A damaged corn crop in Rice County, in central Kansas, August 7.

Jeff Tuttle/Reuters
CICAR 2012 Annual Performance Report to NOAA
Institutional award number NA08OAR4320754 July 1, 2011 – June 30, 2012

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Preface

Document Purpose, Distribution and Contents
The annual report for the Cooperative Institute for Climate Applications and Research (CICAR), a Cooperative Institute (CI) funded by the National Oceanic and Atmospheric Administration (NOAA) Office of Oceanic and Atmospheric Research (OAR), is a requirement of the OAR CI Program. The annual report describes all actively funded research projects and, public information and outreach programs conducted under the CICAR institutional extension award NA08OAR4320754 and the shadow award NA08OAR4320912 for fiscal year ended June 30, 2012. As a contributor to the OAR Cooperative Institute Program, CICAR research will, on a yearly basis, actively address the NOAA next generation Strategic Plan for long-term Climate Adaptation and Mitigation - An informed society anticipating and responding to climate and its impacts.

The CICAR annual report is available in PDF version on line at the NOAA Research Council CI web site http://www.nrc.noaa.gov/ci/locations/index.html and the CICAR web site http://www.cicar.ei.columbia.edu/.

The 2012 CICAR annual report is a comprehensive written review of the administrative and research activity for the Institute’s ninth year of operation, which began July 1, 2011 and ended June 30, 2012.

About CICAR

Mission Statement
The Cooperative Institute for Climate Applications and Research evaluates, understands and predicts climate variability and change through the collection and analysis of modern and paleoclimate data, and the use of Earth system models. We provide climate information to society through education and the development of applications and tools for assessing climate-related risks.

Overview
The Cooperative Institute for Climate Applications and Research (CICAR) was established in November 2003 as a research partnership between the National Oceanic and Atmospheric Administration and Columbia University in the City of New York. CICAR research themes are: (1) Earth system modeling; (2) Modern and paleoclimate observations; and (3) Climate variability and change applications research.

The NOAA funded research portfolio at Lamont grew out of a clear strategic vision of scientists at LDEO and NOAA. This vision stipulated that ocean observations and coupled ocean-atmosphere modeling is key to understanding long-term climate variability and change and to developing climate prediction capabilities. It also emphasized paleoclimate research as providing climate scenarios quite unlike those revealed in the short instrumental record, thus helping to expand our view of the Earth climate system and challenging our conceptual understanding and modeling capability. Actively pursuing these ideas, LDEO scientists have conducted research

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1 The shadow award project report is available at: http://cicar.ei.columbia.edu/?id=ci-annual-report
based on observations (instrumental and proxy), analysis and models and worked with NOAA to form programs and set research directions.

At the core of the CICAR research agenda is the collaboration between LDEO and two NOAA climate-oriented organizations: the Climate Program Office (CPO) and the Geophysical Fluid Dynamics Laboratory (GFDL). The CPO leads the NOAA involvement in the U.S. Climate and Global Change (C&GC) Program and sponsors scientific research aimed at understanding climate variability and its predictability. GFDL is “charged with producing timely and reliable knowledge and assessments on natural climate variability and anthropogenic change” through the development of Earth system models and theoretical understanding. Both these missions are consistent with the CICAR climate research agenda.

Structure
CICAR is administered by Columbia University through its Lamont-Doherty Earth Observatory and is located at the Observatory’s Palisades, New York campus. The Institute consists of the Director, who is an official of Columbia University, an administrative staff, an Advisory Committee, an Executive Board and the scientific and support staff of the CICAR, who are members of LDEO and other units of The Earth Institute, Columbia University. The Geophysical Fluid Dynamics Laboratory, a NOAA Research facility, is the Institute’s principal connection to NOAA.

Research Overview
The Cooperative Institute for Climate Applications and Research develops and promotes research to address a wide range of physical and social science topics consistent with the CICAR mandate. The project summaries appearing in the research section include: observations and model development required for the prediction of seasonal-to-interannual and long-term climate variability; collecting instrumental observations and developing and archiving proxy records for deepening the understanding of climate variability and change; and for the development of tools for providing climate information to society to assess risk and make decisions.

The CICAR program of research and education strives to:
• Create a center of excellence dedicated to understanding the evolution of the Earth’s past and present climate and predict its future trajectory.
• Create a long-term research partnership between NOAA and the Columbia University climate research community to enhance NOAA’s research capabilities in the area of climate observations, modeling and prediction.
• Contribute to NOAA’s goal to enhance society’s ability to plan and respond to climate variability and change by developing methods and tools for providing climate information to users and decision makers.
• Provide a basis for streamlining the administrative process for several established cooperative projects within Columbia University and NOAA – competitive and non-competitive.
• Develop specific research projects that address critical research needs in:
  o Climate modeling and prediction
  o Modern and paleoclimate research
  o Climate forecast applications research
• Create undergraduate-to-graduate level research and education opportunities that reflect NOAA priorities and interest through student participation in related science projects and by bringing NOAA science perspectives into the classroom.
• Identify opportunities and establish means to communicate climate research development to the public to facilitate broader understanding of climate related issues and their impact on society.
• Maintain close contact and research collaboration with other research centers at Columbia, and in particular the International Research Institute for Climate and Society, and the NOAA RISA Consortium for Climate Risk in the Urban Northeast.

Synergies

The CICAR partnership benefits NOAA through synergies with various research centers at Columbia University (CU) particularly within the Earth Institute (EI). Collaborations and joint activities exist between CICAR and the International Research Institute for Climate and Society (IRI); the Consortium for Climate Risk in the Urban Northeast (CCRUN) a NOAA funded RISA and the Center for International Earth Science Information Network (CIESIN). CICAR also maintains ties with Columbia University’s Center for Research on Environmental Decisions (CRED); the Earth Institute Center for Hazard and Risk Assessment (CHRR); and the Columbia Climate Center (CCC).

Research projects and related education activities under CICAR address three overarching themes:

Theme I: Earth System Modeling
• Developing and improving climate models and modeling tools (e.g., data assimilation procedures) to simulate and predict climate variability and change.
• Designing climate experiments with numerical models of varying complexity to test hypotheses regarding, and to promote the understanding of, climate variability and change.
• Applying statistical tools to data and model output to study observed modes of climate variability, their simulation by climate models and their predictability.
• Analyzing historical data to create spatially and temporally uniform information for research and applications.

Theme II: Modern and Paleoclimate Observations
• Developing, collecting, analyzing, archiving, and interpreting climate proxy data records to improve understanding of past climate variability and change on all time scales.
• Monitoring and observing the key ocean regions to understand the ocean role in climate and to improve climate models.

Theme III: Climate Variability and Change Applications Research
• Developing applications and tools that enable the translation of climate research and information to decision makers in the areas of agriculture, water resources, health, economics, and policy.
• Studying the interaction between providers of climate information and users and decision makers to improve communication for the benefit of society.

Operational Strategy by Task
The Institutes primary operational and research strategy is divided into four (4) tasks:

Task I: Administrative activities
Task II: Specialized science support activities
Task III: Proposed and currently funded individual projects
Task IV: Collaborative education program
Executive Summary

1. Overview

The Cooperative Institute for Climate Applications and Research (CICAR) 2012 Annual Report summarizes the research, administrative and educational activities during the 2011-12 fiscal year. This was the ninth CICAR year and the 4th of a 5-year continuation of our post-review cooperative agreement with NOAA. Institute activities reflect a continued commitment to our traditional themes. CICAR continued and expanded its collaboration with the two other NOAA funded projects at Columbia: the International Research Institute for Climate and Society (IRI) and the Consortium for Climate Risk in the Urban Northeast (CCRUN, a NOAA funded RISA). This effort brings together physical of climate research with the applied decision support work that is carried out in the IRI and CCRUN.

Collaboration with GFDL continues to be a key CICAR objective. This objective is recognized and valued by our second NOAA partner, the Climate Program Office, which funds CICAR PIs involved in collaboration with the Laboratory. The CICAR director maintains contact with the GFDL director and individual scientists and with CICAR PIs, particularly those involved in Theme I, to promote a collaborative research agenda. Out of these efforts grew the CPO funded project entitled: “Predicting North American hydroclimate change and variability on the interannual to multidecadal timescale,” which studies the skill of the realistically initialized decadal prediction runs with the new generation of GFDL coupled climate models.

We are also collaborating with GFDL in other ways and make intense use of GFDL models in our study of the Atlantic Meridional Overturning Circulation (AMOC) impact on global climate. Work on this subject is carried out in the context of two CPO funded projects dedicated to this topic and under a DOE funded project to study global decadal modes in a changing climate. Plans to collaborate with GFDL on a climate model simulation of the last millennium, involving intensive comparisons with proxy data were halted by the commitment of the Laboratory to the IPCC Fifth Assessment process but are again under discussion. These efforts also lead to a multi-PI proposal submitted to CPO in the fall of 2009 and funded at the end of the 2010 fiscal year. The “Global hydroclimate variability during the last millennium and into the future” (GloDecH in short) conducts monthly seminars on the project’s research. These presentations and other project-related research activities are accessible at: [http://www.ldeo.columbia.edu/res/div/ocp/glodech/](http://www.ldeo.columbia.edu/res/div/ocp/glodech/).

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1 In line with previous NOAA policy this project and others were funded under separate award numbers and not as CICAR amendments, therefore a project report is not included herein.
CPO also makes funding available for collaboration with NOAA/NCEP to advance their climate prediction system. NOAA’s Office of Ocean of Climate Observations provides funding for the continuing CICAR monitoring of key ocean choke points such as the ocean areas surrounding Indonesia and the Philippines Islands and the areas around the West Antarctic Peninsula, where ocean and sea ice meet the continental ice shelf.

The administrative activities of CICAR are described following this summary. These activities reflect the continued fixed CICAR TASK I budget, which has been frozen at a limit of $100,000 for several years. Our frozen TASK I budget does not meet the rise in the expenses determined by the rising costs of salaries, fringe benefits, travel, communication/publications and supplies. It continues to deny our ability to conduct outreach, support educational activities, etc.

2. Research

During FY12, CICAR administered 35 research projects including the Institute’s core administrative budget. This number includes: 10 projects funded under the Institutional extension award number NA08OAR4320754 and 25 projects funded under the Shadow award number NA08OAR4320912.

CICAR research spans a broad range of subjects that are classified by the three Themes indicated below. This classification is the basis for the organization of the bulk of this report.

**Theme I: Earth System Modeling**: Work under this Theme focused in two complementary areas: (I) Advancing climate prediction and methodologies and model development, and (II) Building predictive understanding of Global, land and ocean climate variability;

Under subcategory (I) we count the following projects:

- **Continued advances in ENSO forecasting**: In FY2010 a group of CICAR investigators lead by Cane was able to use the NCEP CFS prediction system for initialized ENSO predictions.
- **Improving S/I forecast representation**: Through CICAR NOAA/CPO funded a collaborative study to develop a system that allows recalibration of spatial biases in numerical ensemble forecasting. In this study CICAR/IRI PI Goddard is collaborating with NCEP scientists Mendez and van den Dool.
- **Preparing for future decadal prediction**: CICAR PIs (Seager, Cane, Ting, Kushnir) are collaborating with NOAA/GFDL scientists (Rosati, Vecchi, Wittenberg, Msadek) to understand and predict hydroclimatic variations related to decadal Pacific and Atlantic SST variations.
- **Improving model representation of Intraseasonal Variability**: CICAR PI Sobel in a collaborative study funded by NOAA CPO is working on improving the representation of the intraseasonal Madden-Julian Oscillation in the GFDL climate models. The study focuses on the role of wind-evaporation feedback and of the model basic state.
Subcategory (II) projects:

- **Advances in tropical storm research**: CICAR PIs Camargo and Sobel in collaboration with scientists from GFDL (Vecchi, Zhao), the IRI (Tippet), the University of Wisconsin (Kossin), the Australian Weather and Climate Research (Wheeler) and others are funded by NOAA to study the response of tropical storm statistics and behavior (particularly in the North Atlantic) to large scale climate factors, including climate change.

- **Atlantic Multidecadal Variability**: CICAR PIs Kushnir and Ting are studying the interplay between greenhouse gas induced climate change and natural Atlantic multidecadal SST variability (AMV) and the global impacts of these phenomena in observations and IPCC models (CMIP3 and CMIP5). They also study the dynamics and predictability of the AMV in models forced with pre-industrial CO₂ concentrations and the response of AMV to anthropogenic and natural aerosol forcing.

- **Progress in the study of subtropical droughts**: In this work CICAR PI Seager is the lead PI on a large project that is studying the dynamical causes and predictability of subtropical droughts and their response to greenhouse gas forcing. The team working on this project is also looking at the pre-instrumental era using tree-ring and coral proxies and is conducting targeted experiments with SST forced general circulation models. This broader work is done under the GloDecH projects [http://www.ldeo.columbia.edu/res/div/ocp/glodech](http://www.ldeo.columbia.edu/res/div/ocp/glodech).

**Theme II: Modern and Paleoclimate Observations**: Research under Theme II can be broadly divided into two subcategories: (I) Modern observations of oceanic variability and (II) Analysis of paleoclimate observation to advance understanding of long-term, free and forced climate variability. Much of the research under this theme is carried out as part of the CPO funded project Abrupt Climate Change in a Warming World (ACCWW).

- **Observing the Modern Ocean**: Using in-situ, remote sensing, and global dataset analyses CICAR oceanographers observe the modern ocean circulation and gas exchange thus helping quantify the role of the ocean in the global climate system. The main thrusts of this research are:
  - PIs McGillis and Zappa studied the dependence of air-sea gas exchange under various environmental forcings, particularly rainfall. This work was accomplished using laboratory techniques as well as field measurements and helps determine gas exchange coefficients used in bulk formulae, which are used in the global monitoring of air-sea CO₂ exchange.
  - PI Takahashi, in collaboration with a wide network of investigators, which includes scientists from NOAA PMEL and ESRL, continued to update and improve the widely used atlas of Global Ocean pCO₂.
  - PI Gordon and his collaborators in the US and overseas continue to maintain and retrieve data from the passages around the Indonesian archipelago. This is a critical ocean choke point with significance to the global thermohaline circulation and through that on the long-term variability of the climate system.
Another critical ocean region that has been observed and monitored by CICAR oceanographers (Jacobs, Huber, Martinson) in the past decade is the ocean area surrounding the West Antarctic Peninsula. The interaction between the atmosphere, sea ice, and ocean determines the rate of deep-water formation and affects the stratification of the Atlantic and, in time, the entire global ocean. This is another region critical for the effort to improve global climate models. Year after year our scientists are visiting the region, retrieving instruments and re-deploying them to provide more data for monitoring, analysis, and model development.

PIs Schlosser and Smethie and their teams, in two independent studies are using geochemical tracers to study the shallow deep circulation in the North Atlantic.

- **Paleoclimate studies:** For more than a decade LDEO scientists lead a NOAA/CPO effort to understand the large, abrupt fluctuations in the climate of the past, particularly the glacial past and its “rocky” transition into the Holocene. This multi-PI project has been administered by CICAR since the Institute’s inception. The project finally came to an end during FY 2009-10 (carried over this far through a no-funds extension). It is reported here in a series of final reports. In FY 2008-09 NOAA/CPO funded a more focused effort to study abrupt change in warm climates with the aim of evaluating the risk of surprising behavior of the climate system under global warming (ACCWW). This recent project focuses on the Holocene, particularly the last two millennia.

  - PIs Anderson, Denton, Schaffer and collaborators (including Toggweiler of GFDL) synthesized a collection of Southern and Northern Hemisphere, ocean and atmosphere proxies to investigate the transition between the last glacial period and the Holocene.

  - LDEO Tree-Ring Laboratory scientist, working under NOAA funded projects moved forward on work related to extending the available dendroclimatological archives and deriving more information out of it. Cook (with help from Seager) is heading a new effort to reconstruct the hydroclimatic variability of the so-called Old World (Europe, North Africa, Middle East) back one or two millennia in a similar way to his work on North American chronologies. D’Arrigo is participating in a collaborative research to make use of oxygen isotope information retrieved from tree rings.

**Theme III: Climate Variability and Change Applications Research:** This category entails several research projects that support education and outreach related mainly to the dissemination and societal use of climate information. The projects involve enhancement of IRI activities in several experimental areas under seed funding from the NOAA/CPO. Under this category work is exploring the societal application of the abrupt climate change research (Theme II). This study looks at the historical impact of Western US hydroclimate variability on water policy and interstate agreements to draw conclusions regarding the future. Also under this theme is work by PI Zebiak from the IRI on the management of international internships for climate and society and on identifying, sharing and show casing decision support products.
Task I Administrative

Addresses the administrative functions of the Institute and supports the CICAR director and one administrative staff member.

Administrative Staff and Contact Information

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Home page
Advisory Committee Organization Chart

The CICAR Advisory Committee helps define scientific strategies for the Institute that will best address the needs of Climate Services at OAR, which should help NOAA in “providing the transparent, reliable, timely and easily accessible information that America requires.” The Advisory Committee brings together academic and scientific leadership from research divisions and centers at The Earth Institute, Columbia University with expertise in data, science, engineering, health, and education.

The Director and Committee work to develop crosscutting initiatives in support of the NOAA Climate Mission Goal to “Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond.”
Advisory Committee Contact Information

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The CICAR Executive Board members are charged with invigorating the Institute’s commitment to new and existing scientific program areas and counseling the CICAR Director on matters of policy, budget, and ways to improve coordination of research programs with other institutions or agencies.
Administrative Activities July 1, 2011 – June 30, 2012

This past year CICAR Director Yochanan Kushnir participated in a broad range of activities that inform the Institute’s climate science agenda and address private sector stakeholder needs and concerns. These activities advanced the NOAA OAR Climate Program Office climate priorities to improve scientific understanding, assess climate and its impacts, inform mitigation and adaptation choices and promote public climate literacy.

The World Economic Forum Global Fellows Columbia University
July 2011Columbia University, New York
The Fellows took part in a series of workshops and programs on the importance of leadership in an increasingly globalized world. The sciences program, titled “Global Sustainability and Complexity,” aims to promote innovative thinking about global issues. A multifaceted approach to these issues through curriculum on climate science and risk, global public health, resource management, and alternative energy solutions through workshops guided by instruction from Earth Institute faculty including Yochanan Kushnir and Lisa Goddard (IRI), included case studies from ongoing research projects, lectures and decisions games of climate decisions.

The Consortium for Climate Risk in the Urban Northeast (CCRUN), NOAA Regional Integrated Sciences and Assessments (RISA) program
July 2011, New York City Department of Environmental Protection
Kushnir participated in discussions with representatives from the New York City Department of Environmental Protection to learn about City needs in climate information. Topics discussed included the impacts of a changing climate, population growth, urban heat island effects and poor air quality.

June 26 – 27, 2012 Stevens Institute of Technology
Participated in the Extreme Climate Events Workshop, a conference organized by CCRUN to examine the challenges of extreme climate events research, information and public messaging.

October 4 – 5, 2011 Amherst, MA
At the CCRUN 2nd Annual Meeting Kushnir presented relevant CICAR research and participated in discussions of future projects

Cooperative Institute for Alaska Research (CIFAR) Review
July 27 – 28, 2011 Fairbanks, Alaska
Kushnir participated as a CI representative in the site review and preparation of the report to Science Advisory Board.

The Geophysical Fluid Dynamics Laboratory (GFDL)
October 2011 Princeton, New Jersey
Attended the GFDL Symposium community research achievements report in response to previous year’s review.
Led a small delegation of CICAR scientists in a visit to GFDL to present current research and discuss existing collaborations and mutual research goals, and in particular decadal climate variability.

**NOAA Requests for Public Comment**

*August – July 2011*

Kushnir collected information from the CICAR PIs and organized responses to the NOAA Data Sharing Policy for Grants and the OAR strategic plan.

**NOAA Conference Calls and Annual CI Meeting**

*September 2011 – March 2012*

- CI Directors Update Conference Call with Dr. MacDonald
- NOAA OAR Budget Conference Call
- NOAA Research Update Constituent Call
- NOAA Research Update Call
- NOAA CI Directors Meeting (Kushnir unable to attend due to jury duty obligation)

**Office of Science and Technology Policy (OSTP) | The White House**

*February 2012 The Lamont-Doherty Earth Observatory*

The Observatory Directorship hosted a series of discussions between senior Columbia researchers and White House OSTP representative, Senior Policy Analyst Johannes Loschnigg. Kushnir spoke about the CICAR goals, research agenda and challenges.

**The Earth Institute faculty retreat**

*May 2012 New York Botanical Gardens*

- Particular focus on conducting interdisciplinary research on climate and environmental impacts

**CICAR Mini Conference**

*Symposium planned for May 2013 Lamont-Doherty Earth Observatory*

- Build on the research accomplishments spanning 20 years of abrupt climate change studies at Columbia University in partnership with the NOAA OAR Climate Program Office.
- Focus on key outstanding issues and current research work for assessing the potential for rapid future climate change.
  - Ocean change
  - Cryosphere changes
  - Hydroclimate variability and change
  - Climate forcing
  - The human dimension

**CICAR Advisory Committee Meetings**

*May – June 2012 Lamont-Doherty Earth Observatory and The Earth Institute | Columbia U.*

Discussed research strategies for CICAR in the context of a NOAA CI recompete.
Public Outreach and Education

LDEO Open House 2011

On October 1, 2011 CICAR hosted its annual Open House exhibit featuring NOAA-sponsored science at The Earth Institute, Columbia University. Members of the LDEO scientific staff and administration engaged in discussions with the general public and students of all ages, answering questions on a wide range of climate related issues.

CICAR and the Observatory co-sponsored a panel discussion entitled Climate Change and Extreme Weather: are they connected? The panel participants are all connected to CICAR through their NOAA-funded research.

For CICAR this is a volunteer effort with no additional funding beyond the Institute’s Task 1 materials and supplies budget. Posters, handouts, family-friendly projects and checklists all contribute to and support the NOAA mission: Science, Service and Stewardship.
Top: CICAR volunteer Colin Kelley, a PhD student in Climate and Oceanography answered questions from visitors regarding the uncertainties associated with climate change and global warming, and discussed his research on the recent and future drying of the Mediterranean region.

Bottom: CICAR Director Kushnir along with CICAR PI Mingfang Ting addressed visitors’ concerns about climate change and explained why NOAA science matters.
CLIMATE CHANGE AND EXTREME WEATHER
ARE THEY CONNECTED?

Moderated by Heidi Cullen
Communications Director
Climate Central

Suzana Camargo
Lamont Associate Research Professor

Kevin Anchukaitis
Lamont Assistant Research Professor

Richard Seager
Palisades Geophysical Institute
Lamont Research Professor

Jason Smerdon
Storke-Doherty Lecturer

LAMONT-DOHerty OPEN HOUSE
October 1, 2011 • 1:45–2:45 p.m.
Palisades, NY • Monell Auditorium

Cooperative Institute for Climate Applications and Research
EARTH INSTITUTE | COLUMBIA UNIVERSITY

Lamont-Doherty Earth Observatory
COLUMBIA UNIVERSITY | EARTH INSTITUTE
CICAR Researchers Make First Step in Tornado Short-Term Forecasting

A new study recently published in the Geophysical Research Letters by Michael Tippett and colleagues offers the first framework for predicting tornado activity up to a month out with current technology, and possibly further out as climate models improve. Researchers began looking for patterns linking climate and tornadoes by combing through 30 years of data and comparing average monthly atmospheric conditions derived from the North American Regional Reanalysis (NARR) with average monthly tornado counts in regions across the United States. Using a regression procedure Tippett and colleagues identified two key environmental variables associated with monthly tornado activity that were combined into a single index. This index captures the seasonal distribution of tornado counts as well as their inter-annual variability and in tests with output from historical NOAA Climate Focus System forecasts, shows the potential for useful extended range prediction of monthly tornado activity.

Background: Tornadoes are a small-scale and volatile phenomenon and their predictability is usually measured in hours. Tornadoes in 2011 killed more than 500 people, more than in the previous 10 years combined, including a devastating outbreak in April that resulted in $5 billion in insured losses.

Significance: Predicting the potential for monthly tornado activity and their spatial distribution a month in advance could provide emergency management authorities with valuable information for preparedness. Researchers will next improve the index’s reliability to better understand why the forecasts work and to apply the index to probabilistic extended-range predictions of storm activity. This research addresses the NOAA goal – Climate Adaptation and Mitigation.

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Task II Specialized Science Support Activities

Task II provides for specialized support scientists employed by Columbia University, Lamont-Doherty Earth Observatory but located at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, New Jersey. These CICAR employees are meant to enhance the technical and scientific expertise at GFDL required to execute collaborative projects and to address specific needs that require expertise not available at GFDL.

The Institute’s initial five-year budget cycle allowed for five scientific support hires as does the CICAR continuation award, which began in July 2008. To date these positions have not been filled.
Task III Individual and Collaborative Principal Investigator (PI) Research Projects

Task III encompasses the bulk of individual and collaborative PI research at the Lamont-Doherty Earth Observatory, The Earth Institute, Columbia University. This work is supported by grants from NOAA and is compliant with the research themes of the Cooperative Institute for Climate Applications and Research.

The Task III projects strengthen the CICAR research agenda in line with the themes and represent the main thrust of the Institute’s scientific agenda for the coming year.
Theme I Earth System Modeling

INDIVIDUAL AND COLLABORATIVE PI RESEARCH PROJECTS

CICAR Institutional Extension Award # NA08OAR4320754
2. Schlosser, P., *Global Oceanic 3HE Data Sets: Calibration tools for Models of the Upward Branch of the Deep Ocean Global Conveyor*

CICAR Shadow Award # NA08OAR4320912 ¹
1. Camargo, S., *Towards a Better Understanding of the Relationship Between Climate Change and Tropical Cyclone*
2. Cane, M., *Generation and Evaluation of Long-Term Retrospective Forecasts with NCEP Climate Forecast System: Predictability of ENSO and Drought*
3. Goddard, L., *Diagnosing Decadal-Scale Climate Variability in Current Generation Coupled Models for Informing Near-Term Climate Change Impacts*
5. Kaplan, A., *Error Models for Remotely-Sensed Sea Surface Heights and Temperatures in Ocean Data Assimilation*
7. Martinson, D., *Abrupt Climate Change in a Warming World (ACCWW): Abrupt Change in the West Antarctic Peninsula in a Warmer World*
8. Schlosser, P., *ACCWW: Infrastructure*
9. Seager, R., *ACCWW: Modeling and Understanding Late Holocene and Near Term Future Hydroclimate Change*
11. Seager, R., *Predicting North American Hydroclimate Change and Variability on Interannual to Multidecadal Timescale*

TOTAL THEME I PROJECTS: 15

¹ This listing is for reference only. Detailed reports appear in a separate CICAR 2012 Shadow Award Report.
Research Goals
The goal of the project was to examine the simulation of Sahel rainfall in the CMIP5 ensemble. Specifically, we aimed at duplicating previous results from CMIP3 (looking at the trends in 20th century and scenario simulations) and expand them to identify the role of greenhouse gases.

Research Progress
We can point to 2 sets of results, both shedding light on the role of sea surface temperature forcing for Sahel rainfall variations.

The first was obtained using simulations from the CMIP3 archive and is summarized in Figure 1. This is a scatterplot of Sahel rainfall epochal differences versus the relative warmth of the Northern Tropical Atlantic (area average SST in the NTA minus the tropical average). The colors refer to differences between 20th century and pre-industrial, late and early 20th century, mid or late 21st century and 20th century, so that warmer colors depict anomalies in warmer climates. The different symbols refer to different models in the ensemble. This figure indicates that a consistent relationship between SST and Sahel rainfall is maintained into the 21st century, in partial contradiction to previous results (Biasutti et al, 2008). At the same time, it confirms that (i) the specific pattern of warming is key in determining the sign of the Sahel anomalies and (ii) many models show a weak dependence of Sahel rainfall on SST, so that even substantial anomalies in the latter do not create significant anomalies in the former.

The second set of results was culled from the CMIP5 models. We were able to reproduce the major results of our previous work with CMIP3: (i) that the 20th century drying of the Sahel was partly anthropogenic, as shown by the large degree of model consensus on the centennial trend in historic runs; and (ii) that the seasonal evolution of Sahel rainfall anomalies is different in the 20th and 21st century, indicating a delay of the rains in the future.
Moreover, we have expanded on previous work by examining the Sahel response in idealized simulations that can separate the fast (purely radiative) effect of CO2 from the effect of CO2-induced warming. These simulations are uncoupled simulations with fixed SST and either pre-industrial or 4-times-preindustrial CO2 concentration (their difference simulates the fast effect of CO2) and coupled simulations forced by an abrupt CO2 increase (trends in these simulations convey the effect of SST changes).

There is a consistent response across the CMIP5 models: the CO2 radiative forcing, on its own, induces a stronger monsoon, while the SST changes that accompany the CO2 increase force dry anomalies. In both cases the peak anomalies are in August and coincide with peak climatological rainfall. The mechanism by which the superposition of the two effects would give rise to a delay in the rains (dry anomalies in June and peak wet anomalies in September) is currently under investigation.

**Other Research Connections (interagency, partnerships, collaborations)**
Funding by NSF supports parallel research in the delay of the annual cycle under global warming.

**Education & Outreach**
The PIs undertake several educational and outreach activities (including mentoring of undergraduate and graduate students and collaborations with African junior scientists), but without funding from this grant.

**Personnel**
Research Scientists: 2.

**Publications**
We are working on two short papers that will be submitted to GRL before the July 31st deadline for inclusion in the IPCC AR5 report.
Figures

Figure 1. Difference in sea surface temperature between the North Tropical Atlantic (10N to 30N) and the tropical band, plotted against the corresponding change in summertime Sahel rainfall. Different symbols indicate different models in the CMIP3 ensemble. Different colors are for different epochs: red is end(21st) – end(20th), yellow is mid(21st) - end(20th), blue is end(20th) - beginning (20th), and green is end(20th) – pre-industrial.

Figure 2: The response of monthly Sahel rainfall to the quadrupling of CO2 can be decomposed in terms of a response to the associated SST changes (in the absence of direct radiative forcing, left) and by the direct effect of CO2 (in the absence of the SST response, right). The two component of the response are calculated as the trend in the Abrupt4xCO2 runs (left) and as the difference between the SSTClim4xCO2 and SSTClim (right) CMIP5 runs. Each model in the ensemble (for which the runs are available) is plotted with a different color bar; the solid line represents the multi-model mean. Units are in percent of 20th century total annual rainfall.
Research Goals
The main goals of the Lamont-Doherty component of this project were to (1) create a global dataset of helium gas concentrations and helium isotope ratios, (2) to translate these data into a global distribution of mantle-derived dissolved helium, and (3) participate in the comparison of these data with ocean GCMs in order to estimate the flux of mantle helium from the ocean sea-floor. Additionally, we have sought to identify gaps in the knowledge of the geographic distribution of the helium source by comparing source estimates with the observed distribution of mantle helium.

Education Goals
Our educational goals have been to train graduate and undergraduate students in ocean geochemical tracer techniques and to provide internships for public high school teachers and students interested in the Earth Sciences.

Research Progress
The global helium database was assembled, quality controlled, and gridded. The resulting product, integrating over 25,000 measurements from over 1,500 profiles, is a significant milestone in the study of dissolved gas tracers in the Ocean. The helium measurements, merged with neon, temperature and salinity data, were translated to a mantle helium distribution in the global ocean.

Nutrient data from the initial (“one time”) WOCE survey of the ocean has been integrated with the helium data, as well as tritium measurements where they are available.

The Arctic Ocean tritium and helium data has been merged into an Arctic dataset using the same data structures and software as the global helium database, as a prelude to integrating the Arctic with the global database.
The mantle helium database has been used to critique and validate several runs of the Princeton/GFDL ocean model with varying mixing schemes.

The database was used to identify a previously unproven source of mantle helium in the Southern Ocean. The dataset was used to replicate the “Munk” calculation of vertical diffusivities in the abyssal Pacific Ocean, this time with a tracer that enters the ocean in the abyss, as opposed to oxygen and carbon-14, which enter from the atmosphere. The text of an article describing the results of the 1-D model has been prepared; we are currently working on production-quality graphics for submission.

**Highlights**

The previously accepted ocean-floor flux of mantle helium to the ocean was shown to be overestimated by a factor of about 2. (Bianchi, et al., 2010).

Distributions of mantle helium on isopycnal surfaces were used to track the source down to seven specific volcanic formations that we predict are home to active vent fields. (Winckler, et al., 2010).

The effective, passive-tracer based, vertical diffusivity coefficient in the abyssal ocean, away from boundaries, was found to be between 0.6 and 1.2 cm²/s. This value is consistent with the Munk estimate, but is significantly higher than the estimate derived from purposeful, in situ tracer releases in similar areas. (Schlosser, et al., in prep, and presented at the Ocean Sciences meeting, Portland, 2010).

**Societal Benefits**

Vertical exchange between the ocean mixed layer and the abyss is a critical parameter in understanding the fate of CO₂ anomalies in the atmosphere. Vertical exchange, and its variation in time, is also critical to assessing the potential of the ocean to reorganize the partition of heat between the surface and the abyss. Mantle helium, with its distinctive source function and its conservative behavior in the ocean interior, offers novel insights into dispersion and vertical exchange of ocean properties. In that way, it improves the scientific grounding of policy proposals and decisions.

**Awards & Honors**

P. Schlosser was elected Fellow of AAAS and Fellow of the Explorer’s Club. He was a member of the NAS panel on ‘Future Science Opportunities in Antarctica and the Southern Ocean.’

**Education & Outreach**

During the time-period of the Award, researcher Newton has been Program Manager of several Columbia outreach programs, partnering with NYC public schools at the grades 6-12 level. As part of these programs, approximately a dozen high school students have worked as summer interns on projects related to the helium database (cruise preparations, sample tracking, data analysis).
A Columbia undergraduate, Andrew Babbin, worked on the quality control of the helium dataset as part of his Senior Thesis. Babbin coded a routine for semi-automated auditing of error estimates relative to smoothed profiles calculated at each station in the dataset. Babbin is currently a PhD candidate at Princeton University in Oceanography.

A second Columbia undergraduate, Scott Mannis, has been working on quality control of the helium, neon and tritium data collected over the past 5 years.

**Personnel**
Research Scientists: 2.

**Journal articles**


**Conference proceedings**
Theme II Modern and Paleoclimate Observations

INDIVIDUAL AND COLLABORATIVE PI RESEARCH PROJECTS

CICAR Institutional Extension Award # NA08OAR4320754
1. Gordon, A., *Monitoring the Indonesian Throughflow in Makassar Strait*
2. Huber, B., *Weddell Sea Moorings*
3. McGillis, W., *Boundary Layer Experiments of Coral Reef Calcification and Net O₂ Production*
4. Takahashi, T., *Underway CO₂ Measurements Abroad the RV IB Palmer and Data Management of the Global VOS Program*

CICAR Shadow Award # NA08OAR4320912
2. Broecker, W., *ACCWW: Meridional Hydrology Variability and Synthesis of Ocean Circulation*
3. D’Arrigo, R., *Paleoclimate Reconstructions (PR) Challenge: A Community Program to Benchmark Methods Used to Reconstruct the Climate of the Last 1-2,000 Years*
4. deMenocal, P., *ACCWW: Holocene Variability of Atlantic Surface Properties and West African Aridity*
5. Denton, G., *ACCWW: Lessons From Holocene Paleo and Modern Instrumental Records, and Model Simulations*
7. Hemming, S., *ACCWW: Radiogenic Isotope Tracer Paleo-Proxy Scope*
10. Schlosser, P., *ACCWW: Abrupt Climate Change in a Warming World: Synthesis of Tracer Data*
11. Smethie, W., *ACCWW: Modern Instrumental Records-CFCs*

TOTAL THEME II PROJECTS: 15

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1 This listing is for reference only. Detailed reports appear in a separate CICAR 2012 Shadow Award Report.

CICAR 2012 Annual Performance Report
From July 1, 2011 to June 30, 2012
PI Yochanan Kushnir
Research Goals
The ocean, representing 97.5% of Earth's water and consequently a key component of the Earth’s climate system, is segmented into basins (Atlantic, Pacific, Indian, plus a few seas). The form and efficiency of inter-ocean exchanges between these basins govern the global marine characteristics, including sea surface temperature (SST), that the ocean projects onto the climate system [see: Gordon, A.L. (2001) "Interocean Exchange". In: Ocean Circulation and Climate, G. Siedler, J. Church, and J. Gould (Eds.), Academic Press, 303-314].

The 'mega'-archipelago between Southeast Asia and Australia, the only tropical interocean pathway, offering a maze through which warm Pacific water spreads into the Indian Ocean, the Indonesian Throughflow (ITF; figure 1), influencing large-scale oceanic heat and freshwater inventories. As the ITF region is at the nexus of ENSO (El Niño/La Niña) and the Asian monsoon phenomena, it is highly likely, as indicated by model studies, that the ITF impact on SST patterns affect ENSO and monsoon behavior. Recording the ITF is a cost effective way to monitor a core element of the ocean and climate system, with the goal to enable improved climate predictive capability. As Makassar Strait is the pathway for 80-85% of the total ITF, it is the obvious focus of an ITF monitoring array. The Makassar Strait throughflow time series, at 2°51' S; 118°28' E; 2147 m, in the Labani Channel 45 km wide constriction of Makassar Strait, began with the NSF funded Arlindo program in 1996-1998, and continued with NSF funded INSTANT 2004-2006 (November) and NOAA OCO 2006 (December), with the most recent recovery in August 2011. The NOAA OCO project is a cooperative program between the Lamont-Doherty Earth Observatory of Columbia University and the Agency for Marine & Fisheries Research (Balitbang KP), Ministry of Marine Affairs and Fisheries, Indonesia.

Research Progress
The Makassar throughflow time series reveals that after 2006, particularly in 2008-2009 boreal summer (June-September), the Makassar throughflow profile changed
dramatically: the summer velocity maximum increased from 0.7 to 0.9 m/sec and shifted from 140 m into warmer waters at 70 m. HYCOM model simulation indicates that ENSO related changes in the South China Sea (SCS) throughflow, drawn from Luzon Strait, into the Indonesian seas is the likely cause of the observed changes. Increased SCS throughflow during El Niño with a commensurate increase in the southward flow of buoyant, low salinity surface layer water, from the Sulu Sea into the northern Makassar Strait via Sibutu Passage, inhibits the injection of Pacific surface layer from the Mindanao Current into the ITF. During La Niña the Sibutu Passage throughflow is reduced or reversed allowing increase Pacific surface layer inflow. Increased inflow of warmer tropical Pacific water into Makassar Strait during La Niña affects the ITF spread into the eastern Indian Ocean, impacting on the thermocline and SST, with possible impact on climate.

The NOAA funded Makassar moorings is part of a growing international effort to observe the ITF. The Australian Integrated Marine Observing System [IMOS; see: http://imos.org.au/waimos.html] Indonesian Throughflow Moorings forms an important companion to the NOAA-OCO funded Makassar mooring. The Korea Ocean Research & Development Institute (KORDI) is developing an additional international companion program. A. Gordon is a member of the KORDI science advisory group specifically for coordination of ITF observations. KORDI plans to deploy ITF observing moorings in the Maluku and Halmahera seas in 2012/13 to observe the inflow paths from the Pacific Ocean into the eastern Indonesian seas.

The NOAA-OCO Makassar time series data is available in delayed mode at: http://www.ldeo.columbia.edu/res/div/ocp/ITF/cm_data/ The 2009-2011 data will be added in Spring 2012, when the processing reaches near final form.

Intended users of the resulting data and products are the ocean and climate modeler communities, as the ITF is indicative of a larger scale ocean and climate system. Additionally, Makassar Strait has much oil activities. Knowledge of the currents in Makassar Strait enables safer operations and mitigation of possible oil spills. I have informed oil company personnel [at ConocoPhillips, Niko Resources (Limited, Marathon Oil, EXXON-Mobil] of the NOAA-ITF program and provided the time series [including the 2010-2011 segment].
Figure 1. Left Panel: configuration of the NOAA-ITF mooring; Right Panel: Schematic of the Indonesian Throughflow circulation. The primary source for the ITF is the western tropical Pacific at ~ 4°N, but additional inflow is derived from the South China Sea, drawn from Luzon Strait. Topographic sill depths are given in black italics. The blue arrows depict the ITF. ITF transports in Sv (10^6 m3/s) are shown for each passage in green [from the INSTANT program, 2004-2006]. Makassar Strait Throughflow NOAA OCO mooring site is identified.

Highlights

Scientific and Observing System Accomplishments

a. Program Deliverables

The NOAA OCO supported time series within Makassar Strait, which carries 80-85% of the ITF, contributes to the following "observing system’s program deliverables":

- Sea Surface Temperature and Surface Currents, to identify significant patterns of climate variability and change. The ITF influences the SST of the eastern tropical Indian Ocean, Song and Gordon, 2004.
- Ocean Heat Content and Transport, to better understand the extent to which the ocean sequesters heat; to identify where heat enters the ocean and where it emerges to interact with the atmosphere; and to identify changes in thermohaline circulation and monitor for indications of possible abrupt climate change. The Indonesian Throughflow (ITF) affects the heat and freshwater inventories of the tropical Pacific Ocean and Indian Ocean, and associated climate phenomena (see sections b and c, below).
- Air-Sea Exchanges of Heat, Momentum, and Fresh Water, to identify changes in forcing functions driving ocean conditions and atmospheric conditions; and to elucidate...
oceanic influences on the global water cycle. *The ITF affects SST. The increased, warmer, Makassar flow in 2008-2009 is expected to increase the SST in the eastern tropical Indian Ocean and increase sea to air flux of heat and freshwater, with a potential to energize the SE Asian monsoon.*

**b. What did you achieve during FY2011?**

The Makassar time series began with Arlindo in 1996-1998, and continued with INSTANT 2004-2006 and without a gap until recently with funding support from NOAA. The mooring was recovered on 1 August 2011, but was not redeployed because the mooring shipment did not arrive in Makassar in time. The time series in-hand is just fantastic [see subsections c and d], revealing unexpected variability of many aspects of the throughflow. The understanding of these fluctuations will advance our view of the forces that govern the ITF and of its impact on regional oceanography and marine ecosystems. Discontinuity of the time series will be a ‘blow to science’, and associated applications of the insight gained from the observations.

A January 2012 deployment will give us a data gap of 5 months, which is not damaging to the time series. I view deployment as late as April 2012 is not overly damaging. A larger gap extending into the maximum throughflow period of May-Sept 2012 period will require a 're-thinking' of the program, as discussed below, section e.

**c. What Scientific advances were made and/or facilitated through your activities?**

A summary of the science return of the NOAA funded ITF time series is best presented in the following text excerpted from a manuscript in preparation: "South China Sea Throughflow Impact on the Indonesian Throughflow" to be submitted to Nature Geoscience (Authors: A. L. Gordon, B. Huber, E. J. Metzger, R. D. Susanto, H. Hurlburt, Rameyo Adi).

The archipelago between Southeast Asia and Australia offers a maze through which tropical Pacific water spreads into the Indian Ocean, the Indonesian Throughflow (ITF), influencing ocean heat and freshwater inventories and large-scale SST patterns, which influence ENSO and the Asian monsoon. A 1996-1998, 2004-2011 observational time series of the Makassar Strait throughflow, the primary pathway for the ITF, indicates an ENSO role in governing the Pacific Ocean surface water contribution. Here we show that after 2006, particularly in 2008-2009 boreal summer, the Makassar throughflow profile dramatically changed, with the summer velocity maximum increased from 0.7 to 0.9 m/sec and shifting from 140 m to as shallow as 70 m. HYCOM simulation indicates that ENSO related changes in the South China Sea (SCS) throughflow, drawn from Luzon Strait, into the Indonesian seas is the cause of the observed changes. Increased SCS throughflow during El Niño with a commensurate increase in the southward flow of buoyant, low salinity surface layer water, from the Sulu Sea into the western Sulawesi Sea via Sibutu Passage, inhibits the injection of Pacific surface layer from the Mindanao Current into Makassar Strait, to a greater extent than does the shallower Karimata Strait throughflow into the southern Makassar Strait. During La Niña the Sibutu Passage throughflow is reduced or reversed allowing increased Pacific surface layer inflow.
Increased inflow of warmer tropical Pacific water into Makassar Strait during La Niña affects the ITF spread into the eastern Indian Ocean, impacting on the thermocline and SST, with possible impact on climate.

The only tropical connection between oceans is that afforded by the Indonesian seas allowing transfer of Pacific Ocean water into the Indian Ocean. The ITF is approximately 15 Sv (Sv = 10⁶ m³/sec). The complex arrangement of passages and sea of varied dimensions makes for a network of paths of Pacific water spreading towards the Indian Ocean (figure 1). The primary inflow path is North Pacific water flowing into Makassar Strait from where the Pacific water column spreads towards the export passages of the Sunda islands, altered en route by tidal induced mixing, Ekman pumping and sea-air buoyancy flux, into a unique Indonesian stratification, before export across the Indian Ocean near 12°S.

**Figure 2.** Upper right Panel: Time series of along channel flow m/sec within Labani Channel of Makassar Strait derived from observations from Arlindo (1996-98), INSTANT (2004-07) and NOAA ITF (2007-2011) programs. Flow towards the south are negative values. The mooring location is depicted by the red dot on figure 1, and in upper left panel. The velocity maximum shoaled, with increasing maximum speed, through 2007, reaching peak in maximum speed in 2008/2009. The throughflow is weakest in boreal winter, strongest in boreal summer. Lower Panel: North-south monthly velocity anomaly at the mooring site at 60 m from the 2004-2011.
Blue: Makassar ADCP moored time series; red: HYCOM output. The seasonal signal has been removed, and the data smoothed with a 7-month running mean. The gray dashed curve is a 3rd order polynomial fit to the Makassar time series. The apparent regime change in 2007, roughly coinciding with a shift from prolonged El Niño to a period of more frequent El Niño/La Niña transitions. The HYCOM output in Makassar Strait agrees remarkably well with the observations.

The Makassar Strait throughflow was measured at two sites within the Labani Channel, a 45 km wide constriction near 3°S, during the Arlindo program from late 1996 to mid-1998; at the same two sites by the INSTANT program from January 2004 to the end of November 2006 and at the western site during the NOAA ITF program from December 2006 through July 2011 (Fig. 2). The depth profile of the Pacific water flowing into Makassar Strait exhibits thermocline intensification, inducing a cooler transport-weighted temperature than surface intensified profile. The participation of surface ocean water in the ITF is clearly restricted, protecting the warmest of the tropical Pacific water from leakage into the Indian Ocean. The restriction of the surface water component of the ITF is likely a consequence of the injection of low salinity, buoyant surface water from the South China Sea (SCS) into the Makassar Strait, which blocks entry of Mindanao Current surface water into Makassar Strait, diverting it into the North Equatorial Counter Current.

As reported earlier the Makassar southward velocity (Fig. 2) reaches a maximum within the thermocline, tending towards greater speeds as the velocity maximum layer shallows. A distinct seasonal cycle is evident, reaching a maximum during the southeast monsoon (boreal summer), with minimum speeds in the northwest monsoon (boreal winter). During 2006, reaching a more dramatic change in 2008 and 2009, the southward speeds increased and shallowed significantly, from mid-thermocline depths of ~120-150 m to upper thermocline depths of 70-100 m. The Makassar Strait average temperature profile over the 1958-2007 Simple Ocean Data Assimilation (SODA) re-analysis period defines the thermocline layer in the 50-200 m interval with a mean vertical temperature gradient of 0.31°C/10 m. The mean temperature at 140 m is 20°C at one standard deviation of 1.5°C, at 70 m its 27°C at one standard deviation of 2.5°C; the 18°C isotherm heaves upward during El Niño, deeper during La Niña (167 m in the 1997 El Niño; 205 m in the 1999 La Niña). The shallowing of the velocity maximum from 140 m to 70 m observed in 2008 and 2009 draws warmer water into the ITF.

We hypothesize that the change in the Makassar through profile is a consequence of the greater westward transport within Luzon Strait and associated SCS throughflow via Sibutu Passage during El Niño relative to La Niña. The polynomial fit to the smoothed north-south monthly velocity anomaly in Labani Channel at 60 m (Fig. 2) from the 2004-2011 Makassar ADCP moored time series and from HYCOM output shows that the regime change in 2007, roughly coincides with a shift from prolonged El Niño to a period of more frequent El Niño/La Niña transitions. The HYCOM output in Makassar Strait agrees remarkably well with the observations. We investigated the relationships among the SCS throughflow and the Makassar Strait throughflow with the 1/12° non-assimilative global HYCOM experiment 18.2 over the period 2003-2010.
Figure 3: Upper Panel: HYCOM monthly transport anomaly relative to 2003-2010 of the HYCOM layers 1-4, coinciding with the upper ~85-100 m of the Makassar Strait, Sibutu Passage, and the Mindanao-Sulu Sea input from the Western Pacific (see figure 1 for the positions of these sections). Values from HYCOM; seasonal cycles were removed. During El Niño the southward transport of South China Sea surface water within the Sibutu Passage increases, decreasing during La Niña. The Makassar Strait southward surface layer transport is reduced during El Niño, as is the westward surface layer transport between Mindanao and Sulawesi, with the opposite response during La Niña. Lower left panel: HYCOM full depth Luzon Strait transport scales to nino4. The westward throughflow within Luzon Strait, which feeds the South China Sea throughflow into the Indonesian seas, responds to ENSO: larger westward throughflow during El Niño. Lower middle panel: HYCOM full depth Sibutu Passage southward transport is significantly correlated to the Luzon Strait throughflow, both out-of-phase with the Makassar Strait and Mindanao-Sulu transports. Lower right panel: HYCOM full depth Karimata Strait southward transport increases with the Luzon Strait westward throughflow, but with lower correlation and much reduced transport than that of the Sibutu Passage. About 70-75% of the South China Sea throughflow is channeled into the Indonesian seas via Sibutu Passage.
Model output indicates that the Luzon Strait throughflow varies with the ENSO cycles: stronger and cooler during El Niño. The Luzon Strait throughflow estimate ranging from near zero to over 6 Sv, averaging 4.5 Sv, with the HYCOM value used here of 2.9 Sv, warms and freshens within the SCS by an estimated 23 to 49 W/m² and 0.11 Sv (from P-E and river discharge), respectively, making it an important freshwater 'conveyor' of the Pacific western marginal seas. The warmed, freshened SCS water is exported in approximately equal magnitude through Taiwan Strait and into the Indonesian seas (); the latter mainly along two paths: through Mindoro Strait, into the Sulu Sea, with an additional inflow of 1 Sv from the Pacific primarily through Surigao Strait into the Bohol Sea of the Philippines (HYCOM output; the Surigao Strait inflow is estimated from observations at 0.3 Sv), feeding a southward flow in 234 m deep Sibutu Passage into the western Sulawesi Sea and northern Makassar Strait; with the 2nd smaller export through the 45-50 m deep Karimata Strait into the Java Sea, with a HYCOM output, 0.6 Sv.

HYCOM (Fig. 3) shows that the net flow through Luzon Strait is towards the west, into the SCS: larger westward (into SCS) during El Niño, reduced during La Niña. The Sibutu Passage throughflow matches the ENSO dependence of the Luzon Strait throughflow, while the Karimata transport displaying a weak relationship to ENSO, is mostly seasonal. The inflow of the Mindanao Current surface layer into the Sulawesi Sea (Fig. 3), exhibits an ENSO relationship but it is out-of-phase with the Sibutu Passage throughflow; the westward transport of the Mindanao Current surface layer is greater during La Niña. Makassar Strait surface layer throughflow exhibits an ENSO relationship similar to Mindanao Current inflow, albeit at a lower correlation, as the out-of-phase Sibutu throughflow into Sulawesi compensates.

d. Significance of these advances?
We conclude (Fig. 4) that the SCS southward throughflow of low salinity surface layer during prolonged El Niño periods builds a pool of buoyant surface water in the western Sulawesi Sea that inhibits the surface layer contribution from the western tropical Pacific water via the Mindanao Current, into Makassar Strait, the primary pathway for the ITF. The HYCOM results indicate that the Sibutu Passage transport does not fully compensate the reduced Mindanao input (Fig. 3), leading to reduced surface layer contribution to the Makassar throughflow during El Niño. During La Niña, the Sibutu Passage throughflow is near zero or northward, reducing the buoyant pool in the western Sulawesi Sea, permitting greater contribution of western tropical Pacific water into the Makassar throughflow.
Figure 4. Left Panel: The HYCOM results show that the Luzon Strait transport anomaly, which correlated highly with the southward Sibutu Passage transport as part of the SCS throughflow, is out of phase with the Mindanao contribution to the Makassar throughflow. Small or no Luzon Strait throughflow as occurs during El Niño leads to Mindanao equal to Makassar throughflow; large westward throughflow in Luzon Strait as in La Niña, suppresses the Mindanao contribution to the Makassar throughflow. Right Panel: The transfer of buoyant SCS surface water via Karimata Strait inhibits Mindanao injection to ITF in the 0-40 m layer; the SCS surface layer transfer via ~235 m Sibutu Passage allows the full 0-100 buoyant SCS surface layer to enter into the western Sulawesi Sea to inhibit Mindanao injection into the Makassar throughflow, the primary component of the ITF.

In this manner the ENSO sensitive SCS throughflow, by building a 'freshwater plug' in the western Sulawesi Sea during prolonged El Niño periods, results in a deeper, cooler velocity maximum within Makassar Strait; whereas during La Niña the 'freshwater plug' dissipates, leading to an increase, and shallowing into the warmer, upper thermocline layer, of the Makassar Strait throughflow velocity maximum. As the Makassar throughflow amounts to 80-85% of the total ITF, the SCS effect is a major contributor to the overall variability of ITF vertical structure.

Increased, warmer ITF is expected to have an impact on the heat budget of the Indian Ocean, as well as on the residence time of the waters of the tropical Indian Ocean and thermocline and SST patterns. The ITF plume in 2 to 4 years spreads into the central tropical Indian Ocean. The vertical profile of the ITF transport is important in regulating the stratification and surface heat fluxes of the Indian Ocean. A thermocline-intensified ITF, relative to a surface-intensified ITF, cools the surface layer of the Indian Ocean while warming the Indian Ocean below the thermocline. The observed shallowing of the
ITF velocity maximum by way of the SCS throughflow effect, during La Niña, would move the ITF impact on the Indian Ocean closer to that of surface-intensified ITF, warming the eastern tropical Indian Ocean SST and associated links to the monsoon climate, and therefore must be properly represented in ocean and climate models in vertical profile of ITF transport.

e. What, if any, information was jeopardized due to a lack of funding, lack of instrumentation, or inability to carry out the work?

The Makassar time series began with Arlindo in 1996-1998, and continued with INSTANT 2004-2006 and without a gap until recently with funding support from NOAA. The mooring was recovered on 1 August 2011, but was not redeployed because the mooring shipment did not arrive in Makassar in time. A January 2012 deployment was arranged by A.L. Gordon with Niko Resources Limited. Rameyo Adi, Balitbang KP, Indonesia, who oversees the NOAA Makassar time series program, e-mail 26 October 2011: "About the redeployment of the mooring in Makassar Strait, basically I strongly agree with your suggestion and we will contact BP Migas to ask the Oil Company (Niko Resources Co.) to help us on the redeployment BP Migas is the government agency under Pertamina, which manages all the cooperation with oil companies in Indonesia. We will inform you very soon once we have an audience with BP Migas." Unfortunately this did not work out.

A January 2012 deployment would have given us a data gap of 5 months, which is not damaging to the 7.5-year continuous time series. Another opportunity for Niko help in deployment is April 2012 (I believe a long term agreement with the oil industry to service the Makassar moorings would be an effective partnership to reduce the yearly costs of maintaining the time series). Other deployment possibilities from the Indonesian research vessels are being investigated. I view deployment as late as 1 May 2012 as not overly damaging. A larger gap extending into the maximum throughflow period of May-Sept 2012 period would likely end the time series data collection, as the major interannual fluctuations are seen in these boreal summer months.

If the time series resumes before 1 May 2012 then we continue the program, though altering the methods of servicing the mooring. However, should the time series gap extend beyond 1 May 2012, I recommend the following in order to maintain good relationships with the Indonesian marine science agencies and ocean community, so as to keep alive future possibility of collaborative efforts to monitor the ITF variability, and to capitalize on the existing time series:

- Terminate the time series and move into a reduced budget mode to cover a two year ramp-down phase during which the present data are fully processed, made available to the user community, and results published; complete capacity building task currently underway, which is primarily completion of the PhD program for Asmi Marintan Napitu. A third year of Asmi Napitu’s fellowship support may be needed prior to awarding the PhD.
Continue the effort to restart the time series at some time after 1 May 2012. The reorganization described in the following paragraphs offers some hope that we will be successful.

Reorganization details:
Adi message of 27 October 2011: "AMFRD has decided the new research policy and framework as follow:

The Institute of Marine Research and Observation (IMRO) in Bali is under the Centre of Marine Technology Engineering & Assessment (MTEA) management since October 2011;
• IMRO will responsible for all oceanographic & marine dynamic (including sea-air interaction system) research activities, while my center, the Research and Development Centre of Marine & Coastal Resources (CMCR) will focus on marine resources research activities, including the blue carbon and resources management;
• MTEA/IMRO will coordinate the implementation of INAGOOS as well as the collaboration research projects, ITF, JUV and SITE; while CMCR and Capture Fishery Research Centre will continue to make their contribution as member scientists with focus on marine and fisheries resources development. The new contact persons for ITF collaboration research will be Dr. Aryo Hanggono (Director of MTEA), Mr. Berni Subky (Deputy Director), and Dr. Agus Setiawan (Head of IMRO)."
"Following with the policy, AMFRD will send formal letter to LDEO to inform and to clarify about new policy and framework above, while CMCR will be requested to report the on going status, including all output and products for all cooperation works based on the agreement or arrangement respectively. Particularly for ITF project, there will be a new or amended arrangement/agreement required. MTEA/IMRO will arrange to develop the renewal arrangement."

This reorganization has not yet (as of 4 January 2012) occurred, but if it does happen we can negotiate resumption of the Makassar time series with the new oversight directors [with whom there is reason to be optimistic of a successful outcome].

f. For projects involved with data collection, please address the following six questions:
2. Where do your real time data reside? Are the data available online? Not available in real time.
4. Where are your data archived and with what frequency? ~12 months after data retrieval from the field, which is roughly every second year.
5. What is the web site where the data for your program can be accessed?
   http://www.ldeo.columbia.edu/res/div/ocp/ITF/cm_data/
6. Have you successfully retrieved your program’s data from the website or Data Assembly Center where your data reside, just to ensure the accessibility of the data?
   Yes.

**Education & Outreach**
The NOAA funded program includes capacity building. This includes the training of Indonesian researchers in the deployment of the mooring, and in data processing and analysis as well as the attendance of Indonesian researchers at the AGU Ocean Science meeting. In this way the NOAA-OCO funded ITF project is training the next generation of ocean and climate researchers in Indonesia.

The NOAA-OCO project also provides support for Asmi Marintan Napitu from Balitbang KP, presently a graduate student under my supervision at Columbia University. She is now in her 2nd year at Columbia. Asmi's research objective is to use a satellite derived sea surface temperature (SST) data set to investigate the relationship of the spatial/temporal variability of the SST patterns in the Indonesian seas to larger scale climate fluctuations, e.g. ENSO, IOD; and to evaluate the role of Madden-Julian Oscillations in governing the SST patterns and sea-air heat flux within the Indonesian seas. A relationship of SST to the form of the ITF is expected.

**Personnel**
Research Scientists: 2, Research Support Staff: 1, Administrative: 1, Graduate Students: 1.

**Journal articles**

**Conference proceedings / workshops**
Gordon, A.L. (2011) The South China Sea portals are key to understanding the western tropical Pacific surface layer coupling to the ITF. Key Note presentation at the IOC/WestPac meeting in March 2011 in Busan Korea. (not previously reported)
Research Goals

Observations of the properties of deep and bottom waters exiting the Weddell Sea are an essential component of efforts to understand the links among atmosphere, sea-ice, ice shelves and deep water formation processes which contribute to the southern ocean thermohaline circulation and its variability. This project maintains deep and bottom water focused oceanographic 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 Deep and Bottom Water drawn from various sites within the Weddell Sea. Preliminary analyses of the data retrieved from the mooring suite supported by this project through early 2009 reveal significant variability in deep and bottom water characteristics exiting the Weddell, on multi-year time scales as well as annual cycles. Indeed, the annual cycles have been greatly attenuated or are absent in some years. Efforts to elucidate possible changes in bottom water based only on repeat hydrographic measurements may be compromised by both strong annual periodicity and significant interannual variability of the type observed in the moored data set so far. Continuing the time series will be crucial in understanding the nature of the long-period changes already observed in the bottom water, and being able link the observed variability to variations in ocean-ice-atmosphere interactions which determine not just the rates of bottom water formation, but their characteristics as well.

For the performance period 1 July 2011 to 30 June 2012

The Weddell Sea and Orkney Passage moorings were last serviced in March 2011 during cruise JR252 on the BAS vessel RRS James Clark Ross. Mooring M3 was successfully recovered and redeployed. Mooring M2 was not recovered, but a replacement mooring was redeployed at the same location. The three Orkney Passage moorings were recovered and replaced with a new network of 5 moorings with higher spatial resolution across the Orkney Passage.

The next scheduled mooring cruise will take place in roughly March 2013. The work plan for the period 1 July 2011 – 30 June 2012 included:
- Preparation for the mooring cruise, including purchasing of expendable mooring supplies, replacement moored instruments, and shipping of the mooring gear to the UK for transshipment south to the staging port of Stanley, Falkland Islands. Because the cruise is staged out of the vessels’ homeport of Immingham UK, preparation and shipping often must take place nearly 1 year before the cruise date. The mooring configurations are shown schematically in Figure 2.
- Calibration of moored sensors recovered during the March 2011 cruise. Return shipment of moored sensors recovered takes many months following the end of the cruise, pushing the calibration dates into the next FY period.
- Processing of data recovered during the cruise and subsequent distribution of the data on the project web site.
- Upgrading of the existing data set and web products to conform to the recently adopted netCDF-based Climate and Forecast data format.
- Continued analysis of the Orkney Plateau and Orkney Passage time series in collaboration with our BAS colleagues.

**Education Goals**

While this project does not have a specific education component, we continue to strive to engage undergraduate and graduate students in the data analysis activities as the time series data sets mature.

**Research Progress**

**Project Summary**

The world's deep oceans are filled with water masses formed at the continental margins of Antarctica. The Weddell Sea is a major source of these so-called Antarctic Deep and Bottom Waters. Relatively warm, saline Circumpolar Deep Water (CDW) enters the Weddell Gyre to the east of the Greenwich Meridian. As it traverses the gyre, it feeds bottom water-forming processes on the continental shelves, and interacts with floating ice shelves to Weddell Deep and Bottom water types. Because these formation processes include heat exchange with the atmosphere and ice shelves, the properties of the water masses formed carry an imprint of any recent changes in atmospheric and shelf ice characteristics, including temperature, distribution of shelf and sea ice, and shifts in large scale wind stress patterns such as those associated with the Southern Annular Mode (SAM) and ENSO.

This project maintains deep and bottom water focused oceanographic 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 Deep and Bottom Water drawn from various sites within the Weddell Sea. The observation sites were selected to monitor the integrated properties of the outflowing deep and bottom waters after they have traversed the key formation sites in the western Weddell Sea.

The moorings sites are visited approximately every 2 years, with ship time made available under the auspices of an Agreement of Cooperation between Lamont-Doherty Earth Observatory of Columbia University (LDEO) and the British Antarctic Survey.
(BAS). The agreement with BAS provides for sharing of equipment, personnel and data between LDEO and BAS, with BAS providing the ship time to do so. Under this agreement, by sharing material resources with BAS, we have been able to expand the mooring array to encompass the Orkney Passage to the east of the Orkney Plateau, a site of potential escape of Weddell Deep Water into the Southern Ocean. Our collaboration with BAS will continue, so this work is part of an international effort.

Figure 1. Weddell mooring locations, and schematic of deep and bottom water flow from source regions to the mooring array.

Data Collection: Frequency and Availability

Because the ship time required for servicing the moorings is made available on an opportunity basis, the moorings are not serviced at regularly scheduled intervals. We plan for a nominal two-year cycle, but the moorings are designed with a lifetime in excess of three years in the event that ship time is unavailable on the 2-year cycle. Moored instrument data and whatever oceanographic profile data we are able to collect are therefore available on a nominal two-year cycle. The moorings are located in regions that are seasonally covered by sea ice so all data are recorded internally and must be recovered during the service calls. The recovered data are quality controlled, and made available via the web (http://www.ldeo.columbia.edu/res/div/opc/corc-arches/data.shtml) generally within 12-18 months of their recovery from the moorings. Descriptions of the moorings, metadata and processed data are catalogued at OceanSITES (http://www.oceansites.org/).
Figure 2a. Weddell mooring configurations and positions. New temperature and temperature/salinity recorders are purchased in off-field years and phased into the mooring array to allow for return and recalibration of older units.
Figure 2b. Orkney Passage Moorings deployed with LDEO and BAS instruments. RCM current meters are being replaced with acoustic current meters as budget allows.
The users of the data collected since 1999 as part of this project comprise a broad, international pool of researchers and students, which so far have applied the data set to ocean and climate modeling studies, teaching of graduate students, ocean circulation and bottom water research, and assessment of climate model representations of bottom water formation.

**Highlights**

With the recovery of mooring M3 and the 3 Orkney Passage moorings, the Weddell time series has been extended another 2 years. The Orkney Plateau time series is now 11 years long. The Orkney Passage array has been expanded to 5 moorings to provide fuller coverage.

The data are presently available at the project we site http://www.ldeo.columbia.edu/res/div/ocp/corc-arches/data.shtml and by request to bhuber@ldeo.columbia.edu. The data up to 2007 have been deposited with OceanSITES.

**Figure 3.** Time series of potential temperature at the bottom-most sensors on M2 and M3. The data from M3 2009-2011 is from the most recently recovered data set. Mooring M3 was not recoverable in 2009; M2 was not recoverable in 2011 and was not deployed in 2005 owing combined poor weather and failure of a flotation module which caused unscheduled resurfacing of the mooring an hour after deployment.

**Societal Benefits**

Deep and bottom water formation in the Southern Ocean plays a key role in the meridional overturning circulation of the oceans, and hence is a key component of the climate system. Observing and understand the variability in the formation processes over interannual and longer time scales is a crucial component of the climate observation system.
Other Research Connections

Beginning in 2007, this project has benefited from a close collaboration with colleagues at the British Antarctic Survey (BAS). Ship time has been made available under the auspices of an Agreement of Cooperation between Lamont-Doherty Earth Observatory of Columbia University (LDEO) and BAS. The agreement provides for sharing of equipment, personnel, and data between LDEO and BAS to allow the mooring sites to be serviced at nominally two-year intervals, with BAS providing the ship time to do so. Under this agreement, by sharing material resources with BAS, we have been able to expand the mooring array to encompass the Orkney Passage to the east of the Orkney Plateau, a site of potential escape of Weddell Deep Water into the Southern Ocean.

The recently released Southern Ocean Observing System (SOOS) Implementation Strategy (Rintoul, et al., 2012, available at http://www.soos.aq) sets as a high priority sustained moored measurements of key passages in the Southern Ocean. The Western and Northern Weddell sites of deep and bottom water outflow are cited as key locations; the NOAA/ COD Weddell moorings are thus already contributing to the establishment of an international, sustainable Southern Ocean Observing System.

Personnel

Research Scientists: 1, Research Support Staff: 3, Administrative: 1, Graduate Students: 1.
Research Goals
The goal is to employ the boundary-layer gradient method as a plausible and innovative technique. The near bottom flux of a chemical constituent into or out of the sediment or biota on the seafloor is determined from the product of the vertical eddy diffusivity related to drag coefficient estimated from measurements of horizontal velocity at two closely spaced depth just above the seafloor and the concentration gradient of the constituent of interest measured over the same depth interval. We have been able to show that application of this method using oxygen sensors produces net photosynthesis and respiration rates that agree well with those determined by Eulerian and dome methods.

To obtain oxygen fluxes, the Coral Reef Oxygen Sensor System (CROSS) is deployed on the sea floor. It is a lightweight unistructure made of an aluminum frame that stands 1 m high. Two Aanderaa oxygen optodes and a MAVS time of flight 3-D velocimeter are attached. In addition, a Nortek Aquadopp High Resolution profiler is placed on the sea floor to obtain a profile of water velocity every second at 30mm bins for a total of almost 2 meters in height.

Furthermore, the strong utility of the method is that it can be applied to constituents for which no chemical sensor exists but which can be measured from water samples. We have developed water samplers that slowly fill two 1-liter bags from 2 depths simultaneously. The samplers are programmed to collect water every 3 hours, giving us the ability to sample day and night from which we can determine the concentration of total alkalinity (TALK) and from that we can then determine the rate of calcification. The same method can be applied to nutrients as well to determine the uptake or release of ammonium, phosphate, nitrogen dioxide, nitrate and silicon.

The footprint of the measurement is an oval that is approximately 30-50 m2. The boundary-layer gradient flux method has the potential to open up a large spectrum of
chemical constituents for which we will now be able to measure their seafloor fluxes under completely natural, unperturbed conditions.

**Education Goals**
There is a growing recognition within the field of biological oceanography that transport of nutrients and other materials into and out of corals, other sessile animals and benthic algae is mass transport limited and strongly affected by the local flow field surrounding the organism (Atkinson et al. 1992, 1994; Lesser et al. 1994; Baird and Atkinson 1997). This means that we need to move away from methods for measuring metabolism that involve enclosing the organism and altering the hydrodynamic environment to methods that measure flux in the free and ambient environment. Control volume experiments are one approach. This involves measuring the transport of water and material into and out of a water volume in all directions by deploying instruments in all corners of that volume. The method can be powerful, but involves a lot of equipment to measure the full water column for both material and velocity at different corners of the volume. Many different instruments are required, and they must be very accurate and precise in order to get accurate mass balances. This technique also uses the residual of what comes in and out of the vertical control volume surfaces to determine the flux from the top and bottom of the control volume – usually the benthic and air-water interface. The mass-balance technique requires some spatial and temporal averaging in the control volume as well.

**Research Progress**
Boundary layer methods have been used for decades to measure gas exchange over terrestrial surfaces. For example, the DC and GF methods are routinely used to measure the CO2 flux over vegetative fields and forest canopies where the signal to noise ratio for CO2 sensors is high. Infrared gas analyzers (IRGA) are commonly used to measure the CO2 concentration by absorptance (Edson, 2001). The direct covariance method correlates the gas concentration signals with the vertical velocity typically measured using high frequency velocity sensors to provide a direct estimate of the flux:

\[
F_G = \overline{w'G'}
\]

where the overbar represents a time average, and \(w'\) and \(G'\) are the fluctuating components of the vertical velocity and dissolved chemical constituent of interest, respectively. The gradient method assumes that the profile is directly proportional to the flux

\[
F_G = K_M \frac{d\overline{G}}{dz}
\]

where \(z\) is the height above the surface and \(K_M\) is the variable of proportionality known as the eddy diffusivity for mass: \(K_M = u*\kappa z/\phi\). The surface friction velocity \(u*\), von Karman’s constant \(\kappa\), and \(\phi\) is the stability function are all accurately known or measured terms.
As a proof of concept a study was conducted in a shallow, warm-water coral reef environment in La Parguera, Puerto Rico March 2009. ADVs, MAVs, an ADCP, and Aanderaa optode oxygen sensors were deployed on a frame at 0.50 m above the bottom (mean height of the surrounding corals) and at 1.5 m above the bottom. Current speed and oxygen concentration were logged every two minutes over a 48-hr period. At the beginning and end of the deployment the oxygen sensors were positioned side by side to obtain data so that any small offset or biases in the signals could be corrected in the time series. Discrete oxygen samples were collected to provide a check on the accuracy of the oxygen signals. Discrete oxygen samples were also collected upstream and downstream of the location of the boundary layer flux measurements so that oxygen flux could also be determined by the Eulerian upstream-downstream mass balance method (Marsh and Smith, 1978). The data obtained are presented below. Figure 1 shows the oxygen flux computed by the boundary layer flux method as a function of the time of day. The data for the two days are overlapped to emphasize the fact that the data show a very reasonable and repeatable pattern from day to day, i.e. respiration at night and net photosynthesis that increases through the morning and declines during the afternoon.

**Highlights**

The metabolism of Cheeca Rocks Reef, Florida Keys was studied using CROSS during January and May 2012 campaigns. Benthic O2 fluxes were used to calculate net community production using the boundary layer gradient technique. The boundary layer O2 gradient and the drag coefficients were used to calculate productivity ranging from -10 to 15 mmol O2 m-2 h-1. The results of these independent approaches show the current and seasonal rates of metabolism at Cheeca Rocks Reef.

**Societal Benefits**

With the awareness that the surface ocean is becoming more acidic due to the uptake of anthropogenic CO2 and that the resulting decrease in carbonate ion concentration is attributing to a decline in the calcification rate of many organisms, there is a pressing need to develop methods that can easily and reliably measure the calcification rates of these organisms under natural conditions so that any changes that may be occurring can be detected. Two new methods have recently been shown to permit the continuous measurement of in-situ rates of oxygen evolution and consumption of benthic communities. These are the control-volume method (Falter et al. 2008) and the eddy-correlation method (Berg et al. 2003; Berg and Huettel 2008). Both methods show great promise of revolutionizing our understanding of how the photosynthesis and respiration rates of natural benthic communities vary in time and space and what factors control those rates. The lack of a reliable sensor that accurately measures total alkalinity directly or a pair of sensors from which TA can be computed precludes the application of either of these techniques at this time.

**Awards & Honors**

Interagency
NSF and NASA Ocean Acidification research.

Personnel
Research Scientists: 2, Research Support Staff: 1, Undergraduate Students: 6.

Journal articles

Conference proceedings / workshops
AOAT workshop at NOAA May 22, 2012.


Figure 1. Average diurnal net O₂ production from the March 2009 deployment. PAR (dashed-line), CROSS (circles), and SHARQ (squares) are shown for comparison. Vertical bars are the standard deviation. The productivity is light sensitive. Continuous overlap did not exist for CROSS and SHARQ measurements. Over the 8-day period, the diurnal NCP data are in very good agreement.
Figure 2. The Coral Reef Oxygen Sensor System (CROSS) deployed in the reefal system of Cheeca Rocks, Florida Keys. The noninvasive light-weight aluminum frame minimizes flow distortion. The CROSS includes an upward facing MAVS, and 2 optodes at 10 cm and 80 cm. The CROSS contains an internal battery pack for operations and an Autonomous Low Power System that simultaneously measures all instruments on a single purpose processing chip.
Figure 3. Water sampling equipment for Total Alkalinity (TA) to perform BLG flux measurements of calcification and respiration. Each PVC container slowly fills 1-liter bags from two depths simultaneously every 3 hours.
Figure 4. Time series of data from Cheeca Rocks, Florida Keys during May 2012 collected using the boundary layer flux method March 2009. This plot demonstrates the influence of light on coral reef production.

Figure 5. Diurnal trend of Net Community Production (NCP) from Cheeca Rocks, Florida Keys during January and May 2012. Data show periods of net oxygen production (photosynthesis) at midday and net oxygen consumption (respiration) at night. There is significantly more photosynthesis and respiration in May than in January.
Figure 6. Oxygen flux rates from Media Luna Reef, La Parguera, Puerto Rico. Comparison showing good agreement between boundary layer and Eulerian 1D methods.
Research Goals
The primary objective of this proposed investigation is to determine the space-time distribution of the ocean surface \( pCO_2 \) and the sea-air \( pCO_2 \) difference. Combining the sea-air \( pCO_2 \) difference with the \( CO_2 \) gas transfer rate which is being investigated by other scientific groups, a reliable net sea-air flux of \( CO_2 \) over regional to global scales is determined based solely on the observations. The results of the work supported by this grant give us an improved geographical coverage and time trends for the net sea-air \( CO_2 \) transfer flux over the global ocean.

Education Goals
The new observations made for surface ocean \( pCO_2 \) and a multi-year database are quality-controlled and assembled and are submitted to the Carbon Dioxide Information and Analysis Center (CDIAC), Oak Ridge, TN, which is the national and international data center designated for \( CO_2 \) data for the air and oceans. Through CDIAC, students and researchers can freely access the up-to-date, surface ocean \( pCO_2 \) data for their study and analysis.

Research Progress
Version 2011 of the “LDEO Surface Water \( pCO_2 \) Database” has been release to the public via CDIAC <http://cdiac.ornl.gov/oceans/LDEO_Underway_Database/>. This version contains approximately 6.2 million measurements of \( CO_2 \) partial pressure in surface waters over the global oceans during 1957-2011. This version includes about a half million new \( pCO_2 \) data obtained in our field program in the Antarctic and Arctic waters.

Highlights
During the geophysical cruise of the R/V Langseth in September-October 2011 in the Chukchi Plateau area in the Arctic, a 2-dimensional distribution of surface water \( pCO_2 \), SST and salinity was observed. The fresher colder Polar waters have \( pCO_2 \) values, which
are somewhat lower than the atmospheric CO₂, and hence are a weak sink for atmospheric CO₂. On the other hand, the saltier warmer waters of the Pacific origin have considerably lower pCO₂ values due to cooling and biological utilization, and hence are a strong sink for atmospheric CO₂. Figure 1 shows the mean rate of change in surface water pCO₂ observed during the 11-day period between the two sets of orthogonal NW-SE and the NE-SW traverses. The red-yellow (increase in pCO₂) and blue (decrease in pCO₂) banded distribution is obvious. The zones of increased pCO₂ coincide with the colder-fresher Polar waters, and the zones of decreased pCO₂ coincide with the warmer-saltier Pacific waters. Thus, in the Arctic, unlike the subtropical and tropical oceans, the warmer waters have lower pCO₂, and the colder waters have higher pCO₂ and hence are a weaker sink. The sea-air CO₂ flux intensity in the area is governed by the complex distribution of these two water types. These banded distributions of pCO₂, SST and salinity may be a) reflecting sea floor topography, or b) representing the regional circulation (Pacific inflow and Beaufort gyre) is under investigation.

**Figure 1.** Distribution of the mean rate of change in surface water pCO₂ during the 11-day period, September-October, 2011 in the Chukchi Plateau area, Arctic. The red-yellow zones indicate the waters in which pCO₂ increased by the southward flow of the high pCO₂-lower salinity water of the Polar origin, and the blue zones indicate the waters of the Pacific origin with low pCO₂ and higher salinity.

**Societal Benefits**
The accumulation of CO₂ and other greenhouse gases in the atmosphere would cause climate changes, which would impact significantly the global societal structure. The oceans are absorbing about 30% of the anthropogenic CO₂ emitted into the atmosphere, thus partially alleviating the climate change. The rate of CO₂ uptake by the oceans may change in response to the climate change, and is being monitored by the work supported by this grant.

**Other Research Connections**
The pCO₂ measurements are made aboard many US and international ships, which are supported by NOAA (e.g., RV Brown and RV Kaimimoana), NSF (e.g. RVIB Palmer, RV Gould, RV Langseth, RV Atlantic Explorer), USCG (USCGC Healy), Marine Research Institute of Iceland, and many shipping companies (e.g. Explorer of the Seas, Columbus Waikato) and private foundations (MV Turmoil). Without generous collaborations with these government agencies and commercial companies and private foundations, this work would not have been accomplished.
**Education & Outreach**

- Global Ocean Surface Water Partial Pressure of CO₂ Database (Takahashi et al., 2010, 2011) (Open to the public at CDIAC. See the full citations in the “Publications” section.)
- An open web site is established at the following URL for all the participants of the NOAA/VOS program be able to access of the data in a uniform electronic format: [http://www.ldeo.columbia.edu/CO2](http://www.ldeo.columbia.edu/CO2). The site provides not only the numerical data, but also maps showing the ship’s tracks for each data file.
- Served as a member of the scientific advisory committee for the Ocean Carbon Biogeochemistry Program and its subcommittee for the Ocean Acidification Program, which are supported by NSF and other governmental agencies for improved communications among wide range of scientists and broad community.
- Contributed as an author for the international the Regional Carbon Cycle Assessment Project (RECCAP) project.

**Personnel**

Research Scientists: 1, Research Support Staff: 3.

**Journal articles**


**Reports**


Theme III Applications Research

INDIVIDUAL AND COLLABORATIVE PI RESEARCH PROJECTS

CICAR Institutional Extension Award # NA08OAR4320754
2. Zebiak, S., Identifying, Sharing and Showcasing Decision Support Products and Information from the Climate and Societal Interactions Program
3. Zebiak, S., International Internships for Climate and Society

CICAR Shadow Award # NA08OAR4320912
1. Schlosser, P., Abrupt Climate Change in a Warming World: Earth Institute Climate Center

TOTAL THEME III PROJECTS: 4

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1 This listing is for reference only. Detailed report appears in a separate CICAR 2012 Shadow Award Report.
**Research Goals**
Enhance the prospects for economic growth in developing countries through the strategic use of climate information.

**Education Goals**
Produce education materials and outreach activities that improve the ability of water managers to manage hydroclimatic variability.

**Research Progress**
Progress has been made in terms of communicating the results of findings on the economic consequences of hydroclimatic risks and in the production of a published volume based on this research.

**Highlights**
- A deal to publish the manuscript “Managing Hydroclimatic Risk in Water Supply Systems” was finalized with the International Water Association.

**Societal Benefits**
The training material produced as part of this effort will be made available to the public in the form of a book.

**Personnel**
Research Scientists: 1.
Books
Research Goals
To identify, catalog, share and showcase decision-support products and information from the Climate and Societal Interactions Program through climate.gov and a stand-alone CSI database.

Research Progress
Three primary areas of activity in this report period
1. Successfully completed two long-form stories for climate.gov focusing on CSI-funded research. Two other stories are currently in production.
   • Continually updating the Understanding Climate tab with current events, publications, and items of interest to decision makers
   • Rolled out new “Climate & You,” a sector-focused subsection in UC tab featuring reports and decision support tools from CSI-funded projects
2. Propped up a database of CSI-funded projects using Google Sites.
3. Worked closely with David Herring, head of the climate portal, to integrate the CSI program manager’s needs into the portal redesign as well as the new CPO website.
   • This includes how to port the Google Site database to the new CPO site
4. List of successes given to program managers as of last progress report was handed off to Caitlyn Kennedy, CPO science writer, and has basically become the CSI two pager with minor edits

Highlights
1. Continued to be in contact with a number of 78 PIs mentioned in the first project report.
   • Worked with COCA and SARP program managers to develop a survey and methodical approach to gathering more information.
   • In person meeting with PIs and program managers during two site visits to Gainesville and at the Adaptation Futures conference
• Started to help lead bi-monthly RISA PI and PM call with Caitlyn Kennedy, CPO’s science writer, to foster increased RISA engagement with the portal and spread program accomplishments through other avenues such as intra-OAR news
• Following RISA through social media such as Facebook and Twitter to monitor their activity
  o This has resulted in publishing three updates on the Understanding Climate tab on items that would’ve otherwise “slipped through the cracks”

2. Two popular science stories on portal
• Story on farmers in Florida and Alabama represents the portal’s first major attempt at multimedia storytelling
  o Worked closely with a filmmaker and shared experiences with wider portal team as “lessons” for next steps
  o Provided cache of hundreds of photos to Rebecca Lindsey, ClimateWatch editor, for potential future use on ClimateWatch, the portal, or CPO’s site
  o Story is also being used as CPO’s contribution for OAR “In the Spotlight” feature (to be published 6/29)

3. A voice for CSI program managers in portal and website development
• Made sure needs of CSI program managers were addressed in portal redesign

4. Social media expertise
• Conducted semi-formal conversations with Caitlyn Kennedy about the use of social media as she will be running the portal’s social media
  o Provided lessons learned from work on IRI’s social media (Twitter, blog, and Vimeo) and will continue to support the portal’s social media rollout
• Meeting with cross-agency team in July to discuss use of social media in promoting the NCA as it relates to the portal and other mediums

Societal Benefits
Current activities are helping societally relevant research and products developed by CSI funded activities to come into public/interagency view.

Other Research Connections (interagency, partnerships, collaborations)
Taking part in interagency effort (ICE-t) to help promote the NCA

Education & Outreach
NOAA Climate Portal
1. Published two long-form stories on the portal: one on Missouri River flooding in Summer 2011 and the other on SECC engagement with farmers in Florida and Alabama. The latter included two videos produced by filmmaker Kurt Mann and photos from myself.
2. Wrote and found Creative Commons images for 35 updates the Understanding Climate rotator. Of these 17 focused specifically on RISA or RISA-supported research.

3. Worked with a team from different NOAA line offices to pull “Climate and You” from the Data and Service tab to Understanding Climate and update with new information. The section currently includes decision support tools, professional development and training opportunities, and reports and resources for professionals in six sectors.

CSI Database
1. Created a database of nearly 80 CSI-funded projects. Each project has its own page with basic information (title, PI, location, etc.) and a select list of successes and outcomes.
2. Some pages have presentations and publications uploaded, though this is more for demonstration purposes as Google Sites only supports a limited amount of space.
3. Working closely with David Herring to understand how we can port the site to the new CPO site and integrate with information available on the current CPO site to give the public better access to CSI-funded materials.

Social Media for IRI
1. Grew IRI’s Twitter following from 164 followers in April 2011 to 1321 in June 2012.
2. Engaging with social media, expanded IRI’s reach. For example, engaging with partners on social media, IRI’s work on the Sahel will be featured on the Huffington Post in an ongoing suite of coverage on the current drought in the region, reaching a much wider audience than it would’ve through traditional channels.

Miscellaneous
1. Created CSI two-pager, which was co-opted by Caitlyn Kennedy to update all of CSI brochures.
2. Contributed photos from trip to Florida and Alabama to CSI publications.
3. Gave presentation to 80 local high school students on climate change, using CSI-funded work as examples.

Personnel
Research Scientists: 1, Research Support Staff: 2.
Research Goals
The goal of this project was to gather information on the current and potential use of climate information by the International Federation of the Red Cross and Red Crescent Societies.

Education Goals
Students engaged in internships at various Red Cross societies in partial fulfillment of the master’s in Climate & Society.

Research Progress
The internship program contributed to an improvement in the use of climate information for disaster risk management in a number of different countries. Interns also communicated with the IRI regarding how information was being/could potentially be used, which improved mutual understanding of how to improve the use of climate information for disaster risk management.

Highlights
The project led to improvements in the use of climate information in a number of national societies; it also contributed to the development of a Ready-Set-Go framework that both the IRI and the IFRC continue to use to describe and incorporate the use of climate information into disaster risk management.

Societal Benefits
The internship program contributed to the use of climate information, and an improved understanding of the use of climate information, for disaster risk management.

Other Research Connections
Interns also contributed to the development of the third Climate and Society Publication, A Better Climate for Disaster Risk Management.
Personnel

Research Scientists: 7*, Graduate Students: 16 (see listing below).

* Tony Barnston, Walter Baethgen, Mike Bell, Pietro Ceccato, Ale Giannini, Simon Mason, Steve Zebiak

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<tr>
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Publications

Climate & Society Publication: A Better Climate for Disaster Risk Management
Task IV Collaborative Education Programs and Projects

In budget year 2011 - 2012 funds were unavailable to continue the Institute’s commitment to education through support for graduate students and CICAR postdoctoral fellowships.
Table 1. Principal Investigators and Projects July 1, 2011 – June 30, 2012

<table>
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<td>6. McGillis, Wade</td>
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**NA08OAR4320912 Shadow**

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2012 Total projects reported on for all CICAR awards: 35 (includes CICAR Task I funding)

* sub-theme
Table 2. Funding Analysis

CICAR Projects FY 2012 All Awards
Table 3. Personnel Information July 1, 2011 – June 30, 2012

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Table 4. Lead Author: Total Publications July 1, 2003 – June 30, 2012

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Table 4. Lead Author

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Publications 2011 – 2012

Journal articles


Books / articles in books


**Conference proceedings / workshops / reports**

1. **Anderson, R.**, invited talk: Abrupt climate change and CO2: The bipolar seesaw vs. the winds; 12 October 2011, University of Maine, Orono, ME.

2. **Anderson, R.**, invited talk: Abrupt climate change and CO2: The bipolar seesaw vs. the winds; 28 October 2011, University of South Carolina, School of the Earth, Ocean and Environment, Columbia, SC.

3. **Anderson, R.**, invited talk: Abrupt climate change and CO2: The bipolar seesaw vs. the winds; 4 November 2011, Virginia Institute of Marine Science, Gloucester Point, VA.

4. **Anderson, R.**, invited talk: The role of the winds in past climate change and CO2; 29 September 2011, Geophysical Fluid Dynamics Laboratory, Princeton, NJ.


CICAR 2012 Annual Performance Report
From July 1, 2011 to June 30, 2012
PI Yochanan Kushnir

80
Annual Meeting, at the 24th Conference on Climate Variability and Change, New Orleans, LA, 22-26 January 2012.

12. **Cane**, Mark: Climate Variability and Climate Change. Social Science Workshop on Societal Impacts of near Term Climate Stress, Columbia University, Nov16, 2011.

13. **Cane**, Mark: Global precipitation changes shaped by natural and anthropogenic forcing. Fall 2011 AGU.


32. Gordon, A.L. The South China Sea portals are key to understanding the western tropical Pacific surface layer coupling to the ITF. Key Note presentation at the IOC/WestPac meeting in March 2011 in Busan Korea. (not previously reported)


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NOAA lead author
CICAR 2012 Annual Performance Report
From July 1, 2011 to June 30, 2012
PI Yochanan Kushnir

35. **Guleed**, Ali presented his results on dating of a volcanic ash in the Mono Basin at the INQUA meeting in Bern Switzerland in July 2011.


37. **Jacobs**, S. hosted international workshops for the ASEP project (publications above and in progress), and for the ‘IMBIE’ group working on reconciling recent ice sheet mass balance estimates. (MS in prep).


39. **Smerdon**, Jason: Multidecadal Mean-State Variability in the Tropical Pacific and its Connection to Megadroughts in the American Southwest, Climatology, Climate Dynamics and Climate Change Seminar, Department of Geography, University of Giessen, Giessen, Germany, 16 May 2012.

40. **Smerdon**, Jason: Multidecadal Mean-State Variability in the Tropical Pacific and its Connection to Megadroughts in the American Southwest, Joint Colloquium Series, Department of Atmospheric and Environmental Sciences, University of Albany, NY, 30 April 2012.


44. Mariotti³, A., S. Nigam, J. Sheffield, E. Maloney, and J. Kinter, on behalf of the MAPP CMIP5 Task Force Participants, 2012. CMIP5 Task Force Overview. World Climate

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³ NOAA lead author
Research Program Workshop on Coupled Model Intercomparison Project Phase 5 (CMIP5) Model Analysis. 5-9 March 2012, Honolulu, Hawaii, USA.


52. Seager, Richard: Examining the last few decades of hydroclimate variability for evidence of anthropogenic change amidst natural variability. AGU, MIT, April 2012.


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**Ph.D. dissertations**

1. Rahul Sahajpal (CUNY, Queens College) is defending his Ph.D. thesis (Developing geochemical proxies for a high resolution hydroclimate record in Mono Lake basin) on Aug. 2012. His advisor is Gary Hemming and he has also worked closely with Sidney Hemming

2. Sharma, A., 2012, Climate modeling and downscaling for semi-arid regions. Arizona State University. (To complete in August 2012)

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**Total Publications July 1, 2011 – June 30, 2012: 131**
CICAR Extension Institutional Award Progress Report Project Listing

July 1, 2011 – June 30, 2012

AWARD NO. NA08OAR4320754

PROJECT TITLE The Cooperative Institute for Climate Applications and Research (CICAR)

PRINCIPAL INVESTIGATOR Yochanan Kushnir

AFFILIATION Lamont-Doherty Earth Observatory
The Earth Institute, Columbia University in the City of New York

NOAA PROGRAM & DIRECTOR OAR Cooperative Institutes Program
Philip Hoffman 301-734-1090 philip.hoffman@noaa.gov

The CICAR extension institutional award annual progress report for the 12-month period ended June 30, 2012 will be submitted on Grants Online by September 30, 2012. All 10 CICAR projects address the NOAA climate goal to “understand climate variability and change to enhance society’s ability to plan and respond.”

Extension institutional award number NA08OAR4320754

   Amendment # 15
   PI Schlosser
   PM Venkatachala Ramaswamy 609-452-6510 v.ramaswamy@noaa.gov

2. Identifying, Sharing and Showcasing Decision Support Products and Information from the Climate and Societal Interactions Program
   Amendment # 19
   PI Zebiak
   PM Sarah Abdelrahim 301-734-1224 sarah.abdelrahim@noaa.gov

3. PECASE: Improving Economic Development Through Prediction and Management of HydroClimate Variability
   Amendment # 20
   PI Brown
   PM Philip Hoffman 301-734-1090 philip.hoffman@noaa.gov
4. CICAR Administrative Task I  
   Amendment # 21  
   PI Kushnir  
   PM Philip Hoffman 301-734-1090 philip.hoffman@noaa.gov

5. Monitoring the Indonesian Throughflow in Makassar Strait  
   Amendment # 22  
   PI Gordon  
   PM Diane Stanitski 301-427-2465 diane.stanitski@noaa.gov

6. Weddell Sea Moorings  
   Amendment # 23  
   PI Huber  
   PM Diane Stanitski 301-427-2465 diane.stanitski@noaa.gov

   Amendment # 24  
   PI Biasutti  
   PM Daniel Barrie 301-734-1256 daniel.barrie@noaa.gov

8. Underway CO₂ Measurements Aboard the RVIB Palmer and Data Management of the Global VOS  
   Amendment # 25  
   PI Takahashi  
   PM Joel M. Levy 301-427-2462 joel.levy@noaa.gov

9. International Internships for Climate and Society  
   Amendment # 26  
   PI Zebiak  
   PM Daniel Barrie 301-734-1256 daniel.barrie@noaa.gov

10. Boundary Layer Experiments of Coral Reef Calcification and Net O₂ Production  
    Amendment # 27  
    PI McGillis  
    PM Wanninkhof 305-361-4379 rik.wanninkhof@noaa.gov  
    PM Dwight Gledhill 301-734-1288 dwight.gledhill@noaa.gov
The CICAR Shadow Award annual progress report for the 12-month period ended June 30, 2012 will be submitted on Grants Online by July 31, 2012. All 25 CICAR projects address the NOAA climate goal to “understand climate variability and change to enhance society’s ability to plan and respond.”

Shadow Award number NA08OAR4320912

1. Error Models for Remotely-Sensed Sea Surface Heights and Temperatures in Ocean Data Assimilation
   Amendment # 7
   PI Kaplan
   PM Sid Boukabara 301-763-8136 x 195 sid.boukabara@noaa.gov

2. ACCWW: Abrupt Change in the West Antarctic Peninsula in a Warmer World
   Amendment # 11
   PI Martinson
   PM James Todd 301-734-1258 jim.todd@noaa.gov

3. ACCWW: Abrupt Climate Change in a Warming World: Infrastructure
   Amendment # 11
   PI Schlosser
   PM James Todd 301-734-1258 jim.todd@noaa.gov
4. ACCWW: Modeling and Understanding Late Holocene and Near Term Future Hydroclimate Change
   Amendment # 11
   PI Seager
   PM James Todd 301-734-1258 jim.todd@noaa.gov

5. ACCWW: Holocene Variability of the Deep Limb Meridional Overturning Circulation
   Amendment # 11
   PI Anderson
   PM James Todd 301-734-1258 jim.todd@noaa.gov

6. ACCWW: Meridional Hydrology Variability and Synthesis of Ocean Circulation
   Amendment # 11
   PI Broecker
   PM James Todd 301-734-1258 jim.todd@noaa.gov

7. ACCWW: Holocene Variability of Atlantic Surface Properties and West African Aridity
   Amendment # 11
   PI deMenocal
   PM James Todd 301-734-1258 jim.todd@noaa.gov

8. ACCWW Sub-Awardee: Lessons From Holocene Paleo and Modern Instrumental Records, and Model Simulations
   Amendment # 11
   PI Denton
   PM James Todd 301-734-1258 jim.todd@noaa.gov

9. ACCWW: Fluctuations in Ocean Heat and Freshwater Inventory an of Inter-ocean Exchange
   Amendment # 11
   PI Gordon
   PM James Todd 301-734-1258 jim.todd@noaa.gov

10. ACCWW: Radiogenic Isotope Tracer Paleo-Proxy Scope
    Amendment # 11
    PI Hemming
    PM James Todd 301-734-1258 jim.todd@noaa.gov

11. ACCWW: Southern Ocean – Ice Sheet Interactions
    Amendment # 11
    PI Jacobs
    PM James Todd 301-734-1258 jim.todd@noaa.gov

12. ACCWW: 2008 - 2010 Schaefer Mountain Glaciers
    Amendment # 11
    PI Schaefer
    PM James Todd 301-734-1258 jim.todd@noaa.gov
13. ACCWW: Abrupt Climate Change in a Warming World: Synthesis of Tracer Data
   Amendment # 11
   PI Schlosser
   PM James Todd 301-734-1258 jim.todd@noaa.gov

14. ACCWW: Abrupt Climate Change in a Warming World: CFCs
   Amendment # 11
   PI Smethie
   PM James Todd 301-734-1258 jim.todd@noaa.gov

15. ACCWW: Earth Institute Climate Center
   Amendment # 11
   PI Schlosser
   PM James Todd 301-734-1258 jim.todd@noaa.gov

   Amendment # 15
   PI Kushnir
   PM James Todd 301-734-1258 jim.todd@noaa.gov

17. Towards a Better Understanding of the Relationship Between Climate Change and Tropical Cyclone
   Amendment # 19
   PI Camargo
   PM Christopher D. Miller 301-734-1241 christopher.d.miller@noaa.gov

18. The Paleoclimate Reconstructions (PR) Challenge: A Community Program to Benchmark Methods Used to Reconstruct the Climate of the Last 1-2,000 Years
   Amendment # 20
   PI D’Arrigo
   PM Christopher D. Miller 301-734-1241 christopher.d.miller@noaa.gov

19. The Mechanisms and Predictability of Multi-Basin Influences on North American Drought
   Amendment # 22
   PI Seager
   PM James Todd 301-734-1258 jim.todd@noaa.gov

20. Mechanisms and Predictability of the Global Climate Impacts of Atlantic Multidecadal Variability
   Amendment # 23
   PI Ting
   PM James Todd 301-734-1258 jim.todd@noaa.gov
21. Predicting North American Hydroclimate Change and Variability on the Interannual to Multidecadal Timescale
   Amendment # 24
   PI Seager
   PM James Todd 301-734-1258 jim.todd@noaa.gov

22. Diagnosing Decadal-Scale Climate Variability in Current Generation Coupled Models for Informing Near-Term Climate Change Impacts
   Amendment # 25
   PI Goddard
   PM James Todd 301-734-1258 jim.todd@noaa.gov

23. Generation and Evaluation of Long-Term Retrospective Forecasts with NCEP Climate Forecast System: Predictability of ENSO and Drought
   Amendment # 30
   PI Cane
   PM Annarita Mariotti 301-734-1237 annarita.mariotti@noaa.gov

24. The Madden-Julian Oscillation: Model Development and Diagnosis of Mechanisms
   Amendment # 31
   PI Sobel
   PM Daniel Barrie 301-734-1256 daniel.barrie@noaa.gov

25. Recalibrating and Combining Ensemble Predictions
   Amendment # 32
   PI Goddard
   PM Mooney 301-734-1242 kenneth.mooney@noaa.gov
MEMORANDUM FOR: NOAA Office of Oceanic and Atmospheric Research Cooperative Institute Awardees

FROM: Cherri Helms
OAR Cooperative Institutes Program Office

SUBJECT: Performance Reporting

DATE: January 3, 2012

This memorandum provides an explanation of the report content and when to submit the annual performance report for cooperative institute (CI) awards managed by the NOAA Office of Oceanic and Atmospheric Research (OAR). This memorandum covers four categories of awards related to CIs: (1) Main institutional Awards initiated before 2006, (2) Main institutional awards initiated on or after January 1, 2006, (3) Extension institutional awards, and (4) Shadow awards. OAR CIs and the type(s) of their outstanding awards are listed in Table 1 at the end of this memorandum. The schedule for submitting annual reports is based on award category:

1. Main Institutional Awards Initiated before January 2006 – All progress reports will cover the same period and be due according to the schedule established before 2006. The performance period is for one-year period starting on the annual anniversary date of the award. The report is due 90 days after the performance period. Because NOAA’s Grants Online system currently imposes the requirements described for category (2) awards, category (1) awards must initially submit a copy of this memorandum along with a full list of projects that will be described in the performance report that also includes the NOAA Technical Lead when it is submitted within 90 days of the end of the performance period. This list must be submitted as the progress report in Grants Online within 30 days after the award anniversary date and indicate the deadline for submitting the final version of the annual report.

Example: If the main institutional award began on July 1, 2005, then the most recent performance report would cover the period July 1, 2011 – June 30, 2012 and be due by September 30, 2012. The report should include a list of projects that will be described in the performance report and list of all NOAA Technical Lead employees who provided the PI with the funding for each project described in the annual report. This list must be submitted to Grants Online as the main progress report by July 31, 2012 and include text that indicates that the final version of the annual report will be submitted by September 30, 2012. The project list and the final version of the performance report will be re-submitted as the progress report for the one-year period in Grants Online.

2. Main Institutional Awards Initiated on or after January 1, 2006 (this includes previous CIs who successfully competed for a new OAR CI award after January 1, 2006) – The initial progress report covers the first nine-month period and is due 30 days after the initial period. This report is a stand-alone report and should not include other CI projects/awards. Subsequent reports for these awards will cover a twelve-month period and are due 30 days after the end of period.

Example: If the main institutional award begins on October 1, 2011, then the first performance report will cover the period from October 1, 2011 – June 30, 2012 and will be due on July 30, 2012. In addition, this report should only cover projects under the initial performance period. The next performance report will cover the period July 1, 2012 – June 30, 2013 and will be due on July 30, 2013.

3. Extension institutional awards (only applies to initial awards that were created before January 1, 2006) – These awards were created when the NOAA Research Council recommended that CI awards established before January 1, 2006 be extended to allow NOAA additional time to complete competitions under NOAA’s new CI policy (NAO 216-107). The performance period and requirements for submitting a list of
projects that will be reported on are the same as that described in (1). If there is an overlapping period between the main institutional award and the extension institutional award then one master performance report can be attached to both awards, but there should be a clear explanation in the report that the CI is doing this, including a reference to both award numbers, a list of projects under each award and a list of the NOAA Technical Leads (Sponsors) for each project.

(2) Shadow Awards – Shadow awards were created to allow CI projects selected competitively through a NOAA program to be funded for the entire period of the project, even if it extends beyond the end of the main institutional award. Performance reporting requirements are similar to those described for category (1) awards and are associated with the date of the main shadow award and not the period of any individual project, regardless of when the main institutional award began. The annual report for Shadow Award needs to include a progress report for each project and indicate who the NOAA Technical Lead (Sponsor) is.

As a requirement of the cooperative institute cooperative agreement, each institution must submit an annual report that describes all NOAA-funded research activities during the preceding award year that were funded in the proceeding performance period for each CI-associated award. This report is reviewed by the CI Program Manager and the NOAA programs that sponsor the research and becomes part of the official grant file.

When preparing the information in the annual report for the main (or extension) institutional or shadow award(s) described above, please follow the guidelines listed below. The annual reports for Shadow Awards need to include a progress report for each project and do not need to include any tables or additional information described below; however, the institutional award report should include the shadow award statistics in the tabular data since these are being funded through the CI.

(1) NOAA requires all annual reports to be submitted electronically through Grants Online. At their discretion, CIs may send a courtesy copy of the annual report to the OAR CI Program Manager.

(2) A list of all award numbers relating to performance reports found in the report.

(3) The performance reporting period covered in the report.

(4) Include a table of contents.

(3) Annual reports should report on performance for all NOAA-funded projects, including those listed on all amendment documents approved throughout the performance period described in the beginning of this memorandum. These project titles and a description of the annual performance associated with this project should appear in the annual report along with the name of the NOAA Sponsor (NOAA Technical Lead) and NOAA office of the primary technical contact for each project. As described earlier, at least one objective should be clearly stated for each project along with an adequate description of the research that was conducted during the report year.

(4) Federal Program Officers – NOAA Sponsors – can only be listed as Collaborators on the project(s). Federal funding regulations prohibit federal program officers – NOAA Sponsors from writing reports on projects they have provided funding for. The report is to be written and edited by the University lead PI.

(5) For each project, identify the related NOAA Strategic goal(s) as identified in the initial Institutional Award Application. For awards prior to January, 2011, the NOAA Strategic Plan goals are: (Goal 1) Protect, Restore, and Manage the Use of Coastal and Ocean Resources Through Ecosystem-based Management; (Goal 2) Understand Climate Variability and Change to Enhance Society’s Ability to Plan and Respond; (Goal 3) Serve Society’s Needs for Weather and Water Information; (Goal 4) Support the Nation’s Commerce with Information for Safe, Efficient, and Environmentally Sound Transportation; or (Goal 5) Mission Support. For awards issued after January, 2011, the NOAA
Strategic Plan goals are: (Goal 1) Health Oceans; (Goal 2) Weather-Ready Nation; (Goal 3) Climate Adaptation and Mitigation; (Goal 4) Resilient Coastal Communities and Economies; (Goal 5) NOAA Enterprise-wide Capabilities: Science and Technology Enterprise, Engagement Enterprise, Organization and Administration Enterprise.

(6) For all CI awards that are ending a list of projects attached to each ending award should be included.

(7) Since CI general activities are part of the CI proposal, this information should be included in the report. Provide an introductory section that includes:

- a general description of the Institute and its core activities, including all education and outreach activities,
- a list of all the award numbers related to this CI,
- a description of how the CI is managed, including mission and vision statements, and the organizational structure,
- an executive summary of important research activities and results in 1-3 pages,
- a distribution of NOAA funding by Institute task and theme (e.g., pie chart with percentages),
- if the CI-NOAA MOU identified a Council of Fellows and an Executive Board, provide the names of the current Fellows and a list of all meeting dates,
- a general description of Task I activities, including percentage of funding (e.g., pie chart with percentages) used for administration, post-docs/visiting scientists, student support, education and outreach activities, and other research support.

(8) Use appendices to provide:

- Publication Documentation
  - To be reported in the Annual Report
  1. total count of publications for the reporting period and previous periods categorized by NOAA lead author, Institute (or subgrantee) lead author, and other lead author and whether it was peer-reviewed and non peer-reviewed (including presentations);

Example for showing the total number of publications:

<table>
<thead>
<tr>
<th></th>
<th>Institute Lead Author</th>
<th>NOAA Lead Author</th>
<th>Other Lead Author</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peer Reviewed</td>
<td>2010-2011</td>
<td>2010-2011</td>
<td>2010-2011</td>
</tr>
</tbody>
</table>

2. each publication should reference the source that provided the support for the project, i.e. the award number (use the award number last applied to the project), the Grants Online amendment number and Grants Online project title;

3. each publication should reference the publication Journal, including the date published, volume number, page number and citation number;

- To be reported on the Excel Spreadsheet

1. Include only Peer Reviewed publish articles. Breakout each article completed in the active reporting period to show if they are or are not related to Deep Water Horizon (DWH) projects.

Revised on 1/3/2012
2. Do not include the spreadsheet in the report. It should be emailed to the CIPO Program Support Specialist (cherri.helms@noaa.gov).

Example for showing the publication types (see excel spreadsheet):

<table>
<thead>
<tr>
<th>Type</th>
<th>Author(s)</th>
<th>Date</th>
<th>Title</th>
<th>Journal</th>
<th>Page</th>
<th>Code</th>
</tr>
</thead>
</table>

- Employee Support Documentation
  1. the total number of employees by job title and terminal degree that receive at least 50% support from NOAA, postdocs and visiting scientists;
  2. total number of undergraduate and graduate students receiving any level of support;
  3. number of employees (including postdocs and visiting scientists) that received less than 50% annual salary support;
  4. for Institutes that award subcontracts, please obtain only information on the number of supported postdocs and students from your subgrantees.
  5. the number of employees/students that receive 100% of their funding from an OAR laboratory and/or are located within that laboratory;
  6. the number of employees/students that were hired by NOAA within the last year.

Example for showing the total number of employees:

<table>
<thead>
<tr>
<th>Personnel</th>
<th>Category</th>
<th>Number</th>
<th>B.S.</th>
<th>M.S.</th>
<th>Ph.D.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research Scientist</td>
<td>5</td>
<td>0</td>
<td>2</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Visiting Scientist</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Postdoctoral Fellow</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Research Support Staff</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Administrative</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total (≥ 50% support)</td>
<td>34</td>
<td>18</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

Revised on 1/3/2012
Undergraduate Students | 8 |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Graduate Students</td>
<td>6</td>
</tr>
<tr>
<td>Employees that receive &lt; 50% NOAA Funding (not including students)</td>
<td>24</td>
</tr>
<tr>
<td>Located at Lab (include name of lab)</td>
<td>29-AOML, 6-SEFSC</td>
</tr>
<tr>
<td>Obtained NOAA employment within the last year</td>
<td>1</td>
</tr>
</tbody>
</table>

- Other Agency Awards (traditionally Task IV projects) should be listed in table format

Example showing Other Agency awards

<table>
<thead>
<tr>
<th>PI Name</th>
<th>Project Title</th>
<th>Lead NOAA Collaborator</th>
<th>Awarding Agency</th>
<th>Funding Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y. Kogan</td>
<td>Equatorial Oceanography</td>
<td>Mark Kohen</td>
<td>Office of Naval Research</td>
<td>50,000.00</td>
</tr>
</tbody>
</table>

(9) The preliminary project list and final version of the performance report must be submitted by the deadlines described in the beginning of this memorandum. The final version will also be made available on the NOAA CI Web site, [http://www.nrc.noaa.gov/ci](http://www.nrc.noaa.gov/ci).
## Total Number and Type of CI Awards

<table>
<thead>
<tr>
<th>CI</th>
<th>Institutional (before 2006)</th>
<th>Institutional (on or after January 1, 2006)</th>
<th>Institutional Extension (Separate Award No.)</th>
<th>Shadow</th>
</tr>
</thead>
<tbody>
<tr>
<td>CICAR</td>
<td>Expired</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CICOR</td>
<td>Expired</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CICS-Princeton</td>
<td>Expired</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CIFAR</td>
<td>Expired</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CILER</td>
<td>Expired</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CIMAS</td>
<td>Expired</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CIMEC/JIMO</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CIMMS^</td>
<td>Expired</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>CIMRS^</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>CINAR</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CIOERT</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>CIRA</td>
<td>Expired</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>CRES</td>
<td>Expired</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>JIMAR*</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>JISAO</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>NGI^</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

*JIMAR – Report for OAR should only cover NA17RJ1231, NA09OAR4320075 and NA09OAR4320156

^CIMMS, CIMRS and NGI – note the nine month requirement outlined in section (2), this report should only cover your new award.