12th Annual
Community Climate System Model Workshop

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Atmosphere Model Working Group

Data Assimilation for CAM Using the DART Ensemble Assimilation Facility

Jeff Anderson, Kevin Raeder, Tim Hoar, Nancy Collins, and Hui Liu (NCAR)

A state-of-the-art community ensemble data assimilation facility for CAM is provided by NCAR's Data Assimilation Research Testbed (DART). A variety of techniques are available for evaluating CAM in a numerical weather prediction mode. Quick tests of the relative capabilities of model configurations can be conducted by evaluating the quality of short-range forecasts. The ensembles produced by CAM/DART can be used to explore the sensitivity of state variables, producing results analogous to adjoint and linear tangent sensitivity studies but at a fraction of the cost and without the need for a linearized or adjoint model. Process studies in CAM ensembles constrained by observations can give enhanced insight into model systematic errors and include a priori estimates of statistical significance. The CAM/DART system can also be used for direct parameter estimation, finding values of CAM parameters that result in the best fit to observations. Assimilations of remotely sensed measurements of trace gasses are just one of the many new applications of the CAM/DART system that have occurred during the past year. The Data Assimilation Research Section (DAReS) provides training and user support for scientists interested in using the CAM/DART facility for research or education.

An Evaluation of ENSO Asymmetry in the NCAR Models

Tao Zhang and De-Zheng Sun (NOAA)

The asymmetry between the two phases of ENSO is a fundamental property of ENSO, and may hold a key to better understanding the effect of ENSO on its background state (the time-mean state). We evaluate the asymmetry in the ENSO simulated by five NCAR Models by calculating the skewness of the tropical Pacific SST variability. We find that all these models underestimate the asymmetry between the two phases of ENSO. The results suggest that ENSO in the models may have a weaker time-mean effect on the background state than it has in the observations.

Investigating the Regional Influence of the Monsoonal Convection in Northwest Mexico

Matt Barlow and Andy Hoell (University of Massachusetts, Lowell)

The influence of the monsoonal convection in Northwest Mexico on regional circulation and rainfall is examined by enhancing the monsoonal convection in the NCAR CAM and examining the impact of these changes relative to a control run with no modifications. The effects of the monsoonal convection are enhanced by locally modifying the calculation of diabatic heating, an approach that has proven successful in other regions. Previous research has linked the onset of the monsoonal convection in Northwest Mexico with decreased rainfall in a broad swath across the Northwest, Central, and western-Gulf Coast regions of the US. However, the dynamics of this relationship are not clear, especially the question of whether the monsoonal convection actively forces the suppression of US rainfall or whether some third factor, such as the interaction of the westerlies with the North American Cordillera, influences both regions. Here we assess the direct impact of the monsoonal convection by investigating the changes that occur when the monsoonal convection is substantially increased in the model. (Only the diabatic heating is altered in the model and only over Northwest Mexico; otherwise the model is unmodified and the circulation progresses freely.) The changes to regional circulation and their influence on US rainfall are examined in terms of dynamically-forced vertical motion, thermodynamically-forced vertical motion, moisture transport, and convective available potential energy.

The UW Unified Shallow-deep Cumulus Parameterization for CAM

Chris Bretherton and Sungsu Park (University of Washington)

The current status and performance of the University of Washington moist turbulence shallow cumulus parameterization is compared when run with the default Zhang-McFarlane scheme, and when run as the only cumulus parameterization. In the latter case, significant global improvements in the simulated general circulation are found. We also illustrate bias reduction in high-latitude clouds and surface temperature in the UW schemes associated with updating cloud fraction after microphysics.

Reducing a Longstanding Temperature Bias in CAM Using Isentropic Coordinates

Chih-Chieh Chen (University of Colorado, Boulder/NCAR), Philip J. Rasch, Ram D. Nair, and Henry M. Tufo (NCAR)

It has been demonstrated that vertical discretizations of atmospheric general circulation models have a significant impact on atmospheric dynamics. Currently, the NCAR finite volume (FV) dynamical core employs a pressure-based vertical coordinate. It has been noted in several studies that such vertical discretization can create aphysical entropy sources and results in cold temperature biases in the simulated atmosphere.

In this study, a hybrid-isentropic vertical coordinate is implemented within the NCAR FV dynamical core and the simulated climatology is presented. It is found that the isentropic finite volume (IFV) model reduces several biases found in the simulation by the current FV model. The cold temperature bias found in the upper troposphere and lower stratosphere is significantly reduced in the IFV. Additionally, the simulated sea-level pressure distribution by the IFV model shows better agreement with observation.

Sources of CAM3 Arctic Surface Bias from Parsing the Temperature Equation

Richard Grotjahn and Lin-Lin Pan (University of California, Davis)

We will build upon results shown last January at the AMWG meeting. Previously shown were the following. We showed the 3-D structure of the model bias in the Arctic and surrounding region. We showed the 3-D forcing needed by a model using the linearized dynamics of CAM to reproduce that bias. The forcing needed to produce the structures and nearly all the amplitude of the Arctic region bias are either localized to the Arctic region or in the midlatitude storm tracks.

At the June workshop we will show results that further parse the contributions into transient and diabatic contributors to the temperature equation. We shall show the bias fields of the transient eddy contributions (with further splitting into low and high frequencies). We shall show the forcing so parsed into high and low pass frequencies. We shall show the contributions to the bias by individual terms in the thermal equation. Diabatic contributions will be found as a residual.

The goal of this parsing is to narrow down the physical processes responsible for bias; is it mainly due to diabatic processes? and if so what region? Has the bias mainly a high frequency (storm track) source or a low frequency (e.g. NAO) source?

Forecasts of Southeast Pacific Stratocumulus with the NCAR, GFDL and ECMWF models

Cecile Hannay, Dave Williamson, Jim Hack, Jeff Kiehl, and Jerry Olson (NCAR), Steve Klein (Program for Climate Model Diagnosis and Intercomparison), Martin Koehler (European Centre for Medium-Range Weather Forecast), and Chris Bretherton (University of Washington)

We examine forecasts of Southeast Pacific Stratocumulus at 20S and 85W during the East Pacific Investigation of Climate (EPIC) cruise of October 2001 with the ECWMF operational model, the Atmospheric Model versus 2.12 (AM) developed at GFDL, the Community Atmosphere Model version 3.1 (CAM) developed at NCAR, and the Community Atmospheric Model with the University of Washington PBL/Shallow convection scheme (CAM-UW). The forecasts are initialized from atmospheric initial conditions obtained from ECMWF analyses and each model is run for 3 to 5 days to determine the drift from the field data.
Observations during the EPIC cruise show a very stable and well-mixed boundary layer under a sharp inversion. The inversion height and the cloud layer have a strong and regular diurnal cycle. A key problem common to the 4 models is that the forecasted PBL height is too low compared to observations. The same problem exists in the analysis. The ECMWF forecast shows a steady Planetary Boundary Layer (PBL) with no significant decrease or increase of the inversion height. The CAM and CAM-UW unrealistically collapse the PBL depth within 3-day of forecasts. The AM also show some shallowing of the boundary layer but it is less dramatic than in CAM and CAM-UW. The Liquid Water Path (LWP) is underestimated in all the models except in the ECMWF model, which overestimates it. All the models produce a strong diurnal cycle in LWP but there are errors in the amplitude and the phase of the diurnal cycle compared to obsrevations. In particular, the AM and CAM-UW unrealistically collapse the LWP during the afternoon and this, in turn, affects the radiative fluxes at the surface. There is a large spread in the surface energy budget terms between the models and large discrepancies with observations.
Single Column Model (SCM) experiments showed that the vertical pressure velocity has a large impact on the PBL height and LWP. The vertical velocity within the PBL itself plays a determinant role in the collapse or the maintenance of the PBL; in particular, larger values of the vertical velocity below 900 mbar produce a shallowing the PBL. Moreover, the vertical velocity has a marked diurnal cycle: subsidence exists during most of the day but it is interrupted by periods of upward motion in the lower troposphere. The SCM experiments showed that the upward vertical velocity prevents the cloud layer from thinning too much during daytime. We also showed that doubling of the vertical resolution from 30 to 60 levels has little impact on the PBL. Finally, we illustrated that even if CAM and CAM-UW produce very similar vertical structure of temperature and moisture, the 2 models operate very differently at the process level.

Tropical Influences on Southwest Asia Precipitation in a Global Atmospheric Model

Andrew Hoell and Mathew Barlow (University of Massachusetts, Lowell)

The midlatitude dynamic and thermodynamic response to enhanced middle troposphere tropical diabatic heating over the eastern Indian Ocean during the northern hemisphere cold season (December – March) is investigated using the National Center for Atmospheric Research Community Atmosphere Model version 3.1 full global climate model. The dynamic response is similar to the idealized analytic Gill (1980) solution to steady diabatic heating and the thermodynamic response is consistent with theoretical works by Rodwell and Hoskins (1996, 2001) and observational analysis of Barlow et al. (2005). The thermodynamic response indicates that precipitation is suppressed by descending air over Iran, Afghanistan, and Pakistan due to cold temperature advection at middle and upper tropospheric levels. The sensitivity of the midlatitude response to diabatic heating is explored: the long-term steady state response, the short-term monthly response, and the response to variable magnitudes of diabatic heating.

Evaluating Water Vapor in the NCAR CAM3 Climate Model with RRTMG/McICA Using Modeled and Observed AIRS Spectral Radiances

Michael Iacono (Atmospheric and Environmental Research, Inc.)

The direct comparison of modeled and observed spectral radiances provides a detailed means of assessing the simulation of radiative processes in a global climate model. To evaluate the simulation of water vapor in the National Center for Atmospheric Research (NCAR) Community Atmosphere Model (CAM3) by comparing modeled and observed spectral radiances, CAM3 has been modified to include the Optimal Spectral Sampling (OSS) algorithm developed at AER. OSS has been prepared to model radiances for all 2378 channels of the NASA Atmospheric Infrared Sounder (AIRS) spectrometer, which has been measuring infrared radiance spectra from space since 2002. Clear sky AIRS radiances are modeled with OSS in both the original NCAR CAM3 climate model and in a separate version that uses the ARM-supported RRTMG longwave and shortwave models for radiative transfer and applies the Monte-Carlo Independent Column Approximation (McICA). Over various geographic regions for January and July 2004, modeled spectra from each simulation are compared to cloud-cleared measured AIRS radiance spectra. Within the spectral region of relevance to middle and upper tropospheric temperature (700-750 cm-1), differences between modeled and observed brightness temperatures are generally less than 2 K and are mostly insensitive to the radiative transfer method. However, within the spectral region dominated by water vapor absorption (1340-1580 cm-1), brightness temperature differences of 5-10 K are present that vary spectrally and by geographic region, which suggests that significant regional discrepancies in middle to upper tropospheric water vapor are present. Differences in water vapor spectra are somewhat sensitive to the radiation model used.

CAM-Oslo: A CAM3-based AGCM with aerosol-climate interactions

T. Iversen, A. Kirkevag, J.E. Kristjansson, O. Seland, and T. Storelvmo (Norwegian Met. Institute and Univ. of Oslo)

A process-allocated aerosol life-cycle scheme with sulfate, Black Carbon, Primary Organics, Sea-salt, and mineral dust has been included on-line with NCAR-CAM3 by staff at University of Oslo and Norwegian Meteorological Institute. Optical properties and cloud droplet activation is parameterized by tabulations based on first principles. The model has been run both stand-alone and coupled to a slab-ocean model. Results will be shown from both types of runs. Further plans include prognostic cloud droplet (water and ice) number concentrations, more aerosol components, and coupling to a full deep-ocean model (MICOM or HYCOM).

Using Cloudsat/Calipso Observations to Evaluate the Representation of Clouds in CAM

Jennifer Kay (Colorado State University/NCAR) and Andrew Gettelman (NCAR)

We present one full year of cloud observations from CloudSat, a vertically pointing cloud radar, and Calipso, a vertically pointing lidar. These unique observations provide a first view of the global vertical structure of clouds and reveal familiar atmospheric circulation patterns. In our poster, we use CloudSat/Calipso cloud observations to evaluate CAM's representation of clouds and atmospheric circulation patterns. In particular, we highlight model-observation comparisons of previously poorly observed Arctic clouds. Finally, we discuss plans to use CloudSat/Calipso observations to improve CAM's representation of Arctic clouds and climate.

CAM3 Simulations for TWP-ICE Using the CAPT Framework

Stephen Klein, Jim Boyle, and Shaocheng Xie (LLNL), Guang Zhang (University of California, San Diego), Richard Neale (NCAR)

We tested several convective parameterizations in the CAM3 model using the CAPT (CCPP-ARM Parameterization Testbed) approach for the TWP-ICE IOP. In CAPT, the CAM3 is integrated in weather-forecasting mode starting from ECMWF analyses. TWP-ICE IOP is the Atmospheric Radiation Measurement Program's Tropical West Pacific - International Cloud Experiment that was conducted in January-February 2006 in Darwin, Australia. The convection parameterizations tested include the control Zhang-McFarlane, a modified Zhang closure, and the entraining CAPE closure of Richard Neale.

A Stability Analysis of Finite-Volume Advection Schemes Permitting Long Time Steps

Peter Hjort Lauritzen (NCAR)

Finite-volume schemes developed in the meteorological community that permit long time-steps are considered. These include Eulerian flux-form schemes as well as fully two-dimensional and cascade cell-integrated semi-Lagrangian (CISL) schemes. A one and two-dimensional Von Neumann stability analysis of these finite-volume advection schemes is given. Contrary to previous analysis, no simplifications in terms of reducing the formal order of the schemes, which makes the analysis mathematically less complex, have been applied. An inter-scheme comparison of both dissipation and dispersion properties is given. The main finding is that the dissipation and dispersion properties of Eulerian flux-form schemes are sensitive to the choice of inner and outer operators applied in the scheme that can lead to increased numerical damping for large Courant numbers. This spurious dependence on the integer value of the Courant number disappears if the inner and outer operators are identical in which case, under the assumptions used in the stability analysis, the Eulerian flux-form scheme becomes identical to the cascade scheme. To explain these properties a conceptual interpretation of the flux-based Eulerian schemes is provided. Of the two CISL schemes the cascade scheme has superior stability properties.

Sensitivity of MJO to the CAPE Lapse Time in the NCAR CAM3

Ping Liu and Bin Wang (University of Hawaii), and Gerald A. Meehl (NCAR)

Weak and irregular boreal winter MJO in the NCAR CAM3 corresponds to very low CAPE background, which is caused by easy-to-occur and over-dominant deep convection indicating the deep convective scheme uses either too low CAPE threshold as triggering function or too large consumption rate of CAPE to close the scheme. Raising the CAPE threshold from default 70 J/kg to ten times large only enhances the CAPE background while fails to noticeably improve the wind mean state and the MJO. Lengthening the CAPE lapse time from one to eight hours significantly improved the background in CAPE and winds, and salient features of the MJO. Variances, dominant periods and zonal wave numbers, power spectra and coherent propagating structure in winds and convection associated with MJO are ameliorated and comparable to the observations. Lengthening the CAPE lapse time to eight hours reduces dramatically the cloud base mass flux, which prevents effectively the deep convection from occurring prematurely. In this case, partitioning of deep to shallow convection in MJO active area is about 5:4.5 compared to over 9:0.5 in the control run. Latent heat is significantly enhanced below 600 hPa over the central Indian Ocean and the western Pacific. Such partitioning of deep and shallow convection is argued necessary for simulating realistic MJO features. Although the universal eight hours lies in the upper limit of that required by the quasi-equilibrium theory, a local CAPE lapse time for the parameterized cumulus convection will be more realistic.

Extending Scalability of the Community Atmosphere Model

Art Mirin (LLNL) and Patrick Worley (ORNL)

The parallel implementation of the Community Atmosphere Model (CAM) employs a number of different domain decompositions. Currently, each decomposition must utilize the same number of MPI processes, limiting the scalability of CAM to that of the least scalable decomposition. This limitation becomes unacceptably restrictive when including additional physical processes such as atmospheric chemistry or cloud resolving physics. We are generalizing CAM to allow the number of active MPI processes to vary between domain decompositions. We are also introducing new domain decompositions to address new physics scenarios. We report on our progress to date.

A Measurement-based Cirrus Size Distribution Scheme for Use in Cloud Resolving and Climate Models

Brad Baker, R. Paul Lawson, Bryan Pilson, Qixu Mo (SPEC, Inc.), Daniel DeSlover (CIMMS, University of Madison, Wisconsin)

A method was developed to (1) analytically describe ice particle size distributions (PSD) containing particles between 2 and 2000 microns and (2) parameterize the PSD as a function of temperature and ice water content for use in cloud resolving and climate models. Ice particle projected area- and mass-dimension power law relationships were also determined as a function of temperature, with the mass exponent determined from the PSD shape. This provides the needed information for calculating optical properties. The PSD scheme is flexible to account for any amount of small particle artifact produced by the shattering of larger ice particles at the inlet of optical probes that measure the PSD.

ENSO Improvements in CCSM3 in Response to Atmospheric Deep Convection Changes

Richard Neale, Yaga Richter, and Markus Jochum (NCAR)

ENSO in CCSM3 is deficient in a number of aspects: A 2-year period that is too strong, short and regular; same-sign SST anomalies extending across the whole Pacific; variance peaking in August instead of December; and weak, geographically displaced teleconnection patterns. Changes to the atmospheric deep convection intended to improve mean systematic errors in CCSM3 had the welcome, but unexpected effect of improving all of the ENSO deficiencies mentioned above. The results of adding convective momentum transports and dilution of the reference parcel calculation shifted the model's ENSO away from one dominated by a short-circuited delayed oscillator mode. Instead, a more episodic phenomena emerges. It is significantly influenced by enhanced Westerly Wind Events (WWEs), which appear to have a role in initiating and maintaining individual El Nino events. The changes support recent research suggesting the atmospheric component of the coupled system may hold the key to an improved ENSO

A New Technique for Calculating Feedbacks in Climate Models

Karen Shell (Oregon State University), Jeff Kiehl and Christine Shields (NCAR)

Climate models differ in their responses to imposed forcings, such as increased greenhouse gas concentrations, due to different climate feedback strengths. Climate feedbacks in NCAR's Community Atmospheric Model (CAM) are separated into two components: the change in climate components in response to an imposed forcing and the ``radiative kernel,'' the effect that climate changes have on the radiative budget at the top-of-the-atmosphere (TOA). This technique's usefulness depends on the linearity of the feedback processes. For the case of CO2 doubling, the sum of the effects of individual clear-sky components (water vapor, temperature, and surface albedo) on the TOA clear-sky flux is similar to the clear-sky flux changes directly calculated by CAM. When monthly averages are used rather than values from every time step, the global average TOA shortwave change is underestimated by a quarter as a result of intra-month correlations of surface albedo with the radiative kernel. The TOA longwave flux changes do not depend on the averaging period. The zonal averages are within 10% of the model-calculated values, while the global average differs by only 2%. Cloud radiative forcing (DeltaCRF) is often used as a measure of cloud feedback strength. The net effect of the clear-sky feedbacks on DeltaCRF is -1.6 W/m/m, based on the kernel technique, while the total DeltaCRF from CAM is -1.3 W m/m/m, indicating that clear-sky feedbacks contribute significantly to DeltaCRF and make it more negative. Assuming linearity of the DeltaCRF contributions, these results indicate that the net cloud feedback in CAM is positive.

A Locally Conservative (Mass and Energy) Version of the Spectral Element Dycore in HOMME-CAM

Mark Taylor (Sandia National Labs), Jim Edwards (IBM), Steve Thomas and Ram Nair (NCAR)

We will present a new formulation of the spectral element dycore in HOMME-CAM that exactly conserves mass and energy. Conservation requires only minor modifications to HOMME, which uses a spectral element discretization on the cubed sphere combined with the CAM-Eulerian hybrid vertical coordinate system and Leapfrog time integration. Total mass and tracer advection are handled with the same advection scheme and tracers can be advected in conservation form or as a volume fraction. The conservation is local, meaning that the change in mass and energy in each element is given by a contour integral of the flux around the boundary of the element. The advection scheme does not change kinetic or internal energy and so the only dissipation comes from an explicitly added hyper-viscosity term. The method remains oscillatory, but the oscillations are localized and thus much reduced when compared to global spectral methods. Results will be presented from the Jablonowski and Williamson baroclinic instability test and Aqua planet simulations.

Understanding the Response of Clear-sky Greenhouse Effect to El Nino Warming in Four NCAR Atmospheric Models

Tao Zhang (CU, Boulder and NOAA) and De-Zheng Sun (NOAA)

To diagnose the causes of an excessive response of the clear-sky greenhouse effect to El Niño warming in four NCAR atmospheric models, the response of both water vapor and temperature to El Niño warming in the models is examined as a function of height. The percentage response of water vapor to El Niño warming in the models is considerably stronger than the response in the reanalysis in the middle and upper troposphere. The discrepancy in the temperature response between the models and the reanalysis data at all tropospheric levels is within 0.3 K/K, with the maximum discrepancy occurring in the immediate neighborhood of 600 mb. Employing a radiative model, we have calculated the contributions of the excessive water vapor response in the middle and upper troposphere as well as the contributions from the differences in the lapse rate response to the discrepancies seen in the clear-sky greenhouse effect. The results confirm that the main cause of the excessive response of the clear-sky greenhouse effect is an excessive response of water vapor in the middle and upper troposphere. The excessive response of upper tropospheric water vapor is found to be companied with an excessive response in the cloud cover and vertical motion. Biases in both phases of ENSO contribute to these excessive responses to ENSO.

Biogeochemistry Working Group

1500-year CCSM3 Simulation with Perpetual-1870 Climate Forcing

Curt Covey, Krishna AchutaRao, David C. Bader, Bala Govindasamy, Art Mirin (LLNL / PCMDI); Bette Otto-Bliesner and Nancy J. Norton (NCAR); Michael F. Wehner (LBL)

We have extended the low-resolution (T31 atmosphere / 3-degree ocean) 1870 control run of the CCSM3 (Case b30.0048) to a total of 1500+ simulated years, or ~2000 simulated years including the preceding 1780 control run. This represents the longest CCSM3 simulation we know of, other than J. T. Kiehl's 7000-year simulation of the Permian Era some 200-300 million years ago. Our simulation thus provides a unique resource for investigating the CCSM3's long term unforced climate variability in the context of pre-industrial (i.e. pre-global-warming) conditions. Output from our simulation is available on archival storage at the National Energy Research Supercomputer Center, in directory /nersc/afu/u5024/CCSM3/Archive/.
A preliminary look at our output reveals a remarkably stable (perhaps too stable) climate despite the absence of artificial flux adjustments in the CCSM. Globally averaged surface temperature decreases at a steady rate of 0.02 K / century throughout the simulation. If this rate applies to the full ocean, then the model's energy leakage averaged over Earth's surface is

The temporal spectrum of oceanic oxygen variability

Taka Ito (Colorado State University) and Curtis Deutsch (University of Washington)

Changes in dissolved O2 observed across many regions of the world ocean in recent decades have been interpreted as a direct response of ocean circulation and/or biology to climate trends h decadal or longer duration. Little is known however about the spectrum of oceanic O2 variability or its relationship to climate perturbations. Here we show that the rapid, atmospheric variability is capable of generating oceanic oxygen variability with substantial power at decadal frequencies. Because the oceanic ventilation integrates anomalous water mass properties over decadal time scales, one should expect oxygen to exhibit a red spectrum at time scales shorter than that of thermocline ventilation. In addition, the coupling of physical oxygen supply and biological oxygen demand mediated by nutrient cycling, may lead to a peak frequency of O2 variability that is roughly decadal.

Dynamics of Intra-Seasonal Modulation of Convection over Tropical North Africa: Prospect for Enhancing Parameterization Schemes in Climate Models

Akintayo Adedoyin (University of Botswana)

Numerical and climate models have not adequately captured the large and coherent fluctuations in rainfall and wind fields on intra-seasonal time scale over tropical North Africa. This may largely be due to the fact that its origin is still not fully understood. Adequate simulation of this phenomenon would enhance the understating of the modulating effect of mesoscale convective systems, which form the bulk of energy, moisture and momentum transfer within the troposphere of tropical North Africa. A near-correct quantification of these parameters will determine the accuracy, or otherwise, of parameterization schemes in climate models. The dynamics of these fluctuations has been examined with a linearised inviscid form of the hydrodynamical equations, solved in shear with the aid of a two-layer model of the atmosphere. Results confirm the existence of a non-amplifying westward-propagating mode of wavelength 400 km, phase speed 4.0 m s-1 and period of 28 hours.

Role of the Bering Strait on Thermohaline Circulation and Abrupt Climate Change

Aixue Hu and Gerald A. Meehl (NCAR), and Weiqing Han (University of Colorado)

Here we investigate the role of the Bering Strait (BS) in the thermohaline circulation (THC) response to added freshwater forcing (hosing) in the subpolar North Atlantic, through analyzing simulations of a fully coupled climate model with an open and closed BS. Results show that the THC declines similarly with an open and closed BS during hosing. However, the recovery of the THC is delayed by about a century in the closed BS simulation than in the open BS one after the hosing is off. The closed BS prevents the added freshwater being transported from the Atlantic into the Pacific via the Arctic as in the open BS case. Further, the freshwater supply is elevated significantly after the hosing by exporting the freshwater stored in the Arctic during hosing, as sea ice, back to the North Atlantic. This stabilizes the surface stratification there and suppresses the recovery of the deep convection.

Multi-Model Ensemble ENSO Prediction with CCSM and CFS

Dughong Min and Benjamin P. Kirtman (COLA)

Results are described from a large sample of coupled ocean-atmosphere retrospective forecasting during 1982-1998. The prediction system is based on the NCAR CCSM3 and a state of -the-art ocean data assimilation (ODA) made available by the NOAA GFDL. The retrospective forecasts are initialized each January and July of each year, and ensembles of six forecasts are run for each inital month. In generating the ensemble members, perturbations are added to the atmospheric initial state only.The skill of the prediction system is analyzed from both a deterministic and a probalilistic perspective from the preliminary outputs, and is compared to the operation NOAA CFS. For ENSO prediction the CCSM is arguably superior to the operation CFS. However, combining both models in to a multi-model ensemble is superior either model individually.

Chemistry-Climate Working Group

Fast Atmospheric Chemistry in CAM

Philip Cameron-Smith and Peter Connell (LLNL), and Jean-Francois Lamarque (NCAR)

We have implemented the LLNL fast chemical mechanism for the stratosphere as well as the troposphere and started to examine chemistry-climate interactions.

Climate Teleconnections Between Asian Aerosols and Other Regional Climates

Jason English (University of Colorado, Boulder)

Aerosols affect climate by absorbing and/or scattering shortwave and/or longwave radiation. In regions with high concentrations of aerosols, the radiative forcing may be very high. This Radiative Forcing may cause changes in atmospheric circulation which can alter climate in regions distant from the source. Simulations were conducted using CAM to model the effects of Aerosols on regional climate, specifically in regions outside of the aerosol perturbation. Simulations were conducted with current Asian Aerosol RF compared to RF with no aerosols of Asia and the teleconnections with other regional climates were investigated.

Coupled Climate Model Simulations to Bracket the Impacts of Increasing Asian Aerosols Emissions and Aggressive Clean Air Policies in the Future

Manvendra K. Dubey, Yongxin Zhang, Seth C. Olsen, Sumner H. Dean, and Petr Chylek (Los Alamos National Laboratory), Shan Sun and Rainer Bleck (NASA Goddard Institute for Space Studies), and Ulrike Lohmann (ETH Institute of Atmospheric and Climate Science)

We report ensemble simulations of the climatic impacts of changing anthropogenic aerosols (sulfate, organic and black carbon) using the NCAR CCSM3 and NASA-GISS-CGCM coupled models. We investigate two scenarios: 1) increased Asian (China and India) emissions by a factor of three over current levels and 2) a global reduction by a factor of ten.

Globally, the tripling of Asian emissions cools the global surface temperature by ~ -0.12°C and reduces global mean precipitation by ~ -0.8%. The global reduction of anthropogenic aerosols by a factor of ten warms the global surface temperatures by 0.4°C – 0.8°C and increases global mean precipitation by 3.0% – 3.3%. These changes occur less than 10 years after the perturbations takes place. Comparisons of NCAR CCSM3 and GISS-CGCM simulations also suggest that the indirect effects of aerosols are about 1-2 times the direct effects of aerosols.

Regionally, the tripling of Asian emissions results in cooling and a reduction in precipitation primarily in Asia, with cooling (warming) also noted over the high latitudes of Northern (Southern) Hemisphere. The warming and increase in precipitation associated with the global reduction of aerosols are concentrated mainly over polluted land areas in both hemispheres.

Our results provide insights into the climate model sensitivities for changes in aerosol forcings. They underscore the urgency of reducing greenhouse gas accumulation rates as the world reduces air pollution to improve human health and that potential increases in Asian aerosol pollution would likely offset only a small fraction of the warming by greenhouse gases.

Climate Variability Working Group

Coupled Atmosphere – Mixed Layer Ocean Response to the Kuroshio Extension Ocean Heat Transport Variation

Young-Oh Kwon (WHOI) and Clara Deser (NCAR)

We have investigated the winter atmosphere – ocean mixed layer response to ocean heat transport variations in the Kuroshio Extension to enhance our understanding of the mechanisms for extra-tropical decadal climate variability due to large-scale ocean-atmosphere interaction, of which the existence is suggested especially in the CCSM2. The ocean component in the CCSM2 is replaced by an array of simpler thermodynamic column ocean model with explicit mixed layer dynamics, and the decadal ocean geostrophic heat flux divergence anomalies diagnosed from the CCSM2 are specified in the Kuroshio Extension. The equilibrium responses to the Kuroshio Extension geostrophic heat flux convergence consist of warm SST, ocean-to-atmosphere surface heat flux, and baroclinic atmospheric pressure anomalies with low sea-level pressure. Pacific northern ITCZ shifts northwards in response to the Kuroshio Extension heating, and drives secondary responses in the North Pacific via the atmospheric teleconnection. The secondary responses due to tropical teleconnection are equivalent barotropic with high sea-level pressure anomalies, which interfere with the direct response to the Kuroshio Extension heating. The responses are also examined from experiments without any ocean model but with climatological SST boundary condition and specified SST anomalies in the Kuroshio Extension. The responses are similar to those of direct responses to the ocean heat flux convergence in the early winter but weaken much rapidly in the late winter and the responses in the downstream of the prescribed SST anomalies were incorrect because the ocean is not able to interact with the atmosphere.

Expansion of the Hadley Cell Under Global Warming

Jian Lu (NCAR), Gabriel Vecchi (GFDL/NOAA), and Thomas Reichler (University of Utah)

The Hadley Cell (HC) plays a pivotal role in the earth's climate by transporting energy and angular momentum poleward and by organizing the three dimensional tropical atmospheric circulation. Here, we investigate the response of the structure and intensity of the HC to green house gas (GHG) induced global warming by examining the A2 scenario simulations from the Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC). We find that there is a robust poleward expansion and weakening of the HC across most the AR4 models and try to identify possible mechanism for this behavior.

Influence of Mean Climate on Simulation of ENSO

Xiaohua Pan, J. Shukla, and Bohua Huang (George Mason University)

To what extent does the mean climate influence the simulation of the El Niño Southern Oscillation (ENSO) phenomenon? In this study, our hypothesis is that, with a better mean state, the simulation of interannual variability will be improved. A state-of-the-art coupled climate model, the Community Climate System Model Version 3.0 (CCSM3), is used for this study. An experiment designed to improve the simulation of mean climate in CCSM3 (hereafter referred to as Flx)is proposed. In this experiment, an empirical heat flux correction is applied to the surface heat flux into the ocean. The flux correction is time-independent while spatially varying over the global tropical region 30°S-30°N. The magnitude of the heat flux correction is proportional to the annual mean local SST error in the 100-year long-term climate control run (hereafter referred to as Contrl). The simulations of the annual mean, annual cycle and ENSO in Flx are compared with observations and Contrl to examine whether the mean climate has an impact on the simulation of ENSO.

Diagnosis of North American Hydroclimate Variability in IPCC's Climate Simulations

Alfredo Ruiz-Barradas and Sumant Nigam (University of Maryland)

The annual cycle of precipitation, as well as interannual variability of North American hydroclimate during summer months are analyzed in coupled simulations of the 20th century climate. The state-of-the-art general circulation models, participating in the 4th Assessment Report for the IPCC, included in the present study are the American's CCSM3, PCM, GISS-EH, and GFDL-CM2.1; the British UMKO-HadCM3, and the Japanese MIROC3.2(hires). Data sets with proven high quality such as NCEP's North American Regional Reanalysis, and CPC's US-Mexico precipitation analysis are used as targets for simulations.

Climatological precipitation is not easily simulated. While models capture winter precipitation very well over the US northwest, they are challenged over the US southeast in the same season, and over central US and Mexico during summer.

Models' potential in simulating interannual hydroclimate variability over North America during the warm-season is varied and limited to the central US. Models like PCM, and in particular UKMO-HadCM3, exhibit reasonably well the observed distribution and relative importance of remote versus local contributions to precipitation variability over the region. However, in models like CCSM3 and GFDL-CM2.1 local contributions dominate over remote ones, in contrast with warm-season observations. In the other extreme are models like GISS-EH and MIROC3.2(hires) that prioritize the remote influence of moisture fluxes and neglect the local influence of evaporation to the regional precipitation variability.

The significance of SST linkages, in the context of interannual variability of precipitation over the Great Plains, is highlighted by a coherent basin-scale structure resembling the Pacific Decadal variability pattern in observations; the UKMO-HadCM3 model is the one that best reproduces such SST structure.

Climate Model Fidelity: A Tool to Constrain Projections of Climate Change?

Simon C. Scherrer (NCAR)

The idea to constrain the uncertainty in climate model projections using some kind of measure for model fidelity is not new and rather controversial. A recent study by Shukla et al. (2006) using IPCC AR4 model runs indicates that the models which represent today's climate variability and seasonal cycle better exhibit larger changes in 21st century temperatures than the worse models. Here, we explore what we can learn from relating climate model fidelity with projections of climate change. We will show that there are some robust relations between climate model fidelity and change amplitudes for temperature on the regional to global scale. On the grid point scale however, model errors seem unsystematic (random) even for temperature and the skill-change relations primarily related to model biases. We argue that this might be the main reason why the multi-model mean is performing so well in representing today's climate. We will emphasize the relation between errors and changes with a special focus on Northern Hemisphere sea ice and snow pack and their representation in the AR4 models.

NCAR Command Language

Dennis Shea, Christine Shields, and Mary Haley (NCAR) and NCAR VETS

The NCAR Command Language (NCL) is a free interpreted language designed specifically for scientific data processing and visualization. NCL has robust file input and output. It can read in netCDF, HDF4, HDF4-EOS, GRIB1, GRIB2, binary and ASCII data. The graphics are high quality and very customizable.
NCL runs on many different operating systems including Solaris, AIX, IRIX, Linux, MacOSX, Dec Alpha, and Cygwin/X running on Windows. It's available for free in binary format.
The power and utility of the language are evident in three areas:

* file input and output
* data analysis
* visualization

NCL has many features common to modern programming languages, including types, variables, operators, expressions, conditional statements, loops, and functions and procedures.
In addition to common programming features, NCL also has features that are not found in other programming languages, including features that handle the manipulation of metadata, the configuration of the visualizations, the import of data from a variety of data formats, and an algebra that supports array operations.
NCL comes with many useful built-in functions and procedures for processing and manipulating data. There are over 600 functions and procedures that include routines for:

* use specifically with climate and model data
* computing empirical orthogonal functions, Fourier coefficients, singular value decomposition, statistics, etc
* retrieving and converting date information
* drawing primitives (lines, filled areas, and markers), wind barbs, weather map symbols, isosurfaces, and other graphical objects
* robust file handling
* 1-dimensional, 2-dimensional, and 3-dimensional interpolation, approximation, and regridding
* facilitating computer analysis of scalar and vector global geophysical quantities (many based on the package known as Spherepack)

NCL supports calling C and Fortran external routines, which makes NCL infinitely configurable.
NCL uses several other publicly-available software packages and databases for some of its file I/O, data analyses routines, and high-resolution coastlines.

Great Plains Low-Level Jet Variability in the CAM3

Scott Weaver and Sumant Nigam (University of Maryland)

Recently Great Plains low-level jet (GPLLJ) variability mechanisms have been characterized using the high spatiotemporal resolution and precipitation assimilating North American Regional Reanalysis (NARR). GPLLJ index and EOF based analysis on warm season low-level flow over the Great Plains reveals three primary modes of variability that are connected to large-scale circulation variations with substantial hydroclimate impacts.
The sensitivity of precipitation impacts to the placement and strength of the GPLLJ calls for the characterization of the ability of CAM3 to represent this important regional climate feature. Jet variability is characterized in the CAM3 through GPLLJ index regressions on circulation and precipitation, using the NARR results as a benchmark. While some climatological features of the GPLLJ and large-scale circulation are captured, the depiction of GPLLJ interannual variability is lacking in the CAM3.
The strong correlation between the strength of the GPLLJ and precipitation noted in observational

analyses is also investigated to determine if the GPLLJ/precipitation linkage is captured in the CAM3. Does the poor representation of jet variability transfer to the depiction of Great Plains precipitation variations? Analysis of GPLLJ and precipitation anomaly correlations reveals that this important hydroclimate connection is not robust in the CAM3. It is reasoned that these deficiencies may be linked to topographic representation and/or convective parameterization issues.

Addressing Tropical Biases in GFDL's Global Coupled Climate Models

Andrew Wittenberg (NOAA/GFDL)

Global coupled GCMs from the Geophysical Fluid Dynamics Laboratory (GFDL) have performed well in recent model intercomparisons connected with the IPCC Fourth Assessment. But like all current CGCMs run without flux adjustments, the GFDL models retain substantial biases in their simulated tropical climate and variability. GFDL has taken three new avenues to meet these challenges. First, intercomparisons with our peer models in the IPCC AR4 archive, which are clarifying key sensitivities, such as ENSO's sensitivity to the spatial structure of the wind stress response to SST anomalies. The second avenue is a suite of automated diagnostics -- including climatological comparisons with multiple observational products, ENSO regressions to measure air-sea coupling and heat flux damping, correlations with local SSTs to gauge local feedbacks, and wavelet diagnostics to evaluate model spectra -- that provide helpful summary metrics for rapid assessment of coupled and uncoupled simulations.
The third approach is a hybrid coupled model framework -- consisting of the CGCM ocean component coupled to a statistical atmosphere that has been fit to a long run of the CGCM -- which provides an efficient and controllable testbed for isolating coupled sensitivities, intercomparing CGCMs, evaluating new oceanic and atmospheric components, and exploring how climatological biases affect model variability. Together, these three avenues are establishing clear links among CGCMs, intermediate models, and ENSO theory, advancing our understanding of tropical climate and variability and ultimately helping to improve the models used to simulate and predict them.

Using a Two-Oscillator View to Examine the CGCM Deficiency in ENSO

Jin-Yi Yu, Hsun-Ying Kao, and Fengpeng Sun (University of California, Irvine)

By analyzing ENSO persistence barrier in the past four decades (1958-2001), we propose that the ENSO cycle consists of two different oscillators: a central Pacific oscillator which is forced by atmospheric forcing and an eastern Pacific oscillator which is resulted from the air-sea interaction involving the thermocline variation in the cold tongue. When the basic state (such as the thermocline depth) changes, the eastern Pacific oscillator is affected and its onset time changes from decadal to decade. But the western Pacific oscillator is not sensitive to the thermocline depth and maintains its onset time in Spring. As a result, ENSO SST anomalies propagates from eastern to central Pacific in some decades (e.g., before 1976/77) but from central to eastern Pacific in the other decades (e.g., after 1976/77). This view is used to explain the excessive biennial tendency in the NCAR CCSM3's ENSO simulations. We argue that because the CCSM can not produce the annual cycle of the eastern Pacific cold tongue, this model can not produce the eastern Pacific oscillator. In stead, the ENSO cycle produce by the CCSM is dominated by the central Pacific oscillator. In the CCSM, this oscillator is over sensitive to the forcing from Indian monsoon and becomes too strong in the biennial timescale. Based on our view, the excessive biennial ENSO tendency in the CCSM is a separate issue from the lack of a low-frequency (~4 years) component of ENSO in the model. Reducing the biennial ENSO does not necessary lead to the production of a stronger 4-year ENSO. The lack of the 4-year ENSO component is tied to the model performance of cold tongue simulation. The excessive 2-year ENSO component is tied to the model performance of monsoon simulation. Evidences from observational analyses and a series of basin-coupled experiments with the CCSM will be presented to support our view.

Land Model Working Group

What Factors Influence GPP Variability in North America?

Ian Baker, Dave Thompson, Neil Suits and A. Scott Denning (Colorado State University)

We simulate the North American terrestrial biosphere for 20 years (1982-2001) with the Simple Biosphere Model (SiB3) and evaluate variability in Gross Primary Productivity (GPP) in space and time. Anomalies in simulated GPP is dependent on fluctuations in meteorological parameters such as temperature and precipitation, but the seasonality or timing of the variability in the forcing plays a role as well. We attempt to construct mechanistic descriptions of GPP variability (i.e. enhanced GPP in response to anomalously high precipitation or low temperature) and link these mechanisms to modes of climate variability such as ENSO or NAO where possible.

Inclusion of a Semi-arid Shrub Sub-model and a New Formulation for Underground Water in CLM-DGVM

Michael Barlage, Xubin Zeng, Mark Decker, Koichi Sakaguchi, and Xiaodong Zeng (University of Arizona)

CLM-related projects in the Land-Atmosphere-Ocean Interactions group at The University of Arizona are presented. These consist of: (1) A shrub sub-model for DGVM which can grow shrubs in semi-arid regions. A 400-year simulation cycling recent forcing conditions produces PFT percentages that compare well with MODIS-based observations. Simulated shrub coverage peaks around an annual precipitation of 300 mm, grass around 400-1100 mm, and tree at 1500 mm or higher, all in good agreement with MODIS data; (2) A new formulation of Richards equation for underground water transport along with a new water table depth scheme has been added to CLM3.5. A 35-year simulation is compared to in-situ observations and GRACE data; (3) A comparison is presented between CLM output with the above two model changes and flux measurements, and surface and vegetation characteristics over the Walnut Gulch Experimental Site in Southwestern Arizona.

Extreme Hydrologic Events in CCSM3

Marcia Branstetter (ORNL)

One of the key questions is whether the extremes in weather phenomena such as floods and droughts will increase in the future along with increasing global average temperatures. Daily and monthly results from a set of ensemble simulations from the Community Climate System Model (CCSM3) were analyzed to detect extreme highs and lows over a hundred year period from 2000-2100. The ensemble of simulations was from an IPCC A2 climate change scenario. The number of extreme highs in daily precipitation was significantly higher during the latter part of the simulation period in some regions. This period also showed a significant change in runoff during the later years, wetter some places and drier other places. When combined with population data, the human impact of the precipitation extremes becomes more clear. Highlights of such a study for South America point out certain regions of the continent that could experience particular problems. Preliminary results for the Darfur region of Sudan point out the variation in rainfall and extremes within the region.

Developing a Microwave Simulator for Common Land Model

Huilin Gao, Haishan Chen, Rong Fu, and Robert Dickinson (Georgia Institute of Technology)

Climate modeling is essential for 21st century projections; however, how well these models can adequately simulate past climate changes, especially over the regions where in situ observations are sparse, remain unclear. Decades of satellite data has the unique potential to help address this problem. In spite of this, satellite products often vary between different datasets and sensors due to different retrieval algorithms and parameterizations and orbital and instrumentation differences. To minimize these discrepancies among different dataset and between retrieved data and climate model, we have developed a prototype microwave simulator for Common Land Model. With this simulator, we can fly various microwave sensors in climate model according to their orbital and viewing information.
The Community Microwave Emission Model (CMEM), which is constructed and tested by European Center for Medium-Range Weather Forecasting (ECMWF), is implemented to CLM for generating microwave outputs. ARM Oklahoma CART field observation data are used to help calibrate the CMEM. The CLM is forced by a 50-yr high resolution meteorological forcing (1950-2000) globally. The emission model is set to generate multi-frequency radiances to mimic satellite observations such as TRMM Microwave Imager (TMI), Special Sensor Microwave Imager (SSM/I), and Aqua Advanced Microwave Scanning Radiometer – EOSA (MSR-E). The comparisons between modeled and observed radiances indicate modeling skills of outputs (e.g. soil moisture, surface temperature, etc.) according to satellite sensor characteristics. This study demonstrates some preliminary comparisons between observed and modeled radiances.

A strategy for Climate Change Stabilization Experiments

Kathy Hibbard and Gerald A. Meehl (NCAR), Peter Cox (University Exeter) Pierre Friedliengstein (IPSL, France)

Climate models used for climate change projections are on the threshold of including much greater biological and chemical detail. Today, standard climate models (referred to generically as atmosphere-ocean general circulation models, or AOGCMs) include components that simulate the coupled atmosphere, ocean, land and sea ice. Some modeling centers are now incorporating carbon cycle models into AOGCMs in a move towards an Earth System Model (ESM) capability. Additional candidate components for ESMs include aerosols, chemistry, ice sheets and dynamic vegetation. We present a strategy for the use of climate system models as a part of an overall assessment approach. The motivation is to develop a next-generation experimental design following from the scenario approach used in the last several IPCC reports. We specifically address recent developments in climate system models can shed light on greenhouse emission scenarios. Complementary aspects of ongoing model development (e.g., observations and paleoclimate experiments) are important components of a much larger research strategy of which the modeling approach proposed here is one part.

Aerosol Impacts on CLouds and Rainfall Over China: Land vs. Ocean

Menglin Jin (University of Maryland)

This paper provides a prototype study on combining the advanced satellite observations of rainfall, clouds, and aerosol to address rainfall variations induced by aerosol indirect effect. Monthly satellite observations from the Tropical Rainfall Measuring Mission (TRMM) and Moderate

Resolution Imaging Spectroradiometer (MODIS) for Julys of 2000-2005 were analyzed to assess how urban aerosols affect clouds and rainfall over east China and off China sea. Over ocean, at the monthly scale, in July, the aerosol-cloud relation is evident for both light and heavy rainfall events, namely, the cloud effective radius decreases with the increase of aerosol optical thickness (AOT). However, only a weak aerosol-rainfall relation is detectable during light rainfall cases (i.e., rainfall rate the contrary, over land, cloud effective radius did not show any evident relation with the change of aerosols, suggesting that aerosol process is not the only physical process affecting clouds, and that dynamic processes such as convection may play an equally critical role to compensate the effects of aerosols on clouds. The different features of aerosolsâ~@~Y effects over land versus ocean further reveal the complexity of aerosol-cloud-rainfall interaction.

Modeling the Climate Impacts of the Land Surface in CCSM

Peter J Lawrence and Thomas N Chase (CIRES, University of Colorado)

We present the relationships found between the land surface, land cover change, and the climate in the Community Climate System Model through a series of experiments that investigate the effect of: 1) Globally describing the land surface from NASA Earth Observing System (EOS) satellite imagery in the Community Land Model (CLM 3.0) ; 2) Addressing hydrology issues in the CLM 3.0 model that enable evapo-transpiration fluxes to be simulated in the model consistently with those observed in the real world and in other land surface models; and 3) Perform global climate sensitivity experiments with the CCSM with altered land surface parameters that represent the influence of the land cover change on global and regional climate.

Evaluating Modeled Vegetation Phenology over North American Continent with Satellite and Ground-based Observations

Lixin Lu, Reto Stockli, and Scott Denning (Colorado State University), Peter Thornton (NCAR), and Jeff Morisette (NASA)

The land-atmosphere interface plays an important role in the coupled water and carbon cycle as part of the global climate system. Knowledge about the strong seasonal and interannual variability of vegetation phenology (e.g. leaf area index, LAI) and its spatial heterogeneity influences our ability to forecast short-term weather and seasonal climate. Therefore a prognostic simulation of vegetation phenology in response to climate variability and change is needed in today's ecosystem models for use in future earth system models.
Three existing prognostic phenology models are selected to simulate vegetation growth: the Community Land Model version 3 CLM3-CN, CLM3-DGVM, and the Simple Biosphere Model Version 2.5 with the Growth Season Index (SiB2.5-GSI). Off-line model simulations over North America are carried out at 32-km grid spacing by use of the North American Regional Reanalysis (NARR) product. The modeled Carbon, Water and Energy fluxes are validated with measurements from the AmeriFlux network. Both, ground-based LAI measurements (at points) and satellite remote sensing NDVI and FPAR (spatially resolved) will be used to evaluate the modeled prognostic vegetation phenology in response to seasonal to interannual climatic forcings.
Our ultimate goal is to build a globally-applicable vegetation modeling system with prognostic vegetation phenology for use in earth system models. In an outlook we provide insight in our MODIS - based satellite remote sensing data assimilation system which will hopefully be able to address the strong spatial heterogeneity, the seasonal and interannual variability of vegetation distribution and its associated biophysical parameters within the terrestrial water and carbon cycle.

Evaluation of Soil Temperature Climatology derived from simulations with the fully coupled Community Climate System Model version 3.0 over Russia

Debasish Pai Mazumder, Zhao Li, and Nicole Mölders (University of Alaska, Fairbanks)

Accurate prediction of soil temperatures, freezing and thawing of the active layer depth is essential for ecosystem, biogeochemical and hydrologic process studies in high latitudes. Soil temperature simulated at different depths by Community Climate System Model Version 3.0 (CCSM3.0) is evaluated over Russia for three climate episodes (1951-1980, 1961-1990, and 1971-2000) by means of the observations provided by the National Snow Ice Data Centre (NSIDC), and Global Precipitation Climatology Centre (GPCC) and the European Centre for Medium-Range Weather Forecasts reanalysis (ERA40) data. CCSM3.0 well captures the annual phase of soil temperature, but not the amplitude. It predicts slightly too high (low) soil temperature in winter (summer). Root mean square errors (RMSE), on average, are less than 5K. The evaluation shows that the simulated atmospheric temperature forcing contributes to, but is not the main cause for the discrepancy in soil temperature simulation. Errors in simulated precipitation may cause the underestimation of soil temperature in summer. Overestimation of snow depth may contribute to the overestimation of soil temperature in winter. A sensitivity study with slightly altered plant functional types in some part of Russia reveals that differences in vegetation in the model and real world marginally contribute to soil temperature discrepancies. A 10% differences in the percentage of sand and clay, however, can lead to discrepancies between simulated and observed soil temperature. The study shows that soils with high organic components cannot be accurately simulated with soil parameters of mineral soils.
The lower boundary conditions of the model also have great impact on the overall performance of the model. An accurate prediction of the soil temperature requires an accurate lower boundary condition and stability between the precision and the computational time of the model.

Ocean Model Working Group

Ocean Anoxic Events in the mid-Cretaceous Simulated by a 3-D biogeochemical General Circulation Model

Kazuhiro Misumi (Central Research Institute of Electric Power Industry) and Yasuhiro Yamanaka (Hokkaido University)

The mid-Cretaceous is well known for its ocean anoxic events. The causal mechanisms are controversial: stagnant deepwater, high biological productivity in the surface waters, and other possibilities have been suggested. Our study simulated the mid-Cretaceous ocean, using general circulation models combined with a marine biogeochemical cycle model to explore the relationship between thermohaline circulation and biogeochemical cycles and investigate the causes of ocean anoxic events. The simulated thermohaline circulation shows an unsteady inactive state. Oxygen concentrations in the deepwater decrease under the inactive state, but a horizontal gradient develops with higher oxygen concentrations in the Tethys and lower concentrations in eastern Panthalassa. This is not due to the different ages of the deepwater but rather to the differences in biological productivity in the surface water, meaning that the relationship between thermohaline circulation and biogeochemical cycles under the inactive state is different from that in the present ocean. In the standard simulation, assuming the present level of the total amount of phosphate in the ocean, 29 % of the bottom water is anoxic. The experiments increasing the amount of phosphate show its high sensitivity for extending the anoxic region with global-scale anoxia simulated under the doubled amount of phosphate. The high amount of phosphate would be reasonable because the inactive state would induce an imbalance of phosphate between riverine input and sediment output. Therefore, both the inactive thermohaline circulation and the increase in

the total amount of phosphate in the ocean induce the global-scale anoxic condition in the deepwater.

Do Zonal Jets in the World Oceans Interact with Wind-Driven Gyres?

Balu Nadiga (LANL) and David Straub (McGill)

We have previously proposed a model for alternating zonal jets that have recently been observed in the world oceans. Here we investigate the interaction of wind-driven gyres with zonal jets in the context of this model. We find that scale-separation between the two types of circulation can allow them to coexist without significant interaction.

Global Warming Experiment with a High-resolution Global Ocean and Sea Ice Coupled Model

Hyei-Sun Park, Norikazu Nakashiki, and Yoshikatsu Yoshida (Central Research Institute of Electric Power Industry), Frank O. Bryan (NCAR)

The high-resolution global ocean and sea ice coupled model is introduced for climate study purposes. The ocean model is the high-resolution version of POP with a nominal horizontal grid of 1/10 degree and 40 levels. The North Pole of the model is shifted on the Hudson Bay to avoid the numerical singularity of the grid. The sea ice model is CSIM. The horizontal grid structure of the sea ice model is identical to that used in the ocean model.
Global warming experiment is carried out using the high-resolution ocean and sea ice coupled model. Daily forcing is given from the results of the A1B and 20th century experiments with the medium resolution CCSM3 (T85 atmosphere/land and 1 degree ocean/sea ice). At the time of this writing, the model has been integrated for only 2 and half model years on Earth Simulator and NEC SX-8 in CRIEPI. We want to investigate the effects of the eddy-resolving model, even though the integration is too short.

Modeled Regime-Shifts in the North Pacific

Tom (Zack) Powell (UC, Berkeley), Bill Large (NCAR), Steve Yeager (NCAR), Enrique Curchitser and Dale Haidvogel (Rutgers University)

Previous studies have shown multi-decadal, regime-shift-like features in North Pacific sea-surface temperatures. SST was obtained from model solutions derived from the fully-coupled, global Community Climate System Model, version 3.0 (CCSM3). Using an algorithm of Rodionov we explored the effect of model atmosphere resolution on quantities used to determine the regime-shift. Contrasting a high spatial resolution atmospheric calculation (T85, ca. 1.5 deg) with a lower resolution atmospheric formulation (T42, ca. 3 deg), the dominant spatial and temporal patterns (first and second EOFs, and amplitude time-series) agreed closely. However, the high resolution results showed substantially more temporal variability in the strength of the dominant patterns.

Stastical Analysis of the Interannual and Decadal Climate Variability in the Western Pacific

Yu-heng Tseng and Pei-yuan Hshieh (National Taiwan University)

The interannual and decadal climate variability in the western Pacific is statistically analyzed using the satellite data and ECMWF reanalysis. Regional warming is detected by the long term (more than 40 years) climate variables, such as temperature, total column water vapor and wind speed trends. The composite and correlation analysis is used to analyze the anomalies of western Pacific during the damp seasons. Using the temperature and wind speed as the predictors, our multivariate analysis constructs a linear model to forecast the quantity of the local total column water vapor. Empirical Orthogonal Functions (EOF) is used to demonstrate the spatial patterns of climate change in the western Pacific. Singular Value Decomposition (SVD) further shows the covariance between the regional warming fingerprint detection variable fields. Finally, we use the traditional cluster analysis to classify the fields into several regions which can represent the local climate characteristics. Large difference in the water vapor is affected by the temperature and wind speed in the focused areas.

Tracer Distributions in the POP

Daisuke Tsumune of the Central Research Institute of Electric Power Industry

137Cs concentrations are simulated in a global integration of the Parallel Ocean Program (POP) to understand the mechanism of material transport in the ocean, and to assess the skill of an ocean general circulation model in comparison with observational database. Simulated 137Cs concentrations were compared with the Historical Artificial Radionuclides in the Pacific Ocean and its Marginal Seas , HAM database from 1960s to 2000s for 5 decades. Existing of long-term historical database of 137Cs is one of grate advantages for the assessment of models. The vertical and horizontal distributions of the calculated 137Cs concentrations were in better agreement with those of the observed 137Cs concentrations in each decade.

The LANS-alpha Turbulence Model in a Primitive Equation Ocean Model

Mark R. Petersen, Matthew W. Hecht, Darryl D. Holm, and Beth A. Wingate (Los Alamos National Laboratory)

POP, the Parallel Ocean Program developed and maintained at LANL, is widely used by the ocean and climate modeling community. Like all numerical models, computational time limits the spatial resolution at which POP can operate; standard simulations use grids of 0.5 to 1 degree in latitude and longitude. This resolution does not capture the motion of eddies at the Rossby radius of deformation, and thus lacks the correct energy cascade and heat transport at these scales. The Lagrangian-Averaged Navier-Stokes alpha (LANS-alpha) model, developed by Darryl Holm and colleagues at LANL, improves these characteristics with a smoothed advecting velocity and an additional nonlinear term. Results from an idealized channel domain show that the POP-alpha model improves measures that depend on the resolution of mesoscale eddies, such as vertical temperature profile, kinetic energy, and eddy kinetic energy. In some cases these improvements are comparable to a doubling of horizontal resolution, which increases computation by a factor of ten, while the addition of the alpha model parameterization only adds ~30% in computational time.

Regime Shift, Deep Flow

Richard D. Smith (NCAR) and Matthew Hecht (LANL)

We review evidence that, upon reaching 1/10th degree there is a regime shift and the circulation is much closer to what is observed. There are three distinct reasons to expect a regime shift: 1) we resolve the mesoscale; 2) we resolve the topography; and 3) the eddies (the mesoscale) dominate the flow. We launch an investigation into the Deep Flow of the World Ocean based on transport in density classes corresponding to a given isooycnal layer.

Paleoclimate Working Group

Climate conditions in Sweden in a 100,000 year time perspective

Jenny Brandefelt (Stockholm University), Erik Kjellstrom (Swedish Meteorological and Hydrological Institute), Jens-Ove Naslund (Swedish Nuclear Fuel and Waste Management Co.,) Gustav Strandberg (Swedish Meteorological and Hydrological Institute), Barbara Wohlfarth (Stockholm University)

The Swedish Nuclear Fuel and Waste Management Company is planning to build a final repository for all spent nuclear fuel. The radioactivity of the spent fuel will decline to a level that is harmless for biological life in 100,000 years. To explore possible extreme climates that could occur during the coming 100,000 years, global and regional climate simulations are performed. Three cases of extreme climate conditions for Sweden are explored; i) a cold climate with an extensive ice sheet over Scandinavia, ii) a cold climate with permafrost in Southern Sweden and, iii) a warm climate in which the Greenland ice sheet is assumed to have melted. The simulated cold climates will be compared to paleo data from equivalent periods during the last 100,000 years; i) the last glacial maximum around 21 kyr BP and ii) a period within Oxygen Isotope Stage 3 or 2. Some results from the global simulations are shown.

Error Reduction and Convergence in Climate Prediction

Charles Jackson and Mrinal Sen (University of Texas), Gabriel Huerta (University of New Mexico), Yi Deng (AIR Worldwide Corp.), and Ken Bowman (Texas A&M University)

Although climate models have steadily improved their ability to reproduce the observed climate, over the years there has been little change to the wide range of sensitivities exhibited by different models to a doubling of atmospheric CO2 concentrations. We use stochastic optimization to mimic how six independent climate model development efforts might use the same atmospheric general circulation model, set of observational constraints, and model skill criteria to choose different settings for parameters thought to be important sources of uncertainty. As compared to the default model sensitivity of 2.4ºC, each optimized model improved global skill scores by a similar 7% and had nearly identical 3ºC sensitivities, but with different regional responses. The implication is that current generation models are close to a critical level of skill enabling more convergent predictions of change at the largest scales even though regional differences persist.

Hysteresis of Temperature and Surface Energy Fluxes in the IPCC AR4 Model Runs

Daniel Kirk-Davidoff (University of Maryland) and Axel Kleidon (Max Plank Institute for Biogeochemistry)

Couple climate models exhibit a wide range of climate sensitivities. Further, their equilibrium and transient climate sensitivities are poorly correlated, indicating a wide range of effective heat capacties. In this study we use the hysteresis of surface energy fluxes and surface temperatures as a proxy for heat capacity, and compare the spatial distribution of hysteresis among the IPCC AR4 control runs with patterns calculated from reanalysis data.

Using Climate Model Simulations and Data to Understand the Sensitivity to Magnitude and Location of Freshwater Forcings During the Last Deglaciation

Bette L. Otto-Bliesner, Esther C. Brady, Bruce Briegleb, and Nan Rosenbloom (NCAR)

Proxy records indicate that the locations and magnitudes of freshwater forcings to the Atlantic Ocean basin as iceberg discharges into the high-latitude North Atlantic, Laurentide meltwater input to the Gulf of Mexico, or meltwater diversion to the North Atlantic via the St. Lawrence River and other eastern outlets may have influenced the responses of the North Atlantic thermohaline circulation and global climate. Meltwater pulse 1a was associated with significant sea level rise but only a slowdown of Atlantic meridional overturning circulation (MOC), while Heinrich event 1 has less evidence of rapid sea level rise but was marked by near collapse of the MOC. Simulations have been performed with the NCAR Community Climate System Model (CCSM3) in which the magnitude of the freshwater forcing has been varied from 0.1 to 1 Sv and inserted either into the northern North Atlantic Ocean or the Gulf of Mexico. These results show interesting differences in terms of the regional and seasonal responses and the temporal behavior during and after the freshwater event. Implications for detection in proxy records during the last deglaciation will be discussed.

Curvature of Monsoonal Winds over Pangea: A New Paleolatitude Indicator?

Clinton M. Rowe, Robert J. Oglesby, and David B. Loope (University of Nebraska, Lincoln)

Wind-blown sandstones cover large portions of the Colorado Plateau of the southwestern US. These Early Permian through Early Jurassic sandstones reflect transverse dunes that migrated under a distinctive wind regime that varied little in direction through their 100 Myr span. In the north, the dominant winds came from the NE, curving to NW over the southern portion of the plateau. The dunes in the south also reflect a seasonal wind reversal; during much of the year, slightly weaker winds were from the SE. Conventional wisdom, largely based on paleomagnetic evidence, has the Plateau located just north of the equator during the Early Permian, moving north through the Triassic to between 10° and 20°N by the Early Jurassic. Yet the wind regime that formed the dunes appears to have stayed relatively constant, suggesting that the dunes stayed within the same climatic zone. To investigate the climatic controls that may have forced the paleodunes, we made climate simulations for the early Jurassic using the NCAR CCSM3. These simulations yield a strong, hemispherically symmetric monsoon. A zone where northeasterlies (trade winds) curve southward to become northwesterly is clearly identified and coincides with the key features of the paleodunes. This regime, however,occurs between 10° and 20°S, not 10-20°N as suggested by paleomagnetic-based reconstructions. Assuming the winds inferred from the sandstones are correct, either the climate model is very wrong or the northward movement of the Colorado Plateau occurred much later than suggested by current paleogeographic reconstructions.

Using CCSM3 to explore mechanisms for high-latitude warmth at the PETM

Cindy Shellito (University of Northern California), Jeff Kiehl of NCAR, Jean-Francois Lamarque (NCAR), Lisa Sloan (University of California, Santa Cruz)

The Paleocene-Eocene Thermal Maximum (PETM) at ~55.5 million years ago represents at least one interval of very rapid warming during the early Cenozoic. The likely source of this warming was a combination of volcanic activity and a release of methane from hydrates in continental shelves. New data from the Arctic Ocean suggests that summer sea surface temperatures warmed from ~18C to 23C during this interval. So far, climate models have been unable to produce the high Arctic temperatures that were present even before the PETM. Here, we present preliminary results from a new study with Eocene boundary conditions in CCSM3. We test the model sensitivity to a quadrupling of pCO2, from 560 to 2240 ppm, and we examine the sensitivity of Arctic climate to a variation in Arctic basin geography. At 250 years integration, model output indicates a 3.4C warming in the annual average global mean temperature due to the increase in pCO2, with the largest warming in the high-latitudes. Arctic summertime average temperature is still much cooler than proxy estimates, at 3C (560 ppm) and 7-8C (2240 ppm), however, the change in temperature from low to high pCO2 is consistent with proxy estimates for the change across the PETM. Opening an ocean passageway from the Pacific warms the Arctic summer by an additional ~5.5C in the 2240 ppm scenario.

Simulations of the Permian (251 Ma) Monsoon Using CCSM3 (Community Climate System Model, Version 3)

C.A. Shields and J.T. Kiehl (NCAR)

Monsoon dynamics are evaluated for the late Permian (251 Ma) period using the Community Climate System Model, version 3 (CCSM3). Sensitivity experiments have been conducted to test the role of land masses in affecting the monsoon. Both the fully coupled model as well as the atmosphere-only model, Community Atmospheric Model, version 3 (CAM3), are used in this study. The atmospheric response to a removal of the northern hemisphere Pangean peninsula is tested using CAM3. The oceanic response is evaluated by running the fully coupled CCSM3 with not only the northern hemisphere peninsula removed, but the Teyths Ocean equatorial islands removed as well. We find that the fundemental mechanism driving the northern hemisphere Permian monsoon is the location of the sea surface temperature warm pool and not the strength of the land-sea temperature gradient.

Dynamics of Carbon Release and Sequestration during Two Early Eocene Hyperthermals

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In this study we evaluate our theoretical understanding of the complex processes that govern the carbon cycle, and test the sensitivity of coupled climate/biogeochemical models to extreme forcing. We focus on carbon cycle perturbations at the Paleocene-Eocene boundary (55 Mya), referred to as the Paleocene-Eocene Thermal Maximum (PETM). The PETM was accompanied by the release of ~4000 PgC over a period significantly shorter than the residence time of carbon in the ocean (3.0 negative carbon isotope excursion as recorded in marine and terrestrial fossils (e.g. Kelly et al., 1996; Koch et al., 1992) temporally coupled with a worldwide seafloor carbonate dissolution horizon. The climatic impacts of this greenhouse forcing were significant. Sea-surface temperatures (SST) increased by 5°C in the northern high latitudes, 6-8°C in the Southern Ocean and up to 5-8°C in tropical and mid-latitudes.
Implications for the carbon cycle and future modeling strategies are discussed.

Echo of Miocene Climate Optimum in 100-200 years

John You, Nick Herold, Judy Tong, Dietmar Muller and Maria Sdrolias (University of Sydney)

If the predicted global temperature increase of 1-6.3 C by recently released IPCC 4th report is realized by 21st century, the climate situation will be reminiscent of the Miocene Climate Optimum (MCO) occurred in most recent geological history about 15 ma with a maximum temperature of

also about 6 C higher than present. Our study is motivated to make comparison of past (MCO), present and future climate so that we would better understand the mechanism and interplay of human activity with future climate. Here we present results from compilation of proxies and applying NCAR models, especially the contribution of vegetation and changes of sea level and topography.

Polar Climate Working Group

Dynamical systems approach to characterize climate for comparing models to observations

Uma Bhatt, David Newman, Igor Polyakov, and Renate Wackerbauer (University of Alaska, Fairbanks), and Raul Sanchez (ORNL)

Now that the IPCC fourth assessment is finished, the next step is to look hard at our models and evaluate the key processes that we need to improve for the next generation of climate models. To this end, we apply tools from a dynamical systems approach that are designed to probe the temporal dynamics inherent in a time series. These methods provide additional information than what can be obtained from our standard set of climate evaluation methods. Hurst's R/S analysis is one such method that is able to detect differences in the ordering of the time series and make the correlations hidden within them apparent. We will present results that evaluate a suite of CCSM3 simulations and observations using R/S analysis to determine to what extent the model captures the long term dynamics of the real climate systems.

Water Vapor and Cloud Liquid Water Paths over the Northern High Latitudes

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Data from the Special Sensor Microwave Imager, Advanced Microwave Scanning Radiometer, and a surface-based radiometer at Barrow, Alaska are examined for insights into the behavior of water vapor and cloud liquid water over the northern high latitudes. Two satellite retrieval algorithm sets are combined; one contains monthly-mean sea ice fractions, the other contains sea-ice-screened water vapor path (WVP) and cloud liquid water path (LWP) retrievals.
The Wentz water vapor path (WVP) retrieval shows no sensitivity to a proxy for sub-pixel sea ice presence, while the Wentz liquid water path (LWP) retrievals are sensitive to sea ice presence during summertime when atmospheric variability is high but otherwise their sea-ice screening appears effective. The seasonal cycle and 1987-2006 time trends are examined. The WVP annual cycle has an amplitude of 1 cm with a July maximum phasing that is consistent with a continental influence. The springtime LWP increase usually occurs in tandem with the WVP increase and slightly lags the falltime WVP decrease. The maximum lag occurs over the northern Pacific, where the maximum LWP occurs in August, one month later than over the northern Atlantic. The strongest SSMI-derived trend is an increase in wintertime moisture south and southwest of Greenland. An interesting feature is a falltime increase in WVP and LWP north of the Bering Strait which we believe to be real, mostly occurring between 1989-2001, with a subsequent decrease in recent years.
It is hoped that the information on the seasonal cycle may be useful for model evaluation.

Software Engineering Working Group

CAM Performance on Intel-based Clusters

Dmitry Shkurko (Intel Corporation) and Patrick Worley (ORNL)

The Community Atmosphere Model (CAM) was ported to and performance was optimized on two clusters using Intel processors and Infiniband interconnects. In particular, Intel compilers were shown to be successful and effective when porting and optimizing CAM. Optimal compiler and code configuration were identified. Performance and scalability of CAM when using the Finite Volume dynamical core (FVCAM) for a problem resolution of 0.5x0.625 with 26 vertical levels were evaluated for a wide spectrum of process counts. Performance is the best that has been observed for this benchmark on any system.