at the Naval Oceanographic Office Major Shared Resource Center at Stennis, Mississippi.

A52D-03 1425h

A Scalable Spectral Element Eulerian-Lagrangian Global Atmospheric Model :Dynamical Core Tests

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The Navy is currently testing a new dynamical core for implementation into its existing operational prediction system (called NOGAPS). This new dynamical core is based on the spectral element method which combines the high-order accuracy of the spectral transform method with the geometric flexibility of the finite element method. The spectral element method has been shown to yield more accurate solutions than any up-and -coming numerical method while scaling linearly on distributed-memory computers, and allowing for the use of any type of grid including: icosahedral, hexahedral, and adaptive unstructured grids. The Eulerian semi-implicit version of the model presented in this talk yields exponential convergence (as in typical spectral transform models) while yielding forecasts up to 50% more efficient than the Navy's existing operational model. We present results for test cases with analytical solutions to show the accuracy of the model. In addition, we show performance results for the new model on an IBM SP4.

URL: http://www.nrlmry.navy.mil/~giraldo/publications.html

A52D-04 1440h INVITED

On Arctic Environmental Change - 1979-2001 coupled ice-ocean model results

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The Arctic Ocean has been traditionally a challenging region for modeling due to the presence of the multi-year ice pack, complex bathymetry and the grid singularity at the North Pole. Regional models of the Arctic Ocean have been developed in part to address some of these issues and to give feedback to global ocean and climate models on requirements for realistic modeling of this region. Results from a coupled ice-ocean model of the pan-Arctic region, configured at a 1/12-degree and 45-level grid and integrated for seven decades using realistic atmospheric data are analyzed to understand recent climate variability in the region. The primary simulation consists of a 48-year spinup followed by a 23-year interannual run forced with a combination of daily-averaged reanalyzed and operational ECMWF data for 1979-2001. The interannual integration provides insights into the recent climate regime shifts between the late 1970s and the 2000s. Model results allow a large-scale view of the sea ice and ocean circulation and changes. At the same time, high resolution provides means to investigate physical processes controlling large-scale ocean and sea ice conditions and their variability. Our earlier findings point to the atmosphere as a dominant driver of the sea ice and ocean circulation, which is confirmed in this current work. The model suggests a relatively efficient horizontal momentum transfer in the vertical direction from the atmosphere through the sea ice into the ocean. The boundary flow along the perimeter of deep basins appears to be one of the critical oceanic processes both responding to and distributing change throughout the region. Analysis of model results for the 2000s helps with understanding most recent changes observed in the Arctic Ocean. Extrapolation of recent trends provides means for limited prediction of future environmental conditions in the region.

A52D-05 1510h

Coupled Sea Ice Modeling within Global Atmosphere-Ocean Models

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Coupling sea ice models within global atmosphere-ocean models adds several computational and scientific hurdles to the grand challenge of global climate and weather simulation. Producing a truly realistic simulation of polar climate, sea ice cover, thickness and ice drift is still elusive in global models. Problems inherent in the atmosphere, ice, and ocean models all contribute to problems in the sea ice simulations. Numerical stability of ice, atmosphere and ocean models near the poles create limitations in the usable model timestep and grid resolution, so alternate global grids have been implemented in many models. The evolution of coupled ice models from simple slabs to the present dynamic-thermodynamic models with elastic-visco-plastic rheologies, and the future of high-resolution modeling of discrete ice floe interactions will be presented.

A52D-06 1525h

Modeling Study of Arctic Storm with the Coupled MM5-Sea Ice-Ocean Model

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Recent studies demonstrated that the Arctic environment has been undergoing noticeable changes, which are manifested, for example, by the shrinking of sea-ice and the increasing of storminess. This provides a new challenge for weather forecast and synoptic studies in the Arctic region. The reduced and highly variable sea-ice cover naturally changes surface thermal condition and may result in feedbacks between atmosphere and underlying surface. In order to detect such processes and improve weather forecast, we developed a coupled meso-scale modeling system, named as the Arctic MM5, based on the PSU/NCAR MM5 model. In this modeling system, a thermodynamic sea ice model and an ocean mixed layer model were coupled with the MM5 to consider the interactions between the sea ice, ocean and atmosphere. Observations over the Arctic are very limited. However, the SHEBA deployment was carried out from October 1997 to October 1998, which provides valuable measurements. During SHEBA, a well-developed storm process in the middle May 1998 was captured. This storm moved slowly northward from the Bering Sea and the Gulf of Alaska to the Beaufort Sea, bringing about an outstanding warm air advection over the sea ice and leads. We employed our modeling system to carry out a modeling study of this storm process, verified the modeling results with the SHEBA measurements and investigated storm development and associated atmosphere-sea ice interactions.

A52E MCC: 3016 Friday 1340h

Contributions to Middle Atmosphere Science by Solar Occultation Instrumentation IV *(joint with SA)*

Presiding: **L W Thomason,** NASA Langley Research Center**; P L DeCola,** NASA Headquarters**; R Bevilacqua,** Naval Research Laboratory

A52E-01 1340h

On the Influence of the Tibetan High on the Distribution of Column Ozone and Polar Stratospheric Clouds in the Southern Hemisphere

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We describe a new hypothesis regarding a teleconnection between the boreal summer and austral winter: the distribution of ozone in the southern hemisphere is controlled primarily by outflow from the top of the northern Asian monsoon (Tibetan High). The anthropogenic ozone hole which appears each September and October over Antarctica is surrounded by a croissant-shaped ozone maximum in the 40-60S latitude band, characterized by a broad maximum of larger column ozone amounts centered south of Australia (in the Australian High) and lower amounts over the South Atlantic. The shape of the ozone croissant relates directly to the longitudinal distribution of polar stratospheric clouds (PSCs) at high latitudes. The existence of this structure and its particular longitudinal distribution is hitherto unexplained. Observational analyses and numerical simulations will be shown which illuminate the process by which the ozone croissant is established. Solar occultation data from HALOE, SAGE, and POAM are used to characterize the distribution of ozone and PSCs. A major current of air flows out of the Tibetan High across the Indian Ocean, where it runs into the southern hemisphere winter westerly flow. Outflow surges occur in pulses lasting several days, with southward flow generating an anticyclone over the Indian Ocean - Australia sector. The pulsed flow excites a train of Rossby waves which propagate eastward. Descent of ozone-rich air occurs preferentially just to the east of the synoptic anticyclones. Extensive mixing occurs within the train of breaking Rossby waves. The coincident climatological ozone maximum and Australian High are viewed as a 3D mixing lens of higher ozone from above and higher potential vorticity from the tropics. This mechanism brings chemicals from the upper troposphere over Asia into juxtaposition with stratospheric air in the southern middle latitudes and is thus important for a variety of global climate change problems. It contributes to our understanding of interhemispheric transport of important trace gases, how the ozone croissant is formed and maintained, what controls the shape and intensity of the ozone hole, and provides a broader understanding of a new teleconnection in the atmospheric general circulation.

A52E-02 1355h

Reconstruction and Simulation of Stratospheric Ozone Distributions During the 2002 Austral Winter

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Satellite-based solar occultation measurements during the 2002 Austral winter have been used to reconstruct global, three dimensional ozone distributions. The reconstruction method uses correlations between potential vorticity and ozone to derive "proxy" distributions from the geographically limited occultation observations. Ozone profiles from the Halogen Occultation Experiment (HALOE), the Polar Ozone and Aerosol Measurement (POAM) III, and the Stratospheric Aerosol and Gas Experiment (SAGE) II & III are incorporated into the analysis. The reconstruction method is described, and the evolution of the solar occultation data and proxy ozone fields throughout the winter is discussed. The results support the idea that dynamical forcing early in the 2002 winter influenced the morphology of the stratosphere in a significant and unusual manner. The proxy is compared with ozone from mechanistic, primitive equation model simulations of passive ozone tracer fields during the time of the warming. In regions where chemistry is negligible compared to transport, the model and proxy ozone fields agree well. The agreement between, and changes in, the large scale ozone fields in model and proxy indicate that transport processes, particularly enhanced poleward transport and mixing, are the primary cause of ozone changes through most of the stratosphere during this unprecedented event. The analysis culminates with the calculation of globally distributed column ozone during the major warming, showing quantitatively how transport of low-latitude air to the polar region in the middle stratosphere led to the diminished ozone hole in 2002.

A52E-03 1410h

Comparison of Satellite Occultation Ozone Measurements With High Resolution In-Situ Aircraft Observations Using Trajectory Mapping

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Satellite occultation measurements of ozone by SAGE II, SAGE III, HALOE, and POAM III are compared to high resolution in-situ sampling performed on board the DC-8 during the SOLVE II mission. Satellite occultation data are known to have high vertical resolution, however, horizontal averaging across the limb of the atmosphere typically spans a distance of over 200 km. The FASTOZ sensor on board the DC-8 measures ozone every second. At typical flight speeds of 450 knots this sampling rate translates into an ozone measurement approximately every 230 meters. In this study, trajectory simulations are used to facilitate the comparison of ozone measured by the satellites with that observed by FASTOZ. Owing to the limited spatial coverage of both the satellite and in-situ data, trajectories are initialized along an annulus surrounding each of the 13 SOLVE II flight paths. Coincidences between satellite measurements and both forward and backward trajectories then make it possible to compare trajectory mapped satellite data to most of the high resolution in-situ data. Differences are interpreted in the context of vastly different sampling methods and data resolution as well as natural atmospheric variability.

A52E-04 1425h

Antarctic Ozone Loss Rates from POAM Measurements Using the Match Technique

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We have used the trajectory match technique, which identifies pairs of ozone measurements which sample the same air mass, to calculate ozone loss rates from POAM measurements. If the trajectory matches are representative of the entire vortex, in terms of the chemical constituents and solar exposure, then these measured loss rates can be extrapolated to the entire vortex. This technique seems to work well in the Arctic, where the distribution of daylight solar zenith angles (SZA) sampled by the match trajectories is very similar to the vortex average. In the Antarctic, however, we find that the distribution of daylight SZA of the POAM match trajectories is skewed toward high values relative to the vortex average. Using a photochemical box model we investigate the effect of different distributions of SZA on the calculated loss rates and compare the results to POAM measurements.

A52E-05 1440h

Tropospheric Ozone at High Latitudes from POAM and TOMS Measurements

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We derive the tropospheric ozone column at high latitudes based on the stratospheric ozone column from the Polar Ozone and Aerosol Measurement (POAM) III instrument and the total ozone column from Earth Probe Total Ozone Mapping Spectrometer (TOMS). The POAM ozone column in the lower stratosphere compares very well with the ozonesonde lower stratospheric column at POAM latitudes and is well suited for this study. The POAM/TOMS Tropospheric Ozone Residual (TOR) is compared to the tropospheric ozone column (TOC) from ozonesonde stations and from the GEOS-CHEM 3D photochemical transport model. Good quantitative agreement was found between the TOR and the ozonesonde TOC. In addition, comparisons indicate good qualitative agreement in longitudinal variability between the POAM/TOMS TOR and the model TOC. This is the first time the TOR method has been used to examine longitudinal variability in tropospheric ozone at high latitudes. The POAM/TOMS TOR reproduces well the monthly variability in ozone over Europe from March through September, with a maximum during summer due to increased photochemistry.

A52E-06 1455h

Impact of Increased Stratospheric Water Vapor on Denitrification in the Polar Ozone Layer

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Vertical profiles of nitric acid concentrations measured by the Improved Limb Atmospheric Spectrometer (ILAS) on board the ADEOS satellite were analyzed to derive the critical temperatures leading to denitrification in the Arctic and Antarctic lower stratospheres in February and June 1997, respectively. Although the critical temperature for denitrification was a few degrees higher in the Arctic than in the Antarctic, due to greater humidity in the Arctic stratosphere prior to denitrification, the critical temperatures over both poles were unified as a function of T_{NAT} (nitric acid trihydrate saturation temperature). This approach was supported by preliminary analyses for ILAS-II measurements made over the Antarctic in the 2003 winter. On the basis of these results, it was predicted that an increase in the stratospheric water vapor concentration by 1 (3) ppmv will lift the critical temperature by about 1 (2) K, promoting the acceleration of denitrification of the stratosphere with future cooling caused by the accumulation of greenhouse gases.

A52E-07 1510h

Behavior of Stratospheric Chlorine Nitrate During a Recovery Phase of Polar Ozone Destruction in both Hemispheres

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Improved Limb Atmospheric Spectrometer (ILAS) monitored the profiles of ozone and ozone-related species, such as aerosols (or PSCs), nitric acid, nitrogen dioxide, nitrous oxide, methane, and water vapor on a regular basis, 14 times daily at high latitudes (57.1° N - 72.7° N and 64.3° S - 88.2° S) from November 1996 until the end of June 1997. In addition to those chemical species, the newest retrieval algorithm of the ILAS, version 6.0, succeeded to derive chlorine nitrate ($ClONO_2$) profiles for both hemispheres. Nakajima et al. (paper in preparation) compared the ILAS-measured $ClONO_2$ data with three balloon-borne measurements at around 69° N in March though May 1997, and concluded that the $ClONO_2$ data have enough quality for scientific use in 15 to 35 km altitudes, though they may be about 30 % lower values than the validation data. In spite of this systematic bias, the continuous data set of $ClONO_2$ in the polar regions simultaneously observed with many chemical species is variable to understand chemical propagation during a polar ozone depletion event. The measurement period of ILAS covered a recovery phase after Antarctic ozone hole in 1996 and the whole period of severe Arctic ozone depletion in 1996/1997. The boreal winter of 1996/1997 is well known for long-lasting polar vortex resulting in frequent PSC appearance (Hayashida et al., JGR, 2000) and significant ozone loss over the Arctic (Terao et al., JGR, 2002). The time series of the $ClONO_2$ in the Arctic lower stratosphere indicated outstanding enhancement (as high as about 2 ppbv at 475 K and 550 K isentropic surfaces) in late February and in March 1997. As well known, heterogeneous reactions on PSCs convert chlorine reservoir species into active chlorines that destroy ozone. The active chlorines produce predominantly $ClONO_2$ rather than HCl upon deactivation when a sufficient abundance of ozone is available. On the other hand, the behavior of $ClONO_2$ in the recovery phase of the Antarctic ozone hole was quite different. At the 475 K surface, some $ClONO_2$ mixing ratio data indicated extremely low values, corresponding to very low ozone (less than 1 ppmv) in November 1996 in the polar vortex. At the boundary region, $ClONO_2$ mixing ratio was much higher, corresponding to higher ozone mixing ratio (2.5-3.5 ppmv). As examined by Prather and Jaffe [JGR, 1990], HCl are preferably formed under ozone-depleted conditions because of the shift of Cl/ClO and NO/NO_2 ratios toward Cl and NO, resulting in suppression of $ClONO_2$ formation and enhancement of HCl formation through the reaction of Cl and CH_4. Under the assumption of photochemical equilibrium, $[ClONO_2]/[HCl]$ ratio has a linear correlation to $[O_3]^2/[CH_4]$ (Sen et al., JGR, 1999: Voss et al., JGR, 2000). The analysis of $[ClONO_2]/[HCl]$ ratio combined with corresponding HCl/HALOE data shows a good linear correlation in May and June 1997 for the northern hemisphere. The linear correlation is also found even in the southern polar vortex in November 1996, which suggests quasi-photochemical equilibrium condition in the Antarctic late spring.

A52E-08 1525h

Atmospheric Chemistry Experiment (ACE) Lower Stratospheric Trend Measurements: Approach and Preliminary Results based on Comparisons with ATMOS Midlatitude Observations

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The Atmospheric Chemistry Experiment (ACE) was successfully launched on August 12, 2003, into a 73.9 degree inclined orbit at an altitude of 650 km onboard a U.S.-supplied Pegasus XL vehicle. The primary goal of the ACE mission is to measure solar occultation spectra from the UV to mid-infrared for a minimum of two years to determine whether or not the stratospheric ozone layer will begin to recover now that chlorofluorocarbon emissions have been banned. Among the instruments carried by the small Canadian-built satellite is a compact Fourier transform spectrometer designed to measure in the 750-4100 cm-1 region at 0.02 cm-1 spectral resolution. The measurements will provide an opportunity to determine lower stratospheric trends at midlatitudes by comparison of ACE measurements with measurements recorded by the Atmospheric Trace MOlecule Spectroscopy (ATMOS) Fourier transform spectometer at 0.01-cm-1 resolution during its first shuttle flight in 1985. We describe the approach to be used for trend determination, the status of the investigation, and the other data relevant for comparisons.