COOPERATIVE INSTITUTE FOR RESEARCH IN ENVIRONMENTAL SCIENCES

CIRES

NOTE:

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Annual Report
on NOAA Cooperative Agreement NA67RJ0153

July, 1997

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Cooperative Institute for Research in Environmental Sciences

Annual Report
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The Cooperative Institute for Research in Environmental Sciences at the University of Colorado at Boulder has received funding for a number of years through a series of cooperative agreements with the Environmental Research Laboratories of the National Oceanic and Atmospheric Administration. During (university) Fiscal Year 1996-199, two such agreements were in effect, NA37RJ0201 under a no-cost extension year, and NA67RJ0153 under the first year of a new agreement that took effect on 1 July 1996. This document serves as the Final Report for the former of these and the first Annual Report for the latter.

Research at CIRES occurs in collaboration with the various NOAA Environmental Research Laboratories in Boulder, Colorado, including the Aeronomy Laboratory, the Climate Diagnostics Center, the Climate Monitoring and Diagnostics Laboratory, the Environmental Technology Laboratory, the Forecast Systems Laboratory, the Solar Radiation Research Branch of the Air Resources Laboratory, and the Space Environment Center. Research also occurs in collaboration with the National Geophysical Data Center of the NOAA National Environmental Satellite, Data, and Information Service, with some of the support for this research being derived from the cooperative agreement as well. In addition, approximately a third of CIRES research funding is derived from awards from other federal and state agencies. Detailed information about the institute, its personnel, and its connections with the NOAA laboratories is available at the CIRES World-Wide-Web site, which begins at *http://cires.colorado.edu*.

During the past year, CIRES held a scientific program review for NOAA management, so it is appropriate to use that review as a basis for this report. The review consisted of two days of presentations, in the form of posters, of CIRES research projects to NOAA managers and to a panel of distinguished reviewers that were convened especially for the review. The reviewers were Dr. Robert E. Dickinson, Regent's Professor at the University of Arizona; Dr. James R. Holton, Professor of Atmospheric Sciences at the University of Washington; Dr. Jack G. Calvert, Senior Scientist in the Atmospheric Chemistry Division of the National Center for Atmospheric Research; and Dr. Jean-Bernard Minster, Professor of Geophysics at the Scripps Institution of Oceanography and Systemwide Director of the Institute of Geophysics and Planetary Physics of the University of California (who chaired the panel).

Scientific posters were solicited from all parts of CIRES and were organized for the review into four programmatic areas, which were chosen specifically to mesh with NOAA Strategic Plan objectives and which cut across the disciplines of the CIRES administrative structure. Abstracts for posters in Health of the Atmosphere and Biosphere, Climate Analysis and Prediction, Natural Hazards Forecasting and Mitigation, and Integrated Earth System Processes sessions make up the bulk of this report. In addition, a copy of the written reports of the members of the review panel is included here following the abstracts.

It can be seen from this documentation that CIRES is healthy, productive, and vibrant, by all accounts meeting it strategic goal of providing scientific leadership in the environmental sciences. One additional aspect of the past year's activities that will continue to advance this goal is the implementation of a new research career track for scientists and assistants (details are discussed on the CIRES WWW site). By providing an employment environment that recognizes the contributions of the research staff and advances their careers, CIRES has set the stage for continued progress and for advancing environmental science research into the next century.

Health of the Atmosphere and Biosphere
Poster Session

I. ATMOSPHERIC OZONE

A. Basic Processes

Laboratory Studies of Atmospheric HO_x Production Processes
James B. Burkholder, David R. Hanson, and Ranajit K. Talukdar

Odd hydrogen radicals, HO_x, in general and the OH radical in particular, control the oxidizing capacity of the troposphere, the loss of ozone in the lower stratosphere, and a number of other processes in the lower atmosphere. Therefore, a knowledge of the rates of production of HO_x is essential. Laboratory measurements of reaction rate coefficients, photolysis parameters, and heterogeneous reactive uptake coefficients, are needed to quantifying the rate of production of HO_x in the atmosphere. In this poster, the basic information needed to quantify the OH production rates are described. Three examples of studies performed in our laboratory are presented which illustrate that the hitherto accepted OH production mechanism needs revisions. The examples are: (1) Accurate measurements of the quantum yields for the production of $O(^1D)$ in the photolysis of ozone as a function of wavelength and temperature. (2) Determination of reaction rate coefficients, absorption cross sections, and pressure-dependent photodissociation quantum yields of acetone. (3) Quantification of the rate of heterogeneous hydrolysis of $BrONO_2$ to yield HOBr and the rate of photodissociation of HOBr.

Health of the Atmosphere and Biosphere

B. Statospheric Ozone

Observations of Ozone Depleting Chemicals from as High as 32 km in the Stratosphere through the Troposphere to Depths as Low as 4 km in the Ocean.
Andrew D. Clarke, Thomas H. Swanson, Paula R. Wamsley, Fred L. Moore, Shari A. Yvon-Lewis, Jürgen M. Lobert, Laurie S. Geller, Loreen T. Lock, James W. Elkins, James H. Butler, Stephen A. Montzka, Thayne M. Thompson, and Richard C. Myers

Some remarkable events have occurred recently in atmospheric chemistry. Total organic chlorine (from the CFCs, chlorinated solvents, etc.) for the troposphere peaked sometime between late 1993 and early 1994. This is clearly good news for the earth's protective layer, since these chemicals deplete stratospheric ozone. While total organic bromine is still increasing at a slow rate, the decrease of organic chlorine, driven primarily by the reduction in emissions of methyl chloroform

(CH_3CCl_3), exceeds the gains in some of the other halogens when weighted by ozone-depleting efficiency. Thus, the total of effective bromine (from methyl bromide, CH_3Br, halons etc.) and chlorine also is decreasing with time. The Nitrous Oxide and Halocompounds Group of NOAA's Climate Monitoring and Diagnostics Laboratory (CMDL) has been measuring some of these ozone-depleting chemicals since 1977. The group is composed of both CIRES and NOAA employees. This balance has made it possible to participate on major airborne and oceanic campaigns while enhancing the global monitoring program at NOAA's CMDL baseline stations.

Our work has lead to other interesting discoveries. Atmospheric growth of halon H-1211 has continued despite Montreal Protocol restrictions, while atmospheric growth of H-1301 has appeared to decrease. Growth rates of CFC-11 and CFC-12, representing almost 50% of the total organic chlorine in the atmosphere, slowed dramatically by 1993 in response to the Montreal Protocol. A large sink of atmospheric CH_3Br was observed in the ocean and was reported in 1995. This result has had a significant effect on the budget of atmospheric CH_3Br. We have measured dissolved N_2O to as deep as 6 km in the ocean. The ocean is major contributor to the budget of atmospheric N_2O. The atmospheric growth rate of SF_6, used in electrical insulation, has been used to date the air in the stratosphere and calculate atmospheric lifetimes of important ozone-depleting and greenhouse warming trace gases. Our stratospheric measurements of these trace gases lead to the discovery in 1996 that the tropical stratosphere behaves like a leaky pipe, where 50% of the stratospheric air of the tropics is from the midlatitudes. A new instrument was developed and operated on a balloon gondola that measures many of these trace gases in real time up to 32 km above the earth's surface. This poster will present an overview of our group's work.

Health of the Atmosphere and Biosphere

C. Tropospheric Ozone

1. Global Tropospheric Ozone

Atmospheric Profiling with Tethered Kites and Balloons: Results from the North Atlantic Regional Experiment in Nova Scotia, the Azores, and Newfoundland
Michael L. Jensen, Karl G. Knapp, Ben B. Balsley, John W. Birks

A complementary system of tethered kites and balloons were used as part of the North Atlantic Regional Experiment to obtain profiles of ozone mixing ratio, water vapor mixing ratio, and temperature in the boundary layer and free troposphere. High resolution measurements obtained at three different field sites proved the effectiveness of kites and balloons for atmospheric research. The transport of ozone-rich air from anthropogenic sources in the northeastern U.S. was observed in Nova Scotia. Much lower ozone levels in the Azores revealed a lack of significant transport. And very dry and ozone laden air observed at higher altitudes of the troposphere in Newfoundland indicated a potential stratospheric source of ozone.

2. Ozone and Regional Air Quality

Power Plant Plume Dimensions, and Mixed Layer Heights During the 1995 Nashville/Middle Tennessee Ozone Study

C.J. Senff, R.M. Hardesty, R.J. Alvarez II, and R.M. Banta

During the 1995 Southern Oxidants Study (SOS) the airborne ultraviolet differential absorption lidar (UV-DIAL) operated by the NOAA Environmental Technology Laboratory (ETL) was deployed to characterize the three-dimensional structure of ozone and aerosol around Nashville. The UV-DIAL measured ozone concentration and aerosol backscatter from the surface to approximately 2 km height with a horizontal resolution of about 500 m and a vertical resolution of 90 m. The most prominent feature in the ozone distribution measured with the DIAL is a plume of high ozone concentrations over the city of Nashville. The plume extends from the top of the boundary layer down to the surface, and ozone concentrations frequently exceed 100 ppbV while rural ozone background levels are typically around 60 ppbV. The city ozone plume is especially well defined during stagnation episodes that are characterized by high pressure, strong synoptic- scale subsidence, light winds and a build-up of pollutants including ozone over the study region. Over the course of the study, several transects were flown downwind of isolated rural power plants in the vicinity of Nashville. The titration of ozone by NOx in the power plant plumes is readily observable in the lidar measurements to beyond 40 km downwind of the plants, and is used to define the dimensions of the plume. Our observations indicate that the signature of reduced ozone is a more sensitive indicator of plume dimension than the corresponding increase in aerosol backscatter resulting from particulates in the plume. By observing the decrease in aerosol backscatter at the top of the mixed layer, the lidar is also capable of providing measurements of mixed layer height. In the SOS study area we observed a substantial variability in mixed layer height, probably due to the heat island effect of the city of Nashville and different land use patterns in the rural surroundings.

NO_y and SO_2 Emission Loss and O_3 Production Efficiency in Power Plant Plumes in the 1995 Nashville/Middle Tennessee Ozone Study

T.B. Ryerson, M.P. Buhr, D. Sueper, D.D. Parrish, B.T. Jobson, M. Trainer, and F.C. Fehsenfeld

The southeastern United States experiences persistently elevated levels of tropospheric ozone in the summertime. These ozone pollution episodes result from the combination of high NO_x (= NO + NO_2) concentrations, high hydrocarbon concentrations, and the sunny, hot, and humid summer environment. The primary sources of NO_x in the region are urban areas and large coal-fired power plants. Thus the atmospheric chemistry occurring in the plumes downwind of these large, localized sources determines the extent and severity of the ozone problems experienced in the region. We address several questions relevant to ozone production in power plant plumes for this region.

Atmospheric lifetimes of the primary emissions of NO_x and SO_2 in the plumes are calculated from data taken aboard the NOAA WP-3D research aircraft on a flight in the summer of 1995. These lifetimes are significantly shorter than expected, and suggest a loss route for NO_y that is not observed in plumes in other regions of the country. Regional transport of NO_y is limited as a result. Rapid loss of NO_y species also suggests that standard measurement-based methods for calculating ozone production efficiency are not applicable to the plumes studied here.

When NO_y losses are taken into account, calculated ozone production efficiencies are significantly lower than previously estimated. Plume ozone production efficiencies are found to be dependent on NO_x source strength and ambient VOC levels. These findings have implications for the way ozone pollution can be most efficiently managed on local and regional scales for the southeastern United States.

Health of the Atmosphere and Biosphere

D. Development of New Methods to Study Ozone and Ozone-Precursors

Development and Comparison of Chemical Ionization Techniques for the Measurement of HNO_3

L. Gregorey Huey, Donna Sueper, Fred C. Fehsenfeld, R.L. Mauldin III, D.J.Tanner, and F.L. Eisele

A chemical ionization mass spectrometer has been developed for fast time response measurements of HNO_3 in ambient air. The apparatus was characterized in an informal intercomparison campaign at Enchanted Mesa in Boulder, CO. Nitric acid was measured over a wide range of meteorological conditions. Detection limits of less than 15 pptv for a one second integration period were routinely obtained. The apparatus was sufficiently sensitive to measure ambient levels of HNO_3 for all conditions except for periods of fog or heavy precipitation when NO_3 mixing rations were less than 10 pptv.

Health of the Atmosphere and Biosphere

II. AEROSOLS

A. Basic Processes

Laboratory Studies of Heterogeneous Atmospheric Chemistry

M. A. Tolbert and Tolbert Research Group

It has recently become apparent that heterogeneous processes can play a very dramatic, and previously unsuspected, role in the chemistry of the lower stratosphere. This has been most dramatically illustrated by the yearly occurrence of the Antarctic ozone 'hole': a massive depletion in stratospheric ozone over Antarctica each spring since the late 1970's. It is now recognized that

heterogeneous reactions on polar stratospheric clouds are a key step in the ozone loss mechanism. Heterogeneous chemistry may also be important in the troposphere, where particles are even more abundant than in the stratosphere. Research in the Tolbert group is probing heterogeneous atmospheric chemistry in both the stratosphere and the troposphere. Laboratory studies are conducted to probe the chemical and physical properties of the atmospheric particles, as well as their chemical reactivity. An overview of the research projects underway will be presented.

Health of the Atmosphere and Biosphere

B. Tropospheric Measurements

Measurements of Organic Material in Individual Atmospheric Aerosols Using Particle Analysis by Laser Mass Spectrometry (PALMS)

Ann M. Middlebrook, David S. Thomson, and Daniel M. Murphy

Knowing the chemical composition of atmospheric particles is important for understanding their physical, chemical, and radiative properties. Although organic compounds may comprise as much as 50 % (or more) of the aerosol mass, little is known about how prevalent organic species are in atmospheric particles. Furthermore, organic material in atmospheric aerosols is difficult to detect, identify, and quantify because of the semi-volatile, water-insoluble, and non-ionic nature of many organic compounds.

We are developing a new technique, particle analysis by laser mass spectrometry (PALMS), to investigate the chemical composition of atmospheric aerosols. With this technique, we obtain positive or negative ion spectra in situ and in real time from individual particles with diameters greater than 0.16 μm. Because particles are analyzed less than 5 ms after leaving ambient conditions, volatile species such as water and organic compounds can be detected with the PALMS instrument.

Here, we present results from the first Aerosol Characterization Experiment (ACE-1) field campaign in November and December, 1995 at Cape Grim, Tasmania. We show mass spectra of ambient marine particles containing organic material and examine the frequency with which organics were internally-mixed with sea salt. We also analyze the species present with organics to understand their source mechanisms. Finally, we compare laboratory-generated synthetic sea salt particles with organic compounds to the Cape Grim data.

III. INTERACTIONS WITH THE BIOSPHERE

A. Biosphere - Atmosphere Exchange

Identification of the "Missing" CO_2 Sink

K.A. Masarie, P.P. Tans, T.J. Conway, M. Trolier, N. Zhang, and C. Prostko-Bell

The amount of CO_2 in the atmosphere has increased ~30% since the early 1800s due primarily to the emission of CO_2 from fossil fuel combustion. How this increase in CO_2, the dominant anthropogenic greenhouse gas,will impact global climate change is uncertain. Part of this uncertainty arises from an incomplete understanding of the global carbon cycle. Since 1980, global CO_2 emissions from fossil fuel combustion have increased by nearly 20% and vary by only a few percent from year to year. However, the globally averaged atmospheric CO_2 growth rate has varied by more than a factor of 3 since this time and only one-half of the CO_2 emitted by fossil fuel burning (~ 500 Tmol yr^{-1}) remains in the atmosphere. Thus 250 Tmol yr^{-1} CO2 must be absorbed by the oceans and terrestrial biosphere. However, the fraction and temporal and spatial variability of carbon sequestered by these two reservoirs is a topic of much debate. Chemical oceanographers are confident that the oceanic sink is not strong enough to absorb the entire 250 Tmol yr^{-1} while terrestrial biologists doubt that the land biosphere can be a persistent large natural sink. While CO_2 sequestered in the oceans will not likely re-enter the atmosphere soon, CO_2 stored in the terrestrial biosphere is vulnerable to re-release due to human activity and climate change. Thus, identifying the "missing" CO_2 sink is critical to understanding the global carbon cycle. Where the CO_2 produced by fossil fuel combustion is stored, and for how long, will significantly impact projections of global climate change and discussions of CO_2 emission policy. The NOAA/CMDL Carbon Cycle Group operates a cooperative global air sampling network for making long-term systematic observations of atmospheric CO_2 and other trace gas species relevant to the issue of global climate change. The sampling network continues to evolve since its inception in the late 1970s and presently includes nearly 50 locations distributed strategically over the globe. In 1990, measurements of the stable isotopes of CO_2 using mass spectroscopy were added to the suite of analyses of the air samples. Because the marine and terrestrial sinks have different isotopic preferences, the addition of isotopic measurements provide a way to quantify their relative contributions to the total CO_2 sink. The temporal variations and persistent spatial gradients of CO_2 and ^{13}C of CO_2 measured in the network air samples, together with a 2-D model of atmospheric transport, are used to calculate the CO_2 sources and sinks, and partition them into marine and terrestrial components thus providing insight into the whereabouts of the "missing" CO_2 sink.

Biogenic Isoprene: From the Chloroplast to the Atmosphere
Mary Wildermuth and Ray Fall

Isoprene formation in numerous C3 plants is interesting in that 1) large quantities of isoprene are emitted globally (~350 Tg/yr), 2) a plant may release 1-8% of its fixed carbon as isoprene, 3) isoprene emission from leaves is light-dependent, and yet 4) the function of plant isoprene production is unknown. We have previously characterized an enzyme responsible for leaf isoprene emission (isoprene synthase), and now find that the majority of it is located in chloroplasts. Two forms of the enzyme have been detected, including a soluble form in the stroma and a membrane-bound form in the thylakoids. The membrane-bound form has been solubilized and both forms have been partially characterized. These findings lead to a model for isoprene formation in chloroplasts, where light activates one or both forms of isoprene synthase. The thylakoid-anchored enzyme may inject the reaction product, isoprene, directly into the membrane, consistent with a proposed role for isoprene in controlling the membrane fluidity of chloroplasts at high temperatures. The pathway(s) by which isoprene exits chloroplasts to reach the leaf air space remains a puzzle.

B. Bioremediation

Exploration of the Relationship between Tetrachlorohydroquinone Dehalogenase and the Glutathione S-Transferase Superfamily
Darla L. McCarthy, Sandra Navarette, W. Scott Willett, Patricia C.Babbitt, and Shelley D. Copley

Pentachlorophenol (PCP) is a widely used wood preservative. Because of its toxicity, it is considered a Priority Pollutant by the EPA. We are studying the biodegradation of PCP in Sphingomonas chlorophenolica. Tetrachlorohydroquinone dehalogenase is an enzyme required for the degradation of PCP in this bacterium. It converts tetrachlorohydroquinone(TCHQ) to trichlorohydroquinone (TriCHQ) and TriCHQ to 2,6-dichlorohydroquinone (2,6-DCHQ). The reducing equivalents for each step are provided by two molecules of glutathione. There is limited sequence similarity between TCHQ dehalogenase and enzymes in the theta-class of the glutathione S-transferase superfamily. The glutathione S-transferases are involved in detoxification reactions in virtually all forms of life. This sequence similarity might reflect merely the existence of a conserved glutathione binding site or reflect fundamental similarities in the mechanisms of the two enzymes. We have found that, like glutathione S-transferases, TCHQ dehalogenase ionizes glutathione at the active site. Furthermore, the purified enzyme produces substantial amounts of 2,3,5-trichloro-6-(S)-glutathionylhydroquinone (GS-TriCHQ) and an unidentified isomer of dichloro-(S)-glutathionylhydroquinone (GS-DCHQ) in addition to the expected TriCHQ and DCHQ products. Although these are products that would be expected from a glutathione S-transferase-like reaction, we have shown that they are actually produced by enzyme that has undergone some type of oxidative damage. A particularly interesting potential site for oxidative damage is a Cys located

at position 13, only two residues away from the Ser that is likely to stabilize the thiolate of glutathione at the active site. This Cys was converted to a Ser by site-directed mutagenesis. The C13S mutant catalyzes the disappearance of TCHQ as effectively as the wild-type enzyme, but produces only GS-TriCHQ and GS-DCHQ. These results suggest that Cys13 is required for reductive dehalogenation. The kinetics of the reaction catalyzed by the C13S mutant suggest that the tautomer of GS-TriCHQ is an intermediate in the reaction. Thus, the mechanism of TCHQ dehalogenase appears to be similar in some respects to that of the glutathione S-transferases. However, TCHQ dehalogenase has some additional catalytic capabilities that allow it to form reduction products rather than glutathione conjugates.

IV. NEW DIRECTION FOR CIRES/NOAA RESEARCH: WATER

Methane and the Global Carbon Cycle: The Role of Tropical Wetlands

Lesley K. Smith, William M. Lewis, Jr. and J.P. Chanton

Global budgets of methane, an important greenhouse gas, include a significant contribution from tropical wetlands. The floodplains of large tropical rivers, including the Amazon, Orinoco, and others, provide ideal physical conditions for the production and release of methane in large quantities. Most of the available measurements, however, are from the Amazon River, and have been derived from short-term synoptic studies. We measured methane flux over two annual cycles on the Orinoco River floodplain with the purpose of determining the degree of seasonal and spatial variation in emissions, and also of evaluating the generality of
methane release estimates for the Amazon.

Emission rates for the Orinoco floodplain proved to be similar for open water and macrophyte beds, but significantly higher for flooded forest. Ebullition accounts for up to 30% of the methane emissions. Wetland soils exposed by retraction of floodwaters are low, but significant, compared to emissions from flooded areas (0.07 ± 0.25 versus 1.38 ± 0.15 mmol m^{-2} d^{-1}). The flux- weighted average isotope ratio for carbon in the methane was -62 parts per thousand; it differs somewhat from that of the Amazon (-53 ppt).

For the entire Orinoco floodplain, the emission rates are estimated as $1x10^{-5}$ Tg km^{-2} yr^{-1}, which is close to the range of estimates for the Amazon. Using an average flux of 2.5x10-5 Tg km^{-2} yr^{-1} from the Orinoco and Amazon floodplains, we estimate that South American wetlands as a whole emit annually about 12 Tg of methane, or about 10% of global methane output from wetlands.

Health of the Atmosphere and Biosphere

Denitrification in Nitrate-enriched Western Rivers

Arne L. Sjodin, William M. Lewis, Jr., and James F. Saunders, III

Nitrogen dynamics of a plains reach of the South Platte River were studied over a 12-month cycle for the purpose of quantifying denitrification rates. The working hypothesis of the study was that denitrification would be of extraordinary importance in the system because of large amounts of water exchange between the channel and an extensive subsurface alluvium. Denitrification losses of nitrate were quantified through the use of a mass-balance model based on detailed hydrologic information and field quantification of the rates of nitrate accrual through surface and subsurface addition of water and nitrification. Denitrification rates ranged between 4 and 100 mg $N/m^2/hr$. Distance required to achieve 90% reduction of nitrate was as short as 6 km during mid-summer and as long as 300 km during mid-winter. On an annual basis, close to half of nitrate input to a 100-km reach was removed by denitrification (3.6 x 106 kg/yr). Rates of nitrate loss to denitrification (annual mean, 28 mg $N/m^2/h$) and overall percent removal of nitrate by denitrification were approximately 10 times as high as rates documented for rivers in the eastern U.S. The study shows that high rates of hyporheic exchange can support extraordinary rates of denitrification, without which nitrate concentrations in surface waters would now be much higher.

Climate Variability Associated with Midlatitude Air-Sea Interaction.
Mike Alexander, Clara Deser, and Shiling Peng

Midlatitude atmosphere-ocean interaction and interactions between the surface and deeper layers in the ocean may play an important role in seasonal to multi-decadal variability of the climate system. Subsurface data collected at ocean weatherships and mixed layer ocean model simulations indicated that at some locations SST anomalies created in winter can remain undisturbed below the surface in summer and re-emerge at the surface in the following fall/winter. Recent analyses using the National Center for Environmental Prediction ocean data assimilation system indicate that this "re-emergence mechanism" can occur over large portions of the North Pacific Ocean and opens the possibility that thermal anomalies stored within the upper ocean may return to the surface and influence the atmospheric circulation in subsequent seasons.

Upper ocean observations also indicate that abnormally cold water first created at the surface in the central North Pacific during the mid 1970's, propagated down into the ocean, reaching depths of 400 m about 2 years later. Over a period of 15 years this cold water moved slowly down and southward with time following the general circulation of the North Pacific Ocean. The temperature anomalies appear to be subducting from the mixed layer into the deeper ocean along isopycnal surfaces and may play a role in decadal modes of variability discussed by other investigators.

Climate Analysis and Prediction

Northern Hemisphere Weekly Snow Cover and Sea Ice Extent 1978-1995
R.L. Armstrong, M.J. Brodzik, K. Wolter

The extent and variability of seasonal snow cover and sea ice are recognized as important parameters in climate and hydrologic systems. Trends in these two cryospheric variables are also expected to serve as indicators of climate change. The National Snow and Ice Data Center (NSIDC) University of Colorado has developed a northern hemisphere cryospheric product which combines snow and sea ice extent data in a common digital format at weekly intervals for the period October 1978 to June 1995. The data set is provided in an azimuthal equal area (25 km) projection (NSIDC EASE-Grid). The snow cover extent is based on the digital NOAA-NESDIS weekly northern hemisphere snow charts, revised by D. Robinson (Rutgers University) and re-gridded to the EASE-Grid. The original NOAA-NESDIS weekly snow charts are derived from the manual interpretation of AVHRR, GOES and other visible-band satellite data. The sea ice extent is based on the existing NSIDC, polar stereographic, sea ice concentration grids. The NSIDC sea ice concentrations are derived from the SMMR and SSM/I passive microwave brightness temperature data. The data set also includes monthly climatologies describing average extent, probability of occurrence, and variance. Results from a preliminary analysis of spatial and temporal trends in snow

cover and sea ice extent are presented. Our first research application of this data set involves the relationship between Asian snow extent and the timing and duration of the Indian monsoon.

Climate Analysis and Prediction

Microphysical and Kinematic Characteristics of Precipitating Clouds Using Wind Profilers
R. Cifelli, D. Rajopadhyaya, P.T. May, C. Williams, and S.K. Avery

This poster describes research on the kinematic and microphysical properties of precipitating clouds using co-located UHF and VHF wind profiler measurements. The profiler method takes advantage of the different scattering sensitivities of VHF and UHF to precipitation and clear air. At VHF, the wind profiler has approximately equal sensitivity to Bragg scatter from gradients in the clear air index of refraction (i.e., turbulence) and Rayleigh scatter from precipitation targets. In contrast, the UHF profiler is dominated by Rayleigh scatter whenever the precipitation exceeds light rain or drizzle.

A spectra-fitting algorithm developed at CIRES is used to retrieve both the vertical air motions (VHF) and the drop size distribution parameters (UHF) from the wind profiler data. The model uses the VHF data to extract the clear air vertical velocity information (i.e., mean vertical air velocity and spectral width), and to isolate the portion of the spectra associated with precipitation scatter. The model then examines the UHF data to fit the precipitation component of the spectra with an assumed functional form (i.e., Gaussian, Lognormal, Gamma, Exponential). Because the precipitation backscatter observed with the wind profiler is smeared by the clear air, it is essential to obtain an accurate estimate of clear air parameters for the retrieval of the drop size distribution. Once the drop size distribution parameters have been retrieved, the reflectivity, liquid water content, and rain rate can be calculated in a straightforward manner.

Profiler data have been examined from both tropical (Darwin, N.T., Australia) and mid latitude (Platteville, Colorado) sites, representing a wide variety of precipitation regimes. Results indicate that the profiler retrieved rain rates closely match independent rainfall measurements from tipping bucket gauges at the profiler locations, suggesting that the profiler technique could be used to calibrate traditional scanning radar estimates of rainfall (i.e., Z-R techniques). Moreover, because the profiler technique can retrieve the vertical structure of microphysical (i.e., drop size distributions) and kinematic (i.e., vertical air motion) parameters, the effect of precipitating clouds on the larger scale environment can be estimated through diabatic heating and moistening rates. Such information can provide critical ground truth for future space-borne platforms (e.g., TRMM) that will attempt to measure the spatial and temporal variability of rainfall and latent heat production. The microphysical and kinematic data are also important for the initialization and validation of microphysical processes numerical models. The technique described herein complements precipitating cloud research using profiler spectral moment analyses discussed in a separate poster.

Climate Analysis and Prediction

Inter-hemispheric Teleconnection Patterns Through the Partial Synchronization of Lorenz-like Systems

Greg Duane and Peter Webster

The Lorenz system has been suggested [Palmer 1993] as a metaphor for regime-structure in the extratropics, in which a transition between the two halves of the Lorenz "butterfly" corresponds to a transition between blocked and zonal flow, while other motions along the attractor correspond to synoptic transients. The sensitivity of the system to external input, especially in certain regions of its phase space, allows analogue tropical forcing to bias the regime residency distribution. This suggestion is generalized to describe the interactions of the two hemispheres, mediated by the annual cycle and by conditions in the tropics. It has been shown, for instance [Yang and Webster 1990], that tropical heating in the summer hemisphere can affect extratropical jets in the winter hemisphere. By extension, in the presence of tropical westerly ducts, extratropical transients can affect circulation in the extratropics of the opposite hemisphere. To assess the implications of this type of interaction qualitatively, we study the behavior of two intermittently coupled Lorenz systems, with the strength and direction of the coupling imagined to be influenced by the annual cycle and by tropical conditions related to ENSO. It is known that synchronization of coupled Lorenz systems is obtained under ideal conditions [Pecora and Carroll 1990]. The degradation of synchronization behavior is sudied as a function of the intermittency and variation in directionality of the coupling. If we couple more realistic low-order models of the mid-latitude circulation [deSwart 1989], partial synchronization takes the form of periods of synchronization interspersed chaotically among periods of desynchronization. Implications of such partial synchronization for interhemispheric correlations and for predictability are discussed.

Climate Analysis and Prediction

An S-Band Profiler for Tropical Precipitating Cloud Studies

Warner L. Ecklund, Paul E. Johnston, James M. Warnock, Wallace L. Clark, and Kenneth S. Gage

915 MHz profiler observations at Manus Island in Papua New Guinea show backscattering from precipitating clouds above 5 km with significant downward Doppler velocities over 25% of the time. These optically thick precipitating clouds have important effects on the atmospheric radiation balance and redistribute heat and moisture as the frozen particles fall and advect with the background wind. This poster describes a new S-band profiler which we have developed to continuously monitor these precipitating clouds in the Tropics with a increase in sensitivity of about 20 dB.

Warm Pool SST Variability in Relation to the Surface Energy Balance
J.T. Fasullo and P.J. Webster

The warm equatorial oceans in the eastern hemisphere underlie the most convective region on Earth and constitute the divergent focus of large-scale circulation cells such as the Hadley and Walker circulations. A principle aim of the Tropical Ocean Global Atmosphere Coupled Ocean Atmosphere Response Experiment (TOGA COARE) was therefore to understand the mechanisms responsible for maintaining this "warm pool".

Here, the surface energy balance is examined in relation to episodes in which the Warm Pool achieves its greatest temperatures. A composite warm event is created and anomalies both during SST warming and cooling are examined separately to examine the relative roles of each in modifying SST. Domains over both the Indian Ocean and Pacific Ocean are considered. The recent availability of extended reanalysis datasets now allows us to examine trends in the surface energy balance with some confidence. Fluxes from the NCEP/NCAR reanalysis dataset are considered. Evaporation estimates in this dataset are shown to correspond closely to observed amounts. Solar flux estimates from the reanalysis are somewhat less reliable. To compliment the analysis of solar fluxes, therefore, a technique which infers shortwave radiation from observed outgoing longwave radiation is considered.

Results show important roles for both shortwave and evaporative flux anomalies in modifying the temperature of the upper ocean. Somewhat different behavior over the Indian and Pacific domain is revealed and discussed. In particular, the relationship between SST modification and large-scale dynamical systems - such as the intraseasonal tropical oscillation and the Indian monsoon - is identified as central to the issue of SST regulation. The presence of these systems invalidates the representation of the Warm Pool as a "closed system". That is, large-scale convective conditions at any time are not solely the function of the region's SST. It is suggested instead that only through an understanding of the systems and their interaction with the surface, can SST variability be adequately understood.

Deep Convection at Darwin, Australia Observed by Wind Profiling Doppler Radars
Kenneth S. Gage, Christopher R. Williams, Paul E. Johnston, Warner L. Ecklund, W. Bruce Maguire II, Peter T. May, and Kenneth Glasson

Darwin, Australia is located at the southern edge of the Indonesian maritime continent that contains the intense tropical convection that energizes the ascending branches of the Hadley and Walker circulations. Because of its unique location and the diverse mix of observing systems located there, Darwin has become a focal point for international tropical meteorology and climate research. The Darwin wind profilers are located at a site 9 km east-southeast from the Darwin airport. This site

has coordinates (12.5°S, 131°E). The 920 MHz profiler was collocated at the VHF profiler site for collaborative research between the Aeronomy Laboratory and the Australian Bureau of Meteorology Research Centre (BMRC).

Climate Analysis and Prediction

Snow Trends within the Former Soviet Union

Christopher D. Haggerty and Richard L. Armstrong

The National Snow and Ice Data Center/World Data Center - A for Glaciology (NSIDC/WDC-A) has recently acquired snow depth and snow water equivalent data for the former Soviet Union. Records for 1345 stations for the period 1966-1990 were digitized at the Institute for Geography, Moscow under the leadership of Professor Alexander Krenke. The data comprise measurements of snow depth at each station, snow depth averaged over a transect, and snow water equivalent averaged over a transect. Other parameters, describing the surface properties of the snow-cover, are included within this data set but are not used within this analysis. The nonparametric Kendall's tau statistic is used to examine trends in the data. Several areas of significant trends are identified. An area encompassing many of the European newly independent states (the Baltic Republics, Belarus, Ukraine) shows decreasing trends for the winter months (December through March), in both snow depth and snow water equivalent. Conversely several areas in Central Asia show increasing snow trends. The analysis demonstrates the utility of the data set for examining climatological trends in snow cover.

Climate Analysis and Prediction

El Niño, La Niña, and the Nonlinearity of their Teleconnections

Martin Hoerling, Arun Kumar, and Min Zhong

Climate statistics for warm and cold events of the tropical Pacific are analyzed separately for the northern winter periods during 1950-96. Composite analysis of 500-mb heights reveal planetary-scale teleconnection patterns as noted in earlier studies. A new result is the evidence for an appreciable 35-deg. longitude phase shift between the warm and cold event circulation composites, and the two wavetrains appear to have different tropical origins. A large nonlinear component in North American surface climate anomalies is also found that is consistent with such phase shift in teleconnections. In the tropics, rainfall anomalies also show evidence of nonlinear behavior. The maximum rain anomalies along the equator are located east of the dateline during warm events, but west of the dateline during cold events. Idealized atmospheric general circulation model experiments demonstrate a nonlinear climate response that closely resembles the observed composites, including a shift in the equatorial positions of the maxmium rain responses, and a phase shift of teleconnection patterns in the upper troposphere. Further diagnosis using a steady state model indicates that the inherent nonlinearity in the tropical rain response may be largely responsible for asymmetry in North American climate responses to extreme phases of the El Niño/Southern Oscillation.

Climate Analysis and Prediction

Sea Surface Regulation in The Indian Ocean: A Counterpoint to The Pacific Warm Pool
Johannes P. Loschnigg and Peter J. Webster

There have been a number of claims (e.g., Ramanathan and Collins, 1991) that there is a "natural thermostat" that regulates sea surface temperature (SST) to a maximum magnitude of about 303K. Within this scenario, convection is associated with warming SST and the radiational shading of the ocean from the increasing cloudiness cools (and therefore regulates) SST. To substantiate this argument, data from the Pacific warm pool was used.

Whereas certain problems exist with the analysis of data in support of the thermostat hypothesis (see Fasullo and Webster poster), it is interesting to compare the Pacific SST evolution with that in the northern Indian Ocean during the spring and early summer. The region is effectively cloudless and the winds are very weak until the monsoon onset. Theoretical estimates of the SST growth suggest a rate of 3K/month. Yet, even though the high insolation-weak wind regime is maintained the observed SST grows at only 1K/month. Even at that rate the SST becomes the warmest on the globe at that time of the year. Clearly, other factors are regulating temperature than cloud shielding. Using an ocean model it is shown that the regulation is accomplished by ocean dynamical processes.

Climate Analysis and Prediction

Stochastic Forcing of Tropical Interannual Variability: A Paradigm For ENSO?
Andrew Moore and Richard Kleeman

Variability in the tropics occurs on a wide range of timescales. Generally speaking, however, we can divide this variability into two catagories: "low-frequency:"variability with seasonal-to-interannual timescales and longer, and "high-frequency" variability with daily to intraseasonal timescales. Motions at these timescales are not independent, and are coupled. However, on timescales longer than a month or so, the "high-frequency" variability is essentially unpredictable and can be considered as a stochastic noise forcing acting on the "low-frequency" variability. We have examined the conditions under which this stochastic noise forcing can significantly influence the "low-frequency" variability of the coupled ocean-atmosphere system associated with the El-Niño/Southern Oscillation (ENSO). To do this we have applied the ideas of generalised linear stability theory (currently receiving much attention in the literature) to a dynamical coupled ocean-atmosphere model of ENSO. We find that if the stochastic noise forcing in the system has a spatial structure similar to that associated with observed intraseasonal variability, then it can act to enhance and even maintain the low-frequency variability of ENSO. Based on our fundings, a simple paradigm for ENSO is proposed which, if correct, has significant implications for the predictability of ENSO.

Climate Analysis and Prediction

Prediction and Investigation of El Niño

Cecile Penland, Prashant Sardeshmukh, Ludmila Matrosova, Klaus Weickmann, Cathy Smith, and Joseph Barsugli

For several years, researchers at CDC have been supplying skillful forecasts of IndoPacific sea surface temperature anomalies (SSTAs), which are a large part of the important El Niño phenomenon. These forecasts are published in two publications of the National Weather Service: the quarterly Experimental Long-Lead Forecast Bulletin, and the monthly Climate Diagnostics Bulletin, and are also available on the World Wide Web at http://www.cdc.noaa.gov/~mcp/Cecile.forecast.html.

SSTA forecasts are made using Linear Inverse Modeling, which is a method for extracting the relevant dynamical parameters from data under the assumption that the underlying dynamics can be modeled as a stable linear, though multivariate, process driven by geographically coherent white noise. Physically, the white noise represents the broad-band nonlinear dynamics which affect the more slowly-varying "deterministic" (and predictable) part of a measured signal. This assumption has been found to be remarkably appropriate for the description of El Niño as manifested in IndoPacific SSTAs. The assumption passes a variety of tests, including the difficult "tau-test", which suggests that not only can the deterministic dynamics be treated as stable and linear, but also that the parameters associated with these deterministic, linear dynamics can probably be treated as time-independent.

The well-known phase locking of El Niño to the annual cycle is therefore transmitted to the IndoPacific SSTAs through a seasonally-dependent variance of the stochastic forcing. Indeed, stochastic forcing diagnosed from SSTA data using a fluctuation-dissipation relation appropriate only to a stable linear process does yield a seasonally-dependent noise variance. Further, when a stable linear numerical model, using empirically-diagnosed parameters, is driven with nonstationary stochastic forcing, the correct phase-locking of El Niño to the annual cycle is obtained, even though El Niño is not phase-locked to the seasonal dependence of the forcing variance. We emphasize that the forcing variance is the only source of variation with the annual cycle in the model.

It is neither the deterministic dynamics alone nor the stochastic forcing alone, but rather the interplay between the two, which accounts for the growth of El Niño events and their phase-locking to the annual cycle. The (deterministic) normal modes of the system are not orthogonal and their different timescales allow increasingly positive interference during the onset of El Niño. However, because the normal modes are stable, they would, in spite of this temporary growth of field variance, eventually die out without variance being continually added to the system by the stochastic forcing. We are currently engaged in diagnosing the physical character of the stochastic forcing.

Climate Analysis and Prediction

The Basic Dynamics of Extratropical Low-frequency Variability

Prashant D. Sardeshmukh, Mark D. Borges, Matthew Newman, Cecile Penland and Jeffrey S. Whitaker

Much of extratropical low-frequency variability is apparently unpredictable noise, unrelated to tropical SST variations. Although its statistical structure is different from that of synoptic variability, with variance maxima over the eastern rather than western Pacific and Atlantic oceans, it is strongly affected by the behavior of synoptic weather systems as they approach and decay in these regions of diffluent flow. Much of its unpredictability therefore ultimately arises from the unpredictability of synoptic weather systems. The low-frequency variability is also affected by the behavior of tropically forced Rossby waves in these diffluence regions. A clear understanding of eddy-mean flow interactions in these regions (as well as the eddies themselves) would be welcome, but has remained elusive for decades. Progress in this area will have large implications for the predictability of intraseasonal, interannual and even interdecadal variability. Recent work by CDC scientists has helped clarify several aspects of the problem, including low-frequency Rossby wave dynamics, sensitivity studies of Rossby wave forcing and their dependence on season, and understanding the statistics of synoptic weather systems.

Climate Analysis and Prediction

A New Monthly Climatology of Global Radiation for the Arctic and Comparisons with NCEP/NCAR Reanalysis and ISCCP-C2 Fields

Mark C. Serreze, Jason E. Box , James A. Maslanik, and Jeffrey R. Key

Measurements from the Russian "North Pole" series of drifting stations, the United States drifting stations "T-3" and "Arlis II" , land stations, and, where necessary over the northern North Atlantic and coastal Greenland, empirically- derived values from earlier Russian studies, are used to compile a new gridded monthly climatology of global (downwelling shortwave) radiation for the region north of 65°N. Spatio- temporal patterns of fluxes and effective cloud transmittance are examined and comparisons are made with fields from the National Center for Environmental Prediction/National Center for Atmospheric Research (NCEP/NCAR) reanalysis and those derived from the International Satellite Cloud Climatology Program (ISCCP) C2 (monthly) cloud product.

All months examined (March-October) show peak fluxes over the Greenland ice sheet. March, September and October feature a strong zonal component. Other months exhibit an asymmetric pattern related to cloud fraction and optical depth, manifested by an Atlantic side flux minimum. For June, the month of maximum insolation, fluxes increase from less than 200 W m^{-2} in the Norwegian and Barents seas to more than 300 W m^{-2} over the Pacific side of central Arctic Ocean extending into the Beaufort Sea. June fluxes of more than 340 W m^{-2} are found over the Greenland ice sheet. Effective cloud transmittance, taken as the ratio of the observed flux to the modeled clear sky flux, is examined for April-September. Values for the Atlantic sector range from 0.50- 0.60, contrasting with the central Arctic Ocean where values peak in April at 0.75-0.80, falling

to 0.60-0.65 during late summer and early autumn. A relative Beaufort Sea maximum is well expressed during June. The NCEP/NCAR and ISCCP products capture 50-60% of the observed spatial variance in global radiation during most months. However, the NCEP/NCAR fluxes are consistently high, with Arctic Ocean errors in excess of 60 W m^{-2} during summer, reflecting problems in modeled cloud cover. ISCCP fluxes compare better in terms of magnitude.

Climate Analysis and Prediction

Studies of Intraseasonal Climate Variability

K. Weickmann, H. Hendon, J. Bergman, J. Glick, J. Hart, B. Liebmann, B. Mapes, T. Shinoda

Fluctuations of tropical convection and the associated surface winds provide an important forcing for the global atmosphere and ocean. The air-sea coupled interactions that characterize the El Nino/Southern Oscillation and the annual cycle are under intense study and provide some modest hope for seasonal climate predictions. Another coherent phenomenon which interacts with these low frequency phenomena and which provides a focus for our studies of intraseasonal climate variability is the Madden-Julian Oscillation (MJO). The MJO is characterized by large-scale convective flare-ups that develop over the equatorial Indian Ocean every 30-60 days and then move slowly eastward toward the central Pacific. The wet phase of enhanced convection and precipitation is followed by a dry phase where convection is suppressed.

The passage of wet and dry phases of the MJO over the IndoPacific Ocean warm pool is accompanied by many changes, both local and remote. Sea surface temperatures (SST) vary as the presence or absence of convective clouds modify the radiation budget at the surface. The accompanying surface wind variations contribute to the surface energy budget by modulating the surface evaporation from the ocean. The surface winds also induce oceanic waves that propagate to the South American coast and can change SST along their path. Enhanced synoptic and mesoscale convective activity, including tropical cyclones, accompany the MJO convective envelope. Large-scale intrusions of dry air and changes in vertical wind shear influence the behavior of cloud ensembles. Finally, changes in the global atmospheric circulation which range from regional changes over the subtropics and the North Pacific to global changes that are reflected in the length-of-day are observed. Research at the Climate Diagnostics Center that are related to these aspects of the MJO will be presented.

Natural Hazards: Forecasting and Mitigation
Poster Session

Infrasonics Program
A.J. Bedard, Jr., R.T. Nishiyama, S.A. Pezoa, R.G. Craig, R.A. Bloemker

The Infrasonics Program in the System Demonstration & Integration Division (NOAA/ERL/ETL) consists of five principal research areas. Accomplishments in each area are as follows.

Instrument Development:

Design and test of spatial filter.

New sensor design.

Nuclear Test Ban Treaty:

Member of National Academy of Sciences panel to recommend research.

Support International Monitoring System as requested.

Severe Weather Vorticity:

Detected infrasound from tornadoes and mesocyclones.

Working to create a rapid deployment observatory.

Working to install an observatory at a NEXRAD site.

Avalanche Detection:

Deployed observations at Gothic and Silverton, Colorado and verified that avalanches radiate infrasound.

Made recommendations for design of an avalanche detection system.

Earthquake Detection:

Detected infrasound from earthquake epicenters, local Rayleigh wave passages, and intermediate zones.

Natural Hazards

The CIRES Hayward Fault Alarm System; Creepmeters and Co-seismic Slip
R. Bilham and S. Whitehead

More than 2 million people live in east San Francisco Bay within 30 km of the Hayward Fault, for which the probability for a M>7 earthquake in the next 30 years has been estimated to exceed 25%. The fault itself is crossed by many thousands of pipes, roads and several buildings (including the Town Halls of Fremont and Hayward). Four main trunk pipelines convey gasoline, high pressure gas and water through the fault zone to San Francisco across the Bay. The fault is locked below 5 km but is evidently creeping near the surface at rates of approximately 5 mm/yr. Below 12 km the southern most fault is believed also to be creeping at 9 mm/yr. The creeping fault leaves an annual trail of broken pipes and ruptured roads, but because every mm lost in creep is unavailable to drive the next earthquake, its obsequious presence is generally considered to be mitigating property of the fault. However, creep has another important property. Changes in its rate may signify the onset of seismic failure at depth. In view of this possibility, and because when the fault slips in an earthquake

it is important to know immediately where slip occurred, CIRES has installed a network of creepmeters at 20 kmintervals along the fault.

The creepmeters are fixed to points 10-30 m deep using helical piles to suppress near-surface noise. In some cases the piles are instrumented to monitor secular tilt that might otherwise reduce the accuracy of the system. One of these serendipitously penetrated the fault zone providing a measure of creep at 20 m depth. The data are accurate to 2 microns over a range of 2 m, and are relayed to Menlo Park every 10 minutes (approximately the time interval between BART trains crossing the fault during daylight hours). The USGS in Menlo Park have a direct link to the Federal Emergency HQ (FEMA), who have prepared various emergency action scenarios depending on where damage is concentrated. In the past 3 years data from the creepmeters reveal that creep is remarkably linear (rms noise of 0.2 mm). Maximum rainfall effects are <1 mm and perturb the creepmeters for less than 5-10 days. The creep rate at the northern end of the fault (5.7+-0.1 mm/yr), which matches both the 220 ka geological slip rate, and the past 30 year creep-rate, and we conclude that an earthquake on the northernmost Hayward fault is unlikely. At Fremont at the southern end of the fault, a linear creep rate of 5 mm/year is occasionally interrupted by creep events which add an additional 5 mm/year, bringing this also close to the long term slip rate, so that we consider an earthquake south of Fremont is unlikely. However, the creep rate north of Fremont near the southernmost end of the 1868 rupture, doubles over a 1 km long zone implying that dilatational strains on each side of the fault increment annually by more than 2 microstrain. Because the local acceleration in slip rate has prevailed for at least 100 years, the cumulative near fault strain must now exceed 200 microstrain (unless undocumented slip has occurred on minor fault traces). These anomalously high strain values suggest that an earthquake on the central and southern Hayward fault is possible in the immediate future.

Natural Hazards

Identification of Expansive Clay Soils by Field Spectroscopy and Remote Hyperspectral Imaging Methods

Sabine Chabrillat, Alexander F. H. Goetz, and Harold W. Olsen

Swelling soils are a major geologic hazard, and expansive clays and clay-shales cause extensive damage world-wide every year. The cost of post-construction mitigation is prohibitive, and the costs of standard engineering soil tests and creation of regional maps is also very high. One example of this problem is the current situation in the Front Range Urban Corridor in Colorado which is underlain by Cretaceous clay-shales, including the Pierre Shale. The Pierre Shale contains clays, with abundances ranging from 50 to 75%. Smectite is the clay mineral group that has the greatest swelling potential and is responsible for most swelling soil damage in Colorado.

We are developing a field spectroscopic technique for in-situ determination of swelling soil potential. This technique will then be extended to remote measurements with hyperspectral sensors to permit the development of a map of swelling soil potential along the 300 km long Front Range Corridor.

Near-infrared (NIR) reflectance spectroscopy of swelling soils samples shows that it is possible to discriminate among pure smectite and mixed smectite/illite samples, and to detect high water content by spectroscopic means. Also, spectra of montmorillonites exhibit shifts in the 2200 nm absorption band depending on the sodium and calcium content. Sodium montmorillonites have the greatest swelling potential and would be expected to contain greater amounts of water when found in saturated soils. Spectroscopic identifications are well correlated with mineralogical x-ray diffraction analyses and geotechnical engineering tests.

Natural Hazards

Aspects of the Global Streamflow Climatology and Variability
Michael D. Dettinger and Henry F. Diaz

The climatology and variability of streamflow timing, streamflow amounts, and ratios of runoff to locally measured precipitation are presented, using a newly compiled, global dataset of over 1200 monthly streamflow series. The series have been edited to remove major discrepancies and human influences, have been selected to achieve the broadest geographic and longest historical coverage, and have been compiled from public-domain sources. The average series length is about 30 years.

The peak month in mean annual hydrographs at most gages depends on the local peak-precipitation month and the extent to which precipitation is trapped in snowpacks or frozen soils. Lags between peak-precipitation month and peak-streamflow month vary relatively smoothly long from delays in high latitudes and mountainous regions to relatively short delays (0-3 months) nearly everywhere else. In polar regions, the timing of runoff becomes effectively disconnected from precipitation timing and depends on the timing of summer warming, so that lags between precipitation and runoff peaks of up to 11 months are observed. Mean runoff rates (streamflow/basin area) and runoff efficiencies (runoff/local precipitation) vary as functions of general aridity and in response to contributions from orographic sources. Highest runoff rates are centered around the Tropical Western Pacific where some of the most consistent and vigorous convective precipitation falls.

Correlations between annual totals of streamflow and climatic indices such as the Southern Oscillation Index (SOI) and North Atlantic Oscillation (NAO) illustrate near-global streamflow teleconnections. Seasonal SOIs are correlated to streamflows throughout the Americas, Europe, and Australia. The long predictive leads provided by SOI in western North America (SOI of preceding summers predicting to streamflows in following spring) are also applicable in South America and Australia, but appear to fail in other regions. North Pacific sea-surface temperatures (which are themselves functions of tropical Pacific conditions) are well correlated with annual streamflows throughout much of North America as well as Europe and the tropics. Seasonal NAOs are reflected in streamflows in the eastern United States, Europe, and tropical South America and Africa.

Natural Hazards

Human Dimensions of Climate Variability: Applications to Socioeconomic Problems

Roger S. Pulwarty and Henry F. Diaz

Human dimensions-applications research focuses on how social transformations influence social and environmental vulnerability to climate and weather risks, the perception and values applied by society to such risks and, realizing the benefits afforded by developments in climate research, products and services. Human Dimensions refer to the conditioning factors and driving forces that influence human activities and their environmental consequences. By "applications" we mean transformation and communication of relevant research results to meet specific needs of decision-makers in the public and private sectors, and the capacity building needed to facilitate this process i.e. education and training. Cases are drawn from (1) Climate, salmon and society interactions in the Columbia River Basin, (2) Hurricane risk and disaster mitigation, and (3) Decadal-scale climate impacts on water resources management in the western U.S.

The case studies point to a reframing of research goals toward identification of: (1) critical water-related problems, (2) social and economic trends altering demands and influencing the degree of vulnerability of system outputs (agriculture, recreation, power, water quality) to extremes of climate variations and to sequences of events, (3) drawing lessons from past events and measures to increase the flexibility of water allocation among diverse users, in response to interannual variability and longer-term trends, (4) the types of information that scientists can and should produce to substantiate change and, (5) entry points for the application of scientific information to mitigation measures employed by water managers and decision-makers.

Natural Hazards

Paleoclimate Modeling at CIRES/NCAR: Warm Climate Extremes

Robert DeConto, William Hay, Starley Thompson, David Pollard, Esther Brady, and Jon Bergengren

Understanding the dynamics of paleoclimates is critical to our understanding of the comprehensive climate system. Recent advances in *Earth System* climate modeling allow us to explore interactions between the atmosphere, the oceans, the land surface, the biosphere, and the cryosphere in the geologic past. Of particular interest are the warm, ice-free "greenhouse" climate modes of the Phanerozoic, such as the Late Cretaceous (80 Ma), when atmospheric CO_2 was about four times greater than today and the equator to pole thermal gradient was very low. Understanding how low meridional thermal gradients and warm continental interiors were maintained during the Cretaceous and other warm climate modes of the geologic past has become a classic problem of paleoclimatology.

In a new approach to paleoclimate modeling, terrestrial ecosystems have been included as an interactive component of Late Cretaceous climate simulations. We now believe vegetation played

an important role in the maintenance of Late Cretaceous warmth, ice-free poles, and warm winter continental interiors. High latitude forests masked the high albedo of snow cover in winter and spring, increasing surface to atmosphere net radiation, sensible heat flux, latent heat flux, and atmospheric moisture. Increased net radiative flux warmed the atmosphere and enhanced convergence over the continents, drawing in warm moist air from the oceans. High rates of evapotranspiration increased atmospheric moisture, adding to the water vapor feedback component of the greenhouse effect and enhancing the latent heat transport potential of the atmosphere.

To reconcile the role of the Late Cretaceous oceans in maintaining low meridional thermal gradients, a modified version of the Sempter and Chervin Ocean General Circulation Model (OGCM) was applied to surface forcing provided by GENESIS Atmospheric General Circulation Model (AGCM) simulations of the Late Cretaceous. The OGCM showed that ocean heat transport values similar to today can be maintained from Late Cretaceous surface forcing, despite reduced meridional thermal gradients. Most of the ocean heat transport in the Cretaceous was through meridional overturning, not the wind driven circulation as in today's oceans.

Natural Hazards

Predictability of Extreme Climate and Weather Events

R. Dole, K. Wolter, J. Whitaker, C. Smith and A. Loughe

The basic goal of this research is to develop a continuous suite of forecast products bridging the gap between weather and climate, with particular emphasis on providing NOAA with advanced-lead forecast capabilities of extreme large-scale weather and climate events. This work involves generalizing NOAA's current prediction strategy for convective storms, flash floods and hurricanes, to a much broader class of extreme events that includes major floods, droughts, cold waves and heat waves.

The basic approach being investigated at CDC/CIRES, in collaboration with research partners at GFDL and the National Centers for Environmental Prediction, is to develop a staging strategy for predicting large-scale extreme events, beginning with a broad outlook on possible risk areas. For some classes of events, for example, droughts in the southwestern U.S., significantly elevated risks can be identified a season or more in advance based on oceanic boundary conditions, particularly the state of El Niño - Southern Oscillation, or ENSO. There is emerging evidence that ENSO influences the relative risks of some shorter-term, intraseasonal events as well, for example, the likelihood of major flooding in parts of the West Coast, although anomalous boundary conditions alone do not determine the specific timing of such events.

For intraseasonal time scale events, therefore, an alternative approach is used to identify risks of extreme events at advanced lead times. This approach, called ensemble predictions, is essentially a version of a "Monte Carlo" strategy. The basis of this approach is to run a numerical prediction model, in this case the NOAA Medium Range Forecast (MRF) model, many times from slightly different initial conditions, and then to estimate probability distributions of the forecast quantities

of interest from the ensemble of model runs. The choice of different initial conditions reflects both uncertainties in the initial state of the climate system and the fact that the atmosphere's evolution is very sensitive to these uncertainties. Although this research is still in its early stages, preliminary results are encouraging, and indicate that ensemble predictions may be useful in increasing the lead times for alerting the public and decision makers of possible risks of severe large-scale weather events. This increased lead time should be useful in supporting a fundamental NOAA goal of reducing human and economic losses due to high impact weather and climate events.

Natural Hazards

Challenges of Space Weather from an Active Sun

T.J. Fuller-Rowell, M.V. Codrescu, C.N. Arge, and V. Pizzo

CU researchers at NOAA's Space Environment Center (SEC) are active in addressing the demands of the National Space Weather Program. SEC plays a pivotal role as the nation's provider of space weather alerts and warnings of pending solar and geomagnetic activity for the civilian sector. Research includes following the transport of ejecta from the sun (e.g. coronal mass ejections and coronal streamers) through the interplanetary medium, and predicting their arrival and impact on the Earth.

To address the challenge of tracking the flow of plasma from the Sun to Earth we have been engaged in bringing a physics-based research model of the global solar wind into online operations at the SEC forecast center. This model uses the observed magnetic field distribution on the surface of the Sun to predict, by numerical means, solar wind flow velocity and magnetic field polarity variations at Earth. From this, expected values for certain geomagnetic indices and electron fluxes can be obtained.

Another challenge is to understand and predict the effects of these space weather events (known as geomagnetic storms) on the near-Earth environment, when energy is finally dumped into the upper atmosphere. Recent advances in simulating the response with a Coupled Thermosphere Ionosphere Model (CTIM) have shown that the local-time, seasonal, and regional dependencies of the ionospheric response are controlled by interactions between the neutral and plasma environment. Ionospheric changes at Earth during geomagnetic storms cause disruption of communication and navigation systems. The goal is to transition these physically-based numerical models to operational use, through the Rapid Prototyping Center at SEC.

Natural Hazards

Preliminary Results from Air-Sea Interaction Measurements During the Fronts and Atlantic Storm Tracks Experiment (FASTEX)

P. Ola G. Persson, Jeffrey E. Hare, Allen B. White, Christopher W. Fairall

The Fronts and Atlantic Storm Tracks Experiment (FASTEX) was conducted in the North Atlantic Ocean during January-February 1997. The overall objective of FASTEX was to "advance the scientific understanding necessary to enable detailed diagnosis and prediction of the life cycles of eastern oceanic storms and their associated cloud and precipitation systems." During this project, NOAA/ETL performed an air-sea interaction component which used the R/V Knorr as a platform for various flux and remote sensing instruments. The objectives of this air-sea interaction component included to:

1) collect surface flux measurements in a high wind speed, open-ocean environment, the associated sea-state measurements, and quasi-continuous measurements of the mid-oceanic atmospheric boundary layer structure;

2) validate and improve parameterization schemes of the high-wind marine environment;

3) demonstrate the impact of improved parameterizations and/or mid-oceanic boundary-layer measurements on marine extratropical cyclone development and forecasting; and

4) validate satellite and aircraft estimates of surface and near-surface characteristics.

Incorporating the air-sea interaction measurements within this large field program assures downwind validation data with mesoscale detail for assessment of impact of PBL fluxes, and the data necessary for understanding the spatial relationships between surface fluxes and frontal features.

The ship was equipped with a redundant suite of turbulent flux instruments with motion corrections measuring momentum, sensible heat, latent heat, and CO_2 fluxes. Other instrumentation include bulk meteorological instrumentation; radiative fluxes; an in-situ sea-surface temperature thermistor; FSSP and optical array probes for obtaining sea-spray spectra; a TSK wave-height recorder; a 915-MHz wind profiler for obtaining winds up to 3 km; a vertically pointing aerosol/cloudbase lidar for obtaining cloud base and PBL height; and a range-gated X-band radar for obtaining sea-swell orientation. Frequent rawinsondes provide the stratification measurements, and data from three other ships and 6 buoys provide spatial information. Over 130 hours of flux data in wind speeds greater than 15 m/s were collected from at least twelve different storms, with measurements obtained in various stability regimes in various sectors of the storms. This presentation will focus on the objectives of the air-sea interaction component of FASTEX, the instrumentation systems on the Knorr, and summaries of the data collected. Sample preliminary analyses from some of the data systems will also be presented.

Natural Hazards

Modeling and Complexity in the Geophysical Sciences

J.B. Rundle, S.A. McGinnis, K.F. Tiampo

Nonlinear modeling techniques are a relatively recent outgrowth of the rapidly developing field of complexity which are directly applicable in the geophysical sciences. Many processes in the earth are nonlinear in nature and can be modeled more accurately and efficiently with nonlinear methods. Current research focuses on two areas of interest - multi-element interaction models and genetic algorithm inversion techniques. Multi-element interaction models are concerned with the system-level dynamics that emerge when many similar elements interact in according to some global rules. These models include neural nets, slider-block earthquake fault models, and the fault-patch model under development. The fault-patch model is a natural outgrowth of our interest in slider block models and consists of a three-dimensional collection of fault patches in an elastic half-space which interact with each other elastically through time. A genetic algorithm (GA) is a search technique which combines the principle of survival of the fittest with a prescribed random information exchange. This genetic algorithm technique inverts for the volcanic source and other associated physical structures in an elastic half-space given deformation data at the surface of the earth. Specific goals of current research include a better understanding of the physical processes involved - the history and evolution of fault systems from small to large scales or the location and volume of volcanic sources for both prediction and hazard analysis. In addition, we also hope to gain further insight into the nature and extent of their practical applications.

Natural Hazards

Microearthquake Field Study of the Front Range of Colorado

Anne Sheehan, Noah Hughes, and Craig Jones

Though the products of past tectonic activity are structurally evident along the Front Range of Colorado, modern seismicity has been relatively quiet, though not completely inactive. An earthquake of approximate M 6.6 (Spence et al., 1996) occurred in north-central Colorado in 1882, and a cluster of moderate injection-induced earthquakes occurred in 1967. Despite the ample geologic evidence for Quaternary fault movements, the seismicity of the Front Range has remained largely unstudied. The first microseismic data for the Front Range was only recently published (Bott and Wong, 1996).

During the fall of 1996, a local seismic network was deployed across the Front Range near Boulder to record local activity as part of a Field Geophysics course at the University of Colorado. The seismic deployment consisted of three short period three component seismometers with Ref-Tek digital recorders. Station spacing was approximately 15 km. The sensors were in place from early September through late November, and recorded local events as well as regional and teleseismic earthquakes. The stations were supplemented by stations in Golden and Idaho Springs, Colorado, operated by the USGS.

Twenty-three small earthquakes were located withing a 50-mile radius of Boulder during the three-month deployment. The earthquakes ranged from magnitude 0.5 to 2.0 on the Richter scale. The smallest earthquake that a person is able to feel is about magnitude 3, and a quake of 3.5 can cause slight damage. The levels of microseismicity for the Colorado network are found to be midway between levels for California (high rate of seismicity) and New England (low rate of seismicity).

Epicenter locations were determined for each quake and a map of the seismic activity was created. The most quake activity was recorded northwest of Golden. This microseismic distribution canl help isolate faults which may still be active and perhaps to locate previously unknown faults. An understanding of fault locations and activities will lend insight into the modern tectonics of the area.

Natural Hazards

Absolute Gravity and GPS Measurements in Greenland

T. van Dam J. Wahr, K. Larson, D. Robertson, and G. Sasagawa

Changes in the distribution and volume of ice in Greenland or Antarctica could cause vertical crustal motion of up to a few mm/yr around the edges of those ice sheets. The viscoelastic response of the earth to past changes in ice loading could cause vertical motion rates that are several times larger than this. Thus, the visco-elastic effects must somehow be removed before the observations can be used to help constrain the mass balance of the ice caps. Models of the earth's visco-elastic response to surface loads, suggest that this can be done by combining vertical motion measurements with simultaneous observations of gravity.

To apply these ideas, we have begun a multi-year, NASA-funded program to make simultaneous measurements of absolute gravity and crustal motion (using continuously-operating GPS receivers) in Greenland. The program was initiated in July, 1995, so that there are not yet enough data to allow us to constrain the mass balance of the ice sheet. In this talk, we will describe the project, and the theoretical results that motivate it.

Integrated Earth System Processes
Poster Session

Hydrological Cycle Climate Research
John Bates, Wesley Berg, Qian Ye, Gary Wick, Darren Jackson, and Chris Gottschall

The Earth's atmosphere is unique amongst the known planetary atmospheres in that it possesses a complete hydrological cycle. That is, we find water in its three phases: gaseous, as water vapor; liquid, as cloud liquid water; and solid, as ice and snow. The existence of a complete hydrological cycle on the Earth greatly modifies the climate, making this planet hospitable to a wide variety of life. It, however, also greatly complicates understanding and prediction of climate because the water and energy cycles interact in a non-linear way on all time and space scales. On the shortest time scales, within thunderstorms, the three phases of water can be found at the same time within a vertical column in the atmosphere. On seasonal to interannual time scales, the effects of regional changes in sea surface temperature in the Pacific Ocean are communicated globally by changes in the tropical atmospheric hydrological cycle. On decadal to centennial time scales, differences in precipitation minus evaporation drive the global oceanic thermohaline circulation thought by many to be the Achilles heel of long term climate variability. Thus, hydrological cycle climate research truly cuts across all of the NOAA Strategic Plan themes and provides the link between these themes and human dimensions. The CDC satellite climate research group is using a variety of remote sensing data sets to study the atmospheric branch of the hydrological cycle and air-sea interactions.

Earth System Processes

Coherent Doppler Lidar Measurements of Wind Statistics
Rod G. Frehlich, Stephen M. Hannon and Sammy W. Henderson

Eye-safe solid-state coherent Doppler lidars produce high spatial and temporal resolution measurements of the radial component of the wind field. The three-dimensional structure of the atmospheric velocity field is probed by using various lidar beam scanning geometries to convert the statistics of the radial components into traditional statistics. Coherent Doppler lidar measurements of wind statistics are presented for boundary layer conditions using a 2-micron solid-state lidar. The pulse occupies approximately 30 meters and each measurement has a spatial resolution for velocity measurements of approximately 70 meters. The effects of the spatial averaging by the lidar pulse are removed using theoretical corrections as well as computer simulations of performance.

The spatial structure functions with the pulse correction agrees with the Kolmogorov theory with the addition of an outer scale of turbulence for vertically pointed lidar beams as well as beam directions 45 degrees from vertical. In high shear regions, the spatial structure function of velocity fluctuations about the mean velocity also agrees with the Kolmogorov theory. The level of the structure function in the power-law region defines the energy dissipation rate. The estimated structure functions also produce corrections for the velocity variance which remove the effects of the spatial averaging of

the lidar pulse. This permits unbiased estimates of the average velocity, velocity variance, and energy dissipation rate. Profiles or these velocity statistics are presented for a convective boundary layer.

Earth System Processes

A Physical-Statistical Approach to Regionalizing Low Flows

Peter Furey and Vijay Gupta

An equation is introduced which characterizes low flows in river basins. This equation is derived from a simple steady-state model of low flow from a hillside and fits within a transient-state context. Unlike current regional low-flow equations, it is expressed in terms of quantiles and can account for some of the temporal and spatial statistical variability of low flows in a basin. This equation is tested against low-flow data from the Flint River Basin in Georgia and the Gasconade River Basin in Missouri. Data analysis reveals that most predictions made by this equation, but not all, hold true. It suggests a new statistical-dynamical approach to regionalizing low flows in river basins.

Earth System Processes

Large-Scale Mapping of Ocean Surface Currents with Over-the-Horizon Radar

T. Georges, J. Harlan

Results of recent tests with U. S. Navy over-the-horizon (OTH) radars suggest that it is possible to map near-surface currents to ranges greater than 1000 km, with up to 15-km resolution. The technique is similar to that used by commercially available high-frequency current-sensing radars, whose range is limited to about 50 km. OTH radars see far beyond the optical horizon by bouncing their beams off the ionosphere. The effects of ionospheric distortion on the sea echo, previously thought to prevent extraction of currents, can be mitigated by taking advantage of the different time scales of ionospheric motions and ocean currents, and by using land echoes as zero-Doppler references.

Examples of current maps show previously unseen details of the Florida current, the Caribbean Western Boundary Current, and the Gulf of Mexico Loop Current. Using two OTH radars, we recently obtained the first surface current vector map in the vicinity of a hurricane, which shows the development of a storm surge.

Earth System Processes

Lower Tropospheric Dynamics over the Western Equatorial Pacific

Leslie M. Hartten, David S. Gutzler, Paul E. Ciesielski and Richard H. Johnson

Integrated Sounding Systems (ISSs) developed by personnel from CIRES, NCAR, and the NOAA Aeronomy Lab (AL), were deployed for the first time during TOGA COARE (Tropical Ocean - Global Atmosphere Coupled Ocean-Atmosphere Response Experiment). Each ISS consisted of a surface met station, a 915-MHz doppler wind profiler, and an Omega-based balloon sounding system. Data collected by the ISSs during the Intensive Observing Period (IOP) of COARE, 1 November 1992 through 28 February 1993 are being used to investigate the large-scale dynamics of the atmosphere over the western equatorial Pacific during boreal winter. Analysis of the half-hourly lower tropospheric winds measured by the profilers reveals the existence of a strong diurnal cycle at Manus and Kavieng which appears tied to the diurnal cycle of convection over the large island of New Guinea, located a few degrees to the southwest. Inclusion of these profiler winds in an objective analysis of western Pacific sonde winds has improved the resultant analysis and led to changes in the inferred precipitation rate that are compatable with other measures of COARE precipitation. The large-scale divergence computed from the surface and profiler winds shows zonal and temporal variations that are under investigation. The analysis of the ISS data is also providing information that will be useful in future deployments of both ISSs and ship-based wind profilers.

Earth System Processes

Coupled Ice/Ocean Modeling of Baffin Bay and the Formation of the North Water Polynyas

John Heinrichs, Konrad Steffen, and Lakshmi Kantha

Baffin Bay, located between Greenland and Canada, is normally covered by sea ice during the polar night. At its northern end, periodic localized reductions in ice cover occur, exerting an important climatic influence. These polynyas, together called the North Water, form the largest recurrent ice anomaly in the Northern Hemisphere. Topographically channeled winds are the primary driver for the polynyas, but observations of warm surface water suggest the importance of oceanic heat. A 3D coupled ice/ocean model of Baffin Bay was used to evaluate theories about the North Water and examine its sensitivity to changes in forcing. In a control experiment, with initial conditions and forcing typical of polynya events, ice and ocean behavior was generally consistent with observation. Areas of reduced ice cover were produced in the locations and with the size of the real examples and warm water upwelling occurred within the polynyas. An experiment with an isothermal upper ocean at freezing temperature halved the size of the ice anomaly and produced unrealistically low surface heat fluxes. Life cycle simulations with time-variable wind forcing showed that warm water upwelling maintains the polynyas longer. Sensitivity studies confirmed the critical roles of wind and oceanic heat.

Earth System Processes

Arctic Regional Climate System Modeling
Amanda H. Lynch, David A. Bailey and Wanli Wu

The strong sensitivity of polar climate to the simulated surface fluxes of heat, moisture and momentum is undoubtedly responsible for many of the deficiences in the simulations of the Arctic by global climate models. Due to the complexity of the interactions between the atmosphere (including clouds), ocean, land, snow and sea ice, rigorous investigation of these deficiences requires a high resolution, physically based approach. The Arctic Region Climate System Model (ARCSyM) has been developed for studies of ocean-ice-atmosphere and land-atmosphere interactions in the high atitudes on seasonal timescales.

To be shown are some examples of applications of ARCSyM. First is an investigation of the impact of various land surface parameterizations upon the simulation of surface fluxes over the North Slope of Alaska. These land surface parameterizations (BATS, CLASS) are used extensively in GCMs and have been intercompared in the PILPS study, but a detailed assessment of their performance at high resolution in the Arctic, has not been done. In particular, the influence of the snow albedo specification on the spring snow melt and atmospheric seasonal transitions are examined.

Second is a case study of the St. Lawrence Island polynya, located in the Bering Strait. This polynya is a site of localized high rates of heat and moisture exchange, which have an influence upon the downstream flow. A comparison of a climate system model simulation of a polynya formation event is compared with SAR-derived ice vectors, SSM/I ice concentration, AVHRR surface temperatures and station data.

Earth System Processes

Boundary Layer Structure and Surface Fluxes on the Arctic Pack Ice
P. Ola G. Persson, Dominique Ruffieux, C.W. Fairall, and Stephen D. Burk

During the Arctic Leads Experiment (LeadEx 92) in March-April, 1992, NOAA/ETL deployed a suite of surface-based in situ and remote sensors to the Base Camp on the permanent pack ice in the Beaufort Sea near 73°N, 250 km north of the Alaskan coastline. These instruments were used to study the previously poorly documented springtime boundary-layer structure over the Arctic pack ice and have been used for model validation. The sounding data revealed a surprisingly strong diurnal cycle over the pack ice in the lowest 300 m, with the significant daytime mixed layer depth having important implications for the effect of fluxes from leads. Significant low-level spatial variations between sites on the Alaskan coastline and that on the pack ice reinforces the invalidity of assumptions of spatial homogeneity in the Beaufort Sea basin. In addition, many temporal variations, including those in the surface fluxes, were clearly tied to synoptic variations and the passage of storm systems, emphasizing the need for climate models to include changes in the various types of synoptic forcing. Observed surface energy budgets also suggested some significant diurnal

and day-to-day variations in the albedo of the snow-covered surface, calling into question the use of fixed albedo values for dry snow.

Examples are presented of how the observations have been used with both simple and complex models to test and improve data processing techniques, to improve model parameterizations, and to facilitate a better understanding of the physical processes associated with the observations.

Earth System Processes

Program for Arctic Greenland Climate Assessment: Greenland Climatology

Konrad Steffen, Jason Box, and Waleed Abdalati

Climatological observations and surface energy balance studies are the keys to the understanding of the surface processes linked with ice sheet mass balance. Long-term climate records at different sites on the ice sheet were made for the assessment of the snowpack energy and mass balance of the accumulation zone and to gain more complete information of the spatial variation of climate over the ice sheet.

A considerable amount of surface energy and mass balance data as well as some ice cores have been collected at the Swiss Federal Institure of Technology/University of Colorado (ETH/CU) research camp since 1990. The camp is located at the ice sheet equilibrium line altitude (ELA), about 89 km east of Jakobshavn at 69°34' N, 49°17' W on the western margin of the Greenland ice sheet . Six years of detailed climatological and glaciological measurements at the ETH/CU camp provide valuable insight on the magnitude of the seasonal and interannual variability in the equilibrium zone. Based on the ETH/CU camp energy flux measurements, a simple climate sensitivity model calculation showed, that during a 3°C temperature increase scenario, approximately 22 km^3 water equivalent of snow would sublimate. This equals 4% of today's annual accumulation. Large seasonal and interannual variations in air temperature and wind speed were found for the location of the ETH/CU camp based on the six year record. Surface temperature anomalies in the order of -3 C along the west coast of Greenland for the winter months have also been reported since 1990. In contrast, a notable increasing trend of 4.5% per year in melt area has been observed between the years 1979-91, which came to an abrupt halt in 1992 after the eruption of Mt. Pinatubo. A similar trend is observed in the temperatures at six coastal stations.

The Greenland Climate Network (GC-Net) was established in spring 1994 with the emphasis to monitor climatological and glaciological parameters at various location on the ice sheet over a time period of at least 5 years. The objectives of the GC-Net automatic weather station (AWS) network are:

- Assess daily, annual and interannual variability in accumulation rate, surface climatology and surface energy balance at selected locations on the ice sheet where high sensitivity of the ice sheet mass balance to climate anomalies is predicted from modeling results.
- Assess accurate surface elevation, location, near-surface density at the AWS location with the option to revisit the locations in order to get temporal information for dynamic ice sheet modeling.

Earth System Processes

A Probabilistic Recursive-replacement Algorithm for the Generation of Geometrically Embedded Self-similar Networks

Seth Veitzer and Vijay K. Gupta

Prediction of peak discharge in ungauged basins (PUB) is an outstanding problem in surface water hydrology. Regionalization of the physical processes that determine surface flows requires a theoretical understanding of the physical and statistical relationships that connect these processes across a broad range of temporal and spatial scales. Of particular importance in this context are the spatial properties of landforms including river network structure and the spatial and temporal structure of rainfall fields. To understand the effect of the geometric structure of river networks across scales on the scaling structure of floods we present a recursive-replacement algorithm for generating topologically self-similar networks of various relevant topologies. In conjunction with an embedding scheme we generate various types of random networks which fill 2-dimensional space with this construction which have some of the salient features of real river networks.

Earth System Processes

How Does NSIDC Offer Integrated Geoscience Data for Cryospheric Research?

Ronald Weaver

The National Snow and Ice Data Center, located within CIRES is a multi-agency funded data center providing data and information to the cryospheric (snow and ice) scientific community. It is operated under the auspices of NOAA/NESDIS National Geophysical Data Center through the CIRES Cooperative Agreement.

Snow and ice environmental research depends upon multiple data sources ranging from in-situ measurements, aircraft and satellite remotely sensed data, to computer model results. Data sets drawn from such a range of collection methods present unique challenges for acquisition, archival, and distribution, especially in terms of providing products which attempt to break down interdisciplinary barriers.

This poster describes NSIDC efforts in two major areas: production and distribution of data products, and compilation and distribution of information about data (metadata). We present examples of current and planned integrated data sets and descriptions of on-going metadata compilations.

Earth System Processes

Heterogeneity in the Landscape: Implications for Biosphere-Atmosphere Interactions

C. Wessman, A. Bateson, A. Hudak, L. Vierling, G. Asner, M. Shippert

Structural heterogeneity in the landscape constrains biogeochemical processes from local to global scales through biotic and abiotic control on primary productivity and evolution of trace gases. Vertical variation in vegetation drives net canopy assimilation of CO_2 through structural and physiological influences on the fraction of absorbed photosynthetically active radiation (fAPAR). Patterned distribution of vegetation growthforms (e.g. grass, shrub, tree) across a landscape has a great effect on overall fAPAR and large-scale C exchange and storage; and will influence other trace gas fluxes through effects on biotic and abiotic driving factors. Our lab is studying the various aspects of how biogeochemical processes are constrained by heterogeneity within and across canopies; and, importantly, how those processes are altered through human-driven changes in land cover and land use. Studies span a wide range of biome-types: tropical rainforest, savannas, grasslands, and arctic tundra. Field studies, simulation modeling, remote sensing and geographic information systems are combined to understand the mutual feedback between structural patterns and biogeochemical processes.

Earth System Processes

Future Stability of US High Plains Land-Cover

Roberta Yuhas, Alexander Goetz, Jonathan Overpeck, Robert, Webb, David Schimel, and Gifford Miller

The High Plains extend from South Dakota to Texas and include parts of Colorado, Kansas, Nebraska, Oklahoma and New Mexico. Land cover in this region is susceptible to both human land-use and climate-induced land cover change because it is a semi-arid and in many areas must be irrigated to produce crops. Over 100,000 km^2 of this region contain stabilized sand dunes and sand sheets created and reactivated during the last 10,000 years. Based on the paleoclimate record it is clear that a much bigger land-cover change took place prior to significant human land-use than after.

This research blends talents, results, and experience of four different organizations to address the central question of how to develop an effective means to assess how the High Plains, with its economically critical land cover, will be affected in the future. A detailed study of northeastern Colorado is nearing completion. A land-use change assessment for the High Plains using multitemporal Landsat images taken over a 15-year period was recently begun. A new project focusing on the integration of the Landsat data with process modeling to understand the sensitivity of High Plains land-cover to climate and human induced land-use forcing has just begun.

CIRES Scientific Program Review, 1997

Review Panel Reports

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April 18, 1997

Dr. James L. Rasmussen, Director
NOAA OAR Environmental Research Laboratories
SSMC-3, #11618
1315 East-West Highway
Silver Spring, MD 20910

Dear Dr. Rasmussen:

As one of the four-person review team visiting CIRES on April 16-17, 1997, my foremost impressions were that CIRES is a superb organization from its director on down, and that it has done an excellent job in developing a seamless integration between the NOAA mission agency objectives and the CU research culture. In being briefed on the highlights of CIRES activities and educated on its best research though posters, we found all these materials to be well prepared and presented.

Although we regard CIRES as extremely healthy as it currently is, we did discuss possible threats to its success and ways that it might be buffered against such threats and be further strengthened.

I believe that a key to CIRES future will be an institutional emphasis on the quality of its staff and their work, through insuring the retention of its outstanding scientists, maintaining its current high morale, and insuring that future recruitments seek only highest quality staff. For this, CIRES should continue and perhaps accelerate its efforts to provide research staff doing comparable work to faculty with positions that they can view as comparable to faculty appointments, though improvements in job security, salaries, and career tracks where appropriate. Further opportunities should be found for these staff to contribute to teaching at the graduate level both at CU and elsewhere. In addition, it is important to have in place, at an annual or more frequent interval, various awards to better recognize both research success and dedicated service activities.

Much of the work of CIRES depends on high-quality computational facilities. We saw several such individual entities that appeared to be state-of-the-art and well-run; in particular, I was impressed with what NSIDC is building though NASA funds, and what CDC has developed with NOAA support. However, it appeared that parts of CIRES might not have access to such good facilities and that CIRES might not have adequate support for maintaining a good core facility,

either in terms of being able to purchase adequate hardware or maintain adequate staffing.

We were briefed on the CIRES initiative "Water in the West." Overall, we found this a very good fit to the NOAA forecasting mission and to CIRES capabilities. In particular, it is an obvious need for future success in NOAA's efforts to provide seasonal to interannual forecasting. However, it should be recognized that the question is very complex with an extensive federal agency history that must be dealt with in an approach comprehensive enough to provide practical results. In particular, there are many political, legal, and social aspects to the issue that determine how any NOAA products might actually be used, and there are important science areas that might not be adequately covered by current CIRES staff alone. Thus, further planning should recognize the whole range of issues linked to this question, what subset the CIRES initiative expects to advance, why they are uniquely positioned to do this, what are current gaps in expertise required for the initiative to be successful, and what strategies will be followed to fill these gaps though further staffing and further partnerships within the local or regional science communities.

Satellite remote sensing is becoming an increasingly important tool for study of the Earth System and for addressing the NOAA forecasting mission. In that context, CIRES is nearly ideally situated for extensive use of satellite data because of the present multiple strengths in this area on campus, recent CIRES growth in this area, and involvements with EOS. It struck me that, especially in the climate area, the current excellent work could be substantially enlarged or that in general the intellectual understanding of content and optimum use of satellite data could be further enhanced, either though further education of existing staff or possibly new hires in this direction.

Sincerely,

Robert E. Dickinson
Regent's Professor

cc: Dr. Susan Avery, CIRES Director

RED/cas

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April 21, 1997

Dr. James L. Rasmussen, Dir.
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Dear Jim:

This letter is my report of service as a reviewer in the scientific review of CIRES conducted in Boulder on April 16 and 17, 1997. I would like to begin by saying that I enjoyed the opportunity to participate in this review. Although I was previously very much aware of the work on stratospheric meteorology and chemistry within CIRES and at the NOAA Aeronomy Laboratory, and had some familiarity with the work of the Climate Diagnostics Center, I had not fully appreciated the wide range of CIRES research in the atmospheric, oceanic, and earth sciences at CU and in ERL. I believe that Susan Avery and her staff did an excellent job in organizing and conducting the review in a manner that allowed us to sample the breadth and depth of CIRES and to obtain a reasonable basis for evaluation in a short period of time. For an organization the size and scope of CIRES this was clearly not an easy task, and I believe that all four reviewers were very favorably impressed by the professional manner in which the review was organized and carried out.

We were also very impressed by the high level of scientific quality of the work within CIRES, both on the CU campus and at the participating NOAA laboratories, as it was presented to us in the various poster sessions. CIRES has indeed achieved an admirably effective partnership between its university based and ERL based researchers. The presence of *several* very strong NOAA research laboratories in Boulder does of course give CIRES an advantage not shared by some other Joint Institutes. Nevertheless, it is gratifying to note that the Director and Fellows of CIRES have actively participated in creating an environment in which University and NOAA partnerships are effectively developed and maintained.

A major strength of CIRES is the ability to bring several disciplines together to address problems of mutual interest. Although there is much lip service paid to interdisciplinary and multi-disciplinary studies at universities these days, actual examples of successful implementation are fairly rare owing to the reluctance of traditional discipline oriented departments to share assets. The fact that CIRES has its own faculty line has enabled CIRES to make appointments that provide strong benefits in promoting collaborative ventures that cross disciplinary boundaries.

The newly proposed initiative on the theme of *Water in the West* is an excellent idea that has the potential to successfully apply the multi disciplinary approach possible through CIRES to an area of vital societal importance. More work is clearly needed to turn this excellent idea into a detailed proposal. CIRES clearly has the expertise to tackle issues related to the role of climate variability in water resources, and it would seem to make

sense that the CIRES initiative should emphasize the climate aspect at least in its developmental stages.

Through its links to the NOAA laboratories, CIRES provides university students and researchers with access to instrument design and fabrication facilities not available in most individual university departments. The strengths of ERL in remote sensing and other types of instrumentation have, however, apparently not been fully exploited by CIRES. It appears that connections between scientists at ETL and CMDL and the CIRES members at CU in some cases may not be as strong as are those between CIRES scientists at CU and those at some other NOAA labs. CU has strong programs in remote sensing based in departments outside of CIRES (Aerospace Engineering, for example). A logical step would be to entrain some of this excellence in remote sensing at CU into CIRES. I suggest that inviting Professor Judith Curry to become a CIRES Fellow would be an effective step in increasing the visibility of remote sensing within CIRES.

From the material provided to us prior to the review, and from our discussions with members of CIRES, it is clear the CIRES is very effectively managed by the Director Susan Avery and her staff. It also appears that CIRES has strong support from the CU administration, though obviously the severe constraints on the university budget have limited the ability of CU to provide adequate financial support for staff and infrastructure. One particular problem raised by several CIRES scientists was the lack of a mechanism to build and maintain an adequate computer network for the Institute. The administration of CU should consider utilizing a recharge center or other mechanism to insure an adequate computer infrastructure. This is the single greatest infrastructure need in modern earth sciences.

In an era in which salary increases for merit are generally small and infrequent, the efforts of the CIRES Director and Fellows to establish a career track and an award system for CIRES employees are commendable. These efforts should be supported by the administrations of CU and of ERL.

As one of the other reviewers remarked, "CIRES is a jewel in CU's crown". CIRES provides enormous benefits to CU and to NOAA ERL. Through its excellent research and its support of fellowships for young scientists it also plays an important national role in the atmospheric and other earth sciences. It is important that NOAA and CU continue to provide the support needed to sustain and build CIRES as a center of excellence.

Sincerely yours,

James R. Holton
Professor

cc: Professor Susan Avery

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April 18, 1997

Director James L. Rasmussen
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Dear Director Rasmussen:

As a member of the External Review Team, I am pleased to give you my observations made during the CIRES 1997 Scientific Review. There is no question in my mind that the CIRES leadership, the scientists, and their research efforts which I reviewed are of high quality. The documentation provided to the review team was well prepared and most useful in providing the necessary background for us. The format of the scientific presentations was well conceived; the poster presentations by the lead scientists involved in the work allowed a useful personal interaction with the review scientists. The laboratory tours were well planned as well and gave the review team a good sample of the many active experimental groups involved in the CIRES-ERL joint research efforts.

I feel that a special recognition should be given to the obvious excellent leadership of the CIRES Director, Susan Avery. She is a very capable, hard-working administrator to whom much of the current success of the CIRES organization must be attributed. Her conscientious efforts, her broad scientific expertise, and the quality of her judgments is evident. Unfortunate for CIRES is the likelihood that the excellent job which she is doing will attract many advancement opportunities in the both university and federal laboratory administration. It is also a most significant benefit to the CIRES program to have the quality administrative leadership of the University of Colorado which is evident in Vice Chancellor Carol Lynch. She and Dr. Robert Sievers are to be commended for their important roles in integrating this research group into the mainstream of the educational program of the University without any obvious major departmental faculty objections to the growing presence of this largely research oriented institute within their midst.

Although I was impressed with the apparent ability of the CIRES scientists in all of the disciplines to which I was exposed, I will restrict my scientific evaluation primarily to the significance and quality of the scientific activities of the CIRES-ERL (NOAA) in the area of my expertise, atmospheric chemistry. The Boulder area is rich in quality research organizations concerned with atmospheric chemistry (including faculty, scientists, and graduate students in CIRES University of Colorado's Department of Chemistry and Biochemistry, NOAA's Aeronomy Laboratory, NCAR's Atmospheric Chemistry Division, etc.). The contribution which CIRES scientists make to these efforts is becoming an increasing fraction of this total effort. The atmospheric chemistry-related research of CIRES Fellows: John Birks, Ray Fall, Fred Fehsenfeld, Robert Sievers, Susan Solomon, Margaret Tolbert, and that of CIRES research associates: Jim Burkholder, David Fahey,

Paul Goldan, David Hanson, Jerry Harder, Gergory Huey, Gert Hübler, Andy Langford, Steve McKeen, Dan Murphy, A. R. Ravishankara (Ravi), Jim Roberts, Ranajit Talukdar, Michael Trainer, Eric Williams, and their many student fellows and research assistants which comprise their research groups, are at the forefront of current research in the area. These CIRES/NOAA scientists have continued to provide information required in the understanding of the various scientific issues in atmospheric chemistry which concern scientists today (*e.g.*, the ozone hole, tropospheric ozone buildup, global warming, etc.). It suffices to say that the efforts of the CIRES/ERL team of scientists have made it one of the most outstanding groups in atmospheric chemistry today. It seems unlikely to me that this success story could have been written in the short time frame involved without the combination of NOAA issue oriented research planning, its scientific and financial support of the efforts, and the strong leadership of the CIRES scientists, administration, and students.

CIRES is an environmental research institute, and its primary function is to provide quality research in those important existing and developing areas of the environmental sciences in which highly specialized scientific guidance of government agencies is required to answer key scientific questions responsibly. The development and improvement of this program requires the continued review, upgrading, enhancement, training, and recognition of the CIRES scientific staff by the administration. The methods which are in place at CIRES seem to be working well to maintain and improve the research product. However CIRES is an integral part of the University of Colorado (termed by one of our review team as the "Jewel in the Crown" of CU), and as such, its staff has a real challenge, not only to be accepted by the academic faculty, but to be seen as a valuable asset to the university. It is not clear to this reviewer that CIRES staff are now perceived in this light by the academic faculty of CU. They will never be accepted by all, but there are many paths which one can follow to work toward this goal. Although it is probable that the quality administrators within CIRES and CU have more knowledge of the appropriate methods required here, this reviewer offers some limited suggestions.

CIRES staff will accept the obligation to enhance the educational programs of its educational host, provided they are given this opportunity. Active participation in the scientific educational programs of the University by CIRES scientists will occur most readily when they are not only condoned, but fostered by the University Administration, and accepted by the faculty as a real asset to "their" university. University faculty protect and covet their subject areas with an unusual brand of pride, and even selfishness; I can understand this attitude, since I practiced this peculiarly prejudicial art for some years. Remember that in the eyes of many of the academic faculty, he or she is *the* expert in his or her given area of specialization. If such faculty are to share any part of their platform in the classroom with "outsiders", it will usually be done, at least in part, to obtain their own objectives in providing a more attractive, modern, and useful course to the students. The best of all worlds is achieved when the academic staff enhances their course work through the involvement of the "real world" specialist who brings into the course some application of the principles which the professor has been expounding, and shows in a rigorous yet attractive fashion how these principles are used in achieving the answer, or alternative

paths to the solution of some societal environmental problem. It is not necessary or should it be expected, in my opinion, that CIRES staff devote their time to the development of entire courses offered within science departments. A better use of CIRES staff time is to provide significant and relevant input to existing courses. This will only be done if the faculty are sufficiently aware of the potential value of a CIRES scientist's contribution. A special effort may be necessary to introduce the CIRES scientists to the appropriate academic faculty. An obvious route to this end (perhaps now invoked) is the cordial invitation of the members of academic departments, particularly in the sciences, to attend well-planned scientific seminars by CIRES scientists. The circulation of selected CIRES scientific products (publications or summaries) to selected faculty should be investigated as an additional means of introducing CIRES members to them. In some way the unusual talents within CIRES must be given adequate recognition. The CU faculty must gain confidence in certain members of the CIRES scientific staff before they will be sought out, and a truly successful collaborative efforts in course work or joint supervision of graduate and undergraduate research can occur. Of course CIRES scientific staff cannot take on a "Roger Dangerfield" attitude in their search for respect, but they must earn this with continued excellent research work which will be an attraction to the faculty. In the process of impressing the CU science faculty with the prowess of CIRES scientists, it is evident that CIRES scientists can learn a great deal from the academic science faculty, and CIRES scientists should be a prominent feature within the audience at appropriate departmental seminars.

It appears to this reviewer that an equally important educational role for the CIRES scientists is in the "hands on" research training in the environmental sciences which they can provide. This occurs in most of the CIRES ongoing program now, but it is not clear that it is given the whole-hearted support of the academic staff who compete for undergraduate and graduate students in their research efforts. CIRES has grown in recent years to where it may be perceived by many of the academic staff as a serious threat to their future through the possible unfavorable competition for the limited supply of graduate students. The faculty may never admit to it, but if the collaboration between academic faculty and the CIRES scientists becomes commonplace, it will soon become evident to the academic faculty that the input from the best of the practicing research scientists from CIRES may be at least as valuable as their own academic input to many research efforts as well as in classroom instruction.

The proposed "Water Initiative" which is under development by the CIRES administration and scientific staff appears to offer a good scientific umbrella under which the diverse interests and talents of many of the CIRES scientists could be utilized well. Seemingly it could provide planning and realistic solutions to this most important societal problem facing the population of the western U.S. Before launching on such a complex and diverse research area, one should face reality with such questions as: 1) Is CIRES the best qualified research organization to lead a program related to Water in the West? 2) Will the adoption of the program detract from or supplement current strengths within CIRES? I trust that the good judgment of the CIRES/ERL leadership will delay the initiation of any such program until the proper detailed planning is well in hand, the

ground swell of administrative and scientific staff support for this is clear, and that a strong CIRES research effort in the area can provide unique and important inputs to the potential solution of perceived water problems.

I note that description of the Responsibilities for CIRES Fellows is much better defined in the Affiliate/Membership section of our information booklet supplied to us, than is the much shorter, more flexible yet presumably the "accepted" version which is defined in the official By-Laws. Perhaps the Council of Fellows should consider adopting some of these seemingly more appropriate details into the By-Laws.

I hope that these very limited comments will be of some help to you in your program evaluations. It has been a particular pleasure for this reviewer to participate in this review. It was especially gratifying to meet you and the others associated with the NOAA ERL programs and to learn first hand that there are indeed other administrators in NOAA who are high quality, knowledgeable scientific leaders. I have suspected as much in view of my contacts with Dan Albritton and Fred Fehsenfeld whose administrative quality has become legendary among the atmospheric chemistry scientific community.

Sincerely yours,

Jack G. Calvert
Senior Scientist

Copy to: Dr. Susan Avery

Dr. James L. Rasmussen
Director, NOAA/OAREnvironmental Research Laboratories
SSMC-3, #11618
1315 East-West Highway
Silver Spring, MD 20910

Dear Dr. Rasmussen:

I wish to express my deepappreciation for the opportunity to participate in the 1997 scientific review of the*Cooperative Institute fo Research in Environmental Sciences*. A visit to CIRES is always a very pleasant experience, andthis one was no exception, not on from the point of view of thescientific discussions, but also because of thesuperb hospitality the CIRES community extended to th review committee. Ihereby convey my thanks to allCIRES Fellows, to Director Susan Avery, to Dean Carol Lynch and of courset NOAA/ERL for a most enjoyableand fruitful visit.

My report is mostlyextracted from my notes, and includes general impressions, specificcomments, and a few recommendations.

First and foremost, the mostimpressive aspect of CIRES is that it represents an unusually effectivepartnershipbetween the Univers and NOAA. The review left me with the impression ofa seamless cooperation between academic researchers and federal employees o multi-disciplinary researchproblems of national and internationalimportance. At no time during this visit (nor during any of my previousvisits to CIRES) did I perceive the presenceof two separate, parallel communities, other than through name tags orthrough explicit mention of the fact duringdiscussions! In fact, prior to this review, I had not realized the extentof NOAA's presence on the campus, norhad I known that so many different NOAA Laboratories participate in CIRES.This is clearly how joint institutes aresupposed to function, although we all know that this is usually easier saidthan done! It is therefore a tribute to thespirit of cooperation between CU and NOAA, and to the attitude of bothmanagers and researchers from these twocommunities that CIRES i actually working as well as it does. As thelargest of the nine *Joint Institutes*, CIRES setsa standard for all others to emulate.

CIRES is indeed a ratherlarge institute, whose scientists cover quite a remarkable range ofdisciplines in the EarthSciences. From th point of view, the science symposium was quite an eyeopener, and was extremely educationalfor me. All poster presentations were excellent, and one could literally'experience' the level of enthusiasm of theirauthors, scientists and students alike. I really liked the approach ofpreparing posters that cover several related andcoordinated investigations, as opposed to the more traditional 'oneproject-poster' model. This format for areview is a very good one, and I will definitely suggest it to others! Iunderstand that Susan Avery should get thecredit for coming up with this very effective approach to convey thebreadth of the research conducted at CIRESwhile avoiding the danger of completely overwhelming the visitors!

Perhaps one of the majorstrengths of CIRES is its ability to focus expertise in several disciplineson specific scienceproblems. Nowhere is the need for such an approach more evident than inclimate and global change studies. Theposters demonstrated that CIR can do that beyond the shadow of a doubt,with the added interesting twist thatboth the academic research perspective and the agency mission orientedperspective seemed to be married quite har

moniously. I view this as a good sign that it is possible to couplemission-oriented R&D with 'curiosity-driven' research, with a successful outcome. Given the anticipated continueddecline in federally-supported research, thismeans that CIRES is actually well positioned to survive the increasedfiscal pressures we can expect for the years tocome. A second major strength of the Institute lies its instrumentbuilding tradition. Only a few institutions in theEarth sciences have maintained such tradition over the years, and CI isa clear success story in this regard. Onemore characteristic of the Institute that impresses me, is that thedominant strengths of CI have evolved over theyears, a sign that the institute has successfully avoided the danger ofstagnation in its research interests. For instance,(at the risk of sounding parochial!) I note that over a decade ago, solidEarth geophysics played a very important andvisible at CIRES; with the rapid growth of climate-related science,this focus receded to a less visible position inthe early 1990s; neverthel in recent years, solid Earth research atCIRES has seen a significant recrudescence, butwith a decidedly fresh outlook, including som very forward-lookingapplications of GPS geodesy and of complexitytheory, in addition to the more traditional disciplines. This is anindication of a vigorous institution, capable of rejuvenation.

One of the outcomes of therecent retreat described by Director Avery in her introductory presentationis the proposalthe CIRES take lead role in a new 'water in the western US'initiative. Given the very early stage of development ofthis idea, it is difficult to comm on any specific aspect of it at thisstage. The idea is certainly timely and is not anisolated one. What is clearly needed it to flesh it o as a full blownproposal, which should spell out the scope of theproposed initiative, the level of participation of various interestedagencies and their respective roles in the effort, andthe governance of the project. Clearly, NOAA will have to play a majo roleif the initiative is to be developed at alevel where its impact is significant, and therefore, the initiative willneed to be quite visib in NOAA's budget. Ibelieve that CIRES should assume some level of ownership of this proposal,and should therefore become involvedrather directly in the budget process. What CIRES can bring to the table isits interdisciplinary perspective, and itsability to bridge academic research with programmatic science. I think theinitiative will be a cornerstone of futurescientific reviews of the Institute.

At the heart of the matter,of course, is how to keep CIRES as a sustainable center of excellence. Asthe latest of a verydistinguished line of CIRES directors, Dr. Avery should receive specialkudos for her management skills. CIRES conveys an impression that it is run as a tight ship, in which the Directormanages to maintain a rather congenial environment, and where sources of tension (unavoidable among such a large anddiverse group) are dealt with effectively andelegantly. Certainly, the revision of the Bye-laws, an the development ofa career track information package, areextremely positive steps, which have been taken successfully by DirectorAvery and by the CIRES Fellows, in spite ofthe difficulties inherent to such moves. In addition, the Council ofFellows is o of the major assets of CIRES, and itis a very good thing to see this council take an active role in shaping thefuture of the Institute. is populated withvery good people right now, and will surely continue to be, since it isquite evident to any outsider that being a CIRESFellow is a highly desirable status.

However, with the Fellowstaking a more explicit role in determining future directions for theInstitute, and a moredirect responsibility in managing it, several issues come to mind whichdeserve attention. I list them below in no particular order.

Many researchers at CIRESare mostly on 'soft' money support. With the continued fiscalpressures on Federally supported research, this situation is, as it is elsewhere, a cause for concernfor the people involved. A number of major USresearch institutions have recognized this problem and have implemented avariety of remedies, typically in the formof 'bankable' support (from nonfederal sources) which can be used tosmooth fluctuations in extramural support forindividuals. Even though CIRES, with its special relationship to NOAA,offers some degree of intrinsic protection ofits researchers by allowing longer range planning, I think that recruitmentand retention of top scientists on softmoney positions will be easier in the future if some sort of support'cushion' is provided by the Institute. Anotherimportant aspect is the fairness and equitableness of the reward structure.This issue was raised in discussions, andpossible mechanisms to accommodate differences between civil servants andacademic researchers did not seem toodifficult to implement. By the way, the fact that NOAA is contemplating theoption of opening Presidential YoungInvestigator awards to the Joint Institutes is excellent news indeed.

At the same time, theimportance of private sources of support relative to State and Federalresources is likely toincrease in the future. CIRES Fellows have already demonstrated acommendable willingness to engage in public out

reach and to develop private support. It is my firm belief that the kind ofscience that is being done at CIRES is ofgreat interest to t public at large. and to the high-tech industriessurrounding the Boulder area. The Universityshould recognize this potential and assig development officer whosecharge would be to become expertly familiarwith what the Institute has to offer. and to coordinate these funds raisingand outreach efforts.

On a more practical level.the question arises of whether the current staff structure provides foradequate administrative support for a management style in which Fellows take on more directresponsibilities? Shouldn't there be a concomitant restructuring of the staff? Similarly. the infrastructure—such as equipment, computers. etc.— needed tosupport the ongoing research endeavor and to sustain excellence in thelong-term requires a predictable budgetaryinstrument. If this is at all possible within the CU administrative andaccounting structure. implementation of a mechanism which allows amortization and timely renewal of such infrastructurewould help avoid the disrupting effects ofperennial cycling between obsolete and new equipment.

I stated during the finalsession of the review that I thought CIRES to be "a jewel in CU'scrown!" I stand by thatstatement. and sincerely hope that CU's administration agrees that CIRESis worth nurturing, and remains an excellent place in which the Universit should continue to invest. But I wouldlike to add to that statement and return to apoint I alluded to earlier. In an age where partnershi with the FederalGovernment are of ever greater interest—toCongress in particular— it is important to emphasize that CIRES has be and continues to be agenuine success storyin this respect. Not only is it worthy of continued agency support. but itshould be held as an example of how suchendeavors can. and indeed should, be conducted!

Yourssincerely,

Jean-Bernard Minster
Professor ofGeophysics. Scripps Institution of Oceanography
Director,systemwide, Institute of Geophysics and Planetary Physics
University of California

Cc: Dr. Susan K. Avery, CIRES Director