

W. Lawrence Gates Program for Climate Model Diagnosis and Intercomparison (PCMDI) Lawrence Livermore National Laboratory Livermore, CA

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

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A71H-02 1035h INVITED

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

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

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

A71H-03 1050h INVITED

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

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During the mid 1970s global climate models were used to examine climate conditions of the past. Initially these early studies considered how external changes would influence the climate system and the ocean was considered as a fixed boundary condition. By the early 1980s the ocean evolved from a fixed boundary condition, to one acting solely as a moisture source and finally to considering the thermodynamic and dynamic states of the ocean. At the same time, the role of internal boundary condition (greenhouse gas concentrations, continental configuration, rotation rate, ice-sheets) as a means for understanding past climate were being taken into account. Many of the early studies used the National Center for Atmospheric Research (NCAR) community climate model (CCM) as the model of choice for studying paleoclimates. Today climate models are capable of examining the full climate system (atmosphere, ocean, cryosphere, biosphere, ocean) with paleoclimate modelers examining past climates and also attempting to simulate the last 500 years. If these simulations agree with the observed proxy record, then it

may be possible to bracket the natural climate variability prior to the industrial revolution in climate models. Moreover, these types of simulation allow for the analysis of interannual to centennial variability. Consequently, the ability to correctly simulate past climates can only increase our confidence in simulating future climate change caused by anthropogenic greenhouse forcing.

A71H-04 1105h

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

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

A71H-05 1120h

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

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

the West African and Asian monsoon regions (the latter qualitatively consistent with observed trends in All-India rainfall), the tropical Pacific, and in the southern ocean tropical convergence zones.

A71H-06 1135h INVITED

The Asian Brown Cloud

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

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

A71H-07 1150h INVITED

Climate Change Doesn't Just Happen

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

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

A72A MCC: Hall D Sunday 1330h

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

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

A72A-0133 1330h POSTER

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

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We conducted experiments using artificial snow, synthetic air, and sunlight during January, 2002 (the SNOW2002 study) in order to test the influence of neutral and basic pH on the amount of NO, NO₂, and NO_x emitted from artificial snow during nitrate photolysis. We also conducted the first tests demonstrating that illumination of consolidated, sub-millimeter diameter ice particles (e.g., artificial snow) doped with nitrite produces NO_x, confirming that nitrite photolysis occurs in ice and snow. Innovations in NO_x instrument design were also implemented in order to estimate gaseous HONO levels using UV lamp photolysis. Nitrate was introduced into solution as sodium nitrate, pH was controlled using sodium hydroxide. Artificial snow particles were formed by spraying tiny water droplets down into a tall (3 meter) column chilled by a pool of liquid nitrogen at the column base. Although this method of creating artificial snow results in snow that is certainly different than natural snow, the tiny ice particles formed are powdery and sinter quickly. This artificial snow is relatively easy to make and is well suited for determining whether photolysis of nitrate or nitrite is occurring, and whether changes occur at various pH levels.

The amounts of NO and NO₂ produced by nitrate ion photolysis in aqueous solution depends on pH such that NO production is greatly enhanced in basic solutions. Our preliminary results indicate that the pH of the solutions used to make artificial snow does not effect the levels or partitioning of NO_x produced from nitrate-in-ice photolysis. This result suggests that aqueous photochemical analogs of nitrate photolysis may not apply to nitrate-in-ice photochemistry and that more experiments are needed in order to understand nitrate-in-ice photochemistry.

Experiments exploring nitrite-in-ice photolysis demonstrate that there is one to two orders of magnitude more NO_x produced by nitrite photolysis than by nitrate photolysis at equivalent conditions and ion concentrations. This is consistent with the convolution of the wavelength-dependent absorption cross sections of nitrate and nitrite with insolation which indicates that, for equal quantum yields, nitrite is about forty times more likely to photolyze than nitrate. Because nitrite is formed from nitrate photolysis and nitrate may be formed from reactions involving nitrite, nitrate and nitrite levels are not independent in ice (based on analogy with aqueous chemistry). Thus, NO_x emitted from illuminated snow, even snow which initially only contains nitrate, probably results from both nitrate and nitrite photolysis. Photochemically-driven interconversion of nitrate and nitrite in ice, and the ensuing NO_x and HONO production are only beginning to be understood. This poster will describe the SNOW2002 experiments.

Acknowledgements: NSF OPP, Dr. Richard Honrath, Mike Dziobak, DeTour Area Math Students

A72A-0134 1330h POSTER

Interaction of Trace gas Species of Atmospheric Interest With ice: Measurement of the Adsorption Enthalpy of Acetone on ice

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Ice provides an important substrate for heterogeneous chemistry in the stratosphere, the upper troposphere, but also in the cold regions of the planetary boundary layer. Thus, we started to investigate the interaction of trace gases of atmospheric interest (acetone) with ice.

In the upper troposphere, the photolysis of acetone is the main source of HO₂, dominating the one from the reaction of O(1D) + H₂O (Jaegle et al., 2001). Source and sinks of acetone need to be quantified to simulate the concentration of the main atmospheric oxidant (HO₂). Ice cirrus clouds are suggested to be one of the acetone sinks. Thus, the adsorption enthalpy of acetone on ice needs to be investigated because it determines the mixing ratio of acetone between the gas and the particulate phase and the chemistry of the upper troposphere.

In this paper, the chromatographic method applied for the measurement of the adsorption enthalpy of acetone on ice is described. This method uses a chromatographic ice-packed column similar to the one described

by Bartels et al. (2002) and is combined with Proton Transfer Reaction Mass Spectrometry (PTR-MS) for the monitoring of the acetone concentration in the gas phase.

Preliminary results show that the measured standard adsorption enthalpy obtained with a column packed with ice spheres, i.e. (-54±8) kJ mol⁻¹, and with a column packed with a snow sample, i.e. (-56±3) kJ mol⁻¹, are similar and in agreement with the ones derived by Winkler et al. (2002) and from Domine and Hanot (2002), using a low pressure ice coated wall flow tube reactor and a volumetric method, respectively. More investigations are scheduled in the near future using different ice surfaces (ice crystals, fresh snow). We briefly address the atmospheric implication of this study as well as the perspective of the chromatographic & APCI-MS system to investigate other processes of atmospheric interest.

References

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A72A-0135 1330h POSTER

Sources and Mobility of Nitrates in European High Arctic Snow

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Measurements of atmospheric and snow mixing ratios of nitrates and nitrites and their fluxes above the snow surface were made during two intensive campaigns during spring time 2001 in the high Arctic at Ny-Ålesund, Svalbard as part of the EU project "The Nitrogen Cycle and Effects on the oxidation of atmospheric trace species at high latitudes" (NICE).

Of the measured nitrogen species only HNO₃ showed a significant flux above the snow surface, a mean deposition of 8.7 nmol h⁻¹m⁻² was observed in late April / early May 2001. During snowfall periods dry deposition of HNO₃ may contribute up to 10% of the N budget in the snow; however, the main source for N is wet deposition in falling snow.

The surface snow at Ny-Ålesund showed very complex stratigraphy; the NO₃⁻ mixing ratio in snow varied between 65 and 520 ng g⁻¹, the total NO₃⁻ content of the snowpack was on the order of 2700 ng cm⁻². In comparison the atmospheric boundary layer column showed a NO₃⁻ content of only 8 ng cm⁻². The limited exchange, however, between the snow and the atmosphere was attributed to low mobility of NO₃⁻ in the observed snow.

A72A-0136 1330h POSTER

Simulations of Peroxyacetyl Nitrate (PAN) Photochemistry in the Arctic Surface Layer

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Peroxyacetyl nitrate (PAN) is a reservoir compound of NO_x that has the ability to transport NO_x to remote environments, allowing for NO_x photochemistry and/or deposition of nitrogen to these clean locations. Measurements of PAN have been made at Alert, Nunavut and Summit, Greenland aimed at understanding the nitrogen budget at each site. These measurements show concentrations of PAN that are only slowly varying, even during ozone depletion events at sunrise. However, calculations of [PAN], using its primary sources and sinks, indicate a dramatic production rate for PAN when the surface is sunlit. This is inconsistent with the measurement data, illustrating that we are missing an important sink for atmospheric PAN above snow-covered surfaces.

We performed a zero-dimensional model of PAN photochemistry at Alert, Nunavut and Summit, Greenland, which simulated the known gas-phase chemistry of each region, to discern the predicted PAN behavior in each environment. We then adjusted the model sinks to simulate the ambient PAN data, in order to determine the magnitude of the missing PAN sink.

Ambient data from Alert, Nunavut (1998 and 2000), and Summit, Greenland (1999) will be presented, as well as the original model simulations based upon the known gas-phase chemistry of each environment. In addition, we will discuss the magnitude of the missing sink, and the potential for PAN interaction with the snowpack.

A72A-0137 1330h POSTER

A history of C₂-C₄ NMHC and related compounds in the atmosphere from firn air cores in the Northern and Southern Hemispheres

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Firn air samples were collected at sites in both the northern and southern polar regions for the analysis of a wide range of trace gases. Here we report on concentrations levels and recent trends in light non-methane hydrocarbons (C₂-C₄) and selected organic nitrate and halocarbon gases in these core samples. Sites in the Northern Hemisphere included Devon Island (Canada) and North Greenland (NGRIP). Southern Hemisphere sites included South Pole, Dome C, and Dronning Maud Land. Sites in the different hemispheres suggest increases in atmospheric NMHC up to the mid 1970's or early 1980's, followed by a slow decline. The limited distributions tended to follow the trends observed in parent hydrocarbons, with the exception of anomalous increases of methyl and ethyl nitrate with increasing depth in the northern hemisphere cores. The source of the anomalous alkyl nitrate increases (and some related halocarbon increases) has not been determined. Trends in NMHC will also be compared to trends in selected halocarbons (solvents, HCFCs, etc.) to evaluate similarities and differences in sources and emissions over the time periods of the twentieth century represented by the different firn air cores.

A72A-0138 1330h POSTER

Surface Area and Microphysics of the Arctic and Alpine Snowpacks, and Their Role in Air-Snow Interactions

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It is now clear that the snowpack and the lower troposphere can exchange large amounts of reactive trace gases that considerably modify both snow and air compositions. Quantifying these exchanges in coupled air-snow models is at present uncertain because all the physical and chemical processes involved have not been identified or quantified.

The snowpack can be viewed as a multiphase reactor through which air circulates, leading to the adsorption/desorption of gases, heterogeneous photochemical reactions, and to solid state processes such as diffusion into ice crystals. To contribute to the quantification of these processes, we have studied the stratification of the snowpack in the Canadian Arctic, in Svalbard, and in the Alps. We have also measured physical parameters of each observed snow layers, such as density and specific surface area.

Our results indicate that the total surface area of the snowpack ranges from 1000 m² of snow per m² of ground in the Arctic in winter, to 30,000 m²/m² in the Alps in the spring. These large values can lead to significant surface uptake of trace gases, even for species that adsorb weakly to ice surfaces. These surfaces can also lead to elevated rates of heterogeneous reactions.

The snowpack physical and chemical activity, although potentially very high, can be considerably reduced by low snow permeability or by the presence of impermeable ice layers. Thus, we suggest that high snow accumulation rates, as observed in temperate areas such as the Alps and Svalbard, although they lead to high snowpack surface area, may have their activity severely limited by their structure. Cold snowpacks, on the other hand, have a structure that facilitates interactions with the atmosphere.

A72A-0139 1330h POSTER

Eastern-Asian Sources of Dust

Deposited in Northern Greenland at Present

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Recent studies of mineral dust aerosols extracted from snow deposited over the last decade at the North-GRIP, Greenland, ice camp (75.1°N, 042.3°W), have confirmed the eastern Asian source for Greenland dust and extended it to the present day. Previous studies, carried out on ice-core dust, had established this Asian provenance for the last glacial period.

Snow-pit studies have shown that the provenance of the dust appears to vary seasonally, and that the source of the dust during the major spring deposition period is the Takla Makan desert of northwest China. These results were obtained using mineralogical and isotopic (Sr and Nd) composition of the dust, which was compared with the composition of small particles capable of long-range transport in potential source areas (PSA) for Greenland dust.

Here we present an extensive collection of new PSA samples from China and Mongolia which permit pinpointing the other Asian source(s) likely to contribute to the dust deposited in northern Greenland, especially in the low-dust autumn season.

These results will provide new constraints on atmospheric dust-transport models, and will help to better interpret dust compositional variability of ancient ice-core samples.

A72A-0140 1330h POSTER

Preliminary Results on Aerosol Composition at Terra Nova Bay and Dome C (Antarctica) and Evidences of Superficial Snow Post-depositional Effects

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More than 200 aerosol samples were collected on two dimensional classes (micrometric and sub-micrometric fraction) during the last 3 Italian Antarctic Campaigns on coastal (Terra Nova Bay - Ross Sea) and inland (Dome C) Antarctic areas. The sampling was performed by low-volume aspiration pumps using a sandwich of polycarbonate membrane filters having different porosity. Filters were analysed by Ion Chromatography for inorganic anions, cations and methanesulphonic acid (MSA). Contemporaneously with aerosol sampling, recent snowfalls, superficial snow and snow-pit samples were collected. At Dome C, three different snowpits (2.5-7 m deep) were sampled together with very superficial snow crystals in order to correlate aerosol and superficial snow composition and to point out post-depositional processes. The composition of fine and coarse fractions was found to be different in the two stations, the most coastal being characterised by primary aerosol components (mainly sea spray) and Dome C by secondary aerosol inputs, such as non-sea salt sulphate and MSA from biogenic activity. The ionic balance shows a very important contribution of free acidity (H⁺ and carbonate were not directly determined) especially in the fine fractions both in coastal and plateau site. Very high aerosol acidity, mainly at Dome C, prevents the reliable determination of volatile acidic species, such as nitric and hydrochloric acid. These compounds and, to less extent, MSA, show post-depositional effects in the uppermost superficial layers at Dome C, where the low accumulation rate (around 3.0 cm/yr) leads to the re-emission of their acidic forms into the atmosphere. In particular, nitrate is present at very high concentration (ppm) in the superficial snow crystals but its concentration dramatically decreases to very low constant values (few ppb) in the first half-meter of snow deposition. The comparison between aerosol and snow composition and the study of post-depositional processes is necessary for the understanding of the atmosphere-snow interchange processes, helping in the interpretation of paleo-data coming from EPICA-Dome C ice core.

A72A-0141 1330h POSTER

Transformations of Nitrates and Hydrogen Chloride in Low-Temperature Ice Films

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Recent field and laboratory measurements have demonstrated photochemical mediated production and release of NO_x from snow in Earth's polar regions. HCl can also play a role in polar ozone chemistry and is used as a tracer for interpretation of ice core data. Thus, we have initiated laboratory studies on the i.) nonthermal transformation of nitrates on or within ice films and ii.) uptake and autoionization of HCl on low temperature ice surfaces. In particular, we utilize state-of-the-art ultrahigh vacuum surface science techniques that are coupled to sensitive laser ionization detection schemes, time-of-flight mass spectrometry, and infrared reflection techniques. This approach allows control of the ice composition and structure and simultaneous monitoring of the desorbing and trapped products. A discussion of the electronic structure and dissociation dynamics of NaNO₃, pristine ice and HCl containing ice will be discussed. In the latter case, electron-stimulated desorption of cluster ions is shown to be a very useful probe of the uptake and auto-ionization of HCl on low-temperature ice surfaces. Preliminary results on the temperature and wavelength dependent photochemistry of nitrates adsorbed on the surfaces of amorphous and crystalline ice and within dilute frozen nitrate aerosols will also be presented.

A72A-0142 1330h POSTER

Aerosol and chemical loading in the snow cover of northwestern Alaska during the winter of 2001-2002

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We sampled the snow pack during a 1000 km transect from Nome to Barrow in northwestern Alaska. The route crossed the Brooks Range, a mountain belt that stretches west to east across Alaska. Snow samples were taken from 20 sites along the transect. At each site the bottom, middle and top of the snow pack, representing early, middle and late winter snow conditions, were sampled. Ultraclean field and laboratory procedures were used. Specific conductance, pH and major element concentrations were measured from the three snow stratigraphies at all sites. A suite of 30 trace elements was measured from snow samples taken at five of the sites. The results indicate very low trace metal concentrations with Hg, Cd, Pb, and Ni values in the low part per trillion range for all samples. These low concentrations are within the range of those reported from Greenland snow but are an order of magnitude lower than values reported from northeastern Europe and northern Russia. Despite the low trace metal values, concentrations of Arctic haze constituents Cd, Pb and non-sea salt SO₄²⁻ were significantly higher in late winter snow than in snow that fell earlier in the winter. These elevated trace metal concentrations are consistent with increased aerosol loading due to southward expansion of the arctic polar front during the late winter. Surprisingly, trace metal concentrations were as high south of the Brooks Range as they were to the north, suggesting the Brooks Range is not an effective orographic barrier to aerosol transport. Results from this study indicate that the deposition of major and trace elements in snow evolves throughout the arctic Alaskan winter but appears to be spatially homogeneous.

A72A-0143 1330h POSTER

A Statistical Comparison of PSC Model Simulations and POAM Observations

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A better knowledge of PSC composition and formation mechanisms is important to better understand and predict stratospheric ozone depletion. Several past studies have attempted to compare modeling results with satellite observations. These comparisons have concentrated on case studies. In this paper we adopt a statistical approach. POAM PSC observations from several Arctic winters are categorized into Type Ia and Ib PSCs using a technique based on Strawa et al. [2002]. The discrimination technique has been modified to employ the wavelengths dependence of the extinction signal at all wavelengths rather than only at 603 and 1018 nm. Winter-long simulations for the 1999-2000 Arctic winter have been made using the IMPACT model. These simulations have been constrained by aircraft observations made during the SOLVE/THESEO 2000 campaign. A complete set of winter-long simulations was run for several different micro-physical and PSC formation scenarios. The simulations give us ideal knowledge of PSC type (Ia, Ib, or II), composition, especially condensed phase HNO₃ which is important for denitrification, and condensed phase H₂O. Comparisons are made between the simulation and observation of PSC extinction at 1018 nm versus wavelength dependence, winter-long percentages of Ia and Ib occurrence, and temporal and altitude trends of the PSCs. These comparisons allow us to determine how well various modeling scenarios predict POAM observations.

A72A-0144 1330h POSTER

NO₂ vertical profiles retrieved from ground-based measurements during spring time in the Canadian Arctic

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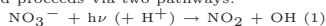
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During the 1990s, Arctic stratospheric temperatures were lower and the breakup of the Arctic vortex occurred later than has been observed in earlier decades. These cold winters have been followed by significant ozone loss. Clear identification of all the processes involved in springtime Arctic ozone depletion is complicated by the strong coupling between transport, formation of solid and liquid aerosols, and halogen activation. One of the key chemical species in the photochemistry of ozone is NO₂. As the role of NO₂ is strongly dependent on altitude, it is desirable to know not only the NO₂ total column, but also its vertical distribution. We have a portable UV-visible grating spectrometer that was deployed at Eureka, Canada (80.1N, 86.4W) in spring 1999, 2000, and 2001. Eureka is part of the Arctic primary station of the Network for the Detection of Stratospheric Change. Among other species, the spectrometer measures stratospheric NO₂ through observation of sunlight scattered from the zenith sky during twilight. Due to the scattering geometry, the NO₂ slant column increases with solar zenith angle (SZA), making it possible to retrieve information about the vertical distribution of NO₂ from the observed slant column variation with SZA. In this paper, we use the optimal estimation technique with a formal characterization of the errors to retrieve NO₂ altitude profiles from slant column observations made at Eureka during March and April. Such measurements can be used in the validation of NO₂ profile measurements made by satellite instruments.

A72A-0145 1330h POSTER**Quantum Yield of Hydroxyl Radical from Photolysis of Nitrate on Ice**Liang Chu¹ (1-530-754-6272; lchu@ucdavis.edu)Cort Anastasio¹ (1-530-754-6095; canastasio@ucdavis.edu)¹University of California, Davis, One Shields Avenue, Davis, CA 95616, United States

The photodecomposition of nitrate generates hydroxyl radical (OH) and NO_x, thereby altering the chemical composition of the snowpack as well as the overlying atmospheric boundary layer. Nitrate photolysis in aqueous solutions has been extensively studied and proceeds via two pathways:



The photochemical behavior of nitrate in ice and snow remains an open issue. Dubowski et al. determined the quantum yield of reaction (1) on ice by measuring the release of NO₂, but suggested that their values may be lower bounds because of incomplete recoveries.

In this study we measured the quantum yield for reaction (1) by following the formation of OH in frozen aqueous nitrate solutions illuminated at 313 nm. Initial experiments showed that the quantum yield for OH (Φ_{OH}) at 263 K was independent of nitrate concentration for all values examined (40 - 3000 μM). However, Φ_{OH} was dependent upon pH, increasing from 0.0022 at pH 2.0 to 0.0034 at pH 7.0, where the listed pH values are those of the bulk solution prior to freezing. The temperature dependence of Φ_{OH} was studied for both ice pellets and aqueous solutions in the temperature range of 239 - 318 K. Φ_{OH} increased monotonically with temperature and the slopes and y-intercepts of $\ln(\Phi_{\text{OH}})$ vs. $1/T$ for the ice pellets and aqueous solutions were very similar. The similarity of these regressions suggests that the photolysis of nitrate in the ice occurs in a "quasi-liquid" layer. Our quantum yields at pH 5.0 for OH were 0.0034 at 263 K and 0.0021 at 243 K; these values are 3 and 8 times higher, respectively, than the Φ_{NO_2} values reported by Dubowski et al. Furthermore, our ice results are approximately 30-40% lower than quantum yields estimated by extrapolation of the room temperature data of Zellner et al. The implications of our results for snowpack and boundary layer chemistry will be discussed.

A72A-0146 1330h POSTER**Measurements of preindustrial methyl chloride from an Antarctic ice core: Natural variability and its implications**Murat Aydin¹ (949-824-5540; maydin@uci.edu)Warren J. De Bruyn² (714-628-7353; debryun@chapman.edu)Eric S. Saltzman¹ (949-824-3936; esaltzma@uci.edu)¹University of California, Irvine, Department of Earth System Science, Irvine, CA 92697²Chapman University, Department of Chemistry, Orange, CA 92856

Methyl chloride (CH₃Cl) mixing ratios were measured in preindustrial air extracted from a shallow ice core from Siple Dome, West Antarctica. Ice core samples were shredded under vacuum and the extracted air was analyzed by gas chromatography with mass spectrometric detection. The samples range in depth from 57 m to 83 m and the gas ages assigned to them span the calendar years 1690 to 1915 AD. The mean CH₃Cl mixing ratio in 22 samples is 499±28 pptv. The data exhibit two full cycles of a 100-year oscillation with an amplitude of approximately 60 pptv, suggesting that there is periodic natural variability in atmospheric CH₃Cl. The origin of this variability is unknown. Assuming that this oscillation in atmospheric CH₃Cl persisted during the last century, the ice core results suggest that the present day natural levels would be 470-480 pptv. Compared with the modern mean value of 530 pptv over Antarctica, these results suggest that the current anthropogenic impact on the atmospheric burden is roughly 10%. Such an extrapolation of the ice core data also implies that there may be a 10% increase in the atmospheric CH₃Cl levels over the next 50 years due to this natural variability.

A72A-0147 1330h POSTER**An Alternate Approach to MATCH for Diagnosing Ozone Loss for the SOLVE Mission**Gary A. Morris¹ (713-348-5727; gmorris@rice.edu)Mark R. Schoeberl² (301-614-6002; schom@zephyr.gsfc.nasa.gov)Bojan R. Bojkov³ (301-614-6846; bojkov@ventus.gsfc.nasa.gov)¹Rice University, Dept. of Physics Astronomy MS-61 P.O. Box 1892, Houston, TX 77251-1892, United States²NASA Goddard Space Flight Center, Mail Code 900 Laboratory for Atmospheres, Greenbelt, MD 20771, United States³NASA Goddard Space Flight Center, Mail Code 916 Atmospheric Chemistry and Dynamics Branch, Greenbelt, MD 20771, United States

The ozonesonde launches for SOLVE were coordinated as part of the MATCH campaign. Using forecast winds and a trajectory code, the MATCH team initialized trajectories at the locations of the ozonesonde launch and predicted air parcel locations over succeeding days. Those predictions were used to trigger subsequent sonde launches so that air parcels are sampled repeatedly. We apply the GSFC trajectory model in a diabatic transport mode driven by winds from the U.K. Meteorological Office to simulate MATCH technique and to derive ozone loss rates in the lower stratosphere during the SOLVE mission, January - March 2000. However, we use a new approach for estimating the uncertainty associated with the ozone loss calculations. By matching the entire profile in 20K potential temperature layers and deriving estimates of the probability of a match from the number of matches and the duration over which advected parcels satisfy match coincidence criteria, we develop a more comprehensive estimate of the errors associated with the ozone loss rates. We compare our results for SOLVE with those produced by the "continuous injection method" of Schoeberl et al. [2002] and with those found by Rex et al. [2002].

A72A-0148 1330h POSTER**Importance of accumulation timing in preservation of HNO₃ at Summit, Greenland**John F. Burkhart¹ (5206260053; johnny@hwr.arizona.edu)Joseph R McConnell² (jmconn@dri.edu)Roger C Bales¹ (roger@hwr.arizona.edu)Manuel Hutterli¹ (manuel@hwr.arizona.edu)¹Department of Hydrology and Water Resources, University of Arizona P.O. 210011, Tucson, AZ 85721-0011, United States²Water Resources Center, Desert Research Institute, 2215 Raggio Parkway, Reno, NV 89512, United States

Concentrations of chemical species preserved in the ice core record can provide a proxy record of paleoatmospheric concentrations and oxidation capacity. Through transfer function modeling these proxy records may be used to validate climate change models, atmospheric photochemical models, and separate

anthropogenic climate forcing from natural variability. Understanding the nonlinear relationship between concentrations in the atmosphere, snow, firn and ice is critical if the ice core proxy record is to be useful for validating atmospheric photochemical models or further developing the records into indices for climate dynamics.

Toward understanding the transfer function model for HNO₃, snow pits were excavated during the spring of 1998 following a wintertime measurement period at Summit, Greenland. Firn profiles of HNO₃ from 10 snow pits collected demonstrate the importance of accumulation timing on the preservation of HNO₃. Using a time series of HNO₃ surface snow concentration and accumulation collected during the 1997-1998 wintertime the firn profiles are re-created and compared with sampled measurements. Results indicate that prior to the summer season, accumulation timing is an important parameter in the preservation of the species. HNO₃ concentrations in the snow pits have a maximum of 12 μM and a mean of 2.6 (SD: 0.05) μM . Concentrations in the surface snow ranged from 1 to 19 μM with a mean of 2.7 (SD: 0.3) μM . The spatial variability of preserved HNO₃ as it is related to accumulation is also demonstrated. Additionally, physically-based transfer function modeling is being conducted to further understand post-depositional processes.

A72A-0149 1330h POSTER**A Study of Aerosol Properties in Dronning Maud Land, Antarctica, during Austral Summers**Claudia Piel¹ (49-471-4831-1496;cpiel@awi-bremerhaven.de); Rolf Weller¹;Andreas Herber¹; Otto Schrems¹; MichaelHuke²; Dietmar Wagenbach²¹Alfred-Wegener-Institut, Am Handelshafen 12, Bremerhaven 27570, Germany²Institut fuer Umweltphysik, University of Heidelberg, Im Neuenheimer Feld 229, Heidelberg 69120, Germany

Within the EPICA project (European Project for Ice Coring in Antarctica) an aerosol sampling program was started in the austral summer season 1999/2000 at the new deep drilling location in Dronning Maud Land (75°S, 0°E, 2892 m asl), Amundsenisen. Investigations of the chemical composition and microphysical parameters of aerosols in both polar regions are of great interest in order to gain a better insight into the related natural biogeochemical cycles. Moreover, an improved knowledge on aerosol properties and chemical composition in this region is needed for the interpretation of trace component profiles retrieved from polar ice cores. However, comprehensive aerosol measurements in central Antarctica are sparse so far and available only for the austral summer months. Up to now, we have conducted 3 years of summer aerosol measurements covering the time period from early January to early/mid of February of each year, including investigations of fresh and daily surface snow. For the daily aerosol sampling a teflon/nylon filter combination was used to collect the particulate and the gaseous phase separately. For that purpose denuder samplings were performed in two of the three campaigns as well. Major ionic components (MSA, sulfate, chloride, nitrate and sodium) of aerosol and snow were analysed by means of ion chromatography. Although this contribution focuses on the major ionic composition of Antarctic summer aerosol and its relationship to fresh and deposited surface snow sun photometer measurements were performed in addition in the last campaign to get information on the aerosol optical depth. Simultaneous measurements at Neumayer Base (71°S, 8°E, 42 m asl) provided information on the lower tropospheric aerosol loading.

A72A-0150 1330h POSTER**Sea salt and mineral dust derived ions in Greenland ice cores as signals of aerosol transport**Marie-Louise Siggaard-Andersen¹

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Concentrations for sea salt and dust derived ions measured on Greenland ice cores reflect conditions for wind driven long-range transport of aerosol a the time of deposition onto the ice sheet.

A continuous record of ion-concentrations covering the climate history over the last glacial has been measured on the North GRIP ice core. From this record trends in ion composition have been derived and are compared to the ion composition measured on the GISP2 ice core in order to quantify changes in source strength and transport efficiency.

A72A-0151 1330h POSTER

A three-dimensional modelling study of the seasonal cycle of sulfur species in the Antarctic atmosphere

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The high-southern latitudes are one of the last regions of the globe where the sulfur cycle remains dominated by its natural component. Moreover, a good understanding of the processes involved in dimethylsulfide (DMS) oxidation is needed to interpret polar ice core records of sulfate and methanesulfonic acid (MSA). Both reasons motivated this modelling study of the sulfur cycle in Antarctica. For this purpose, the Antarctic version (with high resolution and improved physics in the high-southern latitudes) and the sulfur version of the Laboratoire de Météorologie Dynamique Atmospheric General Circulation Model (AGCM), LMD-ZT, have been merged and used to study the seasonal cycle of sulfur species. In a first step, the model results are compared with available measurements of sulfur compounds at high- and mid- southern latitudes. They are realistic but some defects are identified (Cosme et al., Sulfur cycle in the high southern latitudes in the LMD-ZT General Circulation Model, JGR, in press). In a second step, the seasonal cycle of sulfur compounds at an inland site (Dome Concordia) is presented and compared to the analogous results at the coastal site Dumont d'Urville. This comparison suggests that the relative roles of each process of the sulfur cycle (emissions, chemistry, transport) strongly differ from the coastal site to the inland site. At last, an adjoint of the model has been run to provide an inverse history of DMS, sulfate and MSA observed at two Antarctic sites: Dumont d'Urville (coastal Antarctica) and Vostok (inland Antarctica). For both sites, the origins of the sulfur species (type of sources, age, and latitudinal origin) are presented and discussed.

A72A-0152 1330h POSTER

Congener Profiles of Polychlorinated Biphenyls in Firn and ice From Lomonosovfonna, Svalbard.

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In April 2000, a 60-meter ice core was drilled on Lomonosovfonna, the highest elevation ice field on Svalbard. The upper 38 meters, dating to about 1920, were analyzed for 108 polychlorinated biphenyl congeners (PCB). The objective was to identify the historic variability of congener patterns and concentration of PCB at Lomonosovfonna. PCB are known to bioaccumulate to significant concentrations in Svalbard wildlife to the extent that health of some organisms may be threatened. Knowing the input history is vital to understanding how present conditions compare to the past.

Total PCB concentration in surface snow (0 to 0.5 meter) at Lomonosovfonna in 2000 was 464 pg/L, 60% of the highest concentration (777 pg/L) occurring in about the 1960s, the peak production period for PCB. The surface value was about two times greater than in the layer below (0.5 to 1 meter; 229 pg/L). The surface layer also had a greater amount of more volatile, lower molecular mass (MM) PCB congeners than found in the firn below it.

Most PCB found in sub-surface (> 1 meter) Lomonosovfonna ice are from tetra-CB and penta-CB homologues (about 30% of total PCB each) with about 15% of total PCB from hexa-CB. Surface samples (<1 meter) contain more hexa-CB. PCB distribution throughout the profile is dominated by 29 congeners that comprise from 53% to 75% of total PCB, with less in the top meter than in the deeper core. Among the 29 dominant congeners are 7 (and 4 co-eluting) that make up about 25% of total PCB in the top meter and 33 to 40% in deeper layers of the core. These are PCB 49 (and 2 co-eluting PCB 43 + 37), 52, 95, 110, 118, 153 (and 2 co-eluting PCB, 132 + 105). Some of these congeners are among the most persistent PCB and are often found in other environmental matrices.

Our results show that PCB concentrations at Lomonosovfonna are declining from peak periods and that the congener distribution may be shifting away from the 29 dominant congeners to include more high MM PCB, particularly hexa-CB. Tetra and Penta-CB remain the dominant homologues, a pattern not characteristic of PCB in production or of gas-phase air samples. The net deposition of PCB to Lomonosovfonna has apparently favored less volatile, higher MM compounds distributed by the atmosphere to Svalbard.

A72A-0153 1330h POSTER

Altitude Distributions in the Arctic Vortex Derived From Multiple Tracer Relationships

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Canonical trace gas relationships that are established in the middle latitude lower stratosphere are the result of altitude-dependent photochemical decomposition of trace gases and horizontal transport and mixing of the air masses. It has been shown that these relationships change significantly in the Arctic vortex, and, based on the estimates of mixing across the edge of the vortex, these changes result mostly from the differential descent (analogous to the original altitude distribution) of air inside the vortex. The importance of studying the altitude distribution of air comes from the fact that air descending from very high altitudes is completely deprived of photolytic tracers and therefore should cause rapid and dramatic changes to tracer-tracer correlations in the lower stratosphere. The amount of descended air and its ozone content, in turn, influences the estimated flux of ozone-rich air across the edge of the vortex, which affects the calculations of ozone loss in the vortex. An earlier analysis using a simple integral model of the evolution of the midlatitude canonical tracer relationships to the vortex ones indicated that at 20 km in the vortex, about 70% of the air in an air parcel originated at higher altitudes, 10% at lower altitudes and only 20% at similar 20 km altitude. Previous analyses, however, bore an artifact caused by the contribution of photolysis to the different midlatitude tracer-tracer correlations. This study utilizes multiple tracer correlations and a reverse approach to quantify altitude distributions of air in the Arctic vortex air parcels.

A72A-0154 1330h POSTER

Climatic and environmental records from Altai glaciers, Siberia, recovered from ice-cores and snow samples

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A depth/accumulation scale for the Altai glaciers, Siberia, established based on $\delta^{18}O$ and δD firn-ice cores analysis. In sequences of annual layers in the firn-ice cores recovered in 2001 and 2002, the mean annual snow accumulation was found to be 800 mm at 4115 m of the Belukha Snow-Firn Plateau. The transfer function was developed using the seasonality of accumulation layer profile with normalization of data from the nearby meteorological station. The $\delta^{18}O$ and δD firn-ice core records compared with meteorological data and indices of atmospheric circulation patterns using regression analyses revealed a dominant source of moisture from Atlantic Ocean during summer and Pacific Ocean moisture during autumn. At the equal air temperatures the most remote source of moisture from Atlantic Ocean resulted in more negative values of $\delta^{18}O$ composition under the negative values of North Atlantic Oscillation. Changes in the prevailing atmospheric circulation patterns (e.g., NAO, WPO) over the Altai Mountains are also reflected in the major ions content in snow, firn and ice samples. The anthropogenic emission inventory for Altai glaciers developed using ice-cores and snow pits sulfate and nitrate records.

A72A-0155 1330h POSTER

Effects of Ozone and Cloud Cover on Surface Ultraviolet Radiation at High Southern Latitudes

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For over twenty years, the high latitude ozone depletion during austral springs and the increased surface ultraviolet (UV) radiation have caused concern due to the potential for negative biological and ecological effects. Since little long-term information on surface UV is available, the capability of assessing these effects has been limited. For a better understanding of the UV environment during springtime in the polar region, the National Science Foundation (NSF) Ultraviolet (UV) Monitoring Network was established in 1987 by the NSF Office of Polar Programs. Four out of the six sites, Ushuaia, Argentina (54°49'S, 68°19'W), Palmer Station, Antarctica (64°46'S, 64°03'W), McMurdo Station, Antarctica (77°51'S, 166°40'E), and South Pole Station, Antarctica (90°S), were at high southern latitudes. With the data at these four sites for over a decade (1990-2001), we were able to study the behavior of surface UV radiation in the south polar region, including the attenuation provided by total column ozone and cloud cover. To specify the effect of ozone on surface UV radiation, we used effective clear sky irradiances that were estimated from the actual measurements in a reference wavelength band from 342.5 to 347.5 nm throughout all years covered by the data. The effects of cloud cover can be obtained by taking ratios of measured UV irradiances to the corresponding effective clear sky values. We anticipate an upward trend in the surface UV irradiance in response to changes in total column ozone alone over the decadal time scale, and occasional abnormally large and small values due to the combined effects of variability in ozone and cloud cover. The latter case can be demonstrated by the fact that the monthly-integrated irradiance of UVB2 measured for October 1991 is actually 99.2% larger than the smallest value that was observed in October 1990.

A72A-0156 1330h POSTER

Analysis of NO/NO₂ Exchange and the Evolution of ClO/ClONO₂/NO₂ During SOLVEFrank N Keutsch¹ (1-617-495-5922; frank@huarp.harvard.edu)Katherine K Perkins²Eric J Lanzendorf³James G Anderson¹¹Harvard University, 12 Oxford Street, Cambridge, MA 02138, United States²NOAA Aeronomy Lab, 325 Broadway, Boulder, CO 80305, United States³Intel, 3065 Bowers Avenue, Sant Clara, CA 95052, United States

In situ measurements of NO_x, Cl_x and ClONO₂ in the polar vortex during SOLVE are used to study the ClO/ClONO₂/NO₂ subset and NO/NO₂ exchange over a very large dynamic range of ClO (75-1400 ppt). This extremely large dynamic range of measurements over a three month period together with a reanalysis of NO₂ mixing ratios following post-flight lab calibration measurements allowed us to study the above systems quantitatively. Observations of extremely low levels of NO_x within the vortex during the Arctic winter are reported and the observations are used to test models designed to calculate chlorine recovery. The measured NO₂ values agree well with those calculated from NO using a steady-state approximation. Analysis of ClONO₂ calculated from NO₂ using a steady-state approximation indicate that $J(\text{ClONO}_2)/k\text{ClO} + \text{NO}_2$ is ca. 25% too small. Gradual reemergence of NO₂ and ClONO₂ in chemically processed air during the second phase of SOLVE is consistent with photochemical production of NO₂ from reaction of OH with HNO₃ and photolysis of HNO₃. Measurements of NO₂, ClO, and ClONO₂ are used to examine transport related increase of NO₂ levels at the edge of the vortex.

A72A-0157 1330h POSTER

Temperature and Precipitation Trends and Variability in Alaska Since 1950

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The northern hemisphere has experienced a general warming trend in recent decades that is most pronounced at high latitudes. For Alaska, the mean annual temperature has increased approximately 1.4°C for the most recent climate normal (1971-2000). However, it is important to note that the increase is non-linear and exhibits seasonal and spatial variability. In this investigation, climate records for first-order observing stations in Alaska were examined for the period 1950 to 2001. Spatial coverage is such that the three climate regimes in the state (arctic, continental, and maritime) are represented. Seasonal temperature trends show that the greatest warming has occurred in winter. Furthermore, the trend is greater for minimum temperatures than maximum. Although most locations show an increase in snowfall, there is also a coincident decrease in total annual precipitation, the former largely due to an increase in autumn snowfall total.

A72B MCC: Hall D Sunday 1330h

Regional Climate Modeling II Posters
(joint with NG, B, H, OS, GC)

Presiding: A Robock, Rutgers

University; G Stenchikov, Rutgers University

A72B-0158 1330h POSTER

Regional Changes in Extreme Climatic Events

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This study focuses on California as a climatically complex region that is vulnerable to changes in water supply and delivery. A regional climate model is employed to assess changes in the frequency and intensity of extreme temperatures and precipitation. Significant increases in daily minimum and maximum temperatures occur with a doubling of atmospheric carbon dioxide concentration. Increases in daily temperatures lead to increases in prolonged heat waves and length of the growing season. Changes in total and extreme precipitation vary by geographic region.

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Verification and Skills of a Multi Model Ensemble Forecasting System Using a Kernel based Numerical Weather Prediction Model

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The quality of deterministic weather forecasts varies significantly from day to day. The most significant errors on a daily basis are often a factor 2 or 3 stronger than the monthly averaged error. In regional climate simulations it also has been shown that differences between the control and sensitivity simulation is not only due to the initial conditions, but also due to the approximations in the model's configuration. This points to the use of an ensemble of forecasts each generated with different model configurations. In this paper we want to demonstrate, verify and quantify the skill of such an approach to get a more constant and better forecast quality for realtime and climatic applications. In our system 50 ensemble members start from the same large scale weather pattern taken from an analysis of a global model. Each member differs from the other in the choice of the numerical solution of the fast atmospheric processes.

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A Multianalysis Ensemble Modeling of Uncertainties In A Regional Climate System Model

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A multianalysis ensemble of monthly integrations was conducted to examine the response of the internal variability of a regional climate system model to initial and lateral boundary conditions. This study demonstrates that internal variability of the regional model is sensitive to the uncertainties associated with the global analyses and interpolation procedures used. The former is a dominant source to contributions to the model's internal variability, but the latter is not negligible. Simulated surface energy fluxes and precipitation display significant variability in response to the differences between forcing datasets.

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Analysis of a long term Regional Model Simulation

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The use of regional climate models in studying atmospheric dynamics is on the increase in southern Africa, where the MM5 regional model has been used for a range of experiments. Such work has led to the

start of a 15-year climatology simulation for the model so that more accurate evaluation of the model can be made. This paper will look at some of the results obtained from this experiment.

The increasing use of model output necessitates a deeper analysis of the data than is conventionally undertaken. Therefore in addition to comparing time averaged climatic fields from the model to observed station data, the output has been compared to other statistics such as total number of rain days, and indices of wet and dry spell duration. Initial analysis of one year of the long term simulation has shown that the model produces a large positive rainfall anomaly along the eastern escarpment of South Africa. Although positive rainfall anomalies are also present in the interior of the region, these are not as high. The comparison of the number of rain days above 20mm with those of observed data show that although the model produces more rain events, the magnitudes of these events are not high enough to change the actual 80th percentile of the model output drastically. This initial finding has been encouraging and the analysis of the complete long term simulation using these different statistics will be useful in assessing the biases of the model as well as the errors that exist in it. Such analysis will also be of great relevance to the end users of model output.

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Testing the Effects of Increased Horizontal Resolution in a Regional Climate Model for a Climatically Vulnerable Region

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The need for high-resolution simulations of modern and future climates has driven the use of regional climate models in recent years. Regional climate models use a much higher horizontal resolution than global climate models, allowing more detailed investigations of climate at scales of importance to a wide range of parties. Here we explore the effects of increased horizontal resolution on the simulation of climate over the Western U. S. We performed three experiments of modern day climate, using the same boundary conditions, at three different horizontal resolutions, 20 km, 30 km, and 40 km. We compared the experiments with observations of climate and with each other in order to evaluate any improvement or lack of improvement in using the higher resolution. Initial comparisons suggest that a 20 km resolution produces more accurate snow and precipitation results, with temperature results being more similar and accurate between the 20 and 30 km cases.

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Toward 10-km mesh global climate simulations

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An atmospheric general circulation model (AGCM) that runs very efficiently on the Earth Simulator (ES) was developed. The ES is a gigantic vector-parallel computer with the peak performance of 40 Tflops. The AGCM, named AFES (AGCM for ES), was based on the version 5.4.02 of an AGCM developed jointly by the Center for Climate System Research, the University of Tokyo and the Japanese National Institute for Environmental Sciences. The AFES was, however, totally rewritten in FORTRAN90 and MPI while the original AGCM was written in FORTRAN77 and not capable of parallel computing. The AFES achieved 26 Tflops (about 65 % of the peak performance of the ES) at resolution of T1279L96 (10-km horizontal resolution and 500-m vertical resolution in middle troposphere to lower stratosphere).

Some results of 10- to 20-day global simulations will be presented. At this moment, only short-term simulations are possible due to data storage limitation. As ten tera flops computing is achieved, peta byte data storage are necessary to conduct climate-type simulations at this super-high resolution global simulations. Some possibilities for future research topics in global super-high resolution climate simulations will be discussed.