

and gas, is being evaluated to determine the potential for geologic sequestration. The project is supported by the U.S. Department of Energy, Battelle, AEP, BP, The Ohio Air Quality Development Office, and Schlumberger. The major objective of the current phase is to characterize the reservoir at the plant site. Future decisions with regard to CO₂ injection will be subject to the evaluated reservoir properties. The effort includes acquisition of 2-dimensional seismic data, assessment of regional geology, drilling to PreCambrian rocks and formation analysis and testing in a 2,800 meters deep well, reservoir simulations, risk assessment, and stakeholder outreach. The test well reached total depth in summer 2003. Wireline logging and reservoir testing was performed for each section of the borehole, including extensive tests in the lowermost 885 meters to estimate formation properties and pressure gradients. The logs included gamma-ray, neutron and density, and array resistivity, magnetic resonance relaxation for permeability information, elemental composition via capture spectroscopy, and resistivity based formation image. The seismic survey was conducted over approximately 11 miles along 2 lines: one along strike and one along dip. The results of the geophysical surveys combined with the field observations provide an integrated assessment of the major injection parameters for the two main injection reservoirs of interest, the Rose Run Formation and the Lower Maryville formation. In addition, the properties of the potential caprock formations overlying the candidate injection zones were also determined. The results of this characterization will be presented with emphasis on geophysical testing and seismic survey. These results are also being used to conduct reservoir simulations and risk assessment. Eventually, the geophysical tests and reservoir simulations will provide guidance for designing a demonstration project for CO₂ sequestration in deep saline reservoirs at this site and preparing the necessary injection permits should a decision be made to move forward to the next phase. These tests also help improve understanding of the geologic characteristics in the wider Appalachian Basin area and form a basis for assessment of other sites in the region.

GC31A-08 0945h

Carbon Dioxide Sequestration in Fractured Diabase: Experimental Results From Field and Laboratory Studies

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We investigate the potential of CO₂ sequestration in basalt aquifers. Such mafic rocks provide cations like magnesium, calcium and iron to solution, which can facilitate precipitation of carbonate minerals from injected CO₂-saturated fluids and may lead to secure, long-term geological sequestration of CO₂ from anthropogenic sources. We present results from field and laboratory experiments, including results from small-scale CO₂ injections into fractured zones in the Palisades Diabase sill and the underlying Triassic sediments of the Newark Basin Series. Geophysical logging and hydrogeological tests conducted prior to the CO₂ injection experiments indicate several highly fractured zones within the diabase. Porosity varies from less than 3% in massive intervals to maximum 10% in highly fractured zones. Fluid resistivity logs detected water producing and water receiving zones in the diabase. The transmissivity of each of these permeable zones is estimated using flowmeter measurements as well as slug and pump tests to range from 0.0025 to 0.02 m² day⁻¹. A mixed CO₂-water injection (pCO₂ of 1 to 10 bar), with NaCl added as a chemical tracer, into one highly fractured zone isolated in the borehole allows for estimates of the magnitude of flow recovery in the formation. The pH, electrical conductivity and temperature of the injected solution and the flow rate were monitored in real-time. Fluid samples analyzed for major ion chemistry show that the calcium and magnesium concentration in the water increased approximately five times after several days, indicating the neutralization reaction of the CO₂-saturated injection fluid with the host diabase rock. In addition, laboratory experiments with flow-through columns are performed to investigate the dissolution rates of diabase samples in acidified aqueous solutions with pH 1 to 4 at temperatures 20 to 70°. Comparison of field and laboratory results will be presented and the potential for CO₂ sequestration in fractured mafic formations will be discussed.

GC31B MCC: Level 1 Wednesday 0830h

General Global Climate Change Posters (joint with A, B, H, OS, PP, C, PA)

Presiding: M Lemos, School of Natural Resources and Environment, University of Michigan; H Beltrami, St. Francis Xavier University

GC31B-0168 0830h POSTER

Evidence of Younger Dryas Event in Taiwan

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Younger Dryas Event, the reversal of the warming trend heading from Last Glacial Maximum to Holocene, was first discovered about three quarters of a century ago in polar region, is now known as a widespread phenomenon of human dimension. It is generally believed that the Event started in around 11,000 years and ended in around 10,000 years before present of Carbon-14 age. Here we report the progress of our search for records of the Event in a tropic to subtropical land, Taiwan. Means for investigating climatic changes such as Younger Dryas Event in region like Taiwan is difficult to come by. In principle, carbon-isotope composition of lacustrine organic sediments is one suitable proxy for the investigation. Experimental study has so far confirmed this. Presence of unusual dust-storm deposits may also be used for the investigation. It can be argued that glacial-like worlds are also dusty worlds. We have employed both means and the results are encouraging. This report concerns with the carbon-isotope study. We have been analyzing the stable carbon isotope composition of carbon-14 dated core samples from a fossil lake, Tousse Basin, in Central Taiwan. Preliminary results had suggested the presence of a record of the Event. We have recently completed an eight-meter long core samples representing about the past 12,000 years of carbon-14 ages. This is a report of the results. The results confirm unequivocally the presence of a record of Younger Dryas Event in the core. The duration of the Event appears to be about 1,000 years, from about 11000 years to 10000 years before present of C-14 ages; The Event is characterized by abrupt flipping over at both the beginning and the end and large oscillation in between. These are consistent with that of Greenland ice core results and confirm the global nature of the Event. The results indicate that the climate of Taiwan during the Event is probably much colder and dryer than it is now.

GC31B-0169 0830h POSTER

Precipitation Change in Taiwan: Evidence of Impacts of Sulfur-rich Volcanic Eruption and Anthropogenic Process

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Precipitation change in Taiwan during the twentieth century is investigated. Five year running mean indicate that stronger rainfall intensity and larger rainfall variability ensued from rapid economic development and urbanization in 1960s. Four major drought episodes are identified. They are 1906-1910, 1961-1966 1978-1982 and 1993-1995. Above normal rain day is observed during the period between 1906-1960. The observed increase of rainfall variability and intensity during last four decades is inferred to be a consequence of greenhouse warming and anthropogenic aerosols forcing. The coupled occurrence of the episodic high sulfur rich volcanic eruptions and drought events is intriguing. Sulfur-rich volcanic eruption forcing is evident in the Pinatubo eruption in 1991 on the drought episode of 1993-1995. The Agung, and St. Helen coincide with the center of drought episode of about half decade long duration. The salient features of precipitation change in Taiwan illustrate impacts of sulfur-rich volcanic eruption and anthropogenic process.

GC31B-0170 0830h POSTER

Interannual Variability Observed in the Early Summer Climate in the Western North Pacific

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The early summer climate in the western North Pacific is largely controlled by the Baiu phenomenon. The interannual meridional fluctuation of the Baiu front and the relevant large-scale circulations are examined using empirical orthogonal function (EOF) analysis and the composite or correlation analyses based on the EOF time coefficients. The first EOF mode indicates the low-frequency fluctuation with a period of four to five years (LF mode) appearing to the south of 35°N. The development is concurrent with the horseshoe sea surface temperature anomalies (SSTAs) in the entire tropical Pacific that are associated with the El Niño/Southern Oscillation (ENSO). The westernmost SSTAs control the anomalous southward expansion of Baiu front through the modification of convection around 20°-30°N in the western Pacific. The LF mode is negatively correlated with the activity of South-Southeast Asian summer monsoon. The second EOF mode is characterized by the meridional seesaw-like fluctuation with a node around 28°N and by the time scale of biennial oscillation (BO mode). The horseshoe SSTAs again control the mode but with the different spatial phase in the tropical western Pacific through the anomalous convection off the Philippines. The BO mode has the negative correlation with the activity of tropical western North Pacific monsoon. The SSTAs associated with the BO mode tend to be confined to the tropical western Pacific, while the signals of LF mode rather extend in the tropical Pacific-Indian Ocean sector broadly, suggesting that the tropical BO is the aborted ENSO being dominant in the tropical central-western Pacific. The spatial phase of horseshoe SSTAs adjusts the detailed interannual variability in the meridional fluctuation of Baiu front.

GC31B-0171 0830h POSTER

Climate on Abnormal Occurrence of Wildfires around Eurasia and Northern America

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A great many wildfires sometimes occurred around Eurasia and Northern America: especially, Siberia and Mongolia in summer of 1998 and 2002. Generally speaking, the wildfires are caused by extreme hot and dry conditions. We could see what was happened in 1998 (Kimura et al., 2002). Now we can analyze the climatic conditions in 2002. Then we found that the climatic conditions in 1998 and 2002 from Siberia to Northern America. We use the dataset below: (1) Global Surface Summary of Day Data compiled by NCDC (2) NCEP Reanalysis Data (3) JMA Historical Map (4) Wildfire Area Data analyzed by Remote Sensing data. Indeed, in 1998 summer it was high temperature and little precipitation, and it was hotter and drier than that of 2002 summer. We can see the pressure distribution at Sea Level and 500hPa in summer. The ridge or blocking high pressure at 500hPa level is seen over the western Siberia. It corresponds to the high pressure area at Sea Level in Siberia. And also the waves at the 500hPa meander effect to the climate of North America. Next, seasonal change in summer is picked up, as wildfire had seasonal change. Sometimes it rains, but sometimes no precipitation continued more than 2 weeks in Siberia. During this period, the SLP had been high level, and southern component of wind continued to blow. This phenomenon means hot and dry condition was kept. The low relative humidity air mass moved eastward gradually, but sometimes it covered for many days. While this climatic condition continues, many wildfires occurred.

GC31B-0172 0830h POSTER

Occurrence, Frequency and Persistence of Historical Upper Air Flows and Precipitation Trends in Western North America

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We are seeking relationships that reflect historical synoptic upper airflow pattern-precipitation efficacy for a large number of climate stations in western North America. Classification of the historical daily 500 mb surfaces is ongoing for the fall and winter periods, 1960-90, as part of a program to develop high resolution historical and future precipitation scenarios. The Grid Analysis and Display System (GrADS) software is used to display the 500 mb surface as defined by the NCEP/NCAR reanalysis 6 hourly data (grid size 2.5x2.5 degree; window boundaries 15-80 N and 60-160 W). The 500 mb surfaces were classified according to Changnon et al. (1993). The pattern data is undergoing statistical and temporal trend analyses to determine if/how specific pattern occurrence, frequency and persistence impacts daily and seasonal precipitation.

GC31B-0173 0830h POSTER

The Contrast and Relation of Precipitation and Precipitable Water Over North America

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The precipitable water (W), as an important water vapor parameter, has become a conventional meteorological variable with the development in satellite observations and retrieval techniques. The dataset of W can be utilized to extract useful information on hydroclimate. For example, linkages may exist between the W and cloud, precipitation (P), storm, and other meteorological quantities. In this study, the contrast and relation of P and W are clarified at different time-scales over the United States and Mexico by using ten-year daily observational datasets. The contrast of the two variables shows that they have different spatial patterns in both the means and the perturbations of different time-scales. For the P over the land, the mean and the perturbations all have maximum centers over the three regions: South Mexico, the Northwest Coast, and the Mississippi River area. The mean of W that decreases with latitude in general is large over the eastern U.S. and small over the western U.S. and Mexico. However, the maximal perturbations of W, not appearing over the near-equator oceans where the mean gains its maximum, are "attracted" to the ocean-land adjacent areas due to the effect of small heat capacity of land. The relation of P and W possesses unique spatial patterns for different time-scales. At synoptic time-scale, P and W are well positively correlated over the entire US-Mexico although each of them has weak spatial coherence. Positive correlation is more significant over the eastern U.S., especially along the South and East Coasts. At seasonal time-scale, the W has extremely high spatial coherence over the land, all getting maximum in summer and minimum in winter, thus follows the variation pattern of surface temperature. Theoretical analysis confirms that the seasonal W is truly dominated by temperature due to its large annual range over the land, no matter how the relative humidity changes seasonally. In contrast, the seasonal P, which is influenced by atmospheric circulation and land surface process, exhibits distinct local characteristics, and can roughly be categorized into three types. Over the North American monsoon region (Mexico and the Southwest U.S.) along with the Northern Tier and Florida, the P has maximum in summer and minimum in winter. Over the Northwest Coast, maximum P appears in winter and minimum in summer. In the area around the Mississippi River, P has no distinct seasonal tendency. Therefore, the seasonal P and W are continentally controlled by different factors, although locally they could be linked through interactions between surface temperature and atmospheric circulation. At interannual time-scale, the summer averaged correlation of monthly P and W is significantly positive over the North American monsoon region and Florida. In addition to the partial contribution from the synoptic relation of P and W, other factors controlling the interannual relation need to be studied in future.

GC31B-0174 0830h POSTER

Vertical structure of the Arctic Oscillation and Cold Ocean Warm Land regimes and their role in climate change.

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When examined in terms of diagnostics of the atmospheric circulation, recent climate change may be interpreted in terms of increases or decreases in the frequency of occurrence of pre-existing preferred modes of atmospheric behaviour rather than a simple linear shift in the mean climate with superimposed noise. This contrasts with the characteristics of the observed changes in temperature-related diagnostics, which appear much closer to the simple linear picture. While not necessarily inconsistent, the implications of these two views of the nature of climate change need to be explored. In this framework the main purpose of this paper is to use a 40-yr NCEP reanalysis dataset in order to explore the vertical structure of circulation regimes and (at the same time) illustrate the potential role of weather regimes and non-linearity in the emerging anthropogenic signal. An empirical orthogonal function (EOF) analysis is first applied in order to define, for each variable, a reduced phase space based on the leading modes of variability. Then a simultaneous analysis of the four fields is carried out performing a further EOF analysis in the subspace spanned by the leading EOFs of each field. This produced a multi-variable EOF picture of the large-scale vertical (and thermal) structure of the atmosphere. With the three-dimensional structure available, it is possible to assess whether the observed temperature changes are consistent with an increase in certain regime frequencies. Moreover the hypothesis that regime frequency change more than regime structure is checked by performing a regime analysis separately on the first and last 25-yr periods.

GC31B-0175 0830h POSTER

The Potential Impact of Hydrologic Change on Humans in the Arctic

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Freshwater is critical to the sustainability of humans in the Arctic. Water used for drinking or cleaning can promote good health or propagate disease. Water supports the plants and animals used for subsistence harvest. Water prevents or promotes access to food or shelter. Water has always been and will always be integral to the culture of humans in the Arctic. In the past 30 years, the climate in the Arctic has warmed appreciably and there is evidence for a significant polar amplification of global warming in the future. Recent studies suggest that climate change will have a significant impact on arctic hydrology. Changes in the hydrologic cycle will affect both the presence of surface water and the thermal balance in soil. While preliminary evidence suggests a changing climate will have a significant impact on the hydrologic cycle in arctic regions, very little evidence is available to predict how the quality and quantity of freshwater available to humans is likely to change. Even less is understood about how hydrologic changes will affect the health, sustainability, and culture of humans in the Arctic. The overall objective of this research is to understand the vital role of freshwater in the lives of humans in the Arctic, how it has changed in the recent past, and how it is likely to change in the future. We seek to build a model that will allow us to predict climate-induced changes in the hydrologic cycle and their effects on water quality and availability. We will then attempt to understand how these changes will impact the life and culture of people in the Arctic. This study will take place on the Seward Peninsula where climate induced changes in the hydrologic cycle are already being observed. We will draw upon community interaction, historical documentation, field observations, laboratory experimentation, and computer modeling to achieve the project goals.

GC31B-0176 0830h POSTER

Evaluating the Age of Buried Ice in Antarctica Using Ashfall Deposits: New Insights from Deposit Morphology, Grain Shape, and LA-ICP-MS Trace-Element Geochemistry

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Dating of buried ice in the western Dry Valleys region relies on ⁴⁰Ar/³⁹Ar analysis of ashfall deposits within sublimation tills that rest directly on stagnant glacier ice. The oldest ice so dated is >8.1 Ma. The fundamental assumption is that dated ashes are in-situ and have not been transported from surface deposits elsewhere in the Dry Valleys region. Given that the surface of sublimation tills shows well-developed patterned ground, the presumption of ground stability and long-term preservation of in-situ ashfall is questioned. As a test of ground stability, we examined ash-deposit morphology, grain shape, and glass-shard trace-element geochemistry from several ashfall deposits used to provide limiting ages on buried ice and tills in the western Dry Valleys. Detailed field analyses show that ashfall that collects in sublimation tills over buried ice occurs in one of three morphologic settings: surface troughs that delineate sand-wedge polygons, void spaces in gravel-and-cobble lags that overlie active sand wedges, and 1 to 2-cm-wide thermal contraction cracks. Post-depositional sublimation of underlying ice may distort initial deposit morphology through uneven surface lowering. Microscopic analyses of concentrated ashfall deposits that lack detrital sand grains show highly angular glass shards that preserve delicate hair-like spires and thin bubble-wall vesicles. Grain edges are sharp with no chipped, fractured, or pitted surfaces. In contrast, ash deposits containing detrital sand grains show subangular to subrounded shard morphologies with concave fractures and pits on grain edges, all of which are suggestive of abrasion during transport. In such deposits, grains preserving delicate bubble walls and hair-like spires are conspicuously absent. Laser ablation-inductively coupled plasma-mass spectrometry shows that glass shards within each ashfall deposit have uniform trace-element geochemical signatures. If ashfall were eroded and transported after initial deposition, then ashes of different ages and geochemical compositions should be found together in individual deposits. An accurate chronology for buried ice in the western Dry Valleys region of Antarctica has implications for research in atmospheric chemistry (Miocene-aged glacier ice may hold pristine samples of ancient atmosphere), geobiology (ancient microbes are preserved in the ice), and planetary geology (buried ice in Antarctica may serve as an analog for buried ice on Mars).

GC31B-0177 0830h POSTER

Uncertainties in regional climate: intercomparison and evaluation of simulations of present and future climate in California

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We examine simulations of present and future climates in California performed with four regional climate models (RCMs). For the present climate, we compare the results of these models to observations and to results of the global climate models (GCMs) which provided lateral boundary conditions to the RCMs. We

find that in spatially-averaged surface temperature and precipitation the RCMs tend to share the biases of the driving GCMs. For future climate, the different RCMs simulated slightly different greenhouse gas scenarios. We compare simulated responses in surface temperature and precipitation in the RCMs to each other and to results of the driving GCMs. We find no consensus among the models as to the sign of the precipitation response. All the models predict statistically significant increases in temperature, but they do not agree as to the spatial pattern of the surface temperature response.

GC31B-0178 0830h POSTER

The Co-Production of Science and Policy in Integrated Climate Assessments

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This paper examines the use of interactive models of research in the U.S. Regional Integrated Scientific Assessments (RISAS), using as a case study the Climate Assessment of the Southwest (CLIMAS). It focuses on three conditions of interactive models: interdisciplinarity, interaction with stakeholders and production of usable knowledge and on the role of three explanatory variables – the level of fit' between state of knowledge production and application, disciplinary and personal flexibility, and availability of resources – which affect the co-production of science and policy in the context of integrated assessments. It finds that although no single model can fulfill the multitude of goals of such assessments, it is in highly interactive models, which we call iterative, that the possibilities of higher levels of innovation and related social impact are most likely to occur.

GC31B-0179 0830h POSTER

Prediction of Regional Scenarios and Uncertainties for Defining European Climate Change Risks and Effects – PRUDENCE

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Projections of future climate change already exist, but are deficient both in terms of the characterisation of their uncertainties and in terms of their regional detail. To date, the assessment of potential impacts of climate change has generally relied on projections from simple climate models or coarse resolution Atmospheric-Ocean General Circulation Models, although increasing efforts are being made to produce higher resolution climate simulations, particularly at the regional scale. Simple models include, at best, a limited physical representation of the climate system. Coarse resolution precludes the simulation of realistic extreme events and the detailed spatial structure of variables like temperature and precipitation over heterogeneous surfaces e.g. the Alps, the Mediterranean or Scandinavia. Perhaps even more important, regional signals of climate change often reflect the coarse resolution and the patterns of change can be significantly altered when resolution is increased. PRUDENCE is a European-scale investigation funded by the European Commission with the following objectives: 1. to address and reduce the above-mentioned deficiencies in projections; 2. to quantify our confidence and the uncertainties in predictions of future climate and its impacts, using an array of climate models and impact models and expert judgement on their performance; 3. to interpret these results in relation to European policies for adapting to or mitigating climate change. Climate change is expected to affect the frequency and magnitude of extreme weather events, due to higher temperatures, an intensified hydrological cycle or more vigorous atmospheric motions. A major limitation in previous studies of extremes has been the lack of: i) appropriate computational resolution - obscures or precludes analysis of the events; ii) long-term climate model integrations - drastically reduces their statistical significance; iii) co-ordination between modelling groups - limits the ability to compare different studies. These three issues are all thoroughly addressed in PRUDENCE, by using state-of-the-art high resolution climate models, by co-ordinating the project goals to address critical aspects of uncertainty, and by applying impact models and impact assessment methodologies to provide the link between the provision of climate information and its likely application to serve the needs

of European society and economy. PRUDENCE provides a series of high-resolution climate change scenarios for 2071-2100 for Europe, characterising the variability and level of confidence in these scenarios as a function of uncertainties in model formulation, natural/internal climate variability, and alternative scenarios of future atmospheric composition. The first synthesizing results obtained over two years of coordinated research efforts by a total of 21 European full partners from 9 countries and associated participants representing more than 4 additional countries will be highlighted.

URL: <http://prudence.dmi.dk>

GC31B-0180 0830h POSTER

Controlled Landfill Project in Yolo County, California for Environmental Benefits of Waste Stabilization and Minimization of Greenhouse Gas Emissions

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The Department of Public Works of Yolo County, California, USA has been testing an advanced approach to landfill bioreactors, controlled (or "enhanced") landfilling, at its Yolo County Central Landfill site near Davis, CA, since 1994. Overall objectives have been the management of waste landfilling for: (1) rapid completion of total gas generation; (2) maximum, high-efficiency gas capture; (3) waste volume reduction; and (4) maximum greenhouse gas and carbon sequestration benefits. Methane generation is controlled and enhanced through carefully managed moisture additions, and by taking advantage of landfill temperature elevation. The generated landfill methane, an important greenhouse gas, is recovered with high efficiency through extraction from a porous recovery layer beneath a surface geomembrane cover. Instrumentation included a total of 56 moisture and 15 temperature sensors in the two cells, gas flow monitoring by positive displacement gas meters, and accurate quantification of liquid inputs and outputs. Gas composition, waste volume reduction, base hydrostatic head, and a range of environmental compliance parameters has been monitored since 1995. Partitioning gas tracer tests using the injection of two gases at dilute concentrations in the landfill have also been initiated to compute the fraction of pore space occupied by water between the points of tracer injection and tracer measurement. There has been rapid waste volume reduction in the enhanced cell that corresponds to the solids' reduction to gas. Monitoring is planned for the next several years, until stabilization parameters are determined complete. Encouraging performance is indicated by: (1) sensor data; (2) gas generation results; (3) data from landfill cores; and (4) decomposition-related indicators including rapid volume reduction. When data are synthesized, project results have attractive implications for new approaches to landfill management. Over seven-years, methane recoveries have averaged over fivefold the "typical" values for comparable landfill waste. In terms of "greenhouse benefit," fractional VOC and methane energy recovery are estimated to exceed 90%, with corresponding methane and VOC emission reductions. Analyses done for the greenhouse gas mitigation program of the U.S. Department of Energy National Energy Technology Laboratory indicate favorable economics justified on landfill life extension, as well as environmental benefits. The "controlled landfill" project findings suggest potential for low-cost mitigation of waste greenhouse methane emissions, maximum landfill carbon sequestration, and maximization of beneficial energy capture from landfills. Details and results obtained since 1994 will be presented.

GC31B-0181 0830h POSTER

The Roles of El Nino and Solar Forcing on Cloud Cover

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Although cloud cover has a very strong effect on climate, its behavior is so poorly understood that its role is frequently neglected. A potential breakthrough occurred with initial reports that cloud cover could be driven by variations in cosmic rays (H. Svensmark & E. Friis-Christensen, *J. Atmos. Solar-Terr. Phys.* v. 59, n. 11, pp 1225-32, 1997, and N.D. Marsh & H. Svensmark, *Space Sci. Rev.*, pp 1-16, 2000). In this paper we report a detailed analysis of recently extended data now available from the International Satellite Cloud Climatology Project. In a surprise, we find that the major driving force for cloud cover is ENSO (El Nino / Southern Oscillation). In addition, we do find a weak but significant response to solar forcing; however, in contradiction to the previous reports, we find no stronger relationship to cosmic rays than to other solar parameters. For the majority of the 23 cloud types available to us, interannual variability is dominated by changes that follow the NINO3 index of Pacific sea surface temperatures. In particular, increases in high-altitude and vertically extensive cloud cover are observed to follow the motions of warm water throughout the El Nino cycle. Even far from the Pacific, many cloud cover changes are observed to correlate with El Nino, and these data provide a new and previously unexplored tool for understanding the global nature and influence of the El Nino / Southern Oscillation. In contrast, solar forcing of cloud cover is observed in, at most, a few cloud types. Only in the cloud type emphasized by Svensmark, low-altitude clouds detected in the infrared, does the dominant mode of interannual variability make a good match with solar forcing. The extended cloud record provides continued support for solar forcing of this cloud type; however, unlike Svensmark, we find no empirical reason to prefer cosmic ray flux as the forcing mechanism over any other type of solar cycle variation (e.g. irradiance or UV flux changes). Our observations indicate that while the internal redistributions of heat and precipitation associated with El Nino are the dominant influence on most cloud types, there is a weak but significant response to solar forcing present in at least part of the cloud volume.

GC31B-0182 0830h POSTER

Detecting Thermohaline Circulation Changes from Ocean properties

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Significant changes of the thermohaline circulation (THC) are likely to cause abrupt earth climate change. Here we examined several mechanisms controlling the THC variation using a coupled climate system model (NCAR's CCSM2.0). Three experiments are analyzed, a control run (present; CON), and two forced runs: a fresh water hosing run with 0.1 Sv additional fresh water uniformly distributed in northern North Atlantic (NA) between 50 and 70°N (past; HOS), and a transient climate run with 1% CO₂ increase per year (future; TRC). In HOS, THC is weakened to 11.4 Sv from 15.7 Sv in CON by the end of the 100-year hosing, then recovers to its full strength 80 years after the hosing was turned off. The tropical and subtropical Atlantic ocean average over the upper 1000 meter (T_{at1000}) warms by 0.3°C by the end of the hosing, implying a change of 14 Sv in THC for a 1°C variation of T_{at1000} . In TRC, the THC weakens to 14.1 Sv at 2XCO₂ and to 12.6 Sv at 4XCO₂. T_{at1000} increases by 1.1°C at 4XCO₂, where most of the T_{at1000} changes can be attributed to the CO₂ effect. Therefore, the same regression relationship between THC and T_{at1000} do not hold in this experiment as in HOS. EOF analysis of the meridional streamfunction (MSF) in the Atlantic reveals a seesawing pattern of the rate of North Atlantic Deep Water (NADW) and Antarctic Bottom Water (AABW) formation in the first EOF for HOS. When the NADW increases (stronger THC), the AABW decreases. The same is true for CON. Changes in AABW is related to sea ice volume changes in southern ocean. This seesawing pattern of THC agrees with proposed THC oscillation in the past 1500 years. In TRC, as CO₂ increases, the northern NA and the periphery of the Antarctic become warmer and fresher, reducing the surface water density, and resulting in a decrease in both NADW and AABW formation. Other mechanisms examined here are the mean sea surface salinity (SSS) and temperature (SST) contrast between NA and North Pacific (NP), and the steric height gradient (SHG) between 30°S and 60°N in Atlantic. In HOS and CON, it shows a higher SSS contrast related to a stronger THC, but opposite in TRC. However, a colder NP (warmer NA) is related to a stronger THC for both forced runs. The SHG in Atlantic gives the most consistent result among these 3 runs, however, the linear regression shows a 17 Sv change in THC vs a change of one cm/deg-lat in SHG for CON and HOS, but a number increased to 29 for TRC. EOF analyses of the global SST indicate that the first EOF in CON, explaining 14% of the total variance, is a ENSO related

pattern with a 2.6-year frequency. In the forced runs, this pattern becomes the second EOF with a frequency of 3.3- to 4.5-year, explaining 11% and 3% of the total variance for HOS and TRC, respectively. The first EOFs are a general cooling in Northern Hemisphere and warming in Southern Hemisphere in HOS (explaining 12% of the variance) and a global warming in TRC (explaining 70% of the variance). The general conclusion is that the proposed mechanisms used to detecting the THC strength are held for past and current climate condition, but not perfectly held for the future (at least in NCAR's CCSM2.0). The increase in atmospheric CO₂ level seems changed the behavior of the THC, and causes a breakdown of many teleconnections between THC and others.

GC31B-0183 0830h POSTER

CO₂ Emissions from Air Travel by AGU and ESA Conference Attendees

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Air travel by scientists is one contributor to rising concentrations of CO₂ and other greenhouse gases in the atmosphere. To assess the magnitude of this contribution in per-capita and overall terms, we calculated emissions derived from air travel for two major scientific conferences held in 2002: the western meeting of the American Geophysical Union (AGU) in San Francisco and the Ecological Society of America meeting in Tucson (ESA). Round trip travel distance for sampled attendees is 7971 ± 6968 km (1 sigma range given, n=337) for AGU and 5452 ± 5664 km for ESA (n=263), conservatively assuming great circle routes were followed. Using accepted CO₂ production rates for commercial aircraft, mean AGU emissions are 1.3 tonnes per attendee and 12351 tonnes total and for ESA 0.9 tonnes per attendee and 3140 tonnes total. Although small compared to total anthropogenic emissions (2.275 × 10¹⁰ tonnes y⁻¹ in 1999), per attendee emissions are significant compared to annual per-capita emissions; CO₂ emission per AGU and ESA attendee exceeds the per capita annual emission of 42% and 19% of Earth's population, respectively. Per attendee AGU emissions are ≈6% of U.S. and ≈14% of British and Japanese per capita annual emission. Relocation of AGU and ESA to cities which minimize travel distances, Denver and Omaha respectively, would result in modest emission reductions of 8% and 14% (assuming 2002 attendee composition). To form a preliminary estimate of annual CO₂ emissions for scientists in academia, we surveyed Earth Science faculty at our home institution. Mean annual air travel distance for professional activities was 38064 km y⁻¹ (7 respondents). The consequent release of 6.1 tonnes y⁻¹ of CO₂ is 30% of annual per capita emissions in North America, and exceeds global per capita average of 4 tonnes y⁻¹ by 150%. Society and the environment often benefit from scientific enquiry which is facilitated by travel. These benefits, however, might be balanced against the disproportionate share of CO₂ presently produced as a consequence of professional scientific activities. Small reductions (≈10%) might be achieved by optimizing conference locations. Supported by Dalhousie University and the Natural Science and Engineering Research Council of Canada.

GC31B-0184 0830h POSTER

Carbon Dioxide and Water Vapor Fluxes at Reduced and Elevated CO₂ Concentrations in Southern California Chaparral

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This research took two different approaches to measuring carbon and water vapor fluxes at the plot level (2 × 2 meter and 1 × 1 meter plots) to help understand and predict ecosystem responses to elevated CO₂ concentrations and concomitant environmental changes. The first measurement approach utilized a CO₂-controlled, ambient lit, temperature controlled (CO₂LT) null-balance chamber system run in a chaparral ecosystem in southern California, with six different CO₂ concentrations ranging from 250 to 750 ppm CO₂ concentrations with 100 ppm difference between treatments. The second measurement approach used a free air CO₂ enrichment (FACE) system operated at

550 ppm CO₂ concentration. These manipulations allowed the study of responses of naturally-growing chaparral to varying levels of CO₂, under both chamber and open air conditions. There was a statistically significant CO₂ effect on annual NEE (net ecosystem exchange) during the period of this study, 1997 to 2000. The effects of elevated CO₂ on CO₂ and water vapor flux showed strong seasonal patterns. Elevated CO₂ delayed the development of water stress, enhanced leaf-level photosynthesis, and decreased transpiration and conductance rates. These effects were observed regardless of water availability. Ecosystem CO₂ sink strength and plant water status were significantly enhanced by elevated CO₂ when water availability was restricted. Comparing the FACE treatment and the FACE control, the ecosystem was either a stronger sink or a weaker source to the atmosphere throughout the dry seasons, but there was no statistically significant difference during the wet seasons. Annual average leaf transpiration decreased with the increasing of the atmospheric CO₂ concentration. Although leaf level water-use efficiency (WUE) increased with the growth CO₂ concentration increase, annual evapotranspiration (ET) during these four years also increased with the increase of the atmospheric CO₂ concentrations. These results indicate that chaparral or other similar ecosystems, under future elevated CO₂ concentrations, might be even more water stressed than they are under current conditions.

GC31B-0185 0830h POSTER

Long-term pattern of and controls on intra and inter-seasonal variability in net ecosystem CO₂ exchange over wet coastal sedge tundra

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Measurement of net ecosystem CO₂ exchange (NEE) was made on a wet coastal sedge tundra ecosystem in Barrow, Alaska over the growing seasons (June 1 to August 31) between 1999 and 2002 using the eddy covariance technique. The objectives of this study were to quantify the seasonal carbon budget and intra- and inter-seasonal variability of carbon flux as well as examining the control mechanisms on NEE. Climatic conditions changed from year to year, with seasonal average air temperature varying from 1.6 °C to 3.0 °C, precipitation from 57.8 mm to 86.8 mm, and soil moisture content varying 0.40 m³ m⁻³ to 0.76 m³ m⁻³. The 2002 growing season recorded the earliest snow-melt (day 144) among the study years which extended the length of the growing season by 20 days compared to the other three years. Due to the early snow-melt and rapid development of the plant canopy in 2002, considerable carbon uptake took place shortly after the initiation of growth with a peak NEE of - 2.3 gC m⁻² d⁻¹ on day 166, while the maximum carbon uptake (ie. - 5.4 gC m⁻² d⁻¹ in 1999, - 2.8 gC m⁻² d⁻¹ in 2000, and - 2.9 gC m⁻² d⁻¹ in 2001) occurred in the main growing season during the rest of years. An unusual long period of cold air temperature (0 °C) from day 170 to day 190 in 2002 resulting in a reduction in the magnitude of the carbon uptake and changed the ecosystem from a sink to a source. This result may occurred due to the compound effects of restrained plant growth and phenological development and suggests the temperature sensitivity of the wet coastal sedge tundra ecosystem during the early growing season. Although precipitation and soil moisture content varied throughout the growing seasons, the NEE in wet coastal sedge tundra ecosystem was not effected by the changes in precipitation and soil moisture content due to adequate levels of water availability all four years. The wet coastal sedge tundra ecosystem accumulated a total of 70. 0 gC m⁻² season-1, 46.6 gC m⁻² season-1, 51.7 gC m⁻² season-1 and 60.8 gC m⁻² season-1 during over the 1999, 2000, 2001 and 2002 growing seasons respectively. These results indicate that an increase in the growing season may not necessarily cause an increase in the sequestration of carbon by the ecosystem owing to the compound mechanisms controlling ecosystem CO₂ exchange.

GC31B-0186 0830h POSTER

A study of relative humidity dynamics using water vapor trajectories in an idealized GCM

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We present a novel technique for diagnosing the mechanisms controlling the water vapor distribution in an idealized general circulation model (GCM) through the use of multiple passive tracers to track the trajectories of unsaturated air. The model atmosphere is divided into a number of axisymmetric regions, each of limited meridional and vertical extent. When a parcel of air is saturated in a given region, the value of the tracer for that region is set to unity there, and the tracer values for the other regions are set to zero there. The time-mean, zonal-mean tracer fields show the typical pathways that air parcels take between one occurrence of saturation and the next. Because saturation water vapor mixing ratio is a function only of temperature, and mixing ratio is conserved for unsaturated parcels, these tracer fields can be used together with the temperature field to reconstruct the water vapor field. Under a given climate change, the water vapor field reconstructed by this method may perhaps be thought of as a first correction to the assumption of constant relative humidity (the simplest possible model). This method also allows changes in the water vapor field which occur in a climate change to be partitioned into changes due to temperature and changes due to circulation. Results will be presented from a model consisting of the dry GCM of Held and Suarez plus advection of a passive water vapor field which is emitted at the surface, and assumed to rain out immediately upon saturation, but whose latent heat of vaporization is zero so that it does not affect the circulation. In this simple model, the largest errors in the reconstructed water vapor fields are those due to sampling (use of a finite number of tracers). An interesting preliminary result is that, even for a very simple, small climate change in which the radiative-convective equilibrium temperature (relaxation towards which is the only thermal forcing of the model) is increased by one degree everywhere in the atmosphere, the relative humidity change is determined substantially by circulation changes as well as by temperature changes.

GC31B-0187 0830h POSTER

Testing the Dynamical Properties of Climate Models with Observations of Spectrally Resolved Thermal Radiance

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Spectrally resolved, absolutely calibrated infrared radiance measurements made from space are being increasingly recognized as a key observational element of a program to detect and forecast future climate change. Space-based measurements have a number of important characteristics for climate research. They can provide complete global coverage, completing our knowledge of isolated ocean regions where in situ measurements are sparse. The homogeneity of these measurements reduces the complexity and uncertainty inherent in their analysis. Being provided by a single platform means that a careful absolute calibration for one instrument provides reproducible and demonstrable accuracy for an entire mission-length global dataset. One of the main disadvantages of space deployment is that instruments can only directly measure radiance, not the climatic state variables to which we are most accustomed. Although the radiances may be inverted to produce atmospheric profiles and records of other state variables, the complexity and ill-conditioned nature of this problem (Keith and Anderson 1998) make analysis of the radiances themselves a very attractive option. The analysis of the statistical properties of previous spectrally infrared missions has illustrated the detailed information that can be extracted from the means (Harries et al. 2001) and the higher statistical moments (Haskins and Goody 1998). The higher order moments are particularly important in understanding the response of the climate to an external forcing (Leith 1975). In this paper we examine the information content of the dynamical characteristics of a simulated infrared radiance dataset. We show that the dynamical properties can be separated from the statistical properties, yielding different information about the physical mechanisms operating in the model atmosphere. Changes in parameterizations of physical processes in a simple one-dimensional model are shown to independently affect the covariances of the radiation field determined from the empirical orthogonal functions (EOF) and dynamical properties determined from linear inverse modeling (LIM).

GC31B-0188 0830h POSTER

Quantifying Climate Model Parameter Uncertainties

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One potential source of the large spread in sensitivities that exist among climate models in their response to projected increases in atmospheric CO₂ concentrations is the way different models treat convection and clouds and the subjective choices that are made to specify bulk (non-observable) parameters. Quantifying these uncertainties is made much more difficult by the fact that the optimal choice of any single parameter value depends on the values of other key parameters. The solution requires that a multi-dimensional probability distribution be generated that describes regions of parameter space that enable the model to be most consistent with observational data. Toward this end we have devised a new EOF-based multivariate measure of model performance that compares model predictions of 12 quantities with observational or reanalysis data. Using this EOF-based measure of model performance, we have considered 5 key parameters within the NCAR atmospheric climate model (CCM3.10) that are important to convection and clouds and coarsely mapped their linear and non-linear sensitivities to changes in these parameters. We have found that there are multiple regions of parameter space that provide a close match to observational data, which suggests one reason why different modeling efforts may "settle" on different values for the same bulk-parameters.

GC31B-0189 0830h POSTER

Multiple Equilibria in CCM 3.6.6 Coupled to the Oceanic Mixed Layer with Thermodynamic sea ice.

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An atmospheric GCM (Climate Community Model, CCM 3.6.6) is coupled to an upper mixed-layer ocean with thermodynamic sea ice on an aquaplanet. An annually averaged diurnal cycle of insolation is used such that effects of seasonality are neglected. Sea ice is modeled by a simple four-layer thermodynamic sea ice model coupled to the atmosphere-ocean system. A simple form of heat flux to the mixed-layer from below, the so called "Q-flux", is constructed and introduced into the model. All externally specified fields, such as the insolation, the Q-flux, the ozone concentration and the mixed layer depth (50m uniformly), are constant over the year, zonally symmetric and symmetric about the Equator. The Q-flux can be viewed as a crude representation of the poleward oceanic heat transport and thus takes on negative values at low latitudes and positive values at high latitudes. While the shape of the Q-flux is kept constant various choices of its amplitude are used and the model is run to equilibrium for each choice. The outcome of this ranges from very icy climates, with sea ice margins in both hemispheres at 35 degrees, to completely ice-free climates. Between these extremes arises a complex transition which includes both asymmetric climates, with sea ice in one hemisphere and no sea ice in the other, and multiple equilibria, where sea ice at both low and high latitudes are possible under the same external forcing.

GC31B-0190 0830h POSTER

Global Climatological and Real-Time Green Vegetation Fraction from AVHRR

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The global coverage, 0.144-degree resolution green vegetation fraction (GVF) climatological fields have been derived at weekly temporal resolution using 12-year weekly smoothed NDVI datasets, while such smoothed NDVI datasets were obtained by post-launch calibrated AVHRR visible and near infrared radiances that span over the operational period of NOAA-9, NOAA-11 and NOAA-14 satellites. A comprehensive statistical approach was further developed to utilize both the weekly GVF climatology and the real time vegetation anomaly magnitude indicated by vegetation condition index (VCI) to produce high quality near real-time meso-scale grid resolution global GVF fields that are suitable to use by numerical weather, climate and hydrological models. This approach considers different scenarios of the relationship between GVF anomaly and VCI for each week, land surface class and hemisphere. The case studies show that the resulting GVF fields are capable of capturing real-time moderate to strong land surface vegetation anomaly signals while preserving general trend in the climatological datasets. The data products summarized in this study appear to be superior to previously derived GVF climatology.

GC31B-0191 0830h POSTER

Modelling Tropical Forest Productivity Incorporating Spatial Variation And Diffuse Light Within 3-PG

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Rising concentrations of atmospheric carbon dioxide and potential increases in temperature and climatic extremes, have raised concern in the earth-science community, driving the need for better understanding of the exchange of carbon dioxide between the various Earth's ecosystems and the atmosphere. This interest has promoted the development and application of regional (1 to 10km²) and ecosystem (10 to 100km²) scale primary production models, based on plant growth and physiological principles. This research explores one such application of the 3-PG (Physiological Principles Predicting Growth) big-leaf model, to a number of pristine, restored and plantation rainforest sites located in North Queensland, Australia. Model parameters were derived for this specific tropical forest ecosystem and in addition, a variant of the model was developed to include a light-use efficiency modifier based on variations in diffuse radiation (3-PGSD, Satellite Diffuse). Diffuse radiation is derived from remotely sensed estimates of the fraction of photosynthetically active radiation (fPAR). Although the importance of diffuse light has been recognized by the agricultural community for many years, its effects had not yet been explored with large-scale terrestrial primary production models. In this paper, the theory behind the use of diffuse light in ecosystem production modelling is examined. Simulated estimates of monthly forest growth parameters, net primary production and ecosystem dynamics from both the 3-PG and 3-PGSD models are compared and contrasted. The merits of big-leaf models incorporating the effect of diffuse light dynamics versus more complex canopy layer and parameter-intensive models for ecosystem productivity assessment are discussed in relation to these results. This research also provides valuable information into modelling of tropical rainforest growth and productivity given there is a lack of knowledge and literature on the systematic assessment of the carbon pools and fluxes in these regions.

GC31B-0192 0830h POSTER

Stochastic Model of Complexity in Dendrochronology

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The basic assumption of this study is that a stochastic model can reproduce the variability in amplitude and the long-range correlation observed in dendrochronological data. The model is tested for four chronologies from the International Tree Ring Data Bank. For the four samples, we show that the power-spectra follows a power law behavior with scaling exponents close to 0.6. For the four samples, we have found that non-Gaussian distributions, i.e., the Levy distributions, are better suited to describe the temporal variability of the ring index. We also show that a stochastic characterization of the ring index based on a Gaussian distribution fails to capture the temporal variability observed in the original samples: especially, the 'extreme', large values. The results obtained for the samples suggest that some features of the complexity recorded in tree ring indices are universal and can be modeled accordingly. If this is proven correct, this will imply that the temporal variability and the long-range correlation of tree ring indices can be described with the help of five parameters: a scaling exponent controlling the spatial correlation and the four parameters of the Levy distribution constraining the temporal variability. We suggest that we can use these inferences as proxies of climatic variability for the assessing of extreme weather events in a changing climate.

GC31B-0193 0830h POSTER

Evaluation of Freshwater Resources and Sustainability on Small Islands

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Small island states are especially vulnerable to climate change and the associated impacts to freshwater resources. A methodology is proposed to evaluate freshwater resources and the related sustainability issues on small islands. Tools that can be used to evaluate freshwater resources include return period analysis for wet and dry cycles of precipitation and historical long-term analysis of temperature, precipitation, and sea level rise over the record of available data. Additionally, focused analysis on time periods of concern can be performed. This includes development of a water budget to identify critical shortfalls in water supply. Sea-level rise is a particular area of concern to small island states because for some, much of the land area is only 3-4 meters above the present mean sea level. Sea level rise projections, along with critical tidal level evaluation and historical shoreline erosion rates, can help small islands examine how these factors will affect freshwater resources. Finally, an examination of the combined effects of climate change and other stressors to the future status of freshwater resources can be performed. This will help small island states adapt strategies and respond to the projected future status of their freshwater resources.

GC31B-0194 0830h POSTER

Visual Representations Of Non-Separable Spatiotemporal Covariance Models

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Natural processes that relate to climatic variability (such as air circulation, air-water and air-soil energy exchanges) contain inherently stochastic components. Spatiotemporal random fields are frequently employed to model such processes and deal with the uncertainty involved. Covariance functions are statistical tools that are used to express correlations between process values across space and time. This work focuses on a review and visual representation of a series of useful covariance models that have been introduced in the Modern Spatiotemporal Geostatistics literature. Some of their important features are examined and their application can significantly improve the interpretation of space/time correlations that affect the long-term climatic evolution both on a local or a global scale.

GC31B-0195 0830h POSTER

Probabilistic Climate Forecasting

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As a European record-breaking summer draws to an end, climate 'stakeholders' are actively planning for the future, presenting the climate research community with a new challenge. Today's coastal and water-supply engineers do not need 'projections' of how the climate might respond to rising levels of greenhouse gases, no matter how detailed and realistic. Rather they need to know what changes can be ruled out at a given level of confidence. This is probabilistic climate forecasting. The correct procedure for probabilistic climate forecasting begins with a perturbation analysis of the model to identify consistent relationships between observable quantities and forecast variables of interest (this is referred to as: 'mapping the response manifold'). The resulting ensemble is weighted to accurately represent both current knowledge and uncertainty in observations and then used to infer future climate change. Mapping the response manifold in a full-scale, non-linear climate model is a formidable challenge well beyond the capabilities of conventional supercomputing resources. Today the only adequate resource of this scale is presented by the joint idle processing capacity of home and desktop computers of the general public: this is the climateprediction.net approach.

URL: <http://www.climateprediction.net/index.php>

GC31B-0196 0830h POSTER

Towards a rigorous MCMC estimation of PDFs of Climate System Properties.

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We have revised the method for estimating the uncertainty in climate system properties from Forest et al. (2002). To apply a fully Bayesian approach, we first approximate the response of the MIT 2DLO climate model with a statistical model that provides a response surface in the uncertain parameter space. The three-dimensional parameter space is defined as climate sensitivity (S), rate of deep-ocean heat uptake (K_D), and the net aerosol forcing (F_{aer}) and have been identified as the three major uncertain quantities that affect the ability to simulate accurately the 20th century climate record. The availability of this response surface permits one to perform a full Markov-Chain Monte-Carlo (MCMC) sampling of the joint posterior distribution of the parameters. This approach facilitates the testing of methodologies for performing the more computationally intensive project using the complete MIT 2DLO climate model, which is infeasible with current computer resources.

GC31B-0197 0830h POSTER

The Global Climate Anomaly in 1940-1942

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An unprecedented climatic anomaly occurred in the tropics and in the Northern Hemisphere in 1940-1942. During a strong and prolonged El Niño [Bigg & Inoué, *QJRMS* 118 (1992), 125], extremely cold winters were observed in Europe, accompanied by very warm temperatures in Alaska and large parts of the Arctic and a cold North Pacific. The anomalies were strong (comprising the two coldest European winters of the 20th century) and extraordinarily persistent. In addition, exceptionally high values of total ozone are reported [Langlo, *Geophys. Publ.* 18/6 (1952)], pointing to an anomalous stratospheric circulation. Events of this magnitude have a strong economical and environmental impact; the 1940s anomaly even affected World War II. Studying this anomaly in detail contributes to (1) document the extent of 20th century climate variability, (2) understand large-scale coupling processes between the tropics and the extratropics and between the troposphere and the stratosphere and (3) develop tools to analyze past upper-level climate variability prior to 1948, i.e., the reanalysis period. For this study we have compiled, digitized, and re-evaluated several tens of thousands of temperature and pressure profiles from aircraft and radiosonde ascents up to 50 hPa [Brönnimann, *Int. J. Clim.* 23 (2003), 769]. The upper-air data were supplemented with data from the Earth's surface and used to statistically reconstruct monthly upper-level fields for the extratropical Northern Hemisphere up to 100 hPa [Brönnimann & Luterbacher, *Clim. Dyn.*, submitted]. Although the quality of the reconstructed stratospheric fields is not comparable to more recent data, it is sufficient to allow a broad characterization of the circulation at 100 hPa during the early 1940s. In addition to upper-air data, several total ozone series from the 1940s were re-evaluated [Brönnimann et al., *QJRMS* 129 (2003), 2819], providing further information on the stratosphere. In this paper we present an analysis of these new data sets and compare the results to climate model data. It is demonstrated that the climate anomaly at the ground was accompanied in the lower stratosphere by a weak polar vortex and warm temperatures over the polar region, Eurasia, and the North Pacific. The total ozone data show a peak in 1940-1942 in all available records, at sites as far apart as China, North America, central Europe, and the Arctic. The co-occurrence of warm tropical SSTs (due to El Niño), a weak polar vortex and warm lower stratosphere over polar regions, and a total ozone increase is in agreement with findings by van Loon and Labitzke [*Mon. Wea. Rev.* 115 (1987), 357]. Using the 290-yr control run of the Community Climate System Model CCSM-2.0 provided by UCAR we show that such large-scale coupling events are related to an exceptionally large difference between tropical and northern-extratropical SSTs such as during strong El Niños. The coupling most likely proceeds through a change in planetary wave activity in the northern extratropics that manifests itself in a strong Aleutian low and a weak Icelandic low and in a disturbance of the polar vortex in the stratosphere. The 1940-1942 climate anomaly is not well known among scientists, but it is unprecedented in strength, yet exemplary in character, providing a unique opportunity to study large-scale climate variability.

GC32A MCC: Level 1 Wednesday 1330h

Geophysical Field Studies and Techniques Applied to Underground Storage of Greenhouse Gas Emissions in All Phases of Site Characterization, Injection and Storage Operations, and Monitoring II Posters

Presiding: K K Cohen, National Energy Technology Laboratory, U.S. Department of Energy; C Byrer, National Energy Technology Laboratory, U.S. Department of Energy

GC32A-0198 1330h POSTER

The Global Distribution of Candidate Geological CO2 Reservoirs and Their Economic Implications for Deployment of Carbon Capture Technology

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Geological storage of anthropogenic point-source CO₂ is an increasingly important strategy for mitigation of greenhouse-gas emissions. Much research has focused on the costs of capture, with the assumption that storage options would be relatively cheap, plentiful and would be located in close proximity to future CO₂ point sources. But, capture and disposal will take place at the local and regional scale and it must compete with other mitigation options. In this paper we provide an initial examination of the consequence of regionally disaggregated sources and sinks of carbon within the context of a globally disaggregated, long-term analysis of both the geology and the economics of carbon capture and disposal. In our analysis, we assume that large volume CO₂ point sources will seek to sequester their CO₂ in regional reservoirs. We consider sedimentary basins on land and continental shelves. We examine options for saline aquifer, enhanced oil recovery (EOR), and coal storage based on calculated volumes and costs. Shelf and land options are treated as separate options, and very deep saline aquifers are also treated separately. Sedimentary basins are counted as targets broadly, while cratonal areas are excluded. Within basins, pore-volume estimates are made for targets below the critical point of CO₂ assuming typical crustal heat flux and lithostatic pressure. By subdividing the globe into 14 economic provinces as defined by the MiniCAM energy and economic integrated assessment model, we are able to make regional estimates of sequestration loads (i.e., the amount of carbon needing to be sequestered in any time period) and the economic implications of this the degree to which these candidate reservoirs are available in the region. Our preliminary analysis suggests that some regions will see their ability to deploy capture and disposal systems constrained by a lack of quality target reservoirs relative to major sources and population centers in that region, while other regions appear to have sufficient disposal capacity to easily carry them through this century. We examine the regional and global economic implications of the distribution of these sources and sinks in meeting various potential limits to CO₂ concentrations in the atmosphere. We also examine the degree to which the relative abundance of CO₂ capture and disposal opportunities in a region influences the adoption of other emissions mitigation technologies.