lateral growth hence leads into an unstable period (initiation phase) in which a small disturbance might subsequently lead into a new ice age pulse at the glacial initiation point (GPIP).

PEALIAH – the search for a trigger

The Peatland/Ice Age Hypothesis postulates that ice age cycles are generated by peatland growth (vertically and horizontally) in landscapes sculptured by glacial activity. In a running project the aim is to find a mechanism, strong enough to trigger off a new ice age pulse, at the end of an interglacial, when peatlands have made the necessary preparations. The study of peatland stratigraphies and loess sequences in a global scale has revealed the cyclic (c. 1250 years) appearance of peaks in cosmic dust deposition. The additional influx of such dust is believed to fertilize remote ocean surface waters, which subsequently (DMS) leads to increased cloudiness, decreased incoming shortwave radiation and sinking temperatures. The last cosmic maximum is centred over the peak of the Little Ice Age. The opposite situation, with rising temperatures, occurs when cosmic dust influx is low.

Severe Cooling of the NW Atlantic Linked to Gulf Stream Retreat During the Last 10,000 Years

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Climate of the Holocene (12-0 kyr ago) was warm and stable. Temperature records from central Greenland ice cores show none of the large, abrupt variations that characterized the prior 100,000 years of glacial climate. Nor do they show any substantial trend, indicating at most 1°-3°C of cooling. Yet during a steep decline in summer insolation at high northern latitudes--widely believed to pace the growth and decay of continental ice sheets--to values last plumbed during the last glacial maximum period, it is surprising that more severe cooling is not observed. Here we show that the slope waters east of the United States and Canada cooled 4°-10°C during the last 11 kyr. We attribute the cooling to a large equatorward shift in the position of the Gulf Stream from east of Newfoundland in the early Holocene to east of the Mid-Atlantic Bight today. A concurrent trend toward more extreme and/or frequent positive phases of the North Atlantic Oscillation is implicated by 2-4-fold increases in North Atlantic meridional and zonal sea surface temperature gradients. The observed cooling of northwest Atlantic slope waters may facilitate perennial ice growth in eastern Canada and the onset of the next ice age.

T-IV: Hurricanes and Global Warming

Global and Atlantic Basin Tropical Cyclone Activity as Related to Global SST and its Changes

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One of the most misunderstood topics in tropical meteorology is the association of Sea Surface Temperatures (SSTs) and tropical cyclone frequency and intensity.

Recent analysis shows no increase in global TC frequency and intensity over the last 20 years when global mean temperatures have been rising, and satellite technology has advanced to the stage where reliable non-Atlantic intensity estimates can be made. It is also observed that except for the Atlantic and the Northeast Pacific, there is no significant correlation between SST and hurricane intensity in the four TC basins of the Northwestern Pacific, the North Indian, the South Indian and the South Pacific. We have no theory as to why changes of global surface temperature of less than $\pm 0.5^{o}C$ should cause any significant alterations in global tropical cyclone frequency and/or intensity.

In distinguishing between active and inactive Atlantic basin hurricane seasons, the author and his colleagues have found that seasonal changes in SST explain just a small portion (about 10%) of the variance of seasonal and monthly hurricane activity. Other factors such as tropospheric vertical wind-shear, low-level horizontal wind-shear, middle level moisture, strength of the equatorial trough, etc. play much more important roles in explaining seasonal and monthly hurricane variability.

Why do hurricane models fail to accurately predict intensification?

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Over the past thirty or so years, the ability to predict a hurricane's movement has steadily increased, whereas the ability to predict intensity has only increased slightly. There are several reasons for this inability to predict intensification: 1) Errors in initial conditions and the failure to accurately determine the environmental conditions; 2) numerical errors; and 3) lack of understanding of multiphase physics, e.g., sea spray. For this talk, initial and environmental errors will be neglected, and a pathway to examine how errors in physical models influence the intensification process will be discussed. For example, in order to examine model sensitivity to specific physical processes, numerical errors must be minimized. Unfortunately, most hurricane models contain Jacobian elements that are nearly infinite; hence the ability to reduce numerical error and examine errors in model parameterizations is almost futile. To overcome the development of nearly infinite Jacobian elements, a new hurricane-modeling framework has been developed that employs a Newton-Krylov solution procedure. This framework ensures that time and also to some extent spatial scales are resolved and hence for very small grid spacing and time step sizes numerical errors should be extremely small. Furthermore, this new modeling framework includes a multiphase component, and thus could be used to examine multiphase phenomena that occur in hurricanes. During this talk an overview of the analytical equations used in the hurricane model, how these equations are efficiently solved using the Newton-Krylov approach, and results illustrating the strengths of the Newton-Krylov approach will be presented.

Hurricane Lightning: an Indicator of Storm Intensification

X.-M. Shao, D. Suszcynsky, J. Harlin, T. Hamlin, and K. Wiens

Hurricanes generally produce little lightning activity compared to other non-cyclonic storms, and lightning is especially sparse in the eye-wall and inner regions within tens of kilometers surrounding the eye. Lightning can sometimes be detected in the outer, spiral rain-bands, but the lightning occurrence rate varies significantly from hurricane to hurricane as well as within an individual hurricane's lifetime. Hurricanes Katrina and Rita hit the Gulf coasts in 2005 and their distinctions were not just limited to their tremendous intensity and damage caused. They also differed from typical hurricanes in their lightning production rate. Observations by the Los Alamos Sferic Array (LASA) lightning system show that a significant amount of lightning activity occurred within both storms. LASA detects and locates lightning events with a ground-based VLF/LF sensor array. Lightning rates of the two hurricanes went as high as 600 flashes per hour during certain stages of the storms. The common and intriguing feature in both cases was the clear positive relation between the eyewall lightning activity and the storm intensification. Episodic eyewall lightning was detected during a 4-day step-by-step intensification of Katrina; whereas an enormous lightning surge was detected during the rapid intensification of Rita. In both hurricanes, eyewall lightning rejuvenated when they hit the coast. For lightning that occurred inside the cloud, LASA was able to detect the height of the source in addition to its geolocation. The sources were found at heights of 10-15 km, indicating the core of the convection/charging region. Many LASA detected events were also observed by RF receivers aboard several GPS Block IIR satellites, demonstrating the possibility of routinely monitoring lightning and severe weather from space. In the summer of 2006, LASA will deploy three new stations to the Key West, Bahamas, and the Cayman Islands to better cover the hurricane active area.

Predicting Hurricane Impacts on the Nation's Infrastructure: Lessons Learned from the 2005 Hurricane Season

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During the 2005 Hurricane season, many consequence predictions were available to key Federal agencies from 36 to 96 hours before each of the major hurricane US mainland landfalls. These key forecasts included the location and intensity of the hurricane at landfall, areas of significant damage to engineered infrastructure and lifeline utilities, time estimates to restore critical infrastructure services, and the conditions to be found on the ground as emergency and relief crews enter the area. Both the Department of Energy through its Visualization and Modeling Working Group and the Department of Homeland Security provided early forecasts of potential damage to the regionally critical infrastructures. We will briefly outline the methodology employed to develop these critical infrastructure damage forecasts from available numeric weather predictions and provide examples of typical and experimental products delivered to decision makers during the 2005 hurricane season.

This same methodology can answer questions about future cases or scenarios that test the ability of national infrastructures to adapt to repeated weather or climatic disturbances and the resilience of both the engineered infrastructures (energy, transportation, communications) and non-engineered systems (social, political, economic, demographic, geographic) when faced with perceived threats. Public planners need to estimate how demand will change future capacity additions and transmission capabilities. Knowledge of how service demand, economic activity and demographic movement may change is required to study these questions. It also requires knowledge of the effect these changes will have on the regional demand for energy and for the damage and costs to the energy infrastructure produced by storms.

Within this context, we will present an example of how weather, infrastructure, social, economic, and emergency response models might be synthesized into a national capability to provide credible, salient, and legitimate predictions in the critical few days before a storm's landfall and in the long term resilience response.

The Art of Forecasting Extreme Weather Events

James A. Marusek and Susan M. Waggoner

Over the period from 1950 to present, the year 2005 was unique at the extremes. The year had the most Atlantic hurricanes on record (15). The year was tied for second place with the most major Atlantic (Category 3+) hurricanes (7). What may have been overlooked in all the press releases is other record set in 2005. The year had the least intensive tornado season on record, producing only one major (F4/F5) U.S. tornado. Since both tornados and hurricanes are types of cyclones, one over land and the other over sea, and since the Atlantic Ocean and the mainland U.S. are adjacent, a causal relationship may exist. Major Atlantic hurricanes & major U.S. tornados were evaluated and both have strikingly similar frequency distributions represented by Pulse Peak equation. This similarity adds weight to the theoretical interrelationship. Further analysis shows that the relationship at the extremes bears an inverse trend. As a result of these findings, these two types of extreme weather events were combined into a single category called storminess. The yearly storminess index was computed for the past 56-years and the trend analysis was provided. A long-term waveform variation in storminess intensity was noted. Over the period (1950-2005), the variation has not yet reached one complete cycle. Storminess was highest in 1950 (7.8) and dropped to a low in 1987 (4.5) and has since begun to rise to the present (5.2). Storminess appears to be manifest in one of four phases: major tornados, major Atlantic hurricanes, mixed or quiet. This paper presents the methodology and set of rules developed from the storminess analysis to allow forecasters to accurately predict a year or two in advance the most intense and extreme weather years.

Poster/Oral Presentations I

Radiative and Convective Driving of Tropical High Clouds

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Using cloud data from Aqua MODIS and collocated precipitation rates from Advanced Microwave Scanning Radiometer (AMSR), it is shown that rainrate is closely related to the amount of high thick cloud (optical depths of 32<tau<64, and temperatures colder than 245K) across the entire Pacific, making thick cloud amount a better proxy for convection strength than OLR. It is also shown that thin high cloud (t<4), which induces a positive net radiative effect on the top-of-atmosphere (TOA) energy balance, is nearly twice as abundant in the West Pacific (5-15N, 120E-160E) compared to the East Pacific (5-15N, 150W-100W). For a given rainrate, anvil cloud (4<tau<32) is also more abundant in the West Pacific, and anvil clouds are optically thinner there as well. The ensemble of all high clouds in the East Pacific induces considerably more cooling compared to the West Pacific, primarily because of more high, thin cloud in the West Pacific. These high clouds are also systematically colder in the West Pacific by 4-7K. To examine why these high clouds get as cold as they do, we examine whether or not these clouds are convectively driven by low-level equivalent potential temperature, or by the peak in clear-sky convergence. The temperature in the upper troposphere where the equivalent potential temperature is the same as that at the lifting condensation level seems to drive the temperatures of the coldest, thickest clouds, but not of anvil cloud. We show instead, using temperature profiles from GPS occultation, moisture profiles from Microwave Limb Sounder, and a radiative transfer model (to calculate radiative cooling rates and divergence profiles), that there is a one-to-one relationship between the peak in clear-sky convergence and median anvil cloud top temperature. The convergence profiles can thus explain why anvil cloud is warmer in the East Pacific compared to the West Pacific.

Satellite observations of Antarctic Temperature Trends during 1979-2005

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Antarctic radiosonde temperature records indicate significant tropospheric warming over the past 30 winters. However, the handful of stations with sufficiently long upper air temperature records are located almost exclusively along the Antarctic coastal margins. Additionally, radiosonde temperature trends are very sensitive to changes in instrument types which may or may not be documented in the station metadata. Even in the absence of such biases, the sparse network of radiosonde observations provides only a partial picture of decadal temperature trends. The satellite based Microwave Sounding Unit (MSU) offers a nearly spatially complete record of brightness temperatures starting in 1979. Stratosphere contamination is removed from the MSU's troposphere channel following Fu et al. (2004). This retrieval is validated in the Antarctic region by comparing vertically weighted troposphere temperature trends from the radiosonde upper air data to radiosonde-simulated retrieved temperature trends. The accuracy of the retrieval when applied to the radiosonde observations substantiates its ability to remove stratospheric contamination when applied to the MSU data. The spatial pattern of temperature trends from the MSU reveals strong winter warming over most of the continent in agreement with radiosonde trends. However, a considerable portion of the east Antarctic troposphere has experienced significant cooling. This wintertime cooling appears over a broad area absent of stations with long enough upper air records to observe it. The pattern of warming and cooling over the surrounding ocean is also non-uniform and unobserved by the radiosonde network. The MSU provides a reliable and spatially complete troposphere temperature record which is necessary to understand the relative importance of greenhouse gas forcing, the ice albedo feedback and natural variability in the Antarctic climate system.

Thermal Remote Sensing of Total Columnar Water Vapor

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Water vapor retrievals are important to a wide range of disciplines. With the use of satellites, water vapor retrievals can be performed at high spatial resolutions, day and night, and occur anywhere in the world. But how accurate are these water vapor retrievals? This question was explored by taking 50 clear-sky images at the Atmospheric Radiation Measurement (ARM) Program Cloud and Radiation Test Bed (CART) in Oklahoma and 50 images at the NASA Stennis Center in Mississippi. Using Moderate Resolution Imaging Spectroradiometer (MODIS), total columnar water vapor retrievals with near infrared (NIR) and infrared (IR) were validated against water vapor retrievals from the ground-based sunphotometers of NASA's Aerosol Robotic Network (AERONET). The RMS error for IR water vapor retrievals at both locations were more than double the error for NIR retrievals. With the IR water vapor retrievals, there was a wet bias for dry conditions (less than 1.7 cm of water vapor). The RMS error for these conditions was .148 cm at Oklahoma and .635 cm at Stennis. As of July 1, 2005 AERONET released a new water vapor algorithm. This new algorithm was also compared to MODIS NIR and IR water vapor retrievals. There was little change in RMS error for IR retrievals using the new algorithm. The RMS errors for NIR retrievals using the new algorithm doubled with a percent error around 20 percent.

A Novel View of Ocean Warming: Effects of Biogeochemistry and Clathrate Hydrates

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Through photosynthesis within euphotic layer and other biochemical processes in deeper water, world oceans produce a large amount of organic and inorganic materials that have stored the original light energy from Sun as chemical energy. Biogeochemical processes for degradation in deep water eventually convert those materials into several kinds of small gas molecules like CH_4, CO_2, etc. that can be encaged in clathrate hydrates that are slightly buoyant in seawater. The dissociation of ascending clathrate hydrates takes place when the ambient temperature and pressure (or depth) fall outside the hydrates' stability range. Different kinds of clathrate hydrates will then dissociate within different layers of seawater. Once those clathrate hydrates dissociate, they release gas that forms bubbles. Various microbes catalyze the oxidations that generate a significant amount of heat. The bulk of CH4 from methane hydrate is converted into CO2. Both the CO2 and any residual CH4 will escape into the atmosphere while the heat warms the interior ocean (predominantly at intermediate depths). The warmed oceans will then evaporate more water vapor and expel more GHGs into the atmosphere. The atmosphere gets warmed up due to enhanced greenhouse effects. Both the warmed oceans and the atmosphere will keep the atmospheric CO2 concentration high (due to lower solubility of CO2 in warmer seawater. Short-term (e.g. since the industrial revolution) spikes of atmospheric CO2 concentration can be due to many reasons (including anthropogenic factors) and that leads to the warming of ocean from top. As the heat from the atmosphere gradually penetrates the upper layers of oceans, the dissociation of hydrates in seawater accelerates. So does the warming of whole climate system. In the paleoclimatic time scale (e.g. Quaternary), the fluctuations of atmospheric temperature, CO2 and CH4 concentrations appear to be almost synchronized. But, through this close-up examination, the sequence of events is revealed and they are all under the big influence from the "slow-burn" process at intermediate depth of oceans.

Riparian Canopy Evapotranspiration Scaled to the Rio Grande Corridor Under Current Climatic Conditions and Projected Climate Change

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This work analyzes the relationship between climate and canopy evaptranspiration (ET) depletions along the middle Rio Grande corridor in central New Mexico. Canopy vegetation plays a key role in climate forcing by influencing energy, water, and gas exchange with the atmosphere. A middle Rio Grande canopy model has been developed to scale actual ET depletions in riparian native and non-native canopies using remote sensing imagery. The model helps to elucidate natural and anthropomorphic inputs, including climate, to complex landscape structure and function. Characterizing land cover details and scaling biophysical parameters to the landscape is an important component in modeling and understanding local, regional, and global scale climate and hydrological processes. This research is comprised of two separate analyses. The first analysis looks at climate variations along the 320 kilometer reach and compares the seasonal ET depletions during a wet year and a dry year. The results of the analysis show that during a dry year, night-time temperatures remain colder in the southern part of the reach creating a shorter growing season. The colder temperatures in the south are due to increased katabatic flow (cold gravity winds sinking into the valley at night) and the lack of water in the river. In a wet year, the river water likely results in warmer night-time temperatures causing the vegetation to leaf-out earlier. The second analysis models the potential impact to ET with a projected warming trend. Over the next 25 to 50 years, New Mexico's temperatures are expected to increase 3-7 ^{o}C on average, more in winter and at night. Higher night-time temperatures and warmer winter temperatures translate into a longer growing season for the entire reach. These climatic conditions and longer growing seasons will have a profound effect on water loss within the middle Rio Grande basin in central New Mexico.

Recent Ground Surface Temperature Changes in the Albuquerque Basin

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Subsurface temperature profiles can indicate changes in ground surface temperatures, which can in turn be related to atmospheric temperature changes. Typically the small fluid flux in the unsaturated zone (<1mm/yr vapor flux), allows conduction to dominate the heat transfer process; therefore surface temperature changes diffusing into the earth's unsaturated zone should be recognizable from subsurface temperature profiles. Several years ago a study of ground temperatures in the unsaturated zone began at four dedicated piezometer nest sites in the Albuquerque Basin. Results of the study to date have been both informative and perplexing. At one location in the southern part of the Basin it appears that a very unique hydro-geologic environment affords conditions for uncommonly large, vertically upward liquid-water flux. At a second location in the northern part of the Basin, subsurface temperature data suggest a ground surface temperature increase of ~3.8ºC approximately 20 yr ago. Removal of the natural vegetation around the site, and the asphalt paving of two nearby roads about 10 m from the site, are indicated in aerial photos as having occurred ~ 20 yr ago. It is suggested that at this site, urbanization has curtailed the cooling of the earth's surface by vegetation shading and evapo-transpiration, and has also increased absorption of solar radiation with poorly reflective asphalt. Therefore does the inverse problem of climate change affecting ground surface temperature become important, i.e. are man made surface temperature changes affecting air temperature? Two additional sites in the Albuquerque Basin appear to show no surface temperature change, although one of these sites is being approached by development. Hopefully the fourth site will remain undisturbed so that possible air temperature changes may be recognized in the subsurface temperature profile. Results from the first two sites are published in Reiter (WRR, 2006) and Reiter (EEG, in press).

Earth Albedo Changes as a Mechanism for Climate Change

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Big Bear Solar Observatory

Photometric observations of the earthshine have been carried out continuously from Big Bear Solar observatory since 1998, with some sporadic data available during 1994 and 1995. These data have been used to measure the Earth’s large-scale reflectance or albedo. Traditionally the earth's reflectance has been assumed to be roughly constant, but large decadal variability, not reproduced by current climate models, has been reported lately from a variety of sources, including the earthshine data. The reported albedo variability is much larger than the solar irradiance variability from maximum to minimum of solar activity, and thus has a larger potential to change the Earth’s radiation budget at all time scales. Here I will discuss the importance of these decadal trends for global climate, and I will compare the several independent records of Earthâ€™s albedo and clouds that are presently available, making special emphasis on the implication for past and present climate change.

Testing climate models using AIRS data

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Previous work (e.g., Sun et al., Vertical correlations of water vapor in GCMs, Geophys. Res. Lett., 28, 259-262, 2001) has argued that General Circulation Models (GCMs) do a poor job of transporting variations in surface temperature and humidity throughout the free troposphere. We investigate the relationships between atmospheric temperature and humidity and surface temperature and humidity variations in the Tropics in daily satellite measurements, daily historical radiosonde measurements, and daily outputs from six General Circulation Models (GCMs). We show that GCMs approximately capture the temperature relationships, doing a good job in clear-sky regions but a poorer job in convective regions.

Earth's Magnetism

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If we blame global warming on burning of fossil fuels, then what is the blame for global warming for the times before the industrial revolution? For example, what type of warming existed to get rid of the ice age which covered the areas near the two geographical poles to a depth of miles? This is a condition that has persisted since the last magnetic reversal, which occurred about 1,000,000 years ago. Previous to that time, there have been regular reversals on the order of a few thousand of years for the last 5,000,000 years. Prior to that time the evidence is not too accurate. However there is evidence of a glacial period that occurred about 2.2 billion years ago and of course there had to be a resulting global warming period after that global cooling period. This reasoning leads us to believe that global warming and cooling is part of the planetâ€™s normal cycling. The next question is what is the cause of this normal cycling? The answer to that question can be found on my web site, www.earthsgeomotor.com , entitled â€œEarthâ€™s Magnetismâ€. Magnetic reversals are also part of the planets normal cycling with the Normal period being the warming periods and the Reverse period being the cooling period. Repeated ionization, due to internal heat of the interior of the earth, and subsequent separation of charges will produce two magnetic fields due to earths rotation; one field due to electrons which will produce a normal field and the other field due to positive charges which will produce the reverse field.

The Relationship between Cosmic Rays and Hurricanes

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This paper explores a causal relationship between Galactic Cosmic Rays (GCR) and the cloud structure in hurricanes. GCR are high-energy charged particles that originate outside our solar system. GCR interact with the Earth's atmosphere through nuclear collisions producing a cascade of protons, neutrons & muons, which can penetrate through the stratosphere and troposphere. GCR is responsible for almost all of the production of ionization below 15 km. Ions created by GCR collisions can rapidly interact with molecules in the atmosphere and convert to complex cluster ions (aerosols) acting as cloud condensation nuclei (CCN), the building blocks of clouds. Charged molecular clusters, condensing around ions are fairly stable and can grow significantly faster than corresponding neutral clusters. GCR ionization is a major driver in cloud formation. Two phenomena explain the development and growth of the cloud structure within hurricanes. (1) As the air molecules thin out in a low-pressure system, GCR penetration increases. A storm passed through the neutron monitoring station in Thule, Greenland on 19-20 February 2005. The storm produced a pressure drop of 39.5 mm Hg and a corresponding increase in neutrons of 44.8%. (2) GCR flux rate varies by altitude. As the updrafts pull warm moist sea salt impregnated air up from the surface, the exposure rate to GCR ionization increases radically. At the tops of 15 km hot towers above the eye of a hurricane, the GCR exposure rate is 2,000 times greater than at the ocean's surface. These two phenomena, low pressure systems producing enhanced cosmic ray penetration and updrafts providing a conveyor belt to move warm moist sea salt impregnated air into reactive regions of very high GCR concentrations provide a natural formation/intensification mechanism for hurricanes.

New Challenges Threatening the Ozone Layer

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Since the beginning of the 1990's when the importation of fairly used Refrigerators, Air-conditioners and propellants that can easily go broken containing chlorofluorocarbon substances that is capable of destroying the Ozone layer started in commercial quantity in Africa, the African refuse mountains began metamorphosing into mountains of dumped broken Refrigerators, Air-conditioners and Propellants which are collectively becoming a threat to the Ozone layer, because of the continuous discharging of the Chlorofluorocarbon gases by the refuse in to the atmosphere in each passing second..

Nobody can actually quantify the numbers of Refrigerators, Air-conditioners and Propellants imported and disposed in Africa over the last fifteen years, but the facts still remains that the numbers of metamorphosing mountains keeps on increasing in both size and numbers in each passing day. They have even become sources of raw materials for the local blacksmiths, children and refrigerators repairers who use parts of the dumped refrigerators, Air-conditioners and Propellants for their constructions, toys and repairs respectively.

This explains the reason why despite the global efforts toward protecting the Ozone layer by the United Nations (UN), governments, International Organizations and climatologist among many others, but yet the hole in the Ozone layer keeps on expanding and the global temperature keeps on rising which resulted in the unusual phenomenon like the hurricanes "Katrina" and "Rita" the unusual floods in China, Thailand, Mozambique and to some extent even the Tsunami disaster that claims millions of lives in 2004.The Rapid rising in temperature of the Tropical world countries and increase in the cases of cancer patients among many other unusual happenings over the last eight years.

It was in review of the above situation that this research work was conducted and came up with the under listed suggestions/Recommendations:

1. The UN should use its capacity to discourage the importation of fairly used refrigerators, Air-conditioners and propellants to Africa and at the same time assist in the subsidy of the newer ones coming to Africa, so that the average African can afford buying them.

2. The UN through her specialized agencies on climate and meteorology in collaboration with sister related organizations should send their teams of researchers to come and investigate the trend of this ugly situation in other to proffer possible lasting solutions.

3. The African Union (AU), UN and other stakeholders on the World climate change should jointly encourage the companies manufacturing Refrigerator, Air-conditioners and propellants to open their factories in Africa, where their products are needed most, as this will help stop the importation of the fairly used refrigerators, Air conditioners and Propellants.

4. The AU should pass a resolution banning the disposal of these items in the refuse.

5. Special companies in charge of disposing or the recycling of the Refrigerators, Air-conditioners and the propellants should be encourage to come to African countries for their operations.

6. Technicians should also be encourage by the various African governments to retrain the local African black smiths and refrigerator repairers on how to use alternative sources of their raw materials in the absence of the Refrigerators, Air-conditioners and propellants dumped in the refuse.

I believe that if the above suggestions/recommendations are adopted and implemented it will help in saving the Ozone Layer in one hand and protect the entire World in the other.

Using Oceanic Forced Upwelling to Mitigate Global Climate Change

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We propose it is feasible to utilize the oceans' heat content and nutrient load to beneficially mitigate global climate change, at least partially offseting negative effects on the atmosphere of human activities. It is widely observed though not completely understood that upper ocean heat content affects both global and regional weather patterns, e.g. El Nino/La Nina, hurricane intensity, etc. And the deep oceans are the largest potential CO_2 reservoir, serving as a natural sink for atmospheric greenhouse gases. Using arrays of our wave-driven deep ocean pumps (prototypes now being tested), we can bring up large volumes of cold, nutrient-rich deep ocean thus cooling the upper ocean while enhancing the ocean's primary production, absorbing CO_2 and producing oxygen. Our pump simply comprises a buoy, flexible tube, cylinder with valve, cable to connect the buoy and cylinder, and solar panel to power communications & activation, providing remotely-controlled pumping of the cold, higher-nutrient deep (up to 1km) ocean to the surface. Adjacent pumps are connected at the bottom to form a matrix, maintaining relative position one to the next from the sea-anchor effect. If required, periodic seafloor anchoring can maintain absolute position within an ocean basin. Deployment is efficient and low cost as the pumps self-deploy when dropped into the ocean from barges. Pumps would not be deployed in ocean shipping channels, in regions used by recreational boaters, nor where excessive tides or currents are found. In a global application, we estimate 200 arrays each 100km by 100km, requiring 5 million pumps costing $10 billion, would cover about two million km^2 or about 0.55% of the ocean surface. This system could be selectively enabled to partially mitigate the negative effects of mankind's activities on our atmosphere and environment. Secondary benefits include reviving ocean fisheries, and reducing hurricane intensity.

Modeling the Amazon Basin as a Prototype for Global Runoff Process Simulation

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Simulating surface water transport processes at the global scale is vital for understanding the behavior of and interaction between the hydrological, biogeochemical and ecological cycles. Representing these processes will be critical for predicting a vast range of terrestrial impacts of climate change. Models that simulate both channel and floodplain storage and transport at large scales provide hydraulic properties (relative depth and flow velocities) and floodplain inundation characteristics (extent, duration and frequency) that are needed to address the interactions between these hydro-related cycles in climate models. However, challenges associated with the computational demands and required model parameterization and assessment at the global scale are considerable. The Amazon Basin is being used as a prototype to demonstrate an alternative way of modeling the earth's fresh water drainages, in a manner that will rely on and benefit from current vertical column physics approaches such as the NCAR Community Land Model. Using recent advances in hydrologic modeling frameworks, geophysical models and space-based measurements, this research provides a methodology for simulating and assessing large scale hydraulic realism.

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<u>Wednesday, July 19, 2006</u>
W-I: Aerosols and Climate

Aerosols in Polar Regions

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Measurements of aerosol optical depth (AOD) at different wavelengths and Ångström's turbidity parameters have been taken at several Arctic and Antarctic sites over the past eighteen years by various groups using different examples of multi-spectral Sun photometers. The involved research groups are currently participating in the POLAR-AOD program proposed for the International Polar Year planned for the period from March 2007 to February 2009.

The time-patterns of the daily mean values of AOD(500 nm) and of parameter α measured in the Arctic region are presented, as obtained at Barrow, Alert, Summit, Ny Ålesund (AWIPEV research base and Zeppelin station), Hornsund, ALOMAR, Pallas-Sodankylä, and from aboard the Polish research vessel OCEANIA, sailing across the Arctic Ocean in the Spitsbergen area. The results indicate that AOD(500 nm) varies mostly between 0.03 and 0.10 (with an overall mean value of 0.05) for clean atmosphere conditions without clouds and mainly between 0.12 and 0.30 during the Arctic Haze formation period for cloudless conditions, while parameter α assumes values mainly ranging between 0.6 and 1.9. Particular attention was paid to describe the evolutionary patterns of the Arctic Haze throughout the spring, since the values of AOD observed in that period were comparable with those usually measured at mid-latitude stations in the continental areas of the Northern Hemisphere. The historical data recorded at Barrow and some Siberian sites (Dikson Island, Severnaya Zemlya and Kotel'nyy Island) from 1977 to 1991 are also presented in order to define the overall trend of atmospheric aerosol loading for both clean atmosphere and Arctic Haze conditions, and examine the time-variations of these optical parameters due to volcanic eruptions (El Chichon, Pinatubo, Cerro Hudson) and boreal forest fires. Supplemental AOD data in the Svalbard region derived from MERIS observations on board of ESA ENVISAT satellite are also provided to improve the area coverage.

The time-patterns of the daily mean values of parameters AOD(500 nm) and α measured in Antarctica are presented, as taken at five coastal sites (Terra Nova Bay, Mirny, Neumayer, Syowa, Aboa and Marambio) and four high-altitude stations (South Pole, Dome C, Dome Fuji and Kohnen). They show that the cloudless values of AOD(500 nm) mostly range between 0.02 and 0.08 at the coastal sites and between less than 0.01 and more than 0.02 at the high-altitude stations. Correspondingly, parameter α was evaluated to vary mainly between 0.6 and 1.9 at the coastal sites and between 1.0 and 2.1 at the higher stations. Historical AOD data recorded at the Mirny, Molodezhnaya, Plateau and Georg Forster stations are also provided in order to cover the period of ground-based observations in Antarctica from 1966 to early 1991.

The above results have been compared with recent measurements of surface-level aerosol scattering and absorption coefficients, size-distribution shape-parameters and chemical composition data of Arctic and Antarctic aerosols, attaining reliable evaluations of the single scattering albedo characterizing various particle polydispersions and defining preliminary estimates of the direct radiative forcing induced by polar aerosols for different surface albedo conditions.

Aerosol Direct Radiative Forcing-
On the Consistency Of Estimates From
Global Modelling and Observation-Based Techniques

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Our understanding of the impact by anthropogenic aerosol on climate (usually quantified by radiative forcing) is largely based on simulations with global models. Recent results based on simulations with nine different models with state of the art aerosol component modules suggest that anthropogenic aerosol since pre-industrial times at all-sky conditions modified the (solar) radiative energy balance at the top of the atmosphere (ToA forcing) by -0.2W/m^2, with a standard deviation of +/-0.2W/m^2 - if globally and annually averaged. This value refers only to the presence of aerosol and not to 'indirect' effects via aerosol induced modifications to clouds. Although there are significant regional and seasonal variations, this global annual mean for 'To A cooling' by -0.2W/m^2 is surprisingly small, especially when compared to 'To A warming' by anthropogenic greenhouse gases at about +2.4W/m^2. Parallel to modelling, also in order to circumvent uncertainties in aerosol processing, increasingly more measurement based concepts have been introduced as alternative paths for estimates of the aerosol impact on climate. Three of these approaches are outlined. Although their concepts are quite different they all converge at a larger 'ToA cooling' by aerosol at about -0.6W/m^2. Global and seasonal distribution patterns and essential fields on aerosol and environmental properties, which serve as input to radiative transfer simulations in global modelling and alternative approaches are examined to provide answers for this discrepancy.

Fossil-Fuel Soot's Contribution to Global Warming

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An emerging issue in air pollution today is how to improve local air quality and address global warming and regional climate change simultaneously. Particulate black carbon (BC), the main component of soot, is a pollutant that is well known to degrade air quality and impair human health. Soot also absorbs solar radiation, heating the air and reducing sunlight reaching the ground. As soot particles leave the tailpipe of a vehicle, they internally-mix with other particles by coagulation and growth. Van der Waal's forces and fractal geometry enhance coagulation significantly as does evaporation of semivolatile organic compounds (<C24). The internal mixing of soot with other chemicals enhances the solar absorption of BC, as found from experimental and modeling studies, causing BC from fossil fuels and biomass burning soot possibly to be the second-leading cause of global warming after carbon dioxide and ahead of methane in terms of direct radiative forcing. However, the composition of fossil-fuel soot differs significantly from that of biomass-burning particles, causing the climate responses of each to be opposite in sign, with fossil-fuel-soot causing warming and biomass-burning particles containing BC causing net cooling. Because fossil-fuel soot heats the air for a period longer than its lifetime, increases the air's stability and reduces the relative humidity thereby decreasing cloud amount, deposits to snow, and enhances cloud absorption by coagulating with cloud particles and entering cloud drops by serving as CCN when coated, it may be the second-leading cause of global warming in terms of climate response. In this talk, the physical and optical properties and global/regional climate effects of fossil-fuel soot will be discussed.

3D analysis of soot aggregates using electron tomography - implications for soot optical properties

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The optical properties of soot are influenced by the particle shapes. Current global models use Mie scattering theory to calculate optical properties of soot, assuming that the particles consist of non-aggregated spherical monomers. This simplifying assumption underestimates the extinction and scattering efficiency of soot relative to the actual aggregated clusters. We are using electron tomography with a transmission electron microscope (TEM) to obtain three-dimensional (3D) information for individual soot particles. We are obtaining quantitative measurements of the fractal dimension (FD), radius of gyration (Rg), volume (V), and surface area (SA) for soot from the ambient air of an Asian dust episode and from a U.S. traffic source. The values for the Asian dust and traffic emissions are, respectively, FD from 1.9 to 2.6 and 2.0 to 2.3, median values of Rg are 242 and 219 nm, and those for the ratio of SA to the product of V and density are 61 and 94 m2/g. The FD and Rg results differ significantly from measurements made from conventional 2D TEM images, and the others were not previously available for individual particles. Using the new data, we estimate that scattering and absorption by traffic soot particles is, respectively, almost 40 times and 15% greater than those of the unaggregated spherules that are commonly assumed in climate models to estimate radiative forcing. These results will allow one to compute optical properties more accurately than was previously possible and improve estimates of direct radiative forcing and our understanding of the climate impact of soot.

Polar Climate Sensitivity to Absorbing Aerosols

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The prevalence of snow makes the cryosphere highly susceptible to ice-albedo feedback amplification driven by snowpack albedo change. We have integrated dust and BC aerosols into a global modelling framework that accounts for snowpack thermodynamics, aging, and radiative interactions with absorbing impurities. This tool simulates current climate with and without atmospheric and surface aerosol effects, from which we deduce their relative roles in altering polar climate sensitivity.

Our results show that snowpack aging plays a large role in the seasonal cycle of Polar albedo---particularly in explaining the rapidity of springtime polar albedo changes observed by MODIS. Aerosol effects are currently significant only intermittently, in strong boreal fire years, for example. We will contrast our current climate results with simulations of the effects of dust on the polar radiation budget during the LGM, when peri-glacial dust sources were much stronger than present.

In many regions the direct radiative forcing of the atmospheric aerosol is an order of magnitude greater than the surface albedo forcing of the dirty snow. Interestingly, we find that absorbing aerosols in snowpack change temperature more efficaciously than any atmospheric aerosol or greenhouse gas. Absorbing aerosols amplify the strong feedback between snowpack temperature, snow grain size, and albedo. We will show the effects of this amplification on Polar climate, and pay particular attention to Greenland.

Pathways for Homogeneous Droplet Freezing in Tropical Maritime Clouds and the Relationship to Occurrence in Other Cloud Types

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At temperatures colder than about -35C, homogeneous freezing nucleation (HFN) of liquid droplets has recently been recognized as important in determination of composition and radiative properties of cloud ice. In a changing climate, homogeneous nucleation could be a significant factor in altering the earth's radiation balance. More CCN could lead to a greater number of smaller droplets that, in deep convection, could freeze homogeneously to produce more reflective cirrus.

In this study, we will examine the presence of the liquid water phase at low temperatures in tropical maritime convection. In tropical maritime convection, liquid water is readily scavenged and rarely observed at low temperatures. The most-likely pathway for homogeneous nucleation when it does occur in maritime convection is through the freezing of droplets that activate at mid-levels. We place the results for maritime convective clouds in the context of pathways for HFN in continental deep convective clouds and those formed through middle and upper-level lifting, to help focus research efforts on further understanding of the conditions under which the process occurs.

W-II: Climate Change and Climate Sensitivity

Positive Climate Feedback in the Stable Nocturnal Boundary Layer

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Numerous observational studies show a decreasing trend of the average global surface diurnal temperature range (DTR) with minimum temperatures warming more than maximum temperatures. Some investigators have attributed this change in DTR to increases in atmospheric water vapor, cloud cover and changes in surface characteristics. Few papers, however, have considered the role of highly non-linear stable nocturnal boundary layer (SNBL) processes affecting the minimum nocturnal temperature. Here we employ techniques of nonlinear analysis to examine the behavior of the SNBL subjected to changes in incoming radiation and surface characteristics. The SNBL is characterized by a delicate balance between mechanical generation of turbulence from wind shear and the suppression of turbulence by thermodynamic stability. A single column model and nonlinear bifurcation techniques are used to demonstrate the presence of a potentially significant positive feedback in the SNBL that can be triggered from the addition of weak radiative forcing (4-6 W m^{-2}) from greenhouse gases, aerosols or other atmospheric forcing. The results show that in some parameter spaces the bifurcation diagram was "S" shaped with multiple solutions occurring. The implications of these analyses are that decreasing the stability through greenhouse gas forcing (or any forcing that decreases the stability such as surface heat capacity) produces a positive feedback in the nocturnal boundary layer. That is, large increases in surface temperature can occur as the nocturnal boundary layer shifts from a weak turbulent regime which allows the surface to cool to a turbulent regime which mixes warm air from aloft. Thus, this positive feedback may be a key factor in interpreting the observed warming in the nocturnal boundary layer. However, this positive feedback is only a pseudo positive feedback in that it impacts the distribution of heat not the total heat content of the atmosphere.

Using the current seasonal cycle to constrain snow albedo feedback in future climate change

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Differences in simulations of climate feedbacks are sources of significant divergence in climate models' temperature response to anthropogenic forcing. Snow albedo feedback is particularly critical for climate change prediction in heavily-populated northern hemisphere land masses. Here we show its strength in current models exhibits a factor-of-three spread. These large intermodel variations in feedback strength in climate change are nearly perfectly correlated with comparably large intermodel variations in feedback strength in the context of the seasonal cycle. Moreover, the feedback strength in the real seasonal cycle can be measured and compared to simulated values. These mostly fall outside the range of the observed estimate, suggesting many models have an unrealistic snow albedo feedback in the seasonal cycle context. Because of the tight correlation between simulated feedback strength in the seasonal cycle and climate change, eliminating the model errors in the seasonal cycle will lead directly to a reduction in the spread of feedback strength in climate change. Though this comparison to observations may put the models in an unduly harsh light because of uncertainties in the observed estimate that are difficult to quantify, our results map out a clear strategy for targeted observation of the seasonal cycle to reduce divergence in simulations of climate sensitivity.

Impact of Cirrus Clouds and Ice-Supersaturated Regions on the Radiative BudgetSome Estimations and Implications for Gcms

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One of the most challenging problems in Atmospheric Science is the prediction of future climate change. So far, the role of clouds is very uncertain, especially, the role of cirrus clouds, which could constitute to a positive radiative forcing. However, there are only few studies about the impact of cirrus clouds on radiation and (to our knowledge) no studies about the impact of ice-supersaturated regions (ISSRs) on the radiation budget. ISSRs are cloud free airmasses that are supersaturated with respect to ice. They are the potential formation regions for cirrus clouds and persistent contrails. In this study we use idealized vertical profiles and humidity corrected radiosonde profiles (containing ice supersaturation, see Spichtinger et al., 2003) to estimate the radiative impact of ice supersaturation. Especially, the local heating rates inside the supersaturation layer (in cloud free air) could be noticable different from the rates obtained in subsaturated layers at the same altitude. This could affect the local dynamics, because ISSRs can be sustained for a long time at the same altitude. Additionally, we estimate the errors due to the insufficient implementation of the formation of cirrus clouds from ISSRs: To our knowledge there are only two global circulation models (GCMs) which consider the formation of cirrus clouds in a physical way. Therefore we estimate the impact of incorrectly formed cirrus clouds on the radiative budget compared to persistent ISSR in the real atmosphere. From this study we can draw some conclusions on the importance of implementing more correct parameterisations for cirrus cloud formation in GCMs.

Reference: Spichtinger, P., Gierens, K., Leiterer, U., Dier, H.: Ice supersaturation in the tropopause region over Lindenberg, Germany. Meteorol. Z., 12, 143-156, 2003.

MULTI-DECADAL AND MULTI-CENTURY MODES OF ATMOSPHERE-OCEAN GLOBAL CIRCULATION OVER THE PAST 1000 YEARS

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Analysis of meteorological and oceanic data (especially the NOAA-NCAR Reanalysis data of the last 55 years) and paleoclimate proxy records over the past 1000 years indicate that two basic modes of atmosphere-ocean global circulation have occurred on both multi-decadal and multi-century timescales. Mode 1, which occurs during multi-decadal and multi-century periods of warming or warmer mean global temperatures such as the last 30 years (1975-2005) and the Medieval Warm Period (MWP), is characterized by an enhancement of equatorial-polar regional temperature gradients and strengthening of middle-latitude westerly atmospheric circulation. Mode 2, which occurs during multi-decadal and multi-century periods of cooling or cooler mean global temperatures such as the period between the mid-1940's to the mid-1970's and the Little Ice Age (LIA), is characterized by reduced regional atmospheric temperature gradients and reduced middle latitude westerly circulation. The data link variation in other climate cycles such as ENSO, NAO, PDO, Sahel rainfall, and Atlantic hurricane frequency and intensity to these two modes (with varying lags). The data also indicate unique climate signals that typify shorter periods of transition (10-15 years for multi-decadal variation) between these two modes.

We propose that the primary mechanism driving climate change between these two modes is variation in the mean rate of global ocean thermohaline circulation (THC). Mode 1 (global warming) and Mode 2 (global cooling) occur during periods when the mean rate of global thermohaline circulation is reduced and increased, respectively. This relationship between the rate of mean global thermohaline circulation and the relatively subtle global temperature variation that has characterized the stable, relatively ice-free late Holocene climate of the last century-millennium (i.e., reduced THC = global warming) does not appear to apply during glacial periods when ice-albedo feedbacks and orbital changes play a central role.

A Paleoclimate Record of Two Glacial-Interglacial Cycles from the Valles Caldera, Northern New Mexico

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An 81 m long sediment core was obtained from the Valles Caldera of northern New Mexico. A tephra layer at the bottom of the core has been dated to 552 ± 3 ka by the Ar-Ar method. Utilizing the geomagnetic instability time scale, two additional horizons have been dated based on the presence of globally recognized brief magnetic reversals or cryptochrons. The cryptochrons provide ages of 515 ka and ~ 420 ka at 49.6 and 17.25 meters depth in the core respectively. The dated sections of the core cover portions of marine isotope stages (MIS) 14 through 11. The top of the core remains undated, but proxy records obtained from the core (particularly the pollen record) and comparison to deep-sea marine isotope records suggest that the top of the core represents glacial stage 10. The sediments in the core are estimated to span ~175 ka and contain records of 2 full glacial-interglacial cycles. Records generated from the core to date include sedimentology, pollen, C/N, total organic carbon and $d^{13}C$. Glacial stages are characterized by sediments deposited in deeper water, lower organic productivity, and terrestrial plant assemblages dominated by cool and moist species such as spruce. Interglacial stages are characterized by sediments deposited in shallow water, increased productivity, and mixed conifer and hardwood assemblages, including species such as oak that are tolerant of drier conditions. These results are consistent with increased moisture availability in the southwestern United States during glacial periods due to deflection of the jet stream to the south. Climatic excursions, as indicated by the proxy records, are larger in MIS 11 then MIS 13, consistent with deep-sea and ice core records. Interglacial stage 11 could be particularly interesting as an analog for Holocene climate in the southwestern United States (in the absence of anthropogenic climate change) owing to similar orbital parameters.

W-III: Climate and Energy

Temperature Trends and Local Economic Activity Around the World

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www.takenbystorm.info, http://www.uoguelph.ca/~rmckitri/ross.html

Local economic activity has long been known to leave measurable traces in weather data. These have to be filtered out for the identification of global warming trends. A longstanding controversy exists over whether current methods for doing so are adequate, but surprisingly little use has been made of the relevant economic data. We present a new data base encompassing all available land-based grid cells around the world which allows matching temperature trends to detailed economic and social conditions (including local population and GDP density, and intermittency in meteorological monitoring), as well as fixed geographical factors. We find that the spatial pattern of temperature trends in IPCC data is not independent of socioeconomic conditions in the regions of origin. The economic imprints are relatively stronger in poor counties. The effects are significant at the global level and likely add an upward bias to the global trend.

CO_2 Emissions: The Issue of Scale

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Today world energy use and CO_2 production is already well outside commonly considered scales, but nonetheless quite small in comparison to what is likely to come. These scales must be taken into account when examining possible future energy scenarios and when considering solutions to the carbon dioxide issue. In modern industrialized nations, CO_2 emissions are about 20 tonnes per person per year; greater than any other commodity used, with the exceptions of water and air. Global yearly emissions are already more than 20 km^3 at liquid densities, and this could grow by a factor of 10 this century and, in some sense, hopefully will. A world population of about 10 billion people enjoying the lifestyle and prosperity found in modern nations would require 10 times the energy using prevailing technologies. These issues of scale will be discussed and some thoughts given on what it all means.

Guthrie

No abstract submitted at this time.

Reaping Environmental Benefits of a Global Hydrogen Economy: How Large, How Soon, and at What Risks?

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The Western world has taken an aggressive posture to transition to a global hydrogen economy to address air quality, climate change, and energy security concerns. While numerous technical challenges need to be addressed to achieve this it is timely to examine the environmental benefits and risks of this proposed transition. Hydrogen provides an efficient energy carrier that promises to enhance urban and regional air quality that will benefit human health. It could also reduce risks of climate change if large-scale hydrogen production by renewable or nuclear energy sources becomes viable. While it is well known that the byproduct of energy produced from hydrogen is water vapor, it is not well known that the storage and transfer of hydrogen is inevitably accompanied by measurable leakage of hydrogen. Unintended consequences of hydrogen leakage include reduction in global oxidative capacity, changes in tropospheric ozone, and increase in stratospheric water that would exacerbate halogen induced ozone losses as well as impact the earth's radiation budget and climate. We construct plausible global hydrogen energy use and leak scenarios and assess their impacts using global 3-D simulations by the Model for Ozone And Related Trace species (MOZART). The hydrogen fluxes and photochemistry in our model successfully reproduce the contemporary hydrogen cycle as observed by a network of remote global stations. Our intent is to determine environmentally tolerable leak rates and also facilitate a gradual phasing in of a hydrogen economy over the next several decades as the elimination of the use of halocarbons gradually reduces halogen induced stratospheric ozone loss rates. We stress that the leak rates in global hydrogen infrastructure and the future evolution of microbial soil sink of hydrogen that determines its current lifetime (about 2 years) are principal sources of uncertainty in our assessment.

W-IV: Oceans

Biogeochemistry in Los Alamos Ocean Models: Cycling of Sulfur, Nitrogen and Iron in Reduced Forms

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Marine circulation models developed at Los Alamos National Laboratory have evolved from fine resolution physical oceanographic tools into a set of comprehensive, global scale components for Earth System simulators. In the latter capacity, detailed biogeochemistry modules have been steadily introduced. A brief history of our recent biology and chemistry studies is provided beginning from the direct/indirect greenhouse gases, but with emphasis then placed upon aerosol-relevant geocycles. Preliminary global change-driven computations involved surface distributions of CO2, N2O, CH4 and ozone influencing substances. System level connections with atmospheric particles occur through interfacial transfer of volatile or soluble compounds in which sulfur, nitrogen and iron are present in reduced form. Most of our ocean model work in this area has focused on the improvement of mixed layer S schemes, such that dimethyl sulfide (DMS) sources to the atmosphere can be prognosed dynamically. Water column mechanisms are now based on taxon dependent sulfoniopropionate content with enzyme regulation driven by oxidative, osmotic and cryogenic stress. The relationship of cell disruption rate to grazing is being added and should lead to refined seasonality. Coupled surface ocean/lower atmosphere sulfur chemistry calculations have already been performed by our group in the U.S. Community Climate System Model (CCSM). The nutrient ammonia represents a dominant recycling type for mixed layer biological material, but it also supports a flow of basicity into the remote marine troposphere. Prospects will be considered for the calculation of NH3 transfer and effects on aerosol pH. Iron enters Los Alamos ocean models as part of the mineral aerosol matrix. It must be solubilized during transit through the atmosphere by reduction from the +III state. The reactions are driven by acid enhanced aqueous photochemistry in the microlayer surrounding dust particles, so that over the open ocean there are links with DMS oxidation products. We will assess the need for coupled marine/atmospheric simulations of the Fe to S interaction.

Multiple equilibria and abrupt transitions in Arctic summer sea ice extent

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Some coupled model simulations of 21st century climate, including those of the third-generation Community Climate System Model (CCSM3), exhibit rapid and substantial decreases in Arctic summer sea ice extent leading to nearly ice-free summer Arctic conditions. Three factors have been identified as contributing to such behavior in CCSM3: (i) an inverse relationship between open water formed per cm of ice melt and the previous winter's mean ice thickness; (ii) relatively sudden increases or "pulses" of ocean heat transport into the Arctic, superimposed on a more gradual increase that occurs as the climate warms, and (iii) acceleration of melting due to the albedo feedback. In this talk, a very simple mathematical treatment of these processes is described which models the response of yearly values of mean winter ice thickness and summer sea ice extent to changes on ocean heat transport, or OHT. The resulting nonlinear equations are found to undergo a bifurcation to multiple equilibria as OHT increases, provided the albedo feedback is sufficiently strong and that winter ice in the pre-industrial climate is not too thick. Within this regime, there are two stable states, one having finite summer ice extent and relatively thick winter ice, and the other having zero summer ice extent and thinner winter ice. If OHT increases gradually, there is a sudden, hysteretic transition to zero summer ice extent, whereas if fluctuations in OHT are superimposed on this increase the hysteretic transition becomes "blurred", with abrupt decreases in summer ice extent potentially occurring earlier. When parameters such as the strength of albedo feedback are calibrated to CCSM3 values, the system is found to lie within the regime that exhibits multiple equilibria, whereas a model having weaker albedo feedback or thicker pre-industrial winter ice would not. These results suggest that multiple sea-ice equilibria may play a role in the abrupt decreases in Arctic summer ice extent simulated by CCSM3, and that the presence or absence of multiple equilibria may bear on whether a particular climate model exhibits such behavior.

Sea Surface Emissivity- A neglected climate forcing

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The contribution focuses on the thermal emissivity of oceans. The importance of this parameter for the climate system is not yet adequately recognised within the scientific community and thus not yet implemented in climate models. In the first step the wind dependence of sea surface emissivity is quantified, using data generated in the context of satellite remote sensing. It is shown that at constant temperature infrared emittance to space may vary in the range of 5 to 10 W/m², solely based on wind dependent ocean emissivity. Wind and temperature proxies indicate that water emissivity contributes to characteristic climate fluctuations of the past, mainly via positive feedback-mechanisms (glacials/interglacials; abrupt and strong climate variations within glacials). During the Medieval Warm Period and the subsequent Little Ice Age, wind dependant sea water emissivity amplified variations in solar activity in the Atlantic region. Climate proxies and modern instrumental measurements support the hypothesis that 20th century warming can be attributed partially or in whole to natural climate fluctuations, with sea surface emissivity as a dominant amplifier within the climate system.

Fertilizer Runoff Contribution to Oceanic Warming

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It is suggested that agricultural fertilizer runoff may contribute to the warming of bodies of water such as the Gulf of Mexico. Agricultural runoff can be transported via river systems, such as the Mississippi River, so that the local concentration of fertilizer may be enhanced in the Gulf of Mexico. Fertilizer can enhance the proliferation of algae in seawater. Microscopic algae can act as an extinction media for optical radiation, effectively increasing the absorption coefficient for incident solar radiation. As a consequence, the surface of the ocean waters may exhibit higher temperature, on the order of a few degrees Celsius. If this hypothesis is correct, it is possible that the results might be observable from space.

Weijer

No abstract available at this time.

Thursday July 22, 2006

Th: I Aerosol and Cloud Interactions and Feedbacks

Title: Simulations of Aerosol-cloud interactions

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In this talk I will summarize the results of the WMO IAPSAG report, chapter on modeling aerosol-cloud interactions. In addition, I will summarize the results of simulations performed in my research group on aerosol cloud interactions. Simulations in our group of aerosol influences on thunderstorms over Florida, and thunderstorms over and downwind of St. Louis, MO have revealed complex dynamical responses to variations in CCN, GCCN, and/or IN concentrations. This is a result of changes in precipitation rates from these clouds systems. It is shown that once the precipitation cycle is augmented in clouds, they are no longer subject to simple linear thinking as in the Twomey hypothesis or Abrecht's extension of it to drizzling clouds. Both the modeling studies summarized by IAPSAG and our own group show that once the precipitation process is modified, clouds may become optically thicker or thinner, they may rain more or they may rain less, they may become more vigorous or less so depending on the nature of the nonlinear response of clouds to changes in precipitation. Thus the climate response to changing aerosol populations becomes less predictable once those changes alter the precipitation cycle of many cloud systems.

Representing Aerosol-Cloud Interactions in a Global Climate Model: Issues Related to Spatial and Time Sampling

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Climate change scenarios for the future remain unconstrained due to the large uncertainty in aerosol-cloud interactions, arising from issues related to representing cloud response to aerosols in the fields they exist in. To improve current parameterizations of the aerosol indirect effect in the Goddard Institute for Space Studies (GISS) climate model, we use satellite retrievals of aerosol and cloud products from the Moderate Resolution Imaging Spectroradiometer (MODIS) (daily data available at a 1 degree resolution) to constrain simulated cloud response to aerosol changes. To understand the relationships between aerosols (via the aerosol optical thickness) and cloud properties, four different model simulations are evaluated: with and without aerosol effects on liquid-phase cumulus clouds, in addition to liquid-phase stratus clouds; and with model wind fields nudged to reanalysis versus standard model simulated winds. We use correlation matrices, principal component analysis, time series analysis and cluster analysis to examine variabilities in several properties such as: cloud top temperature, cloud top pressure, cloud cover, cloud liquid water path, cloud drop effective radii, cloud optical depth and aerosol optical depth, both from satellite and from the four model simulations. Additional meteorological parameters will also be used to develop regimes within which key features of aerosol-cloud interactions can be isolated. Since model resolution is much coarser (4x5 degrees) than satellite resolution, scale-invariant features from the satellite data will be examined via time averaging or spatial averaging. These results will be used to improve current model parameterizations of the aerosol indirect effect and the response of cloud microphysics to changing aerosol optical depths.

Insights on the indirect effects from aircraft data and process models

Bill Conant

Recent aircraft observations of stratocumulus and cumulus clouds have provided insight into various aerosol-cloud-climate interactions. Here I will summarize results from four field missions, highlighting the successes in linking aerosol composition and concentration to the CCN spectrum, and providing insights into the process of cloud droplet activation. Furthermore, I will highlight how these observations direct our attention to current uncertainties in cloud microphysical processes that govern spatial variations in droplet dispersion and liquid water, and the roles entrainment and droplet kinetics play in these variations. 1-D representations of the cloud-topped marine boundary layer can be used to conceptually illustrate the various indirect effects (1st, 2nd, semi-direct), the timescales over which they operate, and the cloud processes to which they are most sensitive. A more detailed perspective considering the Lagrangian evolution of effective radius through the lifecycle of a cloud element is presented to interpret the observed patterns of droplet concentration and dispersion. These approaches help to interpret the strengths and limitations of results from more detailed sensitivity studies using LES cloud simulations.

A New Climate Dynamics Paradigm: Air Pollution Induces Thermodynamic Forcing Of Upward Convective Heat Transport

Daniel Rosenfield

In deep convective clouds with warm bases, such as prevail in the tropics and during summer in the mid-latitudes, the delayed precipitation due to more and smaller droplets may cause the condensates to ascend to the supercooled levels instead of raining out earlier by processes that do not involve the ice phase. By not raining early, the condensate would then form ice hydrometeors that release the latent heat of freezing aloft and taking back that heat at the lower levels when they melt. The result would be more upward heat transport for the same amount of surface precipitation. The consumption of more static energy for the same precipitation amount would then be converted to equally greater amount of released kinetic energy that invigorates the convection and would lead to a greater convective overturn, more precipitation and deeper depletion of the static instability.

The enhanced aerosol-induced enhanced release of latent heat of freezing aloft may lead to regional scale enhancement of convection, low level moisture convergence and precipitation. In addition, direct heating of the atmosphere by elevated absorbing aerosols may lead to changes in large scale circulation and moisture transport, which in turn changes cloud, precipitation and aerosol distribution. This amount to aerosol modulation and interaction with the large scale overturning motions in the tropics and subtropics, such as the monsoons, and the Walker and Hadley circulations, with compensating effects of rain suppression on the downward branch.

Supporting simulations and observations from the cloud to the climate scales will be presented.

Aerosol-Cloud Interactions: What do In-Situ Observations Tell us and How Can it Constrain and Improve Modelling of the Indirect Effect?

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The effects of aerosols on clouds are recognized as one of the largest sources of uncertainty in assessments of anthropogenic climate change. This uncertainty originates from the nature of aerosol-cloud interactions; many GCM assessments rely heavily on empirical approaches to represent this complex and multi-scale problem, so there is much room for improvement. This talk will present assessments of the aerosol indirect effect using a state of the art global climate model framework. We present methods for constraining and evaluating these novel modeling approaches by using in-situ observations of cloud condensation nuclei, chemical composition and aerosol-cloud droplet number from recent field missions. Finally, we present work on robustly constraining important sources of predictive uncertainty by coupling the in-situ observations with global climate modelling.

Comparison of a Multiphase Particle Model Against a Bin Model for Simulation of Observed Stratus Clouds

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For temperatures greater than freezing, stratus clouds are primarily composed of cloud and drizzle droplets. Unfortunately, current approaches used to model stratus clouds assume that these droplets can be represented using a continuous bin or bulk approach. The use of a continuous approach to represent discrete particles leads to a spurious diffusion of the droplet spectrum, e.g., the number of particles as a function of radius, through both the growth of cloud droplets and their movement. This artificial diffusion is difficult to correct for and does not disappear as the resolution decreases, but in fact becomes larger. Unlike the traditional bin approach, the multiphase particle model treats cloud droplets in a Lagragian manner and hence does not suffer from errors associated with numerical diffusion. But, because of computer limitations, when the particle model employs grid resolutions of the order of a few meters, one particle must represent at the minimum tens of thousands of particles, e.g., a stochastic approach. The use of a stochastic approach introduces a sampling error into the particle model, thus degrading the accuracy of the calculation. To demonstrate the effect of these errors, either numerical diffusion or sampling, on the ability of a model to reproduce dynamical and microphysical features of actual clouds, numerical simulations employing either approach for a stratus deck observed during DYCOM-II will be presented. This comparison not only will serve to document the impact of both errors on the ability of a model to reproduce observed clouds, but also introduce to the community another viable approach for modeling clouds.

A Parameterization of Infrared Radiative Properties of Cirrus/Contrails Containing Small Ice Particles

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University of Washington

Michael Danilin and Steve Baughcum
Boeing Company

A parameterization of infrared radiative properties of cirrus clouds was developed by Fu et al. (1998), which was based on in-situ observed ice particle size distributions with the consideration of nonspherical ice particles. This parameterization, however, is accurate when the effective ice particle size (Dge) is larger than about 10 microns (i.e., an effective radius of about 6.5 microns). For contrail cirrus and tropical tropopause subvisible cirrus, the Dge are often smaller than 10 microns. In this work, we will extend the parameterization of cirrus radiative properties for the Dge ranging from 1 to 10 microns. We will also examine the impact of the consideration of bimodal ice particle size distribution on the broadband radiative energy budget calculations.

Fu, Q., P. Yang, W.B. Sun, 1998: An Accurate Parameterization of the Infrared Radiative Properties of Cirrus Clouds for Climate Models. Journal of Climate., 11, 2223-2237.

Strategies for Using Cloud Observations in Modeling Cloud Feedbacks

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Cloud radiative feedback is the single most important effect determining the magnitude of possible climate responses to human activity. Ice clouds, especially cirrus, have been shown in GCM studies to have a major impact on the Earth's radiation balance from their impact on vertical profiles of heating. In order to improve estimates of heating profiles produced in cloud-resolving and general circulation models and those derived from ground-based remote sensors operated at the Atmospheric Radiation Measurement (ARM) program ground sites, assumptions about cloud particle concentrations, phases and sizes are needed.

Recent observations of cloud microphysics obtained during the Tropical Western Pacific International Cloud Experiment, a field program based out of Darwin, Australia in January-February 2006 that sought to describe the evolution of tropical convection through its entire life cycle, are described. Vertical and horizontal profiles through fresh anvils, aging anvils and generic cirrus were made by the Scaled Composites Proteus aircraft equipped with a complete set of in-situ microphysical sensors to measure the sizes, shapes and phases of cloud particles, including the numbers and shapes of small particles with maximum dimensions smaller than 100 micrometers. These data are summarized here and used to determine bulk cloud microphysical parameters needed for both evaluating results of cloud models and for parameterization development, including estimates of ice water content, mass-diameter relationships, dominant particle habits, bulk single-scattering properties and mass-weighted fall speeds. The properties are examined in the context of cirrus origin, cirrus age, ambient temperature and weather regime. Applications to modeling studies are discussed.

Aerosol Indirect Effects on Deep Precipitation Processes: A Cloud-Resolving Study

Xiaowen Li (GEST center, University of Maryland, Baltimore County)

Wei-Kuo Tao (NASA, Goddard Space Flight Center)

Alexander Khain (Hebrew University of Jerusalem)

Joanne Simpson (NASA, Goddard Space Flight Center)

Atmospheric aerosols serving as cloud condensation nuclei (CCN) can modulate both cloud radiative properties and cloud life spans (the indirect effect of aerosols). Both observations and cloud modeling studies have provided abundant evidences of aerosol indirect effects in shallow cloud types at relatively clean environment, e.g., marine stratus/stratocumulus. However, in deep precipitation systems (e.g., Mesoscale Convective Systems) where dynamical forcing is dominant, the aerosol indirect effects are still unclear. So far observations and modeling studies show wide ranges of variations, from rain suppression to rain enhancement, indicating the complexity of the aerosol-cloud-deep precipitation interactions and the need to examine the details of the complicated interactions between cloud system dynamics and microphysics.

The Goddard Cloud Ensemble (GCE) model with the explicit bin microphysical scheme adapted from the Hebrew University Cloud Model (HUCM) is used here to study aerosol indirect effects on deep precipitation processes, with the emphasis on the impact of CCN number concentrations on their surface rainfall patterns and the cloud system's energy budget. Three cases are simulated in this study: a mid-latitude continental MCS (PRE-STORM, June, 1985), a tropical maritime MCS (TOGA COARE, February, 1992), and a tropical sea breeze convection (CRYSTAL, July, 2001). It is shown through model sensitivity tests that increasing aerosol concentrations may change both microphysical and dynamical structures of these deep convective systems, with the highest sensitivity in the long-lived maritime case where the water vapor is abundant and the background aerosol concentration is low. Detailed analyses of model outputs reveal some of the underlying mechanisms in the aerosol-cloud-precipitation interactions and their relative roles in various environmental conditions. The implications of these sensitivities on large-scale circulations are also discussed.

Th: III Dust and Natural Aerosols

Climate Response and Radiative Forcing from Mineral Aerosols during the Last Glacial Maximum, Pre-Industrial, Current and Doubled-Carbon Dioxide Climates

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Mineral aerosol impacts on climate through radiative forcing by natural dust sources are examined in the current, last glacial maximum, pre-industrial and doubled-carbon dioxide climate. Modeled globally averaged dust loadings change by +92%, +30% and -60% in the last glacial maximum, pre-industrial and future climates, respectively, relative to the current climate. Comparisons to available observations for the last glacial maximum climate are shown. Model results show globally averaged dust radiative forcing at the top of atmosphere is -1.04,-0.53 and +0.14 W/m2 for the last glacial maximum, pre-industrial and doubled-carbon dioxide climates, respectively, relative to the current climate. Globally averaged surface temperature changed by -0.32, -0.14, and +0.06 °C relative to the current climate in the last glacial maximum, pre-industrial and doubled carbon dioxide climates, respectively, due solely to the dust radiative forcing changes simulated here. These simulations only include natural dust source response to climate change, and neglect possible impacts by human land and water use.

Towards Developing Improved Treatments of Mineral Dust Aerosol for Climate and Remote Sensing Studies

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Mineral dust is increasingly recognized as an important atmospheric constituent because it exerts a profound influence on the climate, environment, and human well-being. Growing evidence demonstrates that the properties of dust and thus its impacts vary from region to region. Up to now, all climate models as well as remote sensing retrievals consider dust as a single generic species. Furthermore, a number of apparently conflicting assumptions on dust properties have been done by prior studies, especially those addressing the dust radiative impacts, dust-cloud interactions, dust and atmospheric chemistry interactions, and dust impacts on biological processes in the oceans. Therefore, given that the sources of dust and its distribution in the atmosphere are highly heterogeneous, both spatially and temporally, and that the properties of dust strongly depend on the source region, there is an urgent need to develop consistent treatments of mineral dust which take into account its regional nature.

This paper will concentrate on the results of our ongoing research aimed at the development of new, physically-based treatments of mineral dust on a regional basis. In particular, new data on the physicochemical properties of mineral dust representative of several important dust sources in East Asia and Northern Africa will be presented. This data set was used to re-examine the regional radiative effects caused by mineral dust, especially the ability of dust particles to absorb light. Implications to climate studies and various remote sensing applications will be highlighted along with the emerging problems.

Observational Constraints On the Magnitude of the Global Dust Cycle

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Abstract: The concentration of dust aerosols has been measured for almost four decades, and satellite retrievals of aerosol optical thickness cover an increasingly long span of time. Nonetheless, we show that the mobilization of dust into the global atmosphere remains unknown to within a factor of three. This range includes values that are larger than simulated by present models. The main uncertainty is the identification of source regions, although processes like wet scavenging of dust remain difficult to constrain with observations. Satellite retrievals provide the main constraint on clay particles, and the clay load will be become better known when retrievals distinguish dust from other aerosol species. Stronger constraints upon the silt burden will result from more extensive in situ measurements of concentration and deposition, along with retrievalsof size by AERONET.

Seasonal characteristics of physico-chemical properties of NorthAtlantic marine atmospheric aerosol

S.G. Jennings, Y.J. Yoon, D. Ceburnis, F. Cavalli, O. Jourdan, J.P.Putaud, M.C. Facchini, S. Decesari, S. Fuzzi, and C.D. O'Dowd

Seasonal physico-chemical characteristics of North Atlantic marineaerosols are presented. The aerosol size distribution modal diameters show seasonal variations, and the accumulation mode mass also showed aseasonal variation - minimum in winter and maximum in summer. A super-micron sized particle mode was found at 2 μm for all seasonsshowing 30 % higher mass concentration during winter than summerresulting from higher wind speed conditions. Chemical analysis showedthat the concentration of sea salt has a seasonal pattern, minimum insummer and maximum in winter due to a dependency of sea salt load onwind speeds. By contrast, the non-sea-salt (nss) sulphateconcentration in fine mode particles exhibited lower values duringwinter and higher values during mid summer, which is attributed to thecontribution of organic sub-micron aerosol. The water soluble organiccarbon (WSOC) and total carbon (TC) analysis also showed a distinctiveseasonal pattern. The aerosol light scattering coefficient showed aminimum value of 5.56 Mm^{-1} in August and a maximum of 21 Mm^{-1} in February. This seasonal variation was due to the higher contributionof sea salt in the marine boundary layer during North Atlantic winter.By contrast, aerosols during late spring and summer exhibited largerangstrom parameters than winter, indicating a large contribution ofbiogenically driven fine or accumulation modes. Seasonal characteristics of North Atlantic marine aerosols show the importanceof the relationship between marine aerosol and biological activity,which triggers primary production of oceanic biomass.The quantification of natural sources to aerosol levels for differentaerosol sources (and for different regions) is of crucial importance inreducing uncertainty in climatic effects.

New Chemical and Physical Data of the Volcanic Aerosol

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NHM is Naturhistorisches Museum/Vienna

In the last 10 years fumaroles, passively degassing volcanoes and active lava flows had been the target of aerosol particle sampling and FESEM/EDS studies (Obenholzner et al., 2003). One goal had been the detection of P-bearing particles and gas species. Phosphine (PH3) contents are higher than background at fumaroles (Vulcano island) and cooling lava flows (Mt. Etna). Volcanic P might have become available for the biomass (RNA, DNA) throughout geological times. Particle sampling utilizing a classical filter-bubbler-train showed several unexpected results: 1. Different high efficiency aerosol filters collected different particles. 2. Nucleation of particles happens on the surface of glass micro-fibers. 3. On one single micro-fiber only one metal halogenide nucleates; other fibers in the vicinity are unaffected. 4. Bubbler liquids contain high amounts of elements i.e. Zn, As etc. (ICP-MS) which cannot be related to a gas phase. These data might indicate the existence of +/- soluble nanoparticles.

Deposited and/or nucleated BaSO4 and metal halogenides (Cl, Br, I, F in decreasing order) are common. Even on halite nucleated BaSO4 is present. After the eruption of Popocatepetl v. Ba ions had been detected over Mexico in 1998 (Murphy et al., 1998). Ba is a life-maintaining element for many bacteria. It is unknown if bacteria operating as cloud condensation nuclei also rely on Ba. Tl halogenides are common. N-bearing particles are present as nucleates, as well as deposited REE carbonates at a fumarole of La Fossa crater, Vulcano island.

Nucleated particles might be also present on glass fragments related to eruptions. Deposited and nucleated particles of this study are unknown according to their ice-nuclei capacity. Volcanoes remain being a complex part of the climate puzzle.

Murphy et al., 1998. Science, 282, 1664-1669.
Obenholzner et al., 2003. In: Volcanic Degassing (eds. Oppenheimer, Pyle, Barclay). Geol. Soc. London, SP 213, 123-148.

Posters (Wed PM, display all week)

A Synthesis of Single Scattering Albedo Values of Biomass Burning Aerosol, bserved over Southern Africa during SAFARI 2000.

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Measurements of aerosol optical properties from multi-platform field campaigns can help to improve understanding of aerosol scattering and absorption effects on the Earth's radiation balance. We will present ambient single scattering albedo (SSA) values of biomass burning aerosol from the Southern African Regional Science Initiative (SAFARI) 2000 field campaign. These SSA values at 550nm (SSA_{550}) were calculated using three independent methods. The three methods were in situ measurements of aerosol scattering and absorption made aboard the University of Washington's (UW) aircraft, airborne flux radiometry measurements, and ground-based sun photometer/radiometer retrievals. Layer averaged in situ SSA_{550} values were compared to SSA_{550} values determined by the NASA Solar Spectral Flux Radiometer (SSFR) aboard the UW aircraft on two days, one with a high aerosol loading (aerosol optical depth (AOD_{550}) from in situ data = 0.71), and a low aerosol loading (AOD_{550} from in situ data = 0.16). The high AOD_{550} day revealed agreement within estimated uncertainties (in-situ: 0.84 ± 0.02 versus SSFR: 0.87 ± 0.04), whereas the low AOD_{550} day indicated a small discrepancy given the estimated uncertainties (in-situ: 0.94 ± 0.02 versus SSFR: 0.82 ± 0.09). There were six occasions when the UW aircraft was collocated with the ground-based AERONET sun photometer/radiometers. Five of the six comparisons indicated good agreement, while the sixth appears to have been negatively affected by a significant temporal offset. UW in situ data suggest a campaign-wide SSA_{550} of 0.85 ± 0.03 (mean ± total uncertainty), representing aged smoke (haze) over southern Africa. We propose that this value be used in models to calculate biomass burning aerosol radiative effects. Results from a comparison with AeroCom data will also be presented, which, coincidently, covered the year 2000, overlapping the SAFARI 2000 study period.

Experimental determination of effective refractive indices of aerosols emitted from high-moisture-content biomass combustion

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Combustion of wildland fuels is a major source of carbonaceous aerosols in the atmosphere. Satellites are commonly used for remotely quantifying aerosol concentrations in the atmosphere and for studying aerosols radiative effects on global and regional scales. The quality of satellite aerosol retrievals depends critically upon the modeling of the aerosol optical properties, which strongly depend on the particle Effective Index of Refraction (EIR). EIR is generally used to account for the composite internal and external mixing state of particles. However, little is known about the EIR of aerosols emitted from the combustion of wildland fuels. As part of a study conducted in May-June 2006 at the USFS (U.S. Forest Service) Fire Sciences Laboratory investigating properties of aerosols emitted by fires, we studied the optical properties, size distribution, and morphology of particles emitted from the combustion of many common wildland fuels. Ensemble particle absorption and integrated scattering properties were determined using photoacoustic-spectrometer/nephelometer technique at four different wavelengths, 405, 532, 781, and 870 nm. The particle size distribution was continuously monitored using an ELPI (Electrical Low Pressure Impactor) (Dekati Inc.), while the morphology was studied with scanning electron microscopy. It was found that combustion of three high moisture containing wildland fuels (Fresh Montana Grass, Ponderosa Pine Duff and Alaskan Duff) produced near spherical particles. The near sphericity of the particles facilitates the analysis of the absorption and scattering data and permits to apply Mie theory to derive real and imaginary parts of EIRs. The procedure and results of the analysis for each of the fuels will be presented.

Estimating the Magnitude and Uncertainty of Southern African Biomass Burning Aerosol Direct Radiative Forcing

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During the Southern African Regional Science Initiative in August and September 2000 (SAFARI-2000), many detailed observations of aerosol optical properties were collected during aircraft vertical profiles. We combine the observations with modeling techniques and offer new estimates of the direct aerosol radiative forcing by southern African biomass burning aerosol. Our observation-based estimates of the direct aerosol radiative forcing (RF) range from -7.1 to -8.9 W m2 at the top of the atmosphere (TOA) and -22.9 to -73.0 W m2 at the surface. The largest surface RF arises as a result of a decrease in aerosol single scattering albedo (SSA) and increase in aerosol optical depth (AOD). There is, however, no apparent effect of this change in SSA and AOD on TOA RF, which could have important consequences for interpreting satellite measurements. We also estimate the uncertainty in RF due to instrument uncertainties and uncertainties inherent in common assumptions. The total uncertainty averages ~40% (~3 W m2) for TOA RF and ~10% (~5 W m2) for surface RF. We show that uncertainties in SSA in the solar spectrum contributes ~50% to the total uncertainty associated with RF both at the TOA and the surface. About half the uncertainty associated with SSA in the solar spectrum is associated with the lack of knowledge about the wavelength dependence of SSA. We will discuss the implications of the radiative effects of biomass burning aerosol on the southern African region as well as the importance of the aerosol on a global scale. We also offer comparisons with past studies and comparisons with ground-based Aerosol Robotic Network (AERONET) derived RF estimates.

Multiwavelength Photoacoustic Measurements of Light Absorption and Scattering by Wood Smoke.

Kristin Lewis, William P. Arnott, and Hans Moosmuller
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Simultaneous measurements of aerosol light absorption by a wide range of biomass smoke using the photoacoustic method at 405 nm and 870 nm are reported, along with light scattering measurements obtained with the same instrument using the reciprocal nephelometer method. Angstrom coefficients for absorption were found to range from 1 to 3. Angstrom coefficients for scattering were found to diminish as the Angstrom coefficient for absorption increases. These first of a kind measurements show conclusively that light absorbing organic material is present in wood smoke. Aethalometer measurement comparisons will be presented along with measurements by photoacoustic instruments operating at wavelengths 532 nm, 780 nm, and 1047 nm.

On Regional Impact of Rising Asian Emissions

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A fully coupled chemistry within the WRF (Weather Research and Forecasting) model generally referred to as WRF/Chem, has been used to study the impact of the rising Asian emissions on chemical species, aerosols and hydrological cycles across the North Pacific and North America. A comprehensive emissions inventory that takes into account the greenhouse gases, Ozone precursor gases, acidifying gases, and black and organic carbon emissions is utilized and implemented into the model. The coupled model is run for the month of March in 2001 when the TRACE-P (Transport and Chemical Evolution over the Pacific) field experiment was conducted. Results from the model simulations and comparisons with observations will be presented at the workshop.

Air Pollution Impacts of Ethanol

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Ethanol is often touted as an environmentally friendly replacement for gasoline as a transportation fuel. Ethanol is one of the biofuels argued to shorten the carbon cycle and reduce global warming gases, and its use is growing. However, the air pollution impacts of ethanol are often not discussed. Published emission data for ethanol-blend fuels shows that ethanol emits different amounts of volatile organic chemicals (VOCs) but lower oxides of nitrogen than traditional gasoline. Ethanol emissions also increase substantially with an increase in temperature. We investigate the impact of these changes on air pollution by comparing traditional gasoline with different ethanol-blended fuels (E20, E85). The Master Chemical Mechanism (out of Leeds University in the UK) and a mechanism that uses lumped carbon bond groups are used in a chemical solver (SMVGEAR II) to examine the sensitivities of the production and loss rates of ozone, PAN, and other gases to fuel type, temperature, and other parameters. This result will give better insight into the sensitivities of ethanol chemistry in an urban environment.

Satellite Remote Sensing of Aerosols Generated by the Island of Nauru

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Los Alamos National Laboratory

We use imagery from the Multispectral Thermal Imager (MTI) to search for aerosols generated by the island of Nauru, an island located in the tropical western Pacific Ocean. Nauru frequently displays linear cloud trails for many kilometers downwind of the island, and this study was intended to investigate the presence of aerosols as an aid to understanding those features. The study had three components: 1. a search for specific aerosol plumes, 2. a comparison of downwind and upwind aerosol loading to look for asymmetries, and 3. application of matched filters to increase the visibility of aerosol plumes. The plume search resulted in the finding of three aerosol plumes, two of which are presented as imagery and also radiance profiles. The comparison of downwind and upwind reflectance spectra demonstrated that the radiance is slightly higher downwind of the island, and the residual spectra (downwind minus upwind) have a spectrum consistent with sea salt aerosol. Application of clutter matched filters to MTI imagery accentuated the upper (near-source) sections of an aerosol plume when utilizing a single-scatter albedo signature for coarse-grained sea salt aerosol. We combine our observations with models from the literature to describe a simple mechanism by which Nauru aerosols are created by wave breaking and wind tearing of sea spray, then entrained by island-influenced wind motions.

Enhancement of the Emission of Mineral Dust Aerosols by Electric Forces

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Climate forcing by mineral dust aerosols is one of the most uncertain processes in our current understanding of climate change. The main natural sources of dust aerosols are blowing dust, dust devils, and dust storms. Electric fields larger than 100 kV/m have been measured in these phenomena. Theoretical calculations and laboratory experiments show that these electric fields produce electric forces that can reduce the critical wind speed necessary to initiate dust lifting and can even directly lift mineral particles from the surface. Thus, we conclude that electric forces enhance the natural lifting of mineral dust aerosols.

Global Trends in Visibility: Implications for Dust Sources

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Visibility datasets from meteorological stations worldwide represent a large, and largely untapped dataset that can be used to understand decadal and longer trends in dust storm frequency. Unfortunately the datasets are not necessarily of good quality. In this study, we compare visibility proxies to other dust datasets (AERONET optical depth measurements in dusty regions)to determine the ability of visibility-based dust proxies to provide information on dust storms and dust source variability. We then summarize the long term trends and relationships between visibility data and meteorological and anthropogenic forcings on dust. Overall, both meteorological and human forcings appear to be important in some regions, but this varies by region. Because of the poor quality of the data, however, our results cannot be considered conclusive.

An upper-bound limit on random noise of the calibrated radiance values from MODIS Terra and MODIS Aqua.

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Petr Chylek
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Upper-bound limits on random noise of the longwave calibrated radiance values measured by Moderate Resolution Imaging Spectroradiometer (MODIS) instruments mounted on the Terra and Aqua satellites are estimated.
Cloud-free portions of scenes over the ice sheets of Antarctica and Greenland are assumed to be uniform due to the homogeneity of the surface and low water vapor content of the atmosphere. This implies that variations in the measurements are mostly due to instrument noise.
By computing the mean standard deviation of all 10-by-10 km clear sky areas sampled over the ice sheets for each of the longwave spectral bands, both upper-bound estimations on random noise, as well as relative differences in noise among other spectral bands from both instruments can be calculated. Such information could be crucial for precision retrievals, especially in situations when data from both Terra and Aqua-mounted MODIS instruments are required.

Multi-Satellite Based Estimation of Global Aerosol Direct Radiative Effect Over Land and Ocean

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Aerosols influence the Earth's radiation budget both directly by scattering and absorbing the incoming solar radiation and indirectly by serving as cloud condensation nuclei, thereby, altering cloud microphysical properties that are important in determining the cloud optical properties and its radiative effects. While, the radiative effects of aerosols play an important role in Earth's radiation budget, the magnitude and sign of its influence remains uncertain. This study aims at understanding the role of aerosols direct radiative effect (ADRE) globally based on multi-satellite measurements. In this study we use one year worth of global (land/ocean) shortwave flux data from the Cloud and Earth Radiation Energy System (CERES) in conjunction with aerosol optical depth data from Multi angle Imaging Spectro- Radiometer (MISR) and Moderate Resolution Imaging Spectro-radiometer (MODIS) both to estimate the global aerosol direct radiative effect over land and ocean. The CERES-MISR-MODIS datasets have been collocated in both time and space at CERES resolution. MISR aerosol optical depth product has been exploited to estimate the ADRE over land. Over ocean background, both MODIS and MISR observations have been compared and contrasted. This paper presents a comparison of global ADRE between different regions of the world and between different seasons and discusses the aerosol forcing efficiency. We present a comparison with literature and discuss the possible impacts of ADRE. This work is novel in that it is the first purely satellite based estimate of global (land and ocean both) ADRE.

Compilation of a Global Emission Inventory from 1980 to 2000 for Global Model Simulations of the Long-term Trend of Tropospheric Aerosols

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The approach to create a comprehensive emission inventory for the time period 1980 to 2000 is described in this paper. We have recently compiled an emission database, which we will use for a 21 year simulation of tropospheric aerosols with the GOCART model. Particular attention was paid to the time-dependent SO2, black carbon and organic carbon aerosol emissions. For the emission of SO2 from sporadically erupting volcanoes, we assembled emission data from the Global Volcanism Program of the Smithsonian Institution, using the VEI to derive the volcanic cloud height and the SO2 amount, and amended this dataset by the SO2 emission data from the TOMS instrument when available. 3-dimensional aircraft emission data was obtained for a number of years from the AEAP project, converted from burned fuel to SO2 and interpolated to each year. Other anthropogenic SO2 emissions are based on gridded emissions from the EDGAR 2000 database (excluding sources from aircraft, biomass burning and international ship traffic), which were scaled to individual years with country/regional based emission inventories. Gridded SO2 emissions from international ship traffic for 2000 and the scaling factors for other years are from [Eyring et al., 2005]. We used gridded anthropogenic black and organic carbon emissions for 1996 [Bond et al., 2004]. These emissions were scaled with regional based emission inventories from 1980 to 2000 to derive gridded emissions for each year. Details on the integration of the information from the various sources, including biomass burning, will be provided and the distribution patterns and total emissions in the final product will be discussed.

A Comparison Between the Bin and Stochastic Particle Approach for the 1-D Advection-Condensation Problem

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In this presentation a comparison between the efficiency and accuracy of a particle code against a traditional bin model with respect to the 1-D advection-condensation problem will be illustrated. Because a particle model does not suffer from numerical errors associated with advection, both in space and across bins, the particle approach has a much smaller numerical error than the bin approach and as such will be used as our reference solution; however, the computational cost of a "true" particle model in which each particle represents one droplet is large and to offset this cost, with some loss in numerical accuracy, a stochastic particle model should be used. Thus, a key aspect of this presentation will be to demonstrate how many droplets can be represented by one particle in the stochastic approach to produce the same error for a given cost as was produced by the bin model. Because the approximations employed in the bin model break down as the grid resolution decreases, these comparisons will also be shown under grid refinement. Furthermore, to illustrate the role that turbulent or molecular diffusion plays, error versus cost comparisons using the two approaches will also be conducted under varying levels of explicit diffusion.

The Hydrogen Cycle in a Megacity: Observations and Modeling of Mexico City

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Mexico City with a population of 25 million, the largest mega-city in North America, provides a testing ground for regional and global impacts on air quality and climate of increasing urbanization. To help understand this Los Alamos scientists were a part of an international multi-agency Megacity Initiative: Impact on Regional and Global Environment (MILAGRO) field campaign in Mexico City in March 2006. The Los Alamos team also provided the only measurements of molecular hydrogen in Mexico City. We report the diurnal and weekly observations of molecular hydrogen and CO in Mexico City. A very regular diurnal profile with peak concentrations of hydrogen in early morning caused by the high traffic and shallow boundary layer was revealed. A record level of hydrogen of 5 ppm a factor of 10 above background levels was measured. It is hypothesized that most of the hydrogen is coming primarily from automobiles. However, we did observe emissions from other industrial or power plant sources. Analysis of the H2/CO, CO/CO2, and H2/CO2 ratios are developed as a powerful chemical fingerprinting method to delineate these sources and relate them to combustion efficiency. Finally, regional scale modeling of the Mexico City hydrogen cycle is performed using the Weather Research Forecast: Chemistry (WRF-CHM) model at 1 km resolution. The model results are compared to our measurements to gain a quantitative understanding of hydrogen sources and sinks (soil microbial) in Mexico City. Our findings are significant to the understanding of the global hydrogen cycle and potential perturbations to it from transitioning to a hydrogen economy.

Friday, July 21, 2006

Fr I: Aerosol and Cloud Microphysics and Radiation

Laboratory Studies of Aerosol Transformations and their Implications to Cloud Processes & Climate Change

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While the potential of aerosol to influence climate is recognized, themagnitude of this effect must be better constrained if accurate model predictions of future climate are to be made. To this end, the transformation of SOA from a hydrophobic to a hydrophilic state by atmospheric oxidants (aging) has recently become an area of intense research. In this work, we investigate the aging of oleic acid aerosol by ozone and correlate changes in aerosol chemical composition to changes in CCN activity.

Cloud condensation nucleus (CCN) properties of oleic acid as a function of exposure to ozone are studied in laboratory flow tube experiments coupled to a CCN counter operated at a supersaturation of 0.6%. Corresponding changes in the chemistry of the aging organic particles were investigated via simultaneous sampling with an Aerodyne aerosol mass spectrometer (AMS).

Pure oleic acid and oleic acid/ethyl acetate particles do not activate for all particles diameters up to 250 nm. At a relative humidity (RH) of <1%, the products of oleic acid ozonolysis are CCN inactive at low ozone exposures. High exposures lead to increased CCN activity, but the level of activity became dependent upon residence time within the flow tube (i.e., aerosol/ozone interaction time) as well as the absolute ozone concentration. Consequently, the conventional combination of residence time and concentration (atm*s) to define ozone exposure may not be an appropriate measure for CCN activity. At 23% RH, CCN activity of oleic acid ozonolysis products significantly increased, although pure oleic acid remained inactive. As conditions were changed to effect activation (e.g., by increasing ozone concentration), the AMS results suggest that the condensed-phase concentration of high-molecular-weight polymers sharply decrease while the concentration of azelaic acid increases.

Observations of the REDUCTION Of Aerosol Light Absorption and INCREASE of Biomass Burning Aerosol Light Scattering for Increasing Relative Humidity

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Cyle Wold, Emily N. Lincoln, Patrick Freeborn, and Wei-Min Hao
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A very interesting case of smoke aerosol with very low single scattering albedo, yet very large hygroscopic growth for scattering is presented. Several samples of chamise (Adenostoma fasciculatum), a common and often dominant species in California chaparral, were recently burned at the USFS Fire Science Laboratory in Missoula Montana, and aerosol optics and chemistry were observed, along with humidity-dependent light scattering, absorption, and particle morphology. Photoacoustic measurements of light absorption by two instruments at 870 nm, one on the dry channel, one on the humidified channel, showed strong reduction of aerosol light absorption with RH above 65 percent, and yet a strong increase in light scattering was observed both at 870 nm and 550 nm with nephelometers. Multispectral measurements of aerosol light absorption indicated an Angstrom coefficient for absorption near unity for the aerosols from chamise combustion. It is argued that the hygroscopic growth of scattering is due to uptake of water by the sulfur bearing aerosol. Furthermore, the reduction of aerosol light absorption is argued to be due to the collapse of chain aggregate aerosol as the RH

increases wherein the interior of aerosol does no longer contribute to absorption. Implications for biomass burning in general are that humidity processing of aerosols from this source and others like it tends to substantially increase its single scattering albedo, probably in a non-reversible manner. The chemical pathway to hygroscopicity will be addressed.

Particle Emissions from Laboratory Combustion of Wildland Fuels: Aerosol Optical Properties During Flaming and Smoldering Combustion Phases

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As part of a study at the USFS Fire Sciences Laboratory (FSL) investigating properties of aerosols emitted by fires, we recorded aerosol light absorption and extinction coefficients with high (i.e., second) time resolution. The aerosol single scattering albedo is calculated directly from the measured absorption and extinction coefficients. For fuels with relatively low fuel moisture content, the combustion initially goes through a flaming phase followed by a smoldering phase. The measured aerosol single scattering albedo during the flaming phase is small with values as low as 0.15 recorded. This is due to the formation of black carbon, fractal-like chain aggregates that show strong light absorption but comparatively little scattering. During the transition from flaming to smoldering phase, the light extinction generally stays relatively constant or continues to increase while the light absorption drops dramatically resulting in a single scattering albedo close to one during the smoldering phase. Smoldering combustion is a surface process that begins when most of the volatiles have been expelled from the cellulose fuel. Oxygen diffuses to the surface and reacts exothermally with carbon at temperatures lower than flaming combustion temperatures. This results in the emission of aerosols consisting largely of organic carbon. These aerosols strongly scatter light but absorb light only very weakly or not at all. The difference between the single scattering albedo observed in flaming and smoldering combustion may also explain the lower aerosol single scattering albedo observed for aerosols emitted by wildland fires compared to those emitted from laboratory combustion. Laboratory combustion generally uses fuels of smaller size and often of lower fuel moisture content than naturally occurring fuels. This favors flaming combustion over smoldering combustion, thus resulting in lower albedos during laboratory combustion.

An Absorption Model of Insoluble Particle Activation: Application to Black Carbon

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We present a model of insoluble particle activation based on a modification of the Kšhler equation in which we introduce a term based on the activity of water adsorbed on the particle surface. We parameterize the model using a free energy of adsorption that is obtained by fitting laboratory measurements of water adsorption on the insoluble surface with a multilayer adsorption isotherm. We illustrate the model by application to adsorption and activation data from carbon surfaces. Several features of a suite of measured carbon activation data are captured by the model. In particular, upper and lower bounding curves are predicted for activation supersaturation as a function of diameter. We show a large body of recent activation data which all fall within these bounds. The model also predicts that activation of BC aerosol leads to activation diameters from 3 to 10 times smaller than soluble activation of particles of identical dry diameter. The activation of smaller particles may be expected to impact the size distribution of resulting cloud droplets and thus the aerosol first indirect effect on climate.

Sulfuric Acid and Water Nucleation Under the Conditions Relevant to the Lower Troposphere

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Aerosol nucleation is a gas to particle conversion process in which solid or liquid particles form directly from gas phase species, but the nucleation mechanisms are poorly understood. In particular, nucleation rates meassured under the atmospheric conditions are rare, mostly because of the limited capability to measure low concentrations of aerosol precursors. We apply a chemical ionization mass spectrometer (CIMS) to study atmospheric aerosol nucleation mechanisms under the lower troposphere conditions. Our CIMS, developed by Georgia Tech, measures low concentrations of sulfuric acid (down to $1x10^{-6}$ cm^{-3}) at atmospheric pressures. Sulfuric acid is the major aerosol precursor. We measure aerosol concentrations and sizes with a nano-particle differential mobility analyzer and a water condensation particle counter to calculate aerosol nucleation rates. We use an atmospheric pressure flow reactor to photochemically produce sulfuric acid (H2SO4) from the OH + SO2 reaction. Nucleation takes place in a temperature controlled fast flow reactor. H2SO4 is measured using $NO3^-$ ions as a reagent, and SO2 with $SF6^-$ ions. OH forms from the water photodissociation reaction with a mercury UV lamp (filtered for only $\lambda < 185$ nm). Absolute OH concentrations are calculated based on the known water UV absorption cross sections and the measured photon fluxes. These calculated OH concentrations allow us to calibrate H2SO4 concentrations. Alternatively, we also generate H2SO4 vapors from pure the sulfuric acid liquid samples and compare nucleation rates with those from the SO2 + OH experiments. We compare our nucleation rates with Berndt et al. (2004) that show relatively high nucleation rates of sulfuric acid aerosols which are comparable to the atmospheric observations.

Citation: Berndt, T., O. Bšge, F. Stratmann, J. Heintzenberg, M. Kulmala, Rapid formation of sulfuric acid particles at near-atmospheric conditions, Science **307**, 698-671, 2004.

Modeling and Computation of Thermodynamic Equilibrium and Mass Transfer for Organic Aerosol Particles

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Over the last two decades, a series of modules has been developed in the atmospheric modeling community to predict the phase transition, crystallization and evaporation of inorganic aerosols. In the same time, the research on hygroscopicity of organic-containing aerosols, motivated by the organic effect on aerosol growth and activation, has gathered much less attention.

We present here a new model (UHAERO), that is both efficient and rigorously computes phase separation and liquid-liquid equilibrium for organic particles, as well as the gas-particle partitioning. The model does not rely on any a priori specification of the phases present in certain atmospheric conditions. The determination of the thermodynamic equilibrium is based on the minimization of the Gibbs free energy. The mass transfer between the particle and the bulk gas phase is dynamically driven by the difference between bulk gas pressure and the gas pressure at the surface of a particle.

The multicomponent phase equilibrium for a closed organic aerosol system at constant temperature and pressure and for specified feeds is the solution to the liquid-liquid equilibrium problem arising from the constrained minimization of the Gibbs free energy. A primal-dual interior-point algorithm, together with a Newton method, allows an efficient solution to the phase equilibrium problem. A geometrical concept of phase simplex is introduced to characterize the optimum. The computation of the mass fluxes is achieved with a time splitting algorithm, by coupling the thermodynamics and the dynamics with sequential quadratic programming techniques.

Numerical results show the efficiency of the model, which make it suitable for insertion in global three-dimensional air quality models. The Gibbs free energy is modeled by the UNIFAC model to illustrate the flexibility of the framework. We are extending this framework to study the hygroscopicity of aerosols containing mixtures of inorganic and organic species.

In Situ Measurements of Shortwave Aerosol Optical Properties Relevant for Climate Change

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Climate change is thought to be mainly driven by greenhouse gases accumulating in the earth’s atmosphere. In addition, direct radiative effects of aerosols may either counteract greenhouse gas induced warming or enhance it, depending on aerosol scattering and absorption properties and the spatial distribution of aerosols in the atmosphere. Aerosol scattering redirects the solar radiation with climate effects depending on the scattering coefficient and angular distribution of scattering or phase function. Aerosol absorption heats the atmosphere locally, thereby changing the atmospheric dynamic and reducing shortwave radiation. At the Desert Research Institute, we are developing instrumentation for the in situ characterization of aerosol optical properties, including scattering (Integrating Sphere Integration Nephelometer), absorption (Photoacoustic Instrument), and extinction (Cavity Ringdown/Cavity Enhanced Detection) coefficients, and the angular distribution of scattering as parameterized by the asymmetry parameter. Challenges in measuring these aerosol optical properties and our approaches to solve them will be discussed.

IMPACT OF UNRESOLVED, CORRELATED OR ANTI-CORRELATED SPATIAL STRUCTURE ON THE BULK TRANSPORT OF RADIATION INSIDE AND BETWEEN CLOUDS, WITH APPLICATIONS TO REMOTE SENSING AND ENERGY BUDGETING

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Radiative transfer (RT) theory is needed for both accurate energy budget estimation at scales ranging from a single cell in a 3D cloud process model (~m) to GCM grid cells (~10^5 m) as well as for physically-correct exploitation of remote sensing signals at scales ranging from the smallest satellite pixels (~m) to domains commensurate with a few atmospheric scale-heights (~10^4 m). A major challenge in RT is to account for the bulk effects of unresolved variability irrespective of the artificial computational or observational scale of reference, especially in the study of dense clouds and cloud fields at wavelengths dominated by complex multiple scattering processes unfolding in 3D space and time.

In this talk we describe two very general and interestingly different approaches to this problem based, on the one hand, on the linear Boltzmann equation cast in photon phase-space with randomly varying collision coefficients and, on the other hand, on discrete random point processes. Predictions are made for statistical properties of the mean propagation kernel in homogeneous and isotropic but random optical media using general probabilistic arguments and/or tractable stochastic models. We contrast the radically different results obtained for media with positively- and negatively-correlated fluctuations, i.e., particle clustering and anti-clustering tendencies.

Finally, we present a spectacularly successful application of this statistical transport physics to recent state-of-the-art observations of the mean and variance of solar photon pathlengths in cloudy atmospheric columns using ground-based absorption-line spectroscopy in the A-band of molecular oxygen. Ramifications for GCM parameterizations of shortwave RT and for RT computations in CRMs are discussed. This makes the outlook towards space-based capability in O_2 A-band spectroscopy with NASA's Orbiting Carbon Observatory very exciting.

The speaker (AD) will also share a few memories of Yoram Kaufman, a dear friend and an esteemed colleague during his 5-year tenure at NASA-GSFC's Climate and Radiation Branch, to whom the remote sensing session is dedicated in memoriam.

Fr II: Aerosols and Pollution in Megacities

Megacity Respiration - Mexcico City Example

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Urban areas metabolize inputs of food, fuel, oxygen and other materials and respire trace gaseous species and fine particulates. Megacities, with populations of ten million or more, have mega-appetites and produce large, highly polluted, photochemically active respiration plumes that can severely impact human health, ecosystem viability and climate parameters within their metropolitan areas as well far down wind. Data from 2003 and 2006 fixed site and mobile laboratory measurements within and downwind of Mexico City, North America's largest megacity, will be presented. These data will be used to characterize key emission sources within the city and their temporal and spatial evolution as they move through and out of the metropolitan area. Attention will be focused on the emission and evolution of secondary aerosol precursors, including selected volatile organic compounds, nitrogen oxides, and ammonia, as well as characteristics of both primary and secondary submicron particulate matter.

Optical Scattering Patterns From Single Urban Aerosol Particles At Adelphi, Maryland, USA; A Classification Relating To Particle Morphologies

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Abstract. Angularly-resolved elastic light scattering patterns from individual atmospheric aerosol particles (diameter 0.5-12 micrometers) sampled during fall (October 2004) at an urban site in the Baltimore-Washington metroplex are reported. These Two-dimensional Angular Optical Scattering (TAOS) patterns were collected for polar scattering angles θ varying from approximately 75° to 135°, and azimuthal angles ϕ varying from 0° to 360°. Approximately 6000 scattering patterns were sampled over a span of 18 hours from an inlet located above our laboratory roof at Adelphi, Maryland. Our instrument recorded light scattering patterns of higher resolution and accuracy than have previously been achievable. The patterns suggest that background aerosol particles have diverse morphologies ranging from single spheres to complex structures. The frequency-of-occurrence of particle morphologies inferred from the TAOS patterns is strongly dependent on size. For nominally 1 μm particles, 65% appear spherical (or perturbed sphere) and only about 9% have complex structure (as suggested by their complex scattering features); whereas for nominally 5 μm particles only 5% appear spherical (or perturbed sphere) and 71% appear to have complex structure. The patterns are quantitatively characterized using a degree of symmetry (Dsym) factor, calculated by examining both mirror and rotational symmetries in each pattern. In our measurements, atmospheric particles have two distinct populations; mostly micron-sized particles with Dsym values close to that of spheres, and a population of mostly super-micron particles having a low, but broad range of Dsym values. These observations are consistent with the commonly accepted notion that most micron-sized particles (in the accumulation mode) appear to be nearly spherical, and are probably formed in the atmosphere through gas-particle reactions; whereas most super-micron particles appear to be non-spherical and are likely directly injected into the atmosphere. Our observations suggest that Lorenz-Mie theory may be adequate for most micron-sized particles, but not for supermicron particles.

Photoacoustic Measurements of Aerosol Light Absorption and Scattering at Four Sites in and Near Mexico City

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As part of the Megacity Impacts on Regional and Global Environments, MIRAGE-Mex deployment to Mexico City in the period of 30 days, March 2006, a suite of photoacoustic spectrometers (PAS) were installed to measure at ground level the light absorption and scattering by aerosols at four sites: an urban site at Instituto Mexicano del Petroleo (Mexican Oil Institute, denoted by IMP), a suburban site at the Technological University of Tecamac, a rural site at "La Biznaga" ranch, and a site at the Paseo de Cortés (altitude 3,810 meters ASL) in the rural area above Amecameca in the State of Mexico, on the saddle between the volcanos Popocatepetl and Iztaccihuatl. The IMP site gave in-situ characterization of the Mexico City plume under favorable wind conditions while the other sites provided characterization of the plume, mixed in with any local sources. The second and third sites are north of Mexico city, and the fourth site is south.
The PAS used at IMP operates at 532 nm, and conveniently allowed for characterization of gaseous absorption at this wavelength as well. Instruments at the second and third sites operate at 870 nm, and the one at the fourth site at 780 nm. Light scattering measurements are accomplished within the PAS by the reciprocal nephelometery method. In the urban site the aerosol absorption coefficient typically varies between 40 and 250 Mm^{-1} during the course of the day and significant diurnal variation of the aerosol single scattering was observed. We will present a broad overview of the diurnal variation of the scattering and absorption as well as the single scattering albedo and fraction of absorption due to gases at the IMP site. Insight on the dynamical connections will be discussed.

The Net Radiative Forcing of a Megacity: A Mexico City Case Study

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We assess the radiative forcing budget of Mexico City the largest megacity in North America. While the regional impacts of cities on their surroundings have been rather thoroughly investigated, e.g., air quality and acid rain, relatively little effort has been focused on the net radiative impact of a megacity. The range of radiative impacts from a megacity covers many spatial and temporal scales from local albedo changes to mid-range aerosol effects to long-term global-scale impacts due to trace gas emissions (e.g., CO, NOx, CO2) and chemistry. In this study use both bottom-up and top-down approaches to evaluate the these radiative forcings. From the bottom up we utilize emission inventories, regional and global chemistry-aerosol models (the Weather Research and Forecasting chemistry model (WRF-chem) and the Model for OZone And Related chemical Tracers (Mozart), respectively). From the top down we use in situ measurements of single scatter albedo performed during MILAGRO and satellite observations from the Moderate Resolution Imaging Spectroradiometer (MODIS) instrument and radiative transfer models. As the size and number of megacities increase, metrics such as the net radiative forcing may become increasingly important in comparing the impact of urban centers.

Rahn; No abstract available at this time.

Long Term Trends in Elemental Carbon

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Light-absorbing black or elemental carbon (EC) or soot, plays a key role in the Earth's temperature regulation. EC may be the second biggest contributor to global warming after greenhouse gases, accounting for ~15 to 30% of the estimated global warming [Jacobson, 2001, 2002]. However, the magnitude of the radiative forcing is quite uncertain due to paucity of regionally representative long term EC data. EC aerosols can travel hundreds of km from sources, therefore the EC concentrations at a given location are sum of all emissions within a region. The global climate models need EC concentrations from regionally representative locations to carry out calculations of radiative forcing.We have been conducting aerosol studies at Whiteface Mountain (amsl 1.5 km), NY continuously since July 1978. Owing to prevailing westerly winds this site is subject to frequent pollution episodes which transport high levels of various chemical species including EC from upwind emission sources . An analysis of ten such episodes that occurred from 1983 to 2002 has shown that EC concentrations at Whiteface Mountain truly represent this region. Therefore measurements of EC at this site should be really useful in calculating radiative forcing and testing models predicting atmospheric EC burden based on emissions. The aerosol samples were collected daily. EC concentrations were determined from monthly composites using the thermal-optical(TOT) method. Annual mean concentrations were determined for samples collected from January 1984 thru December 2004.The annual mean EC concentration in 1984 was 375 ng m-3, and except for 1986, it has shown downward trend. A major decrease occurred in 1997 when EC was 76 ng m-3. Since 1997 the concentration has slowly decreased to 36 ng m-3 in 2004. The results will be compared with other data obtained for shorter periods and with upwind emissions.