CICAR
NOAA SPONSORED PROJECT SUMMARIES
July 1, 2004 – June 30, 2005
Theme I: Earth System Modeling

Project Title: ARCHES: Abrupt Climate Change: Modeling Scope

Lead Principal Investigator: Richard Seager  
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: CORC / ARCHES

Research Goals: To understand the causes and mechanisms of abrupt climate changes in the past using numerical models of the atmosphere and ocean.

Research Highlights:
• Proposed global atmosphere-ocean coupling concept of abrupt climate change
• Determined mechanisms of generation of global hydroclimate regimes
• Proposed mechanism for generation of tropical warm pools and mechanisms for changes in their extent.
• Examined potential for greenhouse-gas induced changes in atmosphere circulation to increase drought threat in mid-latitudes

Education Goals: We aim to actively involve undergraduates and graduate students in the research as well as to disseminate results broadly to facilitate public education and better understanding of climate dynamics.

Societal Benefits: The work leads to a better understanding of the causes and mechanisms of dramatic changes in global hydroclimate, including the recent (1998-2004) severe drought in the American West. This work has attracted significant attention amongst the wider scientific community and the public. The work is also of relevance in that increased understanding of regimes of atmosphere-ocean circulation will lead to a better idea of how anthropogenic forcing will impact global and regional climate.

Intranet / Internet: We have prepared a web site on the subject of a paleoclimate and climate modeling perspective on North American drought:  

Databases: All our climate model simulations are served online for unrestricted instantaneous access:  

Publications:
Journal Articles (submitted and in press):


Books / Articles-in-Books:

Results For The 1932 To 1939 Dust Bowl Drought.

(a) The observed precipitation anomaly for the 1932 to 1939 period, (b) the precipitation anomaly from the GOGA ensemble with global SST forcing, (c) the precipitation anomaly from the POGA-ML ensemble with only tropical Pacific SST forcing, (d) the observed SST anomaly and (e) the SST anomaly from the POGA-ML ensemble.

Precipitation units are mm per month and SST units are Kelvin.

GOGA ensemble: a 16-member ensemble with global SST prescribed to vary as in observations between 1856-2005.

POGA-ML Ensemble: a 16-member ensemble with SST prescribed to vary as in observations only in the tropical Pacific is calculated elsewhere by coupling to a 2-layer slab ocean model.
**Lead Principal Investigator:** Mark Cane  
**Affiliation:** Lamont-Doherty Earth Observatory  

**NOAA Program:** Climate Dynamics and Experimental Prediction (CDEP)

**Research Goals:**  
To improve our ability to predict ENSO and to make our predictions as usable as possible to the forecasters at application centers. The efforts are focused on forecast system improvements, ENSO predictability, and data assimilation.

**Research Highlights:**  
- Use of LDEO5 in operational predictions of ENSO events.  
- Initial evaluation of ENSO predictability from long (~150 years) series of retrospective forecasts and analyses of observed data.  
- Evaluation of relative roles of the initial error and the internal atmospheric variability play on restricting the model forecast skill.  
- Use of the model for ENSO predictions to study the predictability of Pacific decadal variability and the impact of external forcing on ENSO variability.

**Education Goals:**  
To train students in the area of ENSO research and prediction; to educate public by making real-time ENSO forecast available via our own and others' websites.

**Societal Benefits:**  
- ENSO variability has a profound influence on year-to-year climatic changes experienced by American public and people around the world. This project strives to improve predictions of ENSO events and investigates the nature of this predictability and its limiting factors.  
- This project also contributes towards the emerging understanding of the interactions between ENSO variability and global change: another issue of significant public interest.

**Intranet / Internet:**  
- http://www.iges.org/ellfb/Jun05/Chen/chen.htm  

**Publications:**  
*Journal Articles (submitted and in press):*  


Dynamical Forecasting of ENSO: A Contribution to the IRI Network

Retrospective Predictions Of El Nino And La Nina In The Past 148 Years

Time series of SST anomalies averaged in the NiNO3.4 region (5S-5N, 120-170W). The red curve is from the analysis of historical ship data by Kaplan et al. (1998), and the blue curve is the LDEO5 prediction at 6-month lead. [Adopted from Chen et al. 2004a]

The Correlation Skill Of LDEO4 When Initialized With The “Best” Initial Conditions
**Project Title:** Describing, Understanding, and Predicting Oceanic Variations Associated with Tropical Atlantic Variability and The North Atlantic Oscillation

**Lead Principal Investigator:** Dake Chen  
**Affiliation:** Lamont-Doherty Earth Observatory  
**NOAA Program:** CLIVAR Atlantic

**Research Goals:**  
The goals in the first year of this multi-institute research project are data collection, processing, and analysis. At LDEO, we extended our objectives to include preliminary numerical experiments to evaluate the effects of anomalous precipitation on tropical ocean modeling and to explore the uncertainty of surface buoyancy forcing.

**Research Highlights:**  
- The interannual variability of precipitation has a significant impact on the upper ocean dynamics and thermohaline structure in the tropics.
- At present, the uncertainty in precipitation forcing can be as large as the variability of each forcing, and so is the uncertainty in the resulting model response.

**Societal Benefits:**  
Our study aims at a better understanding, description, and prediction of Atlantic oceanic precipitation, which will directly benefit the surrounding countries of the Atlantic Ocean.

**Publications:**  
*Journal Articles (submitted and in press):*  
Describing, Understanding, and Predicting Oceanic Variations Associated with Tropical Atlantic Variability and The North Atlantic Oscillation

Figure 1. Composites of model salinity and temperature anomalies due to anomalous precipitation in December-January-February of El Niño and La Niña years, respectively. The upper two rows are latitude-longitude plots at the surface of the tropical oceans, whereas the lower two rows are depth-longitude plots along the equator (5°S-5°N). These are obtained by taking the difference between model runs with and without the anomalous CMAP precipitation. It is clear that the interannual variability of precipitation has significant effects on the thermohaline structure of the tropical oceans, and that such effects are not limited to the sea surface.
Project Title: Multivariate Approach to Ensemble Reconstruction of Historical Marine Surface Winds from Ships and Satellites

Lead Principal Investigator: Alexey Kaplan
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: Climate Change Data and Detection / Climate Observations

Research Goals:
- Developing adequate techniques for multivariate analyses of winds and related variables.
- Use of objective multivariate analysis approach for removing spurious long-term trends in wind data.
- Developing and utilizing the procedure for representing the analysis uncertainty by an ensemble of possible realizations.
- Applying newly developed products for addressing relevant questions about Indian monsoon -- global warming connections and genesis of the PDO

Research Highlights:
- Reconstructions of pressure and surface winds on the basis of new I-COADS compilations,
- Verifiable skill of interannual variability of central equatorial Pacific winds,
- Remarkable persistence of interannual wind anomalies and its importance for the wind-forced tropical ocean simulations.

Education Goals:
Historical analyses of ocean surface winds developed in this project will be used in research projects of students in our group and outside. Making the analyses available via web-interfaced data server ensures wide accessibility of the results for educational purposes.

Societal Benefits:
- We develop wind data sets that help to understand and perhaps predict climate changes. The critical importance of surface wind data for climate variability and climate change studies is well recognized. This project responds to this scientific need.
- National and international climate change assessments (like IPCC) serve to the benefit of the society and scientific community. We work on the data set which will lengthen significantly wind data sets available for climate simulations, and which will provide the user with a straightforward way to take its uncertainty into account. We also expect wide utilization of our products in statistical studies of climate variability, for calibration and verification of paleoclimatic reconstructions, etc.

Intranet / Internet:
http://www.cgd.ucar.edu/~asphilli/DataCatalog/Data/kaplan.html

Databases:
http://www.cdc.noaa.gov/Pressure/Gridded/data.kaplan_slp.html

Publications:
Journal Articles (submitted and in press):


Multivariate Approach to Ensemble Reconstruction of Historical Marine Surface Winds from Ships and Satellites

El Niño of 1877-1878 in analyzed anomalies

Anomalies Of 1877-1878 El Nino Illustrated By Univariate Reduced Space Analyses
Project Title: South Atlantic Ocean-Atmosphere Interaction

Lead Principal Investigator: Andrew Robertson
Affiliation: IRI – International Research Institute for Climate Prediction

NOAA Program: CLIVAR Atlantic

Research Goals:
Seasonal climate forecasts over tropical Africa and South America are hampered by the lack of skillful predictions of sea surface temperatures (SST) in the tropical Atlantic. The mean seasonal cycle and variability of the tropical Atlantic are closely linked to the South Atlantic through the subtropical anticyclone and shared modes of SST variability. In particular, it is hypothesized that the interactions between the El Niño-Southern Oscillation during boreal spring with pre-existing upper-ocean anomalies over the South Atlantic Ocean yield increased predictability of tropical Atlantic variability (TAV). The goal of this project is to make advances in two areas in order to improve seasonal prediction over the tropical Atlantic: (1) physical understanding of ocean-atmosphere interactions over the South Atlantic and their interactions with ENSO and TAV, and (2) simulation of the mean climate and seasonal cycle by coupled ocean-atmosphere general circulation models (GCMs) over the South Atlantic, as a prerequisite to successful dynamical seasonal prediction over the Atlantic sector.

Research Highlights:
- Confirmed from an 1876–1999 data record that the meridional gradient of sea surface temperature in the tropical Atlantic during March–May is more often consistent with the remote response to ENSO than otherwise.
- Identified the Benguela Niño as a potentially important precursor to tropical Atlantic variability.

Societal Benefits:
Accomplishments are an important first step in identifying predictable components of climate in the South Atlantic, in order to improve the skill of seasonal predictions of the West African Monsoon; the latter is of great societal importance to the countries of West Africa.

Project Title: The Role of Orography on the North American Monsoon Onset and Interannual Variability

Lead Principal Investigator: Mingfang Ting
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: Climate Prediction Program for the Americas (CPPA)

Research Goals:
The goal of this project is to develop a better understanding of the onset and interannual variability mechanisms for the North American Monsoon system (NAM). In particular, we are interested in the role of North American topography in the NAM rainfall onset and interannual variability.

Research Highlights:
- Determined the role of North American topography in the maintenance of low-level jet and the United States summer precipitation
- Demonstrated the regional climate model downscaling skills for North American summer precipitation

Societal Benefits:
The results from this project improve our understanding of the NAM rainfall, its relation with Great Plains summer precipitation, and helps with the seasonal forecast of the US precipitation during the summer.

Publications:

Journal Articles (submitted and in press):

The Role of Orography on the North American Monsoon Onset and Interannual Variability

850 Mb Wind Vectors And Magnitude (Shadings) For The GFDL GCM Experiment with full earth topography

(a), without the North American topography (b), and the difference between (a) and (b). Wind vector and shading scale is as shown (in m/s). Without topography the model does not simulate the low-level jet east of the Rockies.

June, July, And August Seasonal Average Precipitation Over The United States from NOAA CPC rain gauge observations

(a), CCM3 simulation with prescribed climatological SST (b), CMM5 simulation with K-F convective scheme and CCM3 lateral boundary conditions (c), and CMM5 simulation with Grell convective scheme (d).
**Project Title:** The Role of Ocean Dynamics in Tropical Atlantic SST  
**Lead Principal Investigator:** Martin Visbeck  
**Affiliation:** Lamont–Doherty Earth Observatory  
**NOAA Program:** CLIVAR Atlantic

**Research Goals:**
- Investigate the mechanisms of tropical Atlantic climate variability with an emphasis of the role of tropical ocean dynamics in seasonal to interannual climate prediction.
- Correct model biases in the tropical Atlantic Ocean.

**Research Highlights:**
- Surface wind forcing errors are the main reason for ocean model discrepancies in simulating the interannual variability of the tropical Atlantic.

**Societal Benefits:**
This ocean-modeling project aims at improving model simulation of interannual variability in the tropical Atlantic, an area where climate anomalies have large societal impacts in areas of water resources, agriculture and health. Improving climate model simulations has the potential to lead to advance climate prediction for this region.

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**Theme II: Modern and Paleoclimate Observations**

**Abrupt Climate Change Studies (ARCHES) Paleoclimate Research:**

**Project Title:** ARCHES: Paleo Sea-Ice Distributions  
**Lead Principal Investigator:** Robert F. Anderson  
**Affiliation:** Lamont-Doherty Earth Observatory  
**NOAA Program:** CORC / ARCHES

**Research Goals:**
This project has two broadly defined objectives:
1. To calibrate (improve) and later apply transfer functions (algorithms) designed to reconstruct sea ice distributions in the Southern Ocean based on the assemblage of diatom species preserved and buried in sediments. This objective has been modified during the latter half of this project to explore and develop a new proxy, based on the abundance of Interplanetary Dust Particles in sediments, for freshwater supply by melting icebergs.
2. To develop high-resolution records of changes in the ventilation (the degree to which the gases in water are equilibrated with the atmosphere) of Southern-Source Deep Water through periods of Abrupt Climate Change.

Ultimately these two objectives will be integrated in that sea ice cover and meltwater supplied by melting icebergs influences the ventilation of newly-formed deep water, as well as having a major impact on air-sea fluxes of heat, moisture, and momentum.

**Research Highlights:**
Preliminary application of a new paleo proxy for ice berg melting found no evidence for surges of the Antarctic ice sheet in a sediment core from the northern Weddell Gyre.

New evidence links the carbon isotopic composition of benthic foraminifera in the deep Cape Basin (SE Atlantic) to surges in the Patagonian ice sheet rather than to abrupt changes in the formation of North Atlantic Deep Water.

Peaks in biological productivity in the vicinity of the Chatham Rise (near New Zealand) provide the first evidence for a manifestation of Heinrich Events in the Southern Ocean.

Societal Benefits:
Understanding the scope and causes of past abrupt climate changes will help determine whether society is threatened by future abrupt climate change associated with global warming.

Publications:
Journal Articles (submitted and in press):


Detrital $^{87}\text{Sr}/^{86}\text{Sr}$ ratios (black line) and benthic $d^{13}\text{C}$ (gray line) plotted against age in core RC11-83 from the Cape Basin.

The arrows point to excursions in the $87\text{Sr}/86\text{Sr}$ (a–d) that visually correlate with excursions in the benthic $d^{13}\text{C}$ record. Features “a” and “a0” (inset) represents the abrupt, synchronous, excursion in both records that immediately precedes Termination 1.

The similarity of the two records is interpreted to reflect a common origin, inferred to be changes in delivery of lithogenic material to the South Atlantic Ocean by ice bergs shed from the Patagonian ice sheet.

From Rutberg et al., 2005.
**Project Title:** ARCHES: Causes of Persistent Century-Scale Change in the North Atlantic’s Holocene Climate

**Lead Principal Investigator:** Gerard C. Bond  
**Affiliation:** Lamont-Doherty Earth Observatory  
**NOAA Program:** CORC / ARCHES

**Research Goals:**
Identify abrupt climate change events in the Holocene and other interglacial period in data from ocean piston sediment record – focusing on the North Atlantic; Study the broader pattern North Atlantic events and their linkages of to other paleo-climate indicators.

**Research Highlights:**
- Confirmed that the petrologic indices of drift ice variations in the North Atlantic during the Holocene reflect large (1-1.5°C) changes in ocean surface temperature.
- Sediment trap data near Greenland confirm that large sea-ice melting events deliver sand-size lithic grains to the sea floor with maximum delivery occurring spring and summer giving clues to the nature of millennial events that occurred during the Holocene.
- The moderate cooling of the atmosphere in the last 4000 years has been driving more NADW production through lowering the surface temperature and increasing density.

**Societal Benefits:**
Develop understanding of abrupt climate change events. Identify abrupt changes in the Holocene – an interglacial period.

**Publications:**

*Journal Articles (submitted and in press):*

Müller, U. C., S. Klotz, M. A. Geyh, J. Pross, G. C. Bond, Cyclic climate changes during the Eemian interglacial in central Europe, Geology, in press.

*Books / Articles-in-Books:*


Comparison Of Slightly Smoothed Tree Ring Radiocarbon With New Petrologic Measurements In Eastern North Atlantic Core GGC53 With Sedimentation Rates Of 55 To 60 Cm/Ka

The results show a close match between the atmospheric radiocarbon and the drift ice index hematite stained grains in robust 500-year cycles. Up pointing peaks in radiocarbon indicate a weaker sun; up pointing peaks in HSG indicate more drift ice and cooler ocean surface temperatures (by about 1°C to 1.5°C).
**Project Title:** ARCHES: Understanding Abrupt Change and the Glacial to Interglacial CO₂ Record

**Lead Principal Investigator:** Wallace Broecker  
**Affiliation:** Lamont-Doherty Earth Observatory

**NOAA Program:** CORC / ARCHES

**Research Goals:**
To understand how ocean circulation has changed over the last 20,000 years and how these changes have impacted climate.

**Research Highlights:**
- Ventilation of the deep sea during glacial time.  
- Events associated with the “Mystery Interval” (17.5 to 14.5 kyrs).  
- The rise in atmospheric CO₂ over the last 8000 years

**Education Goals:**
W.S. Broecker has put considerable effort into making a road map for carbon management. This includes a document entitled *A Business Executive’s Guide to Global Warming*.

**Societal Benefits:**
Publicizing the need to quell CO₂ emissions and how this might be done economically.

**Databases:**

**Publications:**
*Journal Articles (submitted and in press):*

*Books / Articles-in-Books:*

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**Project Title:** ARCHES Lamont-Doherty Sub-Awardee:  
**Mountain Snowlines in the Southern Hemisphere**

**Lead Principal Investigator:** George Denton  
**Affiliation:** University of Maine, Quaternary & Climate Studies

**NOAA Program:** CORC / ARCHES

**Research Goals:**
- The overall goal of the project for the past year was to reconstruct snowline changes in the Southern Alps of New Zealand during the last glacial cycle. New Zealand is situated in the zone of mid-latitude Southern Hemisphere westerlies in the South Pacific Ocean far from any major continental influences or zones of thermohaline down welling. Also, New Zealand is on the opposite side of the planet (and with an opposite insolation signal) from the North Atlantic region, which has produced the classic record of abrupt climate changes. The idea is that a comparison of New
Zealand snowline variations with the North Atlantic abrupt-change records will point to some of the underlying mechanisms.

- The major research activities involved mapping in New Zealand’s Southern Alps in 2004/2005, together with office work during the rest of the year on map digitizing, air-photograph interpretation, and snowline reconstruction from field data. The collaborators in the field were Björn G. Andersen of the University of Oslo, Christian Schlüchter of the University of Bern, Marcus Vandergoes of the University of Maine, and David Barrell of the Crown Institute of Geologic and Nuclear Sciences (IGNS) in New Zealand. B.G. Andersen also carried out the interpretation of air photographs. David Barrell supervised the digitizing of glacial geologic maps at IGNS Dunedin, New Zealand. Trevor Chinn, Alpine and Polar Processes Consultancy, Wanaka, New Zealand, carried out the snowline studies.

Research Highlights:

- A huge, detailed, second-generation map of the LGM moraines near Lake Pukaki has been completed as background for a drilling program in Lake Pukaki itself and for the exposure-dating program proposed here for Year 5.
- The mapping of LGM, late-glacial, and Holocene moraines has been completed in the Ben Ohau and Liebig Ranges on the eastern flank of the Southern Alps. Snowline calculations have been made for moraines in each of the valleys of these two ranges. They show snowline lowerings below today’s values of 670-725 m for the outer LGM moraines, 447 for the outer late-glacial moraines, 168 m for the A.D. 1860 moraine and 360 m for the outermost Holocene moraines.
- Twenty new radiocarbon ages were processed for bark from well-preserved pieces of wood from the lee of Canavans Knob, where they were pushed during the late-glacial advance of Franz Josef Glacier. Fourteen of the original 17 dates gave values in excess of 11,000 $^{14}$C yr B.P. A redating of the other three samples also yielded values greater than 11,000 $^{14}$C yr B.P. the second time around. This result suggests strongly that the late-glacial readvance in New Zealand peaked just before the beginning of the classic Younger Dryas cold reversal in the North Atlantic region. A similar result had already been attained for the classic Punta Bandera late-glacial moraines at Lago Argentino in Patagonia. I now think that this late-glacial readvance most likely represents the culmination of the Antarctic Cold Reversal.
- Mapping and radiocarbon dating were carried out on LGM moraines and outwash plains near Murchison in the northern part of the Southern Alps.
- Four cores were collected from Galway Tarn on the west side of the Southern Alps. The purpose was to obtain accurate radiocarbon dates for a prominent volcanic ash that occurs in all the LGM moraine sequences.

Publications:

Journal Articles (submitted and in press):


Strelin, J., and Denton, G.H., 2005, Las Morenas de Puerto Bandera, Lago Argentino. XVI Argentine Geological Congress, v. in press and online at QSR.
Project Title: ARCHES: Constraining Changes in Winds, the Conveyor and Local Currents During Periods of Abrupt Climate Change

Lead Principal Investigator: Sydney Hemming
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: CORC / ARCHES

Research Goals:
One goal of this project is to study sediment composition and flux of samples along the mid-Atlantic ridge (MAR) to constrain the processes responsible for the distribution, and in the most exciting case, to constrain the position of the ITCZ. This contributes towards our long-term goal to have a map of LGM terrigenous isotope composition for the South Atlantic that is comparable to the Holocene map that exists now. A further goal is continued method development, both for the authigenic ferromanganese and terrigenous detritus components. As mentioned in the year 3-progress report, we have found that not all cores give true marine signals as monitored by the Sr isotope composition of the ferromanganese fraction. We have still not yet solved the problem and will continue the work in year 5. A major shift in the goal for year 4 was a return to the North Atlantic to study high-resolution ocean-atmosphere-ice sheet interaction as well as to characterize major ice rafted detritus (IRD) contributors in the North Atlantic region.

Research Highlights:
- Authigenic ferromanganese oxide-hosted Nd isotopes give high-resolution picture of deep Atlantic ocean circulation over the past 90 kyr.
- Sediment distributions and fluxes in the equatorial Atlantic yield insights into surface and deep ocean dynamics, and may help constrain the paleo-ITCZ
- High resolution studies of ice rafting, coupled with multiple proxies of sea surface conditions and ocean circulation, yield important insights into ice sheet contributions to rapid climate variability in the last glacial cycle

Education Goals:
This funding has also enhanced our ability to contribute to the educational development of students and postdoctoral scientists. The specific goal of the June 04-June 05 interval was to introduce post doctoral research scientist, Martin Roy, to the application of radiogenic isotope tracers in paleoclimate studies- in other words to expand his research tool kit. Roy received his Ph.D. in Glacial Geology, and is naturally interested in extending his understanding of tracing sediment sources. Additionally, Liz Knapp, a Tappan Zee High School student, is working with us on a study of North Atlantic rapid climate/ice sheet variability. And finally, although her salary is supported by an NSF fellowship, graduate student Allison Franzese’s research has benefited from our ARCHES/CICAR funding. Our educational goals are thus best characterized as integration of research and education and discovery based learning. Both Franzese and Roy have mentored more junior scientists, an experience that benefited them as well as their student research helpers.

Societal Benefits:
As we continue to modify our atmosphere with anthropogenic emissions, it becomes more and more relevant to better understand the mechanisms of global and rapid climate variability. All of our goals are motivated by the need to characterize the ocean-atmosphere-ice sheet interactions of the past.

Publications:

20
Journal Articles (submitted and in press):


Sequence Of Events At The Start Of The Last Ice Age (Piotrowski Et Al., 2005)

The $\delta^{18}$O of benthic foraminifera changed first, indicating ice sheet growth and deep water cooling. This is followed by a shift in the $\delta^{13}$C of benthic foraminifera (same samples), indicating a combined change in circulation and/or carbon storage in the ocean. The terrigenous detrital composition changes after the shift in $\delta^{13}$C, and indicates a change in local current movements (difficult to distinguish surface and deep in this setting, but the non-synchronous change in the terrigenous Sr and authigenic Nd is an important test of the interpretation of the authigenic Nd). Finally, the authigenic Nd, best interpreted as a deep circulation tracer, changes. This is taken to provide important constraints on the role of deep ocean circulation in driving climate change and most simply implies that deep ocean circulation responded to initiation of the ice age, but reduced circulation did not trigger it.
Project Title: ARCHES: Patterns and Timing of Deglacial Climate Change in the Equatorial Pacific

Lead Principal Investigator: Jean Lynch-Stieglitz
Affiliation: Lamont-Doherty Earth Observatory / Adjunct Research Scientist

NOAA Program: CORC / ARCHES

Research Goals:
To characterize and understand the modes and mechanisms of equatorial Pacific ocean-atmosphere coupling during glacial-interglacial transitions, particularly as they relate to variability in the eastern Pacific cold tongue-Intertropical Convergence Zone and associated oceanographic front. The strategy has been to measure Mg/Ca and $^{18}$O of planktonic foraminifera in a north-south transect of cores between 2 South and 7 North, and use them as proxies of the oceanographic front and its temporal variability.

Research Highlights:
- Weakened equatorial front during the LGM
- Southward shift of the Pacific ITCZ during the LGM
- Average LGM cooling of the equatorial cold tongue of $\sim 2 \, ^{\circ}C$

Societal Benefits:
The response of the tropical Pacific and the ENSO system to future climate change is an issue of great societal significance but remains subject to large uncertainty. The long-term dynamics of this system and its susceptibility to future change can best be understood by reconstructing its past variability and its links with past global climate states. Our research demonstrates a clear link between variability in the ITCZ (likely driven by extratropical forcing), and in tropical Pacific SSTs and SST gradients on glacial-interglacial timescales. In conjunction with other studies, our results show that this link operates on a spectrum of timescales, from the interannual to the orbital range, and therefore is relevant for how the tropical Pacific ocean-atmosphere system will respond to climatic warming in coming decades. More specifically our results caution that a possible shift of the ITCZ to the north due to differential warming of the hemispheres can lead to a strengthening of tropical SST gradients and of the Walker circulation with significant climatic and hydrologic impacts in North America and around the world.

Publications:
Journal Articles (submitted and in press):


Books / Articles-in-Books:
ARCHES: Patterns and Timing of Deglacial Climate Change in the Equatorial Pacific

Holocene records of ITCZ variability (top), zonal SST gradient in the Equatorial Pacific (middle), and ENSO frequency (bottom).

Cariaco Basin Rainfall, Atlantic 10°N

(Eaup et al. 2001)

Pacific SSTs

- MD98-2161 (G. ruber Mg/Ca)
- MD98-2176 (G. ruber Mg/Ca)
- V21-30 (G. ruber Mg/Ca)
- V21-30 (G. sacculifer Mg/Ca)+1K
- V19-28 (G. ruber Mg/Ca)+2K

ENSO frequency

expressed as number of events in 100-year non-overlapping windows.
Inferred from Laguna Pallcacocha (Ecuador) sediment color intensity
(May et al. 2007)
SECTION 1: OBSERVATIONS

Research Goals:
To understand through observations and to assess model ability to simulate, the global scale ocean circulation that is associated or possibly promotes climate change.

Research Highlights:
- Agulhas leakage “collects” the buoyancy introduced into the three major ocean basins from the Southern Ocean, and passes it directly into the Atlantic Ocean. This promotes the meridional overturning circulation of the Atlantic Ocean.
- The Indonesian throughflow boosts the Agulhas Current by ~10Sv and in so doing enhances the sea to air heat flux south of Africa and the leakage into the Atlantic Ocean, hence the meridional overturning circulation of the Atlantic Ocean.

Education Goals:
To relate to undergraduate and graduate students at Columbia University the nature of climate change and the ocean’s role in that process.

Societal Benefits:
Recent paleo-climate studies supports the notion that the Aguilhas leakage and the associated Indonesian throughflow precondition the northern North Atlantic for formation of North Atlantic Deep Water, which strongly influences the climate of the land areas surrounding the North Atlantic. Changes in Aguilhas leakage may allow prediction of changes in northern climates.

Publications:
Journal Articles (submitted and in press):

SECTION 2: MOORINGS

Research Goals:

Install and maintain three deep and bottom water focused moorings south of the South Orkney Islands in the Northwest Weddell Sea to provide a time series of the combined outflow (currents and temperature/salinity) of Antarctic Bottom Water drawn from various sites within the Weddell Sea. As the time series is compiled, it will be examined for indications of climate variability on sub-decadal time scales. A section of CTD/tracer stations is reoccupied during the service cruises as time and conditions permit.

We rely on opportunistic scheduling of vessel time provided by a variety of sources, so timing of cruises for maintaining the moorings is approximate. Research goals remain flexible so we can take advantage of ship time opportunities as they arise.

Research Highlights:

- Recovered and redeployed 2 moorings after a nearly 4 year deployment
- Extended the CORC-ARCHES Weddell time series data set to nearly 6 years, including a period that spans the breakup of the Larsen B ice shelf in early 2002.

Societal Benefits:
Changes in deep and bottom water outflow characteristics from the Weddell may be indicators of climate change on global scales. The CORC-ARCHES data set is potentially an important resource for identifying and understanding climate change processes.

Intranet / Internet and Databases:

ARCHES: Modern Observations SECTION 2: MOORINGS

Positions of the ARCHES moorings on a schematic representation of the major flow paths of Weddell Sea dense water bottom water, and on a potential temperature section along a track crossing the moorings.
Project Title: ARCHES: Southern Ocean Modeling and Analysis

Lead Principal Investigator: Douglas Martinson
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: CORC / ARCHES

Research Goals:
Improve our quantification of the nature (magnitude, temporal-spatial distributions) of ocean-ice variability in the western Antarctic Peninsula region.

Research Highlights:
- Quantified ocean sensible heat flux to WAP - (Earth's most rapid winter regional warming)
- Found jump in heat content in shelf waters on WAP continental shelf prior to 1990s

Education Goals:
Acquaint school children with Antarctic field science (accomplished by Rich Iannuzzi's "live" from the field to elementary school classrooms when in the field).

Societal Benefits:
Quantification of ocean's contribution to the WAP warming and possibly to rapid melt of glaciers on WAP.

Publications:
Journal Articles (submitted and in press):

Martinson and Pitman, Role of the Arctic in Glacial terminations, in revision for Climatic Change.

Martinson, Stammerjohn, Iannuzzi, Smith, Palmer, Antarctica, long-term ecological research program first twelve years: Physical Oceanography, Spatio-Temporal Variability, submitted (to editor) of special DSR issue.

Jump in ocean sensible heat content (above freezing) over the continental slope of the western Antarctic Peninsula region between 1990s and previous decades (number of values used in decadal averages indicated at bottom of graph).

We have shown that this slope water is the source of heat on the continental shelf where it is vented, contributing to the Earth's most rapid regional warming. Size of multi-decadal averages given by red arrows about horizontal lines showing averages.
Project Title: ARCHES: Tracer Observations of Deep Formation and Circulation in the Southern Ocean

Lead Principal Investigator: Peter Schlosser
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: CORC / ARCHES

Research Goals:
- Improve understanding of deep-water formation in the Southern Ocean and in the North Atlantic, including its variability.

Research Highlights:
- We published a manuscript on the continued reduction of Greenland Sea Deep Water formation
- We assembled maps linking the global helium isotope distributions to the Southern Ocean where ventilation occurs
- We are close to publishing a manuscript on water/ice interaction in the Ross Sea, which shows very distinct cores of water formed by this process. This water mass participates in deep water formation in the Pacific sector of the Southern Ocean.

Education Goals:
- Train students in the field of observational studies of oceanic circulation, specifically in the area of tracer oceanography.

Societal Benefits:
The project is of public interest because it follows the evolution of the water masses in the Greenland Sea, which underwent an abrupt change around 1980 (reduction in GSDW formation rate by ca. 80%). There are also rapid changes observed in the Arctic Ocean and it will be interesting to see if these phenomena are linked to the transition into the greenhouse world.

Publications:
Journal Articles (submitted and in press):
ARCHES: Tracer Observations of Deep Formation and Circulation in the Southern Ocean

Figure 1. Station maps of RV Johan Hjort cruises in the Norwegian and Greenland Sea. Circled regions indicate the locations of the central gyres. Topography contours are drawn in 500-m steps from 500 m to 3500 m.
**Project Title:** ARCHES: Tracer Observations of Deep Formation and Circulation in the Southern Ocean

**Lead Principal Investigator:** William Smethie  
**Affiliation:** Lamont-Doherty Earth Observatory  
**NOAA Program:** CORC / ARCHES

**Research Goals:**  
The research goals for the 2004/2005 year were to continue collecting and analyzing seawater samples from newly formed Denmark Strait Overflow Water and its precursors and from deep and bottom water outflow from the northwest Weddell Sea, and to publish a manuscript on circulation and melting under the Ross Ice Shelf based on a time series of CFC and hydrographic data. Another goal was to collect CFC data from ship of opportunity cruises to continental shelf/slope regions around the Antarctic continent.

**Research Highlights:**  
- The rate of formation of Ice Shelf beneath the central and western Ross Ice shelf was estimated to be about 0.85 Sv (10⁶ m³ sec⁻¹) and the residence time of this water beneath the Ross Ice Shelf was estimated to be 3.5 years.  
- The basal melt rate of the Ross Ice Shelf that occurs during the formation of Ice Shelf Water was estimated to range from 20 to 60 km³ yr⁻¹.

**Education Goals:**  
To provide research opportunities for undergraduate and graduate students in our laboratory and on cruises.

**Societal Benefits:**  
One potential impact of global warming is melting of the Antarctic Ice shelves and a rise in sea level. This study provides an estimate of the basal melt rate of one of these ice shelves, the Ross Ice Shelf, and this is important to understanding ice shelf dynamics.

**Publications:**  
*Journal Articles (submitted and in press):*  
These samples were collected in May 2002 as part of the seasonal surveys carried out by the Iceland Marine Science Institute. High CFC-12 concentrations above the Greenland slope extending from about 1700 m to about 2500 m are observed in the plume of Denmark Strait Overflow Water (DSOW) flowing southward and lower concentrations are observed to the east in Iceland-Scotland Overflow Water that has entered the western North Atlantic basin through the Charlie-Gibbs Fracture Zone to the south.

Vertical Section Of CFC-12 Taken In May 2003 At The Same Location Described In Figure 1.

The CFC distribution is similar to the May 2002 section with highest concentrations above the Greenland continental slope and lowest concentrations above the Iceland continental slope. But the CFC-12 concentration in the DSOW plume is lower than in May 2002 and the extent of the DSOW plume is smaller. This shows that DSOW entering the North Atlantic in May 2003 was not as well ventilated as DSOW entering in May 2002, reflecting annual variability in the formation of this important water mass.
**Project Title:** Collaborative Research: Development Of A Blended Living Gridded Network Of Drought Reconstructions Of North America

**Lead Principal Investigator:** Edward Cook

**Affiliation:** Lamont-Doherty Earth Observatory

**NOAA Program:** Climate Change Data and Detection / Climate Observations

**Research Goals:**

The development of a blended living North American drought reconstruction grid, one that can be continuously updated as new instrumental data becomes available and used for operational assessments of developing droughts and wet spells.

**Research Highlights:**

- The new instrumental drought grid is nearing completion.
- The North American tree-ring network has been greatly expanded.
- The computer program for reconstructing drought is nearing completion.

**Societal Benefits:**

Operational assessment of developing droughts compared to those that occurred in the same area over the past 1000 years will help in determining the true significance of the current drought. The long drought reconstructions may also lead to the development of improved forecasting methods.

**Databases:**

The North American Drought Atlas


**Publications:**

*Journal Articles (submitted and in press):*


The Old (Top) And New (Bottom) North American Drought Reconstruction Grids (+) And Tree-Ring Networks (D)

The grid has been expanded from 286 to 402 points and the network from 835 to 1147 annual tree-ring chronologies. The tree-ring network will also continue to grow.
**Project Title:** Atmosphere and Coastal Ocean CO₂ Measurement Platform - SABSOON

**Lead Principal Investigator:** Wade McGillis

**Affiliation:** Lamont-Doherty Earth Observatory

**NOAA Program:** Carbon Cycle Program

**Research Goals:**
- Measure the pCO₂ in the atmosphere and ocean at South Atlantic Bight Synoptic Offshore Observational Network (SABSOON). High-resolution IR detection of CO₂ will be compared to flask measurements.
- Determine ΔpCO₂ at the tower using the high-resolution IR technique in order to estimate the coastal air-sea CO₂ flux variability.
- Quantify and describe the temporal variability in atmosphere and ocean CO₂ concentrations.
- Determine the relative importance of biological and physical controls on CO₂.
- Determine the influence of coastal ocean carbon on the North American terrestrial carbon cycling.

**Research Highlights:**
- Successful design, deployment and testing of submicroatm pCO₂ measurements autonomously made form a coastal ocean tower.
- Discovery that coastal atmospheric CO₂ signal has terrestrial and marine sources.
- System is remotely assessed from anywhere.

**Education Goals:**
The tower-based pCO₂ system is open to the community through active outreach programs though WHOI, Lamont-Doherty at Columbia University and NOAA.

**Societal Benefits:**
- A combination of resources including both time series stations and ship surveys of sea surface and atmospheric CO₂ on the continental margins are required to properly assess the United States coastal carbon component of the (North American Carbon Program) NACP. In this research, a system to measure CO₂ in the ocean and in the atmosphere has been invented in the laboratory, fabricated, and deployed on an ocean tower on the continental shelf of the United States. This pCO₂ system is capable of making calibrated atmospheric CO₂ measurements comparable to CMDL island stations in addition to in situ sea surface CO₂ concentrations. In addition to high-quality (0.2 ppm) and high-frequency CO₂ measurements taken every ½ hour, in the future, monthly CMDL flask analysis of CO₂, N₂O, SF₆, CO, and CH₄ will allow us to quantify and understand the sources of variability in the atmosphere while continuous measurements of dissolved O₂ and monthly measurements of total CO₂ will allow us to quantify and understand sources of variability in the ocean.

- With a clear understanding of the sources and magnitude of variability that exists in the Atlantic Bight, ocean observation sites will become an integral part of the existing atmospheric CO₂ measurement network. As with other CMDL island measurement locations, the marine boundary layer offers a very stable environment for making CO₂ measurements. Unlike terrestrial sites, these sites are not as affected by large diurnal changes in the planetary boundary layer causing a rectification of the CO₂ concentration during the summer. In the ocean we will test the hypothesis that the SAB is net heterotrophic. The coastal tower system will also address the following questions: [1] how accurate can CO₂ measurements be made on unmanned platforms off the coast (less than 0.2 ppm)? [2] What are the scales of variability in
atmospheric and surface water CO₂ concentrations and air-sea fluxes in the coastal ocean?

Intranet / Internet:
www.whoi.edu/mvco
http://www.ldeo.columbia.edu/~csweeney/tower/tower_co2_sys_wk1.htm

Atmosphere and Coastal Ocean CO₂ Measurement Platform - SABSOON

Synoptic Weather Mixes Air From Contiguous US With Air Over Coastal Oceans

East Coast Observational system (ECOsystem) is a network of coastal sites that currently provides information on physical processes in the ocean and atmosphere. CO₂ measurements at the South Atlantic Bight Synoptic Ocean Observational Network (SABSOON) would complement the Martha’s Vineyard Observatory (MVO). All together, ECOsystem will provide a range of coastal carbon processes that influence the carbon budget on North America.

This figure shows atmospheric CO₂ (left axis) and water vapor (right axis) over a 3-day period (August 13 – August 15, 2005).

The dry concentration of CO₂ remains steady at global mean values (380 ppm) for most of this period but shows plumes of atmospheric CO₂, which are presumably from point sources inland. Here we need to look at wind direction and trajectory maps during this time period.
Project Title: SOLAS OASIS Platform

Lead Principal Investigator: Wade McGillis
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: NOAA Environmental Technology Lab

Research Goals:
This project focuses on development of an Ocean-Atmosphere Sensor Integration System (OASIS) that will be capable of taking a wide variety of measurements on oceanic and atmospheric processes. OASIS is composed of three parts: (a) reusable, solar-powered, autonomous, navigable, 2-way communication-capable (via Iridium modems), GPS-located, low cost (<$20K) Surface Autonomous Vehicles (SAVs); (b) low-cost, low-power, biogeochemical and air-sea process sensors; and, (c) NASA’s “Sensor Web Technology” software for command and control of individual and group OASIS fleet deployments. The project will interface a suite of air-sea flux and biogeochemical sensors on the OASIS fleet; implement NASA's Sensor Web Technology (SWT) software to support command and control of the craft; and, develop and field-test both fleet and individual crafts under a variety of scenarios aimed at addressing several focused science and environmental monitoring issues. A variety of operational sampling modes—Station Keeping, Ocean Transit, Coastal Mapping, and Dynamic Cluster Mapping—will be developed. In addition to already commercially available sensors, such as Conductivity-Temperature devices for sea surface temperature (SST) and salinity (SSS), additional sensors will be developed and interfaced to measure air-sea gas, momentum and heat fluxes and ocean bio-optical properties. Field-testing of the crafts and sensor suites will focus on addressing the interplay between air-sea flux processes, ocean physics and ocean phytoplankton dynamics.

Research Highlights:
- High-end meteorological sensors for air-sea heat fluxes, gas fluxes, and momentum fluxes have been procured.
- Columbia University and NOAA/ETL are fabricating sensor suite.
- Fall 2005 the Platform will be tested at the Duck Field Research Facility (http://frf.usace.army.mil/).

Education Goals:
The educational and outreach goals are described in the main proposal by the PI John Moison at the NASA Wallops Flight Facility: http://www.csc.noaa.gov/cots/progress_reports/oasis_04.pdf.

This project will be involved in several educational efforts. A brief description of each is presented below:

Undergraduate Summer Internships: Each summer, NASA sponsors a number of undergraduate students to participate in a number of summer internship programs. The engineering group at NASA will seek to involve several of these interns in the development and testing portion of this project.

NASA-UMES Summer Internship Program (NUSIP): NASA is presently sponsoring a summer internship program with the University of Maryland, Eastern Shore (an historically black college) to bring young engineering, math and computer science students to work at NASA Goddard Space Flight Center at Wallops Island. John Moisan will work with the programs coordinator (Ms. Lisa Johnson) to obtain one to two students per year to work with NASA engineers in developing OASIS platforms, sensors and software.
Summer High School Internships: NASA Goddard Space Flight Center has summer high school internships available for local area high school students to introduce them to engineering, math, and science careers. The proposed effort will support the participation of two additional summer high school students in this program. In the past years, students have worked on both laboratory and web-development projects. The focus of the proposed internships will be to give the students experience in applied engineering, sensor and software projects. Students will participate over a ten-week period. They will be given a focused project that they will work with engineers or programmers to complete.

NOAA-ETL Summer High School Program: During the past 3 years, NOAA-ETL has established a relationship with a group of exceptional high school science students from the State College Area High School in Central Pennsylvania. Under the guidance of Earth Science Teacher Dr. Thomas Arnold, these students travel to a remote location to conduct a small-scale data-taking expedition. Additional high school students from Scotland also participate in these experiments, which are designed to give the students real-life experience in the field. The students learn to conduct science and to use the meteorological, biological, and hydrological instrumentation in an actual field expedition. As a result of their efforts, the students are able to compile 2-3 posters to be presented at the annual American Meteorological Society’s Conference on Education.

Co-Investigator Jeffrey Hare (University of Colorado and NOAA-ETL) has acted as advisor to these expeditions during the Wyoming-2000 and Montana-2002 experiments. The responsibilities include providing instruments, masts, and data-logging computers, traveling to the camp to instruct the students on the use of the equipment, and providing guidance to the students during the analysis, interpretation, and presentation stages.

As an element of the proposed research, the high school students from State College Area High School will be invited to visit the NASA Wallops facility in order to witness the development of the OASIS platform and experience the exciting possibilities that the vehicle offers. This will give the advanced high school science students the opportunity to see the NASA scientists and engineers at work and give them exposure to the possibilities that working in the sciences provides. Additional field trips may be scheduled for the nearby Wallops Island Marine Science Center, which is operated by the Marine Sciences Consortium of Pennsylvania. Funds are requested within this proposal to support this planned activity.

Societal Benefits:
The primary mode of our community outreach efforts will occur through presenting our results in a timely manner through publication in scientific journals and through presentations at meetings and workshops. In addition, we will broadcast the developments of the platform and the sensor suites through regular notices on the Ocean.US web site newsletter. Additional outreach efforts will be conducted through the NASA outreach coordinator, Brian Campbell. Mr. Campbell’s task is to present NASA science advances to the education community through lectures and web notifications.
**SOLAS OASIS Platform**

**Drawings of OASIS**
The propulsion system, solar panel power arrangement, and mast are show. Sensors will be mounted on the mast and hull. The sensor enclosure hub will be a cylindrical enclosure ensconced in the OASIS hull.

**The meteorological package will be integrated with OASIS Sept-Nov 2005.** The instruments include motion system, 3-D sonic anemometry, water vapor, temperature, and carbon dioxide.
Theme III: Applications Research

Two (2) research projects have as their secondary definition Theme III:

1. Multivariate Approach to Ensemble Reconstruction of Historical Marine Surface Winds from Ships and Satellites (major Theme I) – PI Alexey Kaplan

2. Collaborative Research: Development of a Blended Living Gridded Network of Drought Reconstructions of North America (major Theme II) – PI Edward Cook

Task IV: Collaborative Education Program and Projects

THEME I: Earth System Modeling

Project Title: Understanding Climate Change from the Medieval Warm Period to the Greenhouse Future

Lead Principal Investigator: Richard Seager
Affiliation: Lamont-Doherty Earth Observatory
NOAA Program: GFDL / LDEO Collaborative

Research Goals:
Model and understand the changes in global climate, and changes in climate variability, over the period from 1000AD to 2200AD. Our primary purpose is to understand future changes in climate as a result of changes in external forcing and greenhouse gas concentration with particular emphasis on regional changes such as variations in rainfall over North America, Africa, and the Asian Monsoon. The idea is to put present and projected climate variability in the context of the past. Climate variability in the modern period of instrumental data is analyzed and simulated to determine the mechanisms of climate variability and climate change. The same models will be used to simulate the climate history of the last millennium and the results compare to proxy evidence to see if the knowledge gained on the modern period can also explain these past climate variations. This will enable us to assign more confidence to model predictions of future climate. The last millennium is chosen a time when significant undulations in climate: the so-called Medieval Warm Period and the Little Ice Age occurs and there is information on variations in solar and volcanic forcing and sufficient high-resolution proxy records available for model verification. The project emphasizes collaboration with GFDL scientists to address research goals that are common to LDEO AND GFDL and support for young researchers.

Research Highlights:
• North American droughts are forced by decadal SST anomalies in the tropical Pacific
• Topography is important for the simulation of the low-level jet and summertime rainfall over the North American Great Plains
• Indian Ocean SST can alleviate Indian Monsoon droughts during El Niño events
• Objective algorithm used to search the history of stratospheric “sudden warmings” in GFDL model simulations.
• Improved “matrix transport” method for fast simulation of biogeochemical tracer transport in ocean models
• Tracing subtropical water vapor in a GFDL model shown that the generation of dry subtropical air is due mainly to isentropic transport by extratropical eddies and to a lesser extent to the Hadley circulation
• Develop web-browser based LDEO server for GFDL model data. This allows LDEO researchers rapid access to GFDL model data for analysis
Education Goals:
Facilitate maximum involvement of young scientists by dedicating most of the funding to support advanced PhD students and postdoctoral scientist. Create an environment, which fosters cross-disciplinary collaboration between meteorologists, oceanographers, applied mathematicians, and geochemists.

Societal Benefits:
Increase understanding of climate processes leading to droughts in the US and other locations.
- Increased understanding of tropical forcing of global climate variations
- Increased understanding of climate sensitivity to solar and volcanic forcing
- Putting human influence on climate in the context of natural climate variability
- Seeking to improve Indian Summer Monsoon rainfall prediction
- Advancing climate modeling through model-observation comparisons
- Introducing young scientists to NOAA related science and research priorities

Intranet / Internet:

Publications:
*Journal Articles (submitted and in press):*


The "post− minus pre−1976" difference in Jan−May precipitation, as measured by the difference between two time intervals: 1976-1978 and 1961-1976

Shown are: (a) Observation based on the CAMS dataset. (b) The GCM ensemble average of 16 runs forced with observed SST prescribed in the tropical Pacific and calculated using a variable-depth mixed layer everywhere else (POGA-ML experiment). (c) The GCM ensemble average of 48 runs with time varying SST prescribed over the entire global ocean (GOGA experiment). (d) The thirty-year average of the difference between a pair of the long integration of a GCM with global SST held fixed at their pre- and post 1976 shift states. Units are in mm/day with color scales indicated at bottom. White areas indicate insufficient data or very weak signals (within±0.1mm/day). The domain shown is 150°W−30°W and 60°S−60°N (Figure 2 from Huang et al, 2005). The GCM in all experiments is the NCAR CCM3 atmospheric model. The figure demonstrates that the model is capable of simulating many of the details of the change in precipitation over the Americas during the 1976 "climate shift", including the wetting of North America after 1976. The results also show that the changes are not due to rectification effect of interannual SST variations but are linearly related to the change in the decadal means. The similarity between the POGA and GOGA ensemble results indicates the precipitation changes were forced from the tropical Pacific.
THEME III: Applications Research

Project Title: M. A. Program in Climate & Society

Lead Principal Investigator: Mark Cane
Affiliation: Lamont-Doherty Earth Observatory

NOAA Program: Office of Global Programs

Research Goals:
This is an educational program.

Research Highlights:
- Successful design and execution of a unique interdisciplinary curriculum that has not been carried out at the master's level at any other educational institution.
- Successful completion of the master's degree by all 18 graduate students in the 12-month timeframe; they will receive their degrees in October 2005.
- Summer internship and job placement at prestigious institutions and prominent names in the field of climate/society interactions (e.g., Pew Center, Environmental Defense, UNDP, CISA).

Education Goals:
The twelve-month M.A. Program in Climate and Society trains professionals and academics to understand and cope with the impacts of climate variability and climate change on society and the environment. This rigorous program emphasizes the problems of developing societies.

Societal Benefits:
Graduates of the M.A. Program in Climate and Society will form a group of uniquely qualified public and private sector professionals and researchers. The interdisciplinary curriculum challenges students to think in an integrated fashion about climate, climate impacts, and challenges to development from the very beginning. These graduates are able to address environmental and social phenomena from an integrated perspective that focuses on understanding multiple facets of a problem, from energy policy, energy demand, malaria epidemic mitigation, famine, drought, and flood early warning and mitigation, water resources management, environmental journalism, communication of climate variability and climate-related risks, and environmental secondary education.

The students' research has resulted in a number of societally useful products, including:
- A better prediction scheme for Ethiopian rainfall
- Integration of climate information into malaria control efforts in Ethiopia
- Better understanding of climate influences on locusts in the Sahel
- A curriculum on Climate and Society for secondary schools
- Improved agricultural data sets for south India
- Climate-based Reservoir analysis for New York City

Intranet / Internet:
http://www.columbia.edu/climatesociety
Students in the *Masters of Arts Program in Climate and Society* participate in unique interdisciplinary curriculum designed around climate and climate impacts, with particular attention paid to the developing world. These master’s students receive personalized attention from some of the leading researchers in the field.

*Photo credit:* Bruce Gilbert