A52F MCC: 3018 Friday 1600h

Ocean/Atmosphere Modeling III

(joint with OS, NG)

Presiding: **A Wallcraft,** Naval Research Laboratory**; L P Davis,** DOD High Performance Computing Modernization Program

A52F-01 1600h INVITED

Mountain-Wave Induced Rotors in the Lee of Three-Dimensional Ridges

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Mountain waves forced by elongated ridges are often accompanied by low-level vortices that have horizontal circulation axes parallel to the ridgeline. These horizontal vortices, known as rotors, can be severe aeronautical hazards and have been cited as contributing to numerous aircraft accidents. In spite of their obvious importance, mountain-induced rotors still remain poorly understood, particularly with respect to three-dimensional aspects of the flow. In this study, the dynamics of rotors forced by three-dimensional topography are investigated through a series of high-resolution idealized simulations with the non-hydrostatic COAMPS model. The focus of this investigation is on the internal structure of rotors and in particular on the dynamics of small-scale intense circulations within rotors that we refer to as "sub-rotors". These are the first known simulations of sub-rotors in three dimensions, likely because explicit simulations have only just recently become computationally feasible with the new generation of massively parallel computers. The calculations were performed on an SGI Origin 3000 at the DoD Major Shared Resource Facility High Performance Computing Facility at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi as part of the DoD Challenge program. Simulations are conducted using an upstream reference state representative of the conditions under which rotors form in the real atmosphere; in particular a vertical profile approximating the conditions upstream of the Colorado Front Range on 1200 UTC 3 March 1991. This is a few hours prior to a B737 crash at the Colorado Springs, CO airport that was initially linked to rotors and near the time when rotor clouds were observed in vicinity. The topography is specified as a 1000-m high elongated ridge with a half-width of 15 km on the upstream portion and 5 km on the downstream side. In several experiments, a 500-m circular peak with a half-width of 7.5 km is used to investigate the sensitivity of the rotor dynamics to topographic variations in the cross-flow direction. As many as six nested grids are used with a minimum horizontal resolution of 22 m and 90 vertical levels in order to resolve the internal rotor structure and sub-rotors. The simulation results indicate a thin sheet of high-vorticity fluid develops adjacent to the ground along the lee slope and then ascends abruptly as it is advected into the updraft at the leading edge of the first trapped lee wave. This vortex sheet is primarily forced by mechanical shear associated with frictional processes at the surface. Instability of the horizontal vortex sheet occurs along the leading edge of the "parent" rotor and as a result coherent sub-rotor circulations subsequently develop. These sub-rotors intensify and are advected downstream or back toward the mountain into the parent rotor at low-levels leading to an enhancement of the near-surface horizontal vorticity. Horizontal vorticity within the sub-rotors are enhanced several fold. The horizontal vorticity generation appears to be enhanced near the edges of the wake emanating from the circular peak due to vortex stretching of the parent rotor and also further maximized due to stretching associated with three-dimensional turbulent eddies. The results suggest that preferred regions of intense rotors may exist near topographic features that enhance vortex stretching.

A52F-02 1630h

Multi-Year Simulations of the Middle Atmosphere with NOGAPS-ALPHA

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The Navy's Operational Global Atmospheric Prediction System (NOGAPS) is the Department of Defense's global weather forecasting and data assimilation system. The centerpiece of this system is a spectral numerical weather prediction (NWP) model of the physical processes driving the atmospheric circulation. The current operational version of the NOGAPS model provides output from the surface up to ∼10 hPa (approx. 30 km altitude). A major research effort is presently underway to extend NOGAPS forecasting capabilities to higher altitudes, thereby improving weather forecasts at all levels by fully resolving important global circulation patterns throughout the full depth of the atmosphere. This effort has led to the development of the NOGAPS-Advanced Level Physics High Altitude (NOGAPS-ALPHA) model. NOGAPS-ALPHA extends to 0.01 hPa (approx. 80 km) and contains a number of new physics modules necessary for middle atmospheric applications, including updated radiative heating, gravity wave drag, and constituent transport with parameterized photochemistry. The longer time scales associated with middle atmospheric processes require multi-year simulations in order to characterize model performance. Results of a 5-year simulation with NOGAPS-ALPHA at T79L54 will be presented, describing the seasonal evolution of stratospheric winds and temperatures and their impact on tropospheric NWP.

A52F-03 1645h

Increasing Simulation Speed in a Coupled Ocean/Atmosphere Model by Using Mixed-Resolution, Parallel Components

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The traditional goal of a coupled ocean/atmosphere model is to accurately simulate the current climate and the primary application of the resulting model is to the prediction of future climate. The constant push for higher resolution and more and better physical parameterizations in these models has kept their simulation speed, simulated years per wallclock day, nearly constant despite a decade of growth in computer power. The Fast Ocean Atmosphere Model is a coupled ocean/atmosphere general circulation model designed to take advantage of Moore's Law and maximize simulation speed. The fundamental design choice in FOAM is the use of mixed-resolution components: the spectral atmosphere model is kept fixed at the relatively low resolution of R15 while the finite-difference ocean model employs a medium resolution grid with an average spacing of less than 2 degrees. The resulting model has an output of nearly 100 years per day on a single IBM Regatta node. FOAM is also well suited for the 16 and 32 processor Linux clusters that are becoming common equipment for small research groups and individual researchers. Despite the low resolution, FOAM is able to simulate much of the observed variability of the climate system, including ENSO and mid-latitude decadal variability, without flux corrections. FOAM can also reproduce the major effects of CO2 increase seen in higher resolution models. FOAM has also found many applications in paleoclimate, performing simulations of the Neo-Proterozoic and early Holocene.

URL: http://www.foamodel.org

A52F-04 1700h INVITED

Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM)

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This DoD HPC Challenge project is part of a coordinated effort to provide ocean prediction on eddy-resolving scales globally. The long-term objectives are to simulate, understand, nowcast and forecast the global ocean circulation. Traditional ocean models use a single coordinate type to represent the vertical, but no single approach is optimal for the global ocean. The HYbrid Coordinate Ocean Model (HYCOM) combines all three approaches choosing the optimal distribution at every time step. It is isopycnal in the open, stratified ocean, but makes a dynamically smooth transition to a terrain-following coordinate in shallow coastal regions, and to z-level coordinates in the mixed layer and/or unstratified seas. This approach retains the advantages that each individual vertical coordinate system offers, HYCOM has been configured for the North Atlantic and Pacific Ocean with a resolution of 1/12 degree and globally with a resolution of 3/4 degree (equatorial). We will first report on the performance of the model and on the ability of the hybrid coordinate to accurately represent the oceanic circulation in these three configurations. We will then describe a near real-time data assimilation version of the 1/12 degree North Atlantic, a component of the Global Ocean Data Assimilation Experiemnt (GODAE).

URL: http://hycom.rsmas.miami.edu

A52F-05 1715h

Pacific Ocean Modeling Using the HYbrid Coordinate Ocean Model (HYCOM)

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One component of the DoD HPC Challenge project on "Basin-scale Prediction with the HYbrid Coordinate Ocean Model" has been the development of a high resolution, Pacific version of HYCOM. The configuration for the Pacific (20°S - 66°N) has an equatorial grid resolution of 1/12° and 20 vertical coordinate surfaces. Surface forcing includes wind stress and speed, thermal forcing, precipitation, relaxation to sea surface salinity and monthly varying river runoff. Closed boundaries exist in the Indonesian Seas, the Bering Strait and along 20°S. A 3° buffer zone is included along 20°S with relaxation to monthly climatological temperature and salinity. The model has been integrated with both monthly climatological and 6-hourly interannual European Centre for Medium-Range Weather Forecasts forcing. It accurately simulates the large-scale circulation gyres and the major current systems. Near the western boundary in the vicinity of Luzon Strait and Taiwan, model-data comparisons of velocity as a function of depth indicate the climatological forced simulation agrees closely with the observations. The tropical current systems (South Equatorial Current, North Equatorial Counter Current, Equatorial UnderCurrent (EUC), and subsurface, off-equator Tsushiya jets) also compare very well against available velocity observations. Interannual variability is clearly evident in the simulation with 6-hourly forcing. In typical years, zonal velocity of the EUC along the equator shoals and strengthens from west to east. During the 1982-83 El Nino, the velocity core is essentially level with uniform magnitude across the central Pacific Ocean. In addition, Pacific HYCOM produces a coastally trapped wave generated

by Hurricane Juliette that propagates poleward along the Mexican coast, into and out of the Gulf of California before continuing its poleward journey along the west coast of the Baja California Peninsula. High correlations exist between modeled and observed sea level along its path.

URL: http://hycom.rsmas.miami.edu/

A52F-06 1730h

1/32° Global Ocean Modeling and Prediction

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The resources of a three-year Department of Defense (DoD) High Performance Computing (HPC) Challenge project was crucial in the development a data-assimilative 1/32° global ocean nowcast/forecast system, which included the associated basic research and exploratory development. This system is scheduled for transition to the Naval Oceanographic Office (NAVO) in the first quarter of FY04. This 1/32° global system will be an upgrade to the existing 1/16° NRL Layered Ocean Model (NLOM) nowcast/forecast system which is operational at NAVO. A critical issue in forecast system design is determining the resolution required. Ocean models require finer resolution and more computer time than atmospheric models in part because the space scales for variability due to flow instabilities (oceanic mesoscale eddies vs. atmospheric highs and lows) are about 20-30 times smaller than found in the atmosphere. We need to resolve the oceanic eddy space scale very well because (1) upper ocean - topographic coupling via flow instabilities has a major impact on the pathways of many upper ocean currents (including mean pathways) and very fine resolution of the flow instabilities is required to get sufficient coupling, (2) very fine resolution is required to obtain (a) inertial jets and sharp oceanic fronts which span major ocean basins as observed and (b) the associated nonlinear recirculation gyres which affect the shape of large-scale ocean gyres, (3) it is necessary to resolve small islands and narrow passages which affect current pathways and current transports in many regions, (4) in data assimilative mode we do not want the ocean model to "fight" the data because the natural behavior of the ocean model is inconsistent with the observations, and (5) a very high horizontal resolution model is needed to help get an accurate mean sea surface height field to add to the deviations obtained from satellite altimetry (observations alone do not provide sufficient resolution to do this). The need for 1/32° resolution (~3.5 km at mid-latitudes) has been demonstrated through extensive research, including essential contributions from earlier DoD HPC Challenge projects as well as non-challenge HPC usage. These projects also helped establish 1/16° (~7 km at mid latitudes) as the minimum resolution needed for a fully eddy-resolving global ocean prediction system. Major improvement in model simulation skill was obtained with an increase to 1/32° resolution, but only modest additional improvement with a further increase to 1/64° resolution. Hence, our target resolution globally is 1/32°. The ocean model, after 30 years of climatological spinup, was run interannually spanning the period 1979-present. In addition to re-equilibration, the climatological simulation was used to fix problems that arose, optimize model parameters, assess the impact of the resolution increase on model realism and dynamics and to perform climatological model-data comparisons. These results were used to generate statistics and a model sea surface height (SSH) mean for data assimilative experiments. The model assimilates SSH from 3 satellite altimeters (ERS-2, GFO and JASON-1) and sea surface temperature from satellite IR imagery. Assimilation of satellite altimeter data is critical in allowing the model to map individual current meanders and eddies. Forecast experiments were then initialized from the data assimilative experiments. Results from this 1/32° system were then compared with observed data to assess model realism and the value added of the resolution increase from 1/16° to 1/32°.

A52F-07 1745h

Simulation of a Landfalling Hurricane Over the Gulf of Mexico Region Using Weather Research and Forecasting Model

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The Gulf costal states region is prone to the highest national frequency to severe weather accompanied by huge economic loss. The region lacks adequate study with regard to significant coastal processes - "weather dynamics". Understanding modeling and predicting the coastal processes and dynamics is important in improving weather forecasting. A mesoscale modeling investigation of tropical cyclonehurricane forecast over the Gulf of Mexico has been undertaken pertaining to NOAA's interest to assess and predict environmental changes, protect life and property and provide decision makers with reliable scientific information. In the present study the Weather Research and Forecasting *WRF* model is run on a high performance computing environment using non-conventional datasets. Data from the PennStateNCAR MM5 v.3 model is fed into the WRF v.1.3 model as initial and lateral boundary conditions to simulate the surface features of a case oriented 2003 landfalling hurricane. Simulation parameters include seal level pressures, surface fluxes, sea surface temperature, wind direction and magnitude, and precipitation. The results will be compared with aircraft observations taken by the National Hurricane Center. This model output is then incorporated into a decision support matrix. The results of the model simulations will be presented and discussed.

A52G MCC: 3016 Friday 1600h

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

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

A52G-01 1600h

Changes in stratospheric water vapor derived from HALOE, 1991-2003

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Interannual changes in stratospheric water vapor are examined using Halogen Occultation Experiment (HALOE) satellite measurements over 1991-2003. Anomalies in water vapor with an approximate 2-year periodicity originate near the tropical tropopause, and propagate vertically and latitudinally with the mean stratospheric transport circulation (in an analogous manner to the seasonal tape recorder). Unusually low water vapor anomalies are observed in the lower stratosphere for 2001-2002. The water vapor changes in HALOE data are well correlated with temperature anomalies near the tropical tropopause. Comparisons of the HALOE data with balloon measurements of lower stratospheric water vapor at Boulder, Colorado (40N) show some agreement for interannual changes during 1992-2002, but decadal increases observed in the balloon measurements for this period are not observed in HALOE data.

URL: http://acd.ucar.edu/~randel/H2O_changes.html

A52G-02 1615h

The Long-Term Change in Stratospheric Water Vapor Isotopes

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More than 20 years of observations from high altitude aircraft of high-resolution infrared absorption have been analyzed, using non-linear least squares spectral fitting, to retrieve stratospheric column amounts of $H_2{}^{16}O$, $H_2{}^{17}O$, $H_2{}^{18}O$ and HDO. Total vertical column amounts above 12 km are retrieved. However, analysis of the information content of the solar viewing geometry shows that most of the contribution to the column comes from altitudes below 25 km. So the measured column amounts may be considered as lower stratospheric amounts. The lower stratosphere is a difficult region to observe, especially for H_2O. It is above the in situ sampling range for most aircraft. The strong absorption by H_2O makes the lower stratosphere difficult to measure remotely by both surface and satellite techniques. Observations by our remote sounding spectrometer, from a platform at the base of the stratosphere, are optimum for determining lower stratospheric water vapor amounts. The advantage of having deployed the same instrument over such a long measurement period and the uniform analysis of all the data make this data set extremely useful for long-term trend analyses. Water vapor plays an important role in chemical and radiative processes in the lower stratosphere and upper troposphere. We expect lower stratospheric water to have a latitudinal and a seasonal variation, as well as a long-term trend. However, the dominant component of the water variation is found to be a linear long-term trend. Monthly averaged column amounts of $H_2{}^{16}O$, $H_2{}^{17}O$, $H_2{}^{18}O$ and HDO for the period from 1978 to 2000 are presented to show the latitudinal distribution of these isotopes in both hemispheres. Results show an increase at mid-latitudes of approximately 3 % / year in all isotopes. Annual trends diverge at low latitudes for the four isotopes with the increase in HDO being much depressed.

A52G-03 1630h

Comparison of POAM III Water Vapor Measurements With a Microphysical Model During the SH Winter

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The Integrated Microphysics and Aerosol Chemistry on Trajectories (IMPACT) model is used to examine processes leading to dehydration in the Southern Polar stratosphere. Air parcels are advected along 3-D trajectories to establish a temperature history throughout the winter season. The temperature history is used by the model to simulate the processes of nucleation, freezing, and uptake of gases onto the aerosol surface. The values of several parameters are varied in order to establish their effects on dehydration and polar stratospheric cloud formation. Model results are compared to water vapor and extinction measurements obtained by the Polar Ozone and Aerosol Measurement (POAM) III instrument. The amount of dehydration at the end of the season is sensitive to minimum temperatures encountered along the trajectories, and therefore to any biases in the temperature minima in the UKMO [or other] assimilation model inputs. Preliminary results show that the model dehydration agrees well with the POAM measurements when ice particle formation is dominated by heterogeneous nucleation.

A52G-04 1645h

Cloud Structure Over Tropical Pacific During 1985–1999: Preliminary Analysis

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