EXTERNAL REVIEW
OF THE
COOPERATIVE INSTITUTE FOR CLIMATE APPLICATIONS AND RESEARCH
COLUMBIA UNIVERSITY
NEW YORK, NY

SUBMITTED TO THE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
SCIENCE ADVISORY BOARD
ON
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SUMMARY

The External Review Panel of Cooperative Institute for Climate Applications and Research (CICAR) met on October 4 and 5, 2006 at the Lamont-Doherty Earth Observatory (LDEO) of Columbia University in Palisades, New York to review the science research, science management, education, and outreach activities of CICAR over the period 2003-2006. The Review Panel found that two of the three CICAR research themes – earth system modeling and paleoclimatology – are progressing quickly and in interesting directions; that the management of CICAR is in capable hands, though significant financial challenges await the CICAR leadership in the near future; and that CICAR's efforts in education and outreach need greater attention than has heretofore been the case. Based upon these findings, the Panel issued six recommendations for CICAR and two for NOAA. The Review Panel concluded that CICAR is a valuable member of the NOAA CI community and assigned an overall rating of Outstanding.

The membership of the Review Panel is provided in Appendix I. The Agenda (Appendix II) proposed by CICAR and NOAA was acceptable to the Panel and generally followed with a few changes. In addition the Panel was provided with a briefing book detailing the scientific, management and budgetary facts about CICAR prepared by the Director of CICAR, Yochanan Kushnir (Appendix III).

I. Overview of CICAR

CICAR is a cooperative institute (CI) of NOAA. It was the first CI to be established by a competitive award based on a Congressional mandate: "Establishment of a Joint or Cooperative Institute within the National Oceanic and Atmospheric Administration (NOAA) Office of Oceanic and Atmospheric Research (OAR) Joint and Cooperative Institute Program." CICAR was established in November 2003 at the Lamont-Doherty Earth Observatory.

The CICAR goals are stated in the CICAR Annual Performance Report for July 1, 2005 to June 30, 2006:"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."

The task of the Review Panel was to evaluate the extent to which these goals are being successfully pursued. We note that about three years have passed since the designation as a Cooperative Institute and the term of the award was for five years.

II. Science Plan

A. What is the scientific (not programmatic) vision for the institute?

B. *How is it related to the NOAA Strategic Plan?*
C. *What are the goals and objectives?*
D. *What criteria are used to measure progress in accomplishing these goals and objectives?*
E. *What are the major scientific themes?*
    1. *How were they identified?*
    2. *Which themes/sub themes are near completion?*
    3. *What are the emerging thematic areas? Why?*
F. *Scientific partnerships*
    1. *What is your relationship to the OAR Laboratories and other NOAA entities?*
    2. *What, if any, formal procedures do you have for cooperative planning?*

The science plan of CICAR is organized under the following themes:

1. Earth System modeling
2. Modern and paleoclimate observations
3. Climate variability and change applications

The Review Panel strongly endorses these themes because they highlight and play to the strengths of the collaborative partners, GFDL and Lamont. CICAR has the potential to be hugely successful if it fully exploits the synergy between GFDL (replete with Earth System models and modelers) and Lamont/Columbia (rich in paleo observations and knowledge of the instrumental record). CICAR has made an outstanding start in opening up collaborations that are already bearing fruit.

Themes 1 and 2 are moving ahead (see remarks in Science Review section). However, the third theme of CICAR's science plan, "Climate Variability and Change Application Research" is less well articulated, as is openly acknowledged by CICAR's Director. This theme is admittedly the most difficult to develop, particularly in the setting of a world-class geophysical science research observatory. It was clear to the panel that the focus of CICAR research on abrupt and decadal climate, with implications for specifying the dynamics of climate variability, will generate knowledge of definite value for decision makers. An excellent example is the drought work in the western states cited below and its relevance for regional water planning and development over the next two to three decades. Research in this temporal domain represents a big improvement over long-term average climate change predictions in terms of decision value. However, the role of a climate research institute such as CICAR in defining the mechanisms for enhancing society's ability to access, comprehend, and utilize this knowledge are not yet clear. It should be stated here that there was disagreement among the panel members on the degree to which CICAR should be involved in applications at all.

A continuum of applications research may be defined reaching from theoretical work on decision making under uncertainty that draws upon decision theory and the field of psychology on one end of the spectrum to actual product development and direct

interaction with key decision makers at the other end. CICAR is initiating discussion on both ends of this spectrum by interacting with researchers from the broader Columbia campus. The Center for Research on Environmental Decisions (CRED) is involved in work on decision making under uncertainty with a focus on climate variability and change, drawing on the fields of psychology and anthropology. At present no collaborations have been developed between CICAR and CRED but we encourage further exploration of ideas.

Recommendation: CICAR should seek out active research collaborations with CRED investigators in order to develop and advance the Climate Variability and Change Applications Research theme.

Another group under the umbrella of the Earth Institute is the Global Roundtable on Climate Change (GROCC), which facilitates direct interaction between researchers and stakeholders such as private firms, non-profit groups, and government representatives on the topic of climate change through a regularly scheduled round table discussion. Although there is merit to the argument that one does not want to encourage researchers to spend too much time in the field "explaining climate" to stakeholders, there is valuable two-way information flow that occurs when scientists have some direct contact with real-world decision makers. We would encourage CICAR to participate in this sort of activity on a regular basis as a mechanism for refining research objectives.

Recommendation: CICAR should actively participate in GROCC roundtables in order to develop and advance the Climate Variability and Change Applications Research theme.

III. Science Management

A. *How does the Institute identify new intellectual opportunities?*
B. *What are some recent examples of intellectual opportunities?*
C. *What is the strategy for new starts (projects, techniques, campaigns, etc.)?*
D. *How much of the Institute resources are reserved for new opportunities or bright ideas?*
E. *What is the demographic structure of the Institute employees?*
F. *What is provided for human resources development? (Recruitment, Rewards, Training)*
G. *What is the state of the financial health of the Institute? (Provide a budget summary and identify imbalances or needed adjustments.)*
H. *How does the Institute intend to work towards accomplishing its financial goals?*
I. *Are their any issues in interacting with NOAA that require attention?*
J. *Are their any issues in interacting with the University that require attention?*

The overall impression of the panel was that CICAR is being managed well. In particular, there was strong agreement that CICAR's Director, Dr. Kushnir, is highly

capable both as a scientist and as a people manager. Although one of the stated functions of CICAR to "coordinate" NOAA-funded research across the Lamont campus requires relatively small investment in time and effort, all the CICAR affiliated research staff that we had the opportunity to interact with at the review expressed their satisfaction with the process. Many spoke of the benefit of feeling that they were part of a research group as a large benefit. Others emphasized the benefits of having greater interaction with GFDL than might have been possible without the CICAR connection.

CICAR reviews the general content of all proposals submitted from Lamont to NOAA, and if the theme is relevant to CICAR it is submitted under the auspices of CICAR. In the past, successful proposals were subsequently funded as an amendment to the CICAR award. Recently, however, some NOAA program managers have bypassed the CICAR funding route using, instead, the University system. This latter process undermines the role that CICAR plays as a coordinator and integrator of NOAA-relevant research being carried out at Lamont.

Recommendation: NOAA should support Columbia's decisions regarding requests for funding successful proposals through the CICAR cooperative agreement.

Funding: The panel found a few areas of concerns regarding funding streams. We list some concerns observed during our review.

Evidently the post-doctoral program that had been supporting a number of junior researchers in collaborative research with GFDL is currently on hold as funds have been stripped out of GFDL's budget. Since this line is currently the only mechanism to support post-docs, a major linkage with GFDL is now broken. Given the importance of this linkage, as well as the central nature of post-doctoral support in the productivity of CICAR, the fact that the only support comes through GFDL makes CICAR highly vulnerable.

Recommendation: NOAA should address this vulnerability through one of two ways. 1) That a specified amount of funds, possibly enough to support two or three post-doctoral students a year, be awarded to CICAR through the Climate Program Office. These funds could possibly be jointly managed by GFDL and CICAR in the selection of candidates to fill the positions. 2) Increase the CICAR discretionary funds by an amount equal to support for two to three post-doctoral researchers.

A second issue related to funding concerns the program ARCHES, which is the source of roughly half of the research funds associated with CICAR. Because of the fundamental nature of this program an attempt should be made to incorporate as broad a cross section of Lamont scientists as is reasonable. Certain investigators active in this area are not being funded through ARCHES.

Recommendation: CICAR should identify all current LDEO researchers active in ARCHES-related research and encourage them to seek funding through CICAR/ARCHES.

Diversity: It is within NOAA's broad mandate to address the problem of under-representation of ethnic minorities in science research, and CICAR can potentially direct some effort in this direction. Minorities are under-represented at Columbia University and therefore activities in education that are intended to encourage minorities in the fields of science will have to look outside the university for opportunity. The panel was told that CICAR's Director has already made contact with the head of a program in Remote Sensing at City College of the City University of NY (CUNY), a college with a very high minority student body. To date, a plan has not been formulated for a program of interaction.

Recommendation: CICAR should proceed with this contact at City College to develop a program of participation with the Remote Sensing group, and NOAA, through the Climate Program Office, should provide funds specifically for this purpose.

It was noted by the panel that educational activities, be they oriented toward increasing minority participation in science or simply to improve the general public's knowledge of climate variability and change, are "unfunded mandates" expected of the Cooperative Institutes but rarely supported financially.

Interactions between CICAR and IRI (International Research Institute for Climate Applications and Research): The Lamont Campus of Columbia University houses two outstanding NOAA-funded research institutions in the Cooperative Institute for Climate Applications and Research (CICAR) and the International Research Institute for Climate and Society (IRI). These two impressive institutions have different research agendas and unique expertise but they are both ultimately concerned with the role of climate in society. We concluded that both institutes could benefit from greater interaction.

Recommendation: CICAR should expand the simple measures of interaction that have already begun with IRI, such as an occasional seminar series and joint mentoring of graduate students and post-docs, to help foster mutual appreciation and build connections between these significant and socially-relevant research efforts.

Relationship to GFDL programs: If the complementarity of the skills and interests of GFDL and Lamont scientists is exploited to the full, CICAR is likely to be a huge success. To the extent that funds allow, we encourage regular meetings between Lamont and GFDL scientists. It is important to engage in frequent face-to-face meetings discussing common science interests, much as recommended above for CICAR/IRI interactions.

IV. Science Review

A. What are the Institute's most recent scientific highlights and accomplishments? (Note that this is an opportunity for early-mid career scientists to become acquainted to/by upper NOAA management).

A vigorous and innovative scientific research program has been organized under the CICAR program. This integrated and adaptable program is currently focusing on drought dynamics and prediction, exploring the exchange and transport of carbon dioxide, water, salinity, and other major properties of the global oceans, and on the formation of intermediate and deep waters and their role in abrupt climate change. Exciting research results were presented to the Review Panel by the principal investigators, post-doctoral scientists, and graduate students during the two-day site visit. Comprehensive summaries of the interesting research conducted by this cooperative institute can be obtained from the CICAR Annual Report for 2006, available at http://www.ldeo.columbia.edu/cicar/).

The Review Panel is impressed with the CICAR program for paleoclimatic, observational, and model-based analyses of abrupt climate change and climatic variability over the past millennium and into the greenhouse future. The proxy-based paleoclimatic science being orchestrated under the CICAR initiative is an important area of expertise not otherwise available at NOAA or GFDL. Scientists at Lamont-Doherty have also contributed to our understanding of the meridional overturning circulation of the global oceans, an area of considerable activity in NOAA and specifically GFDL. Investigating present and past ocean variability remains a key focus of the NOAA funded ARCHES project under CICAR.

The data set of North American drought indices reconstructed from tree rings is arguably the finest high-resolution paleoclimatic data set yet developed and has permitted a synoptic examination of decadal drought from the Medieval Period to the present. These gridded drought reconstructions helped stimulate a dynamical explanation for decadal drought over North America and elsewhere that has been reproduced in the coupled model experiments also conducted under the auspices of the CICAR cooperative arrangement with GFDL. This CICAR paleodata-climate model inter-comparison is an historic achievement with potential for long-range prediction of seasonal to decadal drought. Due to the precarious current condition of federal funding for paleoclimatology, the NOAA support for paleoclimatic research under CICAR has added significance to the climate science community.

The drought project seemed to us to be marvelous example of CICAR at its best. It offers the prospect of illuminating the proxy record of North American drought going back many hundreds of years through (i) robust theoretical ideas about moist convection and tropical circulation (ii) diagnostic studies of analyzed fields based in the instrumental record (iii) high-end atmospheric models which have the ability to plausibly predict rainfall patterns given an SST distribution (iv) the role of coupled atmosphere-ocean phenomena such as ENSO in setting tropical Pacific SST patterns and (v) IPCC-class coupled models that project out in to the future.

Through ARCHES, and now CICAR, there is continued support for time-series and tracer observations of 'choke points' in the ocean (such as the Indonesian through flow) and of intermediate and bottom water (particularly in the southern ocean), important elements of the meridional overturning circulation of the ocean. It is impossible to understate the importance of such unique observations. However, these observational components are as yet poorly integrated in to the broader themes of CICAR, with its emphasis on collaboration with the modeling efforts at GFDL. There appears to be little synergy here between modern observations, and scientists exploring underlying mechanisms and attempting to encode them into models. It would be of enormous benefit to GFDL to work closely with observers who actually know what is going on in the ocean. At present, ocean PIs within CICAR seem to be working without the benefit of the broader goal and wider collaboration that is facilitated by CICAR. We encourage such collaborative efforts in the future.

Recommendation: CICAR should seek greater integration of the observational aspects of oceanic circulation its research portfolio.

V. Educational Outreach

A. *What types of educational activities/opportunities (K-12, undergraduate and graduate students) does the institute offer on an ongoing basis?*
B. *What are the current and planned outreach efforts?*

Scientists in the CICAR program are active in the educational programs of the University at all levels. The time is uncompensated by CICAR even where the teaching and guidance clearly involve CICAR activities. The effort is considered to be the logical expression of the University enterprise. The extension to pre-college levels is continuing expressions of the commitment of Lamont scientist to such activities such as open house days and occasional internships for high school teachers and others.

VI. Summary and Conclusions

In summary, the overall opinion of the panel was very positive. The panel deems that during the three years since the creation of the institute major progress has been made towards achieving the initial objectives of CICAR.

Dr. Y. Kushnir, the Director, has demonstrated that he is very capable managing the institution. The science conducted by CICAR scientists and funded by NOAA is considered to be world class. The panel was very impressed by the scientific presentations and by the positive discussions that they had with individual PIs. It is the impression of the panel that both GFDL (NOAA) and LDEO (CU) are already profiting from the interaction between the two institutions. This synergy is particularly evident in the value to NOAA research provided by the LDEO paleoclimate records and the analysis performed by CICAR scientists.

Still, there are problems that CICAR must address.

1. The co-existence of two NOAA funded institutions with similar objectives at the Lamont Campus, the IRI and CICAR, was a main point of discussion for the panel. The panel recommends that already existing interactions between the high-level science conducted at CICAR and the applications of the research performed at IRI be enhanced.

2. The panel was sympathetic with the concerns about the reduction in funding that CICAR suffered due to budget cuts at GFDL. The budget cuts resulted in, among others, the cancellation of the joint GFDL-CICAR Post Doctoral program. This is an important component of the collaboration, and it is recommended that NOAA provide funds by any one of a number of means to continue this program.

3. The panel, while recognizing the generic nature of the issue in universities, is concerned with the lack of diversity at CICAR. The panel recommends that the project already started to work with the remote sensing group at City College be pursued with NOAA funds specifically dedicated to the effort.

Appendix I

CICAR Review Panel

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Karl K. Turekian is the Sterling Professor of Geology and Geophysics at Yale University. His undergraduate degree in Chemistry was from Wheaton College (Illinois) and his Ph.D. in Geochemistry was from Columbia University. He joined the Yale faculty in 1956. His major fields of research involve the use of radioactive, radiogenic and light stable isotopes in problems involving the atmosphere, oceans and Earth's surface as well as planetary history. He has served on numerous NRC committees, the most recent of which was the Committee on the Surface Temperature Reconstructions for the Last 2000 Years (released on June 22, 2006). He is a member of the National Academy of Sciences and a Fellow of the American Academy of Arts and Sciences. He holds the Maurice Ewing Medal of the American Geophysical Union, the Goldschmidt Medal of the Geochemical Society and the Wollaston Medal of the Geological Society of London.

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John Marshall is currently a Professor in the Program in Atmospheres, Oceans and Climate at the Massachusetts Institute of Technology (MIT) and Director of MIT's Climate Modeling Initiative. He is also a faculty member of the MIT-Woods Hole Oceanographic Institution Joint Program in Oceanography/Applied Ocean Science and Engineering. His current research interests center on climate and the general circulation of the atmosphere and oceans and the development and application of mathematical and numerical models of key physical and biogeochemical processes, most notably the MITgcm (MIT General Circulation Model) (http://mitgcm.org/). He received his B.Sc. in Physics from Imperial College in 1976 and his Ph.D. in Atmospheric Physics from Imperial College in 1980.

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Jennifer Phillips is currently an Assistant Professor at the Bard Center for Environmental Policy at Bard College. Her research focuses on the use of climate information in agricultural decision making. After many years of working with farmers in East and Southern Africa from her positions as research scientist at the NASA Goddard Institute for Space Studies and the International Research Institute for Climate Prediction at Columbia's Earth Institute, she is now studying adaptation to climate change and risk management related to extreme climate events among farmers in the Hudson Valley. She also leads a team conducting research through Columbia's Center for Research in Environmental Decision making. She holds a B.S. in Geography from Hunter College, and an M.S. and Ph.D. from Cornell University in Soil, Crop and Atmospheric Sciences.

[4] Silvia Garzoli, Ph.D.
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Silvia Garzoli is currently Director of Physical Oceanography Division of NOAA's Atlantic Oceanographic and Meteorological Laboratory in Miami, FL. Her main field of interest is the dynamics of the ocean and its relation to climate. As a sea-going oceanographer, her main field of expertise is in the use of long-term moored instrumentation to study the oceanic circulation and its relation to climate. For a large part of her career, she conducted and directed national and international research programs in several oceanic regions of the world. This includes the tropical Atlantic, the Brazil Malvinas Confluence in the South Western Atlantic, the Indonesian throughflow at the strait of Makassar, the Benguela Current system south of South Africa, and the North Brazil Current north of Brazil. In addition to the analysis of the observations that she has collected during her research expeditions, she has also worked with the products of numerical models to further analyze the data and understand the physics of the processes involved. She is currently involved in different projects directed to monitor and study the Atlantic Meridional Overturning Circulation and the meridional heat transport in the Atlantic.

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David W. Stahle is currently Distinguished Professor and Director of the Tree-Ring Laboratory, Department of Geosciences, University of Arkansas-Fayetteville. He received his B.A. in Anthropology from the University of Arizona (1973), his M.A. in Archaeology from the University of Arkansas (1978), and his Ph.D. from Arizona State University in Geography/Climatology (1990). His research concentrates on the development of long, climate-sensitive tree-ring chronologies from the United States, Mexico, and southern Africa; the reconstruction and analysis of past climate from these exactly dated time series; and the social and environmental impacts of past climatic extremes, especially decadal drought. He also founded the Ancient Cross Timbers Consortium (http://www.uark.edu/xtimber) to unite universities, government agencies, conservation organizations, and individuals around the research, education, and conservation potential of the extensive old-growth woodlands that still survive across the ecotone between the eastern deciduous forest and the grasslands of the southern Great Plains.

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Joseph M. Prospero is currently a Professor in the Division of Marine and Atmospheric Chemistry at the Rosenstiel School of Marine and Atmospheric Sciences, University of Miami. He is also Director of the Cooperative Institute for Marine and Atmospheric Studies (CIMAS) in the Rosenstiel School. CIMAS is a Cooperative Institute with the National Oceanic and Atmospheric Administration (NOAA) and, as such, facilitates cooperative research in the atmospheric and marine sciences between NOAA and the University. His research interests focus on the chemistry of the marine atmosphere with an emphasis on aerosols. Much of his research centers on the long range transport of particles from the continents to the oceans. He holds a Ph.D. in Nuclear and Physical Chemistry from Princeton.

Appendix II

Science Review Agenda
October 4-5, 2006
Lamont-Doherty Earth Observatory

Wednesday, October 4, 2006: Lamont Hall, Building #14

Morning Session

8:15 - 9:00 Review panel executive session

9:00 - 9:15 Welcome: *G. Michael Purdy, Lamont-Doherty Earth Observatory, Director*

9:15 - 9:30 Welcome: *David I. Hirsh, Columbia University, Ex. V. P. for Research*

9:30 - 10:30 CICAR organization overview and science agenda: *Yochanan Kushnir, CICAR Director & Doherty Senior Research Scientist*

10:30 - 11:00 *Break*

11:00 - 11:40 NOAA perspectives:

Climate Program Office: *Chester Koblinsky, Director* (20 min.)

GFDL: *Ants Leetmaa, Director* (20 min.)

11:40 - 12:00 CICAR & the University - education synergies: *Mark Cane, Columbia University, Chairman, Dept. of Earth and Environmental Science*

12:00 - 12:15 Earth Institute welcome: *Steve Cohen, The Earth Institute at Columbia University, Executive Director & Chief Operating Officer*

12:15 - 1:45 *Lunch (hosted)*: All & Review panel executive session *(at the panel's discretion discussions with C. Koblinsky & A. Leetmaa)*

Afternoon Session

1:45 - 3:45 CICAR science highlights

3:45 - 4:00 *Break*

4:00 - 5:00 Reception & poster session: *discussions with research leaders, early career researchers, and students*

Review of the Cooperative Institute for Climate Applications and Research

Science Review Agenda *(continued)*

Thursday, October 5, 2006: Monell, Building #13

Morning Session

Monell Room 205

8:30 - 9:15 Review panel executive session

Monell Lower Lobby

9:15 - 10:15 Lamont-Doherty Earth Observatory Overview: *M. Purdy*

CICAR research synergies: *Intro - Y. Kushnir*

The IRI: *Steve Zebiak, Director General*

CIESIN: *Bob Chen, Interim Director*

The Earth Institute: *Peter Schlosser*

Monell Room 205

10:15 - 11:15 Review panel executive session *(at the panel's discretion with CICAR PI representatives)*

11:15 - 11:30 Break

11:30 - 12:30 Review panel executive session *(at the panel's discretion with M. Purdy & Y. Kushnir)*

12:30 - 2:00 Lunch *(unhosted)*

Afternoon Session

2:00 - 4:00 Review panel executive session

4:00 - 4:15 *Break*

4:15 - 5:00 Debrief: *Review panel & CICAR Director Y. Kushnir*

Appendix III

CICAR Review Briefing Book

NOAA Scientific Advisory Board Review

Cooperative Institute for Climate Applications and Research (CICAR)

October 4-5, 2006

Table of Contents

OVERVIEW

The Cooperative Institute for Climate Applications and Research (CICAR) established in November 2003 is a research partnership between the National Oceanic and Atmospheric Administration and Columbia University In The City of New York. CICAR is administered by Columbia University through its Lamont-Doherty Earth Observatory (LDEO, http://www.ldeo.columbia.edu/) and is located on the Observatory's campus in Palisades, New York. CICAR provides an integrated scientific vision and unified administrative identity to all NOAA funded research and associated activities of the Observatory and in other Columbia University units.

CICAR's primary NOAA research partner is the Geophysical Fluid Dynamics Laboratory (GFDL). Since its inception, CICAR PIs receive most of their NOAA funding from the Climate Program Office (CPO) and from GFDL. CICAR works with CPO and GFDL to develop and maintain research that bears direct relevance to NOAA climate goals and address the objectives of the NOAA Strategic Plan under the Climate Mission Goal.

CICAR research is organized in three themes: (1) Earth System Modeling; (2) Modern and Paleoclimate Observations; and (3) Climate Variability and Change Applications Research. This thematic context emphasizes the distinct scientific and technical capabilities of LDEO and Columbia University, particularly the Earth Institute (http://www.earth.columbia.edu/), which places LDEO at the center of other Columbia University units with expertise in social sciences (such as policy, and economics), biological and medical sciences, and engineering, all under a common goal to address the complex physical and human issues facing the planet and its inhabitants.

To assist the Director in his scientific duties, CICAR maintains an Advisory Committee, with members from the Lamont Senior Staff and other Columbia Earth Institutes units. The Director reports to an Executive Board chaired by the LDEO Director. From the Board the CICAR Director receives guidance and feedback regarding his scientific management of the Institute.

This briefing document provides answers to the questions listed in the NOAA Science Advisory Board guidelines for the periodic review of NOAA Cooperative Institutes.

1. SCIENCE PLAN

a. Scientific Vision

CICAR's scientific vision regarding the study of the Earth climate grew out of five decades of climate research at LDEO and a rich history of interaction with NOAA. Throughout its 54-year history LDEO has been a world leader in advancing the understanding of the Earth System, including physical, dynamical, chemical, and biological components. During these years the Observatory developed an unusually broad research portfolio in basic earth sciences that ranged from seismological study of the earth's deep interior to studies of the oceans, atmosphere, and the climate system. Lamont's core science programs are distinguished by a synergy among a diverse range of observational, experimental, and modeling studies. As part of this diversity, climate

studies at LDEO include a broad array of research efforts in ocean physics, geochemistry, and biology; atmospheric physics, dynamics and chemistry; and terrestrial hydrological and biological processes. The main goal of these activities is to understand how the climate system has behaved from the distant geological past to the present in response to external and internal forcing and to assess how it will respond in the future to the influence of anthropogenic forcing.

LDEO's collaboration with NOAA began almost three decades ago to address a growing mutual interest in climate prediction. During the time that lead to the establishment of CICAR in the summer of 2003, LDEO scientists worked with NOAA to form pioneering, bold programs that set new research directions, helped create a broader and more fundamental understanding of the Earth climate, and lead to the establishment of new operational capabilities in data assimilation, prediction, and the societal application of climate information. CICAR emerged out of the NOAA-LDEO collaboration to broaden the existing partnership and strengthen its formal relationship. Out of our past collaboration, and the growing need within NOAA for science-based climate information, grew the 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."*

To achieve its goal CICAR relies on NOAA funded projects and a close collaboration with our NOAA partners, particularly GFDL and the CPO. This collaboration enables us to focus our research on topics relevant to the NOAA climate mission and to also feed back into the NOAA process of strategic research planning. It is important to note that most CICAR PIs are only partially funded by NOAA and that their CICAR projects often complement or extend research supported by other sources, in directions beneficial to NOAA. Moreover, there are some cases where CICAR projects form the core and motivation for research funded by other sources.

b. Scientific Themes

Research projects (and related education activities) under CICAR address three broad and complementary themes:

<u>Theme I: Earth System Modeling</u>, including:

- Developing and improving climate models and modeling methodologies to simulate and predict climate variability and change.
- Designing climate experiments with numerical models and analysis of data to develop predictive understanding of climate variability and change.

- Assimilating historical data using statistical and dynamical models to create spatially and temporally uniform information for research and applications.

Theme II: Modern and Paleoclimate Observations, including:

- Developing, collecting, analyzing, archiving, and interpreting climate proxy data records to improve knowledge and understanding of past climate variability and change on all time scales.
- Studying the ocean circulation through in-situ and remote observations and through the analysis of tracer data for the purpose of monitoring the state of the ocean, to understand the ocean role in climate, and to verify and improve climate models.
- Observing the exchange of mass, heat, and gases (including greenhouse gases) between ocean and atmosphere to gain quantitative understanding of the ocean's role in energy and mass transfer in the climate system.

Theme III: Climate Variability and Change Applications Research, including:

- Developing applications and tools that facilitate the use of climate research results and climate information for 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 of climate information for the benefit of society.

c. Relation to the NOAA Strategic Plan

CICAR's research is directly aligned with NOAA's mission goal to "*Understand climate variability and change to enhance society's ability to plan and respond*." An examination of the NOAA 5-year strategic plan 2005-2010 (available at: http://nrc.noaa.gov/Docs/NOAA_5-Year_Research_Plan_010605.pdf) reveals that CICAR research projects and synergies address all the "performance objectives" of the "Climate Mission Goal" as detailed below:

- *Describe and understand the state of the climate system through integrated observations, analysis, and data stewardship*: CICAR's portfolio includes the collection of climate observations and the development of new technology to improve the collection of observations and we perform research into data assimilation techniques and prepare homogeneous, uniformly gridded datasets for research and applications.
- Improve climate predictive capability from weeks to decades, with an increased range of applicability for management and policy decisions: CICAR research directly addresses the subject of climate prediction through modeling and analysis. We study climate predictability and develop prediction methods and models. CICAR is currently working in close collaboration with NOAA GFDL on a national plan for developing a program for decadal climate prediction and the assessment of future abrupt climate change.

- Reduce uncertainty in climate projections through timely information on the forcing and feedbacks contributing to changes in the Earth's climate: CICAR is collaborating with NOAA GFDL on analyzing the results of IPCC model integrations looking into the climate of the 21 Century to understand and resolve model discrepancies and to assess the robustness of the projections. Our current work focuses in particular on the changes in the global and regional hydrological cycle and on the interplay between internal and forced climate variations. CICAR research also addresses the measurement and mapping of components of the global carbon cycle, such as the CO_2 exchange between ocean and atmosphere.
- *Understand and predict the consequences of climate variability and change on marine ecosystems*: Currently CICAR has no funded projects in this area. However, the LDEO Biology and Paleo Environments Division conducts research into these areas and can potentially participate in NOAA funded research.
- *Increase number and use of climate products and services to enhance public and private sector decision-making*: CICAR currently provides climate information for decision making in the form of climate datasets and climate forecasts. Through its synergies with other Columbia University institutions and programs CICAR has the potential to provide NOAA directly with added-value products such as vector mapping of climate data jointly with geographical and social data and the understanding of climate decision-making on the individual and institutional level.

d. Goals and Objectives

In the context of its Mission Statement, and as an outcome of a continuing dialog with our NOAA partners, particularly the OCP and GFDL, we have come to identify a single, focused activity that would combine an efficient use of our capabilities towards a pressing national priority. We thus are determined to actively contribute to the development of a national capability of prediction/projection of climate evolution from the present into the middle of the 21 Century, with particular emphasis on the assessment of the likelihood of abrupt climate change and the evaluation of the associated impact on society. This is one of the objectives listed in the NOAA 5-year Strategic Plan under the Climate Mission Goal.

This goal integrates activities in the current research portfolio under the three CICAR themes: modeling, observations, and applications and adds a unified future vision. We intend to pursue this goal in the remaining years of the present agreement and into the next one. This overarching goal encompasses the following specific objectives:

- Advance understanding of abrupt climate change events in the geological past by improving the description of their spatial and temporal attributes. Develop conceptual models of these events, their processes and feedbacks, and test them with dynamical/numerical models.
- Assess the likelihood for abrupt climate change under anthropogenic forcing due to such processes as changes in tropical SST gradients, the slowdown of the ocean

overturning circulation, the melting of sea ice in the polar regions, and the regional interference between natural and forced climate variability.

- Develop predictive understanding in the following areas:
    - Global and regional hydro-climate variability – droughts and floods. Particular emphasis on changes in flooding potential and drought intensity and persistence in North America but also in changes in the African and Asian monsoons.
    - Changes in tropical and extratropical storms and in the spatial and temporal distribution of heat waves.
    - Processes that govern the rate of sea level rise, including the melting of glaciers in Greenland and Antarctica.
- Contribute to the monitoring and data collection of the ocean circulation in key areas to study key climate processes, such as inter-ocean exchange and intermediate- and deep-water formation, to enable early detection of significant changes in these processes, and to enable the testing and improvement of climate models.
- Contribute to the monitoring of ocean air-sea exchange of heat and CO_2 to provide data on the variability of climate forcing agents.
- Develop methodologies for making objective model-based assessments on future climate evolutions on times scales from seasons to decades.
- Develop applications based on model projections that can be used for making decisions in various areas of societal importance.

e. Measuring Progress in Meeting Goals and Objectives

There are several ways in which the CICAR Director can review and measure progress towards its goals and objectives.

- CICAR maintains an internal Advisory Committee, which is chaired by the CICAR Director (see Section 4a below). The Committee meets several times a year on a routine basis and also by special need to assist the Director in addressing organizational issues, setting long-range and interim research and education goals, and reviewing progress towards these goals. For information on the structure and membership of the Advisory Committee see: *http://www.ldeo.columbia.edu/cicar/org/*
- The CICAR Director reports twice a year to an external Executive Board, chaired by the LDEO Director and whose membership includes representatives from the University and from NOAA (see section 4a below). The Director's report includes a progress report and a response to action items requested in preceding Board meetings. The Board members discuss and comment on the report and recommend future action. The CICAR Advisory Committee members are invited to observe the Board's discussion.
- The CICAR director convenes a meeting of the entire group of CICAR PIs once a year, to report on the state of the Institute and set goals for the current year. The progress of the Institute is discussed.

- The preparation of the annual report to NOAA (due during a period of 90 days following the end of the CI budget year – on June 30) is another mechanism available to the Director for monitoring Institute progress. It includes a detailed report from all the CICAR PIs on their individual project and a report on the CICAR Office education and outreach activities. The CICAR Administrator edits the individual reports and adds summary tables and graphs to provide an overall view on the annual progress. The Director reviews the report and prepares an executive summary and an outlook for the subsequent year.
- The CICAR Director also meets several times a year with the Lamont Director (and Chair of the CICAR executive Board) to address various research and administration issues and to review progress towards the Institute's goals.

f. Scientific Partnerships

CICAR's primary NOAA partners are the Climate Program Office (CPO) in Silver Spring, MD and the Geophysical Fluid Dynamics Laboratory (GFDL) in Princeton, NJ. The CPO leads the NOAA's participation in the interagency U.S. Climate Change Science Program (CCSP) 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. Additional collaboration with NOAA extends to other offices and laboratories such as the Office of Climate Observations (OCO), the National Climatic Data Center (NCDC), the Earth System Research Laboratory (ESRL), the Atlantic Oceanographic and Meteorological Laboratory (AOML), and the Pacific Marine Environmental Laboratory (PMEL).

In its 2003 proposal CICAR outlined a plan to stimulate collaboration between GFDL and LDEO/Columbia, based on organizing seminars or workshops on mutually interesting topics, co-mentoring of graduate students and postdoctoral research scientists, and importantly, a continuous dialog, between the Directors of CICAR and GFDL.

During the three years of CICAR operation we have followed our proposal. Meetings and discussion between the two Directors started immediately after CICAR was established. The LDEO Director took part in several of these meetings. The dialog between GFDL and CICAR has often included senior research scientists on both ends and lead to the development of a common future vision, along the lines presented above in Section 1d above (*Goals and Objectives*).

The highlight of the close interaction between CICAR and GFDL is the establishment of a GFDL-CICAR collaborative project, funded by GFDL, to study and eventually simulate the climate of the last millennium with the GFDL coupled climate model. The unique aspect of this project is that most of its funding goes toward supporting graduate students and postdoctoral scientists working under joint GFDL-LDEO mentorship. The project was launched in CICAR year two, after a joint GFDL-LDEO workshop that discussed and agreed on the project goals. The project has been successful in establishing several collaborations between individual researches and yielded important scientific results that are now making their way to press. Funding for this collaboration was

curtailed due to cuts to the GFDL budget last year. However, work on the project continues in hope that funding will be renewed in the future.

Other relationships with NOAA mentioned above are maintained centrally (by the CICAR Office) or by individual PIs involved in collaborating with NOAA partners. The GFDL Director and one GFDL senior scientist sit on the CICAR Executive Board that oversees the development of the research vision of the Institute and its operations. Also on this Board is the Director of the CPO, the Director of the National Center for Environmental Prediction (NCEP) – Climate Prediction Center (CPC) and a senior representative from the NOAA. Thus a broad range of NOAA views have input into the CICAR research vision and the actual planning of research activities. This interaction also brings CICAR into the view of a broad NOAA community.

The CICAR mission also benefits from synergies with other centers and units of the Earth Institute and Columbia University. Most prominent are our collaborations and interactions with the International Research Institute for Climate and Society (IRI, http://iri.ldeo.columbia.edu/), the Center for International Earth Science Information Network (CIESIN, http://www.ciesin.columbia.edu/), the Center for Climate for Research on Environmental Decisions (CRED, http://www.cred.columbia.edu/) and the Earth Institute Center for Hazard and Risk Assessment (CHRR, http://www.ldeo.columbia.edu/chrr/). These centers conduct research that may be funded by other government agencies, yet it is highly relevant to the CICAR mission. It is the responsibility of the CICAR Director working together with the CICAR Advisory Committee, to facilitate the collaboration and interaction with these centers to facilitate the CICAR mission and to extend the resources available to NOAA. Interaction with the companion Columbia Institutes and Centers listed above is facilitated through the collaboration of individual PIs as well as through the participation of representatives from CICAR on their committees and boards and vice versa. It is our goal to expand and strengthen the interaction and with our partners at Columbia formally and through actual collaborative research.

2. SCIENCE REVIEW: HIGHLIGHTS AND ACCOMPLISHMENTS

AbRupt climate CHangE Studies (ARCHES): This is a group of projects funded by NOAA CPO with the goal to "describe, understand and assess the likelihood of (future) abrupt changes in the climate system, and to identify the mechanisms involved" (see http://www.ldeo.columbia.edu/res/div/ocp/CORC-ARCHES/). The unique aspect of this effort, which began in 1998 and preceded CICAR, is that it combines paleoclimate research based on the collection and analysis of climate proxies, modern ocean observations, and numerical climate modeling – all addressing the goal stated above with different tools while maintaining dialog. Since its inception ARCHES funded research by different groups of investigators across LDEO and in other research institutions. It also sponsored lectures and workshops on a wide variety of related topics that reached into the larger climate research community and created a forum for discussion and debate on the challenging science of abrupt change. A steering group of scientist, several of whom have performed research under ARCHES, routinely advised NOAA on the subject of abrupt

change. This effort is now entering its synthesis stage and is slated to produce a comprehensive review of past research by the end of this calendar year. Among the recent ARCHES achievements are:

- Atlantic Ocean Freshening. Documentation of a systematic freshening through the western basins of the Atlantic Ocean between the 1950s and the 1990s. In essence, the overflow system that ventilates the deep Atlantic Ocean has freshened over a 40-year time span. The results extend a growing body of evidence indicating that shifts in the oceanic distribution of fresh and saline waters are occurring worldwide in ways that suggest links to global warming and possible changes in the hydrologic cycle of the Earth.
- Change in Southern Ocean Bottom Water. Implemented an ocean time series station in the North Western Weddell Sea to document climate variability and change in one of the sources for Southern Ocean Bottom water.
- Warming in Weddell Sea. Documented a steady increase in subsurface temperatures in the Weddell Sea over the last 20 years.
- The Gulf Stream and North Atlantic Climate. Assessed the relative importance of seasonal storage and release of heat by the ocean, movement of heat by ocean currents, and movement of heat by the atmosphere for determining the climates around the North Atlantic Ocean. Emphasized the role of atmospheric flow, rather than ocean currents, in making Europe's winter warm and Eastern North America cold. This allows a more sure assessment of the climate impacts of a possible future slowdown of the thermohaline circulation.
- Changing ENSO. Changes in ENSO over the last century and a half have occurred abruptly and caused global climate impacts. By many measures the 1976/77 transition was an abrupt climate change that had serious consequences for climate around the world. We have demonstrated that these decadal changes in ENSO state are predictable, to a useful degree, years in advance. We predict that the 1997/98 El Nino ended the post 1976 warm state of the tropical Pacific ushering in a cold state that will last a decade or more from now.
- Droughts. We have related decadal changes of ENSO to droughts and wet conditions over North America. Significant droughts in the Great Plains in the 1930s (the Dust Bowl) and mid Nineteenth Century, and in the Southwest in the 1950s, have been related by modeling to persistent La Nina conditions. Similarly the rapid onset of drought in the West since 1998 is related to the end of the post 1976 warm state of the tropical Pacific and can be expected to last.
- Global Teleconnections. Determined that snow-line lowerings during the Last Glacial Maximum, the Younger Dryas, and the Little Ice Age are in phase in the mid-latitudes of the northern and southern hemispheres, indicating that abrupt climate change can occur globally, not just regionally.
- Weakening SST Gradients. Determined that meridional and zonal gradients of sea surface temperature in the equatorial Pacific Ocean were much less than today during the LGM, implying that either thermal structure of the upper ocean or wind-driven upwelling was substantially different from modern conditions
- Paleo Evidence for Subantarctic Connection. Found substantial increase in biological productivity within the Subantarctic zone of the Southern Ocean

associated with Heinrich events, the first clear manifestation of these events at high southern latitudes, likely related to reorganization of meridional overturning ocean circulation.

Understanding Climate Change from the Medieval Warm Period to the Greenhouse Future: With the establishment of CICAR efforts were made to create a genuine collaboration between Columbia and GFDL. In discussion with the GFDL Director it was decided to build this collaboration by supporting research by early career investigators: mainly graduate students and post-doctoral researchers, working under joint mentorship of senior investigators from Lamont and GFDL. The goal was to focus it on work that involves the study of GFDL model simulations. Funding for this project was provided by GFDL. It included a number of studies with a common goal to study climate variability during the recent past, as far as high resolution proxy data and observations, and to assemble the best available information on the forcing (solar and volcano) to allow a coupled mode simulation of the last 1000 years. Due to budget constraints, the project continued only for two years but the work during that time was convincingly productive in both scientific output and institutional collaboration. The major highlights of this work are as listed below:

- Studied mechanisms governing North American droughts to elucidate the pivotal role played by decadal SST anomalies in the tropical Pacific. The study included a comparative study between the characteristics of the simulations conducted with the NCAR CCM3 model (LDEO integrations) and the GFDL coupled and uncoupled model, which highlighted the robustness of the tropical Pacific link.
- Examined the role of SST anomalies in different tropical ocean basins to demonstrate the secondary contributions from the Indian and tropical Atlantic Oceans.
- Applied an objective algorithm to search the history of stratospheric "sudden warmings" in GFDL model simulations.
- Traced subtropical water vapor in a GFDL model shown that the generation of dry subtropical air is due mainly to isentropic transport by extratropical eddies and to a lesser extent to the Hadley circulation
- Examined Sahel rainfall in historical and future simulations with the GFDL model and attributed part of the observed drying to anthropogenic forcing.
- Examined model simulations (NCAR and GFDL) of sea ice and its variations to better constrain the future risk of drastic and rapid sea ice reductions in the Arctic in the near future.

Other Projects: Most of the remaining CICAR research is supported under competitive grants from the CPO. These are individual PI projects addressing a broad range of observational and modeling studies.

- Observational studies in this category examined the feasibility of using surface ocean salinity for obtaining information on the temporal variability of precipitation over the ocean.

- New instruments to measure surface CO2 and heat exchange are being developed and tested via collaboration between CICAR and investigators from NOAA and NASA and the collection and mapping of global ocean CO2 exchange over the ocean – crucial information for understanding and monitoring the global carbon cycle – continues.
- CICAR scientists continued their modeling and analysis research to improve the prediction of seasonal-to-interannual climate variability by developing new methods for assimilating data into the Lamont Intermediate Coupled Model to initialize prediction and assessing the influence of data errors on forecast performance and improving intermediate model performance.
- Using GCM and regional model experiments demonstrated that topography is important for the simulation of the low-level jet and summertime rainfall over the North American Great Plains
- Regional climate variability and predictability over the Americas and the Atlantic was also addressed in several independent investigations, which together contribute to the overall goal of building an improved capability of global climate prediction for the 21st century.

More information on these projects can be gleaned by examining our 2005 and 2006 Annual Reports.

3. EDUCATION AND OUTREACH

a. Educational Activities and Opportunities

CICAR education activities are intertwined with the research. Many of the CICAR PIs mentor graduate and undergraduate students, summer interns, and employ or collaborate with postdoctoral research scientists. All these activities are addressed in more detail in our annual technical reports.

CICAR research outcomes feed into and benefit from links to the formal education process at the Department of Earth and Environmental Sciences (DEES), the Department of Earth and Environmental Engineering, and the School of International and Public Affairs. These links are manifested by the design and scope of many programs and courses that bring climate education to a wide spectrum of disciplinary and inter-disciplinary students. CICAR PIs directly participate in the education process. Students on all levels also benefit from participation in CICAR sponsored research even if they do not directly benefit from NOAA funding.

In the last three years we also received NOAA funding specifically for the purpose of promoting education on relevant topics. NOAA directly funded scholarships to selected students in the Columbia Masters program in “Climate and Society”, administered under the Department of Earth and Environmental Sciences. This is a 12-month program that trains professionals and academics to understand and cope with the impact of climate variability and change on society worldwide.

NOAA also provided partial support for the 2005 International SOLAS (Surface Ocean Lower Atmosphere Study) Summer School. The School included advanced

theoretical lectures as well as practical workshops to introduce students to the SOLAS system and the physics of air-sea exchange. In this year's sessions 28 Students from the US joined 40 students from 19 other countries.

Funding from GFDL was used during the last two budget cycles to enable the LDEO-GFDL collaborative project of "Understanding Climate Change from the Medieval Warm Period to the Greenhouse Future" that emphasized funding to support research by junior investigators in graduate and postdoctoral research.

b.Outreach Efforts

The proposed CICAR administrative budget laid out a modest amount of funding for education and outreach activities. This included funds for web site development and maintenance and for partial support of undergraduate internships in CICAR science. The CICAR website (http://www.ldeo.columbia.edu/cicar) features information about CICAR objectives, themes, and administrative structure. It also displays research highlights, outcomes of CICAR workshops and symposia, and special educational aids directed at the young K-12 audience that were developed as part of our outreach effort. In addition we established a tradition of maintaining a "CICAR Tent" in the Lamont Open House – an annual fall time event open to the local and regional community and visited by youngsters and adults, families and school groups. Here we provide a forefront to all of NOAA supported research on campus as well as a showcase to other NOAA activities, such as weather prediction and ocean explorations.

CICAR supports one summer college student each year in research consistent with CICAR themes. The student is chosen out of the pool of applicants to the highly popular LDEO Summer Intern Program for Undergraduates (http://www.ldeo.columbia.edu/edu/progs/intern.html), which is supported mainly by NSF. The CICAR Intern is chosen out of the normal applicant pool to this program but for projects that focus on Climate and Society and Climate Education. The integration of a CICAR intern in this program allows us to expose the interest in NOAA science at LDEO to a community of students from different academic institutions in the US. In addition, we were fortunate to host a 2006 Hollings Scholar (http://www.orau.gov/noaa/HollingsScholarship/) who worked with CICAR scientists on a project of historical climate reconstructions.

Last year we established initial contact with the NOAA Cooperative Remote Sensing Science and Technology Center (CREST) at the City University of New York. We sketched initial plans for collaboration on joint education ventures. These contacts can bring CICAR research (generally on aspect different than the CREST research) to a more diverse community. We plan to continue these contacts in this budget year and formalize a procedure for the visitor exchange and the mutual exchange of interns.

4. SCIENCE MANAGEMENT PLAN

a. General Information of CICAR Science Management

CICAR science management plan starts with its governance structure and the general approach to organizing its various research projects (sub-award) by Task and Theme. This structure is common to most (if not all) NOAA Cooperative Institutes as directed by NOAA. CICAR governance builds on a core administrative unite (hereafter the CICAR Office) and two panels of experts oversee the Institute science program: the CICAR Executive Board and the CICAR Advisory Board. A short description of each of these functions is provided below:

CICAR Tasks and Themes: To manage administrative and research budgets, CICAR's activities are divided by Tasks based on their administrative context. Within each Task projects are classified by Theme. CICAR Themes are described above in Section 1b. CICAR Tasks are:

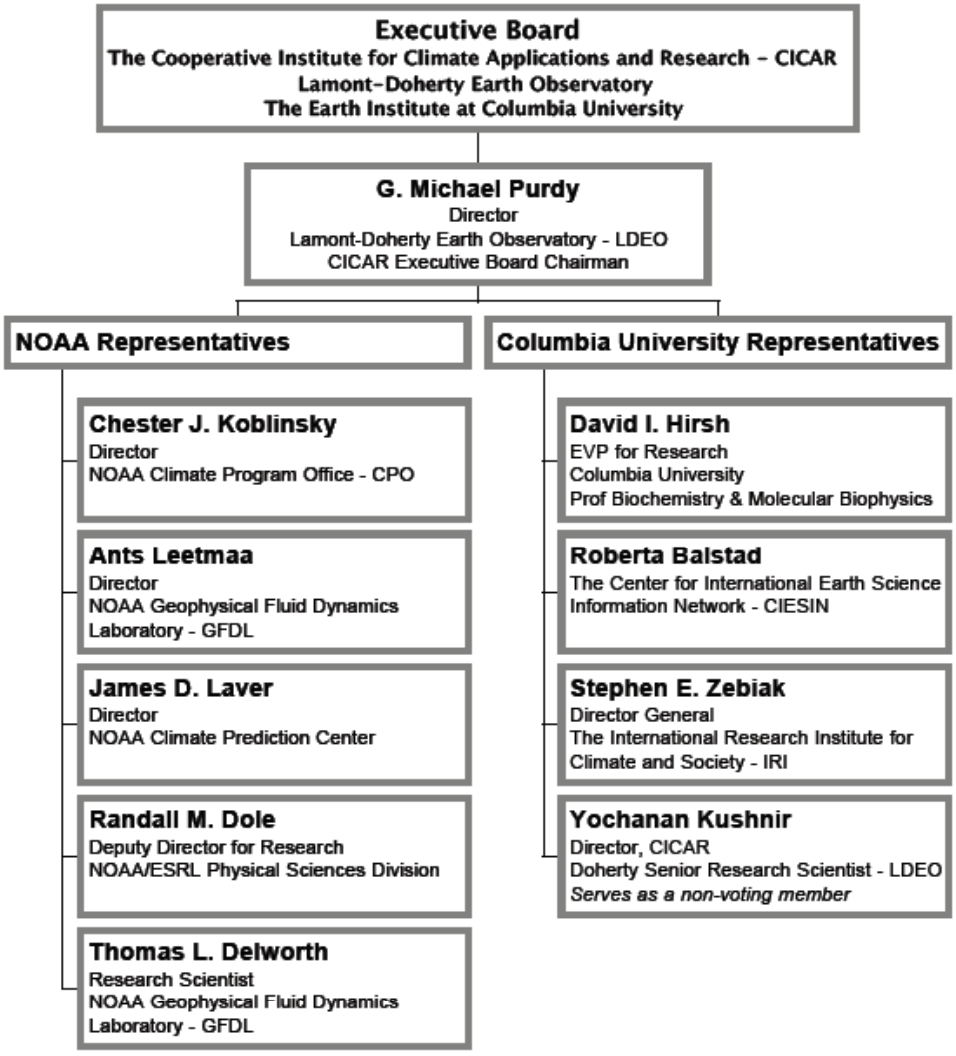
- *Task I: Administrative activities*: this Task facilitates the operation of the CICAR Office (see below) and other administrative activities related to managing the CICAR grant and its sub-awards. The funding of Task I is shared equally between NOAA and Columbia University through the cost sharing arrangement built into the CICAR Cooperative Agreement.
- *Task II: Specialized science support activities*: this Task was defined in the 2003 CICAR Proposal to provide for specialized support scientists that are employed by Columbia University, Lamont-Doherty Earth Observatory but are located at the Geophysical Fluid Dynamics Laboratory (GFDL). These CICAR employees could be hired to enhance the technical and scientific expertise at GFDL required to execute collaborative CICAR projects or to address specific needs that require expertise not available at GFDL. In the present 5-year agreement we provided for five such support scientist positions. To date, these need have not arisen and this Task is not active.
- *Task III: CICAR projects (sub-awards)*: This task encompasses the bulk of individual and collaborative PI research at Columbia University (LDEO and other Earth Institute Units), that is supported by grants from NOAA and complies with CICAR's themes and mission. It is comprised of currently funded research projects as well as new ones that strengthen the CICAR research agenda in line with the themes. Task III represents the main thrust of the CICAR research agenda for the next two years.
- *Task IV: Collaborative education program*: This Task features collaborative, educational activities primarily in support of undergraduate and postdoctoral research. It was intended to fund a select group of CICAR junior scientists in projects that emphasize collaboration with NOAA, particularly GFDL.

The CICAR Office: Is the point administrative unit of the Institute, which houses the CICAR Director and the CICAR Program Administrator. The Office oversees the scientific, educational, administrative, and outreach activities of the Institute and

maintains ties to other synergetic activities within the University. The Director oversees the sound scientific and administrative operation of the Institute. In particular he provides the scientific leadership for the Institute and nurtures a productive communication and collaboration between Columbia and NOAA. The Program Administrator assists the director in carrying out the short and long-term operations of the institute, such as maintaining communication with LDEO Administration, and the day-to-day communication with the NOAA Cooperative Institute Program Office. Additionally, the Program Administrator assists the director in managing the preparation and distribution of the Institute technical reports, the CICAR web site, and other outreach efforts.

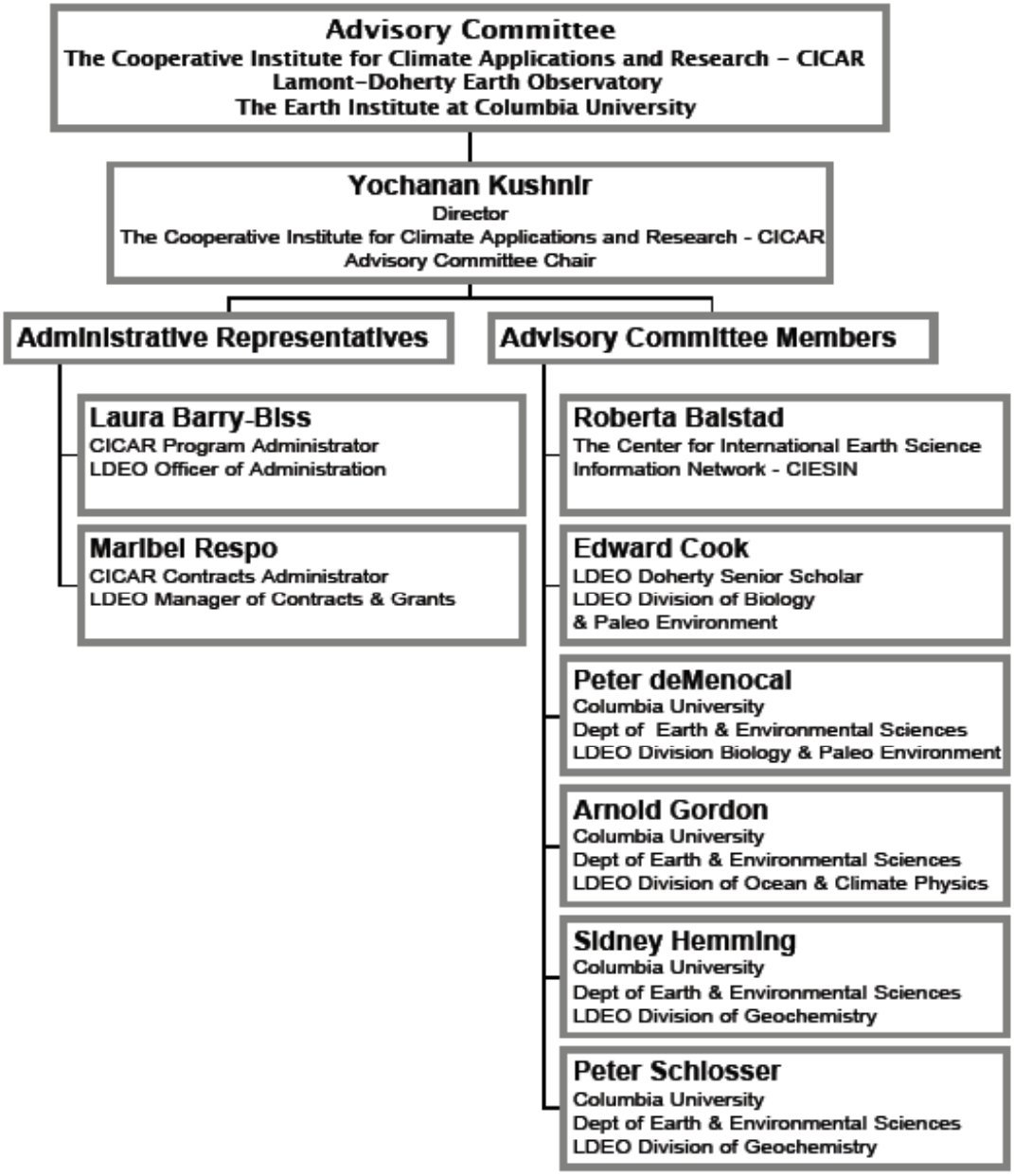
The CICAR Executive Board: The CICAR Director reports twice a year to an Executive Board chaired by the LDEO Director. The Board is charged with reviewing the Institute activity, in particularly in areas of science and education and recommends ways to invigorate the Institute commitment to new and existing scientific program areas. The Board counsels the CICAR Director on matters of policy, budget, and ways to improve coordination of research programs with other institutions or agencies. The organizational chart of the Board is attached below. It lists the names of the current Board members and their titles.

CICAR Executive Board Organizational Chart



The CICAR Advisory Committee: The CICAR Advisory Committee includes senior personnel who represent different LDEO and Columbia University research units and LDEO administration. Board members are usually but not necessarily involved in CICAR research. The committee is chaired by the Director and convenes at least twice a year and additionally at the discretion of the CICAR Director. Its goal is to address subjects of scientific leadership, research coordination, strategic planning, and priority setting. The group's collective knowledge is a valuable resource for the Director in his decision-making responsibilities. An organizational chart listing the current members of the Committee and their titles is attached below:

CICAR Advisory Advisory Committee Organizational Chart



b. How Does the Institute Identify Intellectual Opportunities

CICAR is making use of several mechanisms to identify intellectual opportunities. The first is built into the CICAR governance structure described above in Section 4a. That structure facilitates interaction with and within the Advisory Board and the Executive Board that is important in identifying and promoting intellectual opportunities. The governance structure, particularly the CICAR Office and the Advisory Board, also facilitate smooth interaction with the CICAR PIs. In addition we maintain frequent

communication with our NOAA partners to compare priorities and discuss new research directions.

Identification of new opportunities can start at the governance level and develop through Committee and Board discussion to the individual PIs. It can also grow "from the bottom up", starting with ideas from individual PIs to be prioritized and acted on by the governance mechanisms. Individual PIs can obviously also pursue intellectual opportunities announced by NOAA as part of the NOAA Announcement of Opportunities and subject new ideas for research through to the competitive process.

c. What are some recent examples of intellectual opportunities

The following are examples of identifying and pursuing intellectual opportunities:

- *Collaboration with GFDL on* "Understanding Climate Change from the *Medieval Warm Period to the Greenhouse Future"*: In the 2003 CICAR proposal we laid out a plan to facilitate collaboration with GFDL which included joint mentorship of students and postdocs. Immediately after the CICAR award was announced we began working with GFDL to identify the research subject that will serve as the integrated theme for collaboration. At that time GFDL was vigorously pursuing the goal of conducting the so-called "IPCC integrations". They demonstrated that their new generation of coupled models is capable of producing an excellent simulation of the 20th century climate and were keenly interested in applying them to a large array of relevant problems. At LDEO, two new and closely related scientific discoveries were made both directly related to CICAR. One was the successful realization of the "U.S. Drought Atlas": a tree-ring based annual reconstruction of soil moisture condition over the contiguous U.S. for the entire last millennium. The reconstruction revealed climatic difference between an extremely dry medieval interval and a wet interval during the "Little Ice Age" adding important information on the global influence of these events. The other related LDEO achievement was the successful simulation of the observed hydroclimate history of the US with GCMs forced with global observed SST. All the large and protracted droughts that struck the U.S. West and the Great Plains during the last 150 years were simulated, including the Dust Bowl drought. Particularly striking was the ability of the model forced only with tropical Pacific SST and with either climatological conditions or a coupled mixed layer elsewhere to provide an almost identical simulation as the first. This was evidence for the pivotal role of tropical Pacific SST in forcing droughts and pluvials over North America. On the basis of these important scientific advances at LDEO and GFDL and scientific progress elsewhere, LDEO and GFDL scientists identified an opportunity to extend the study of the mechanisms of climate variability to the entire millennium as a way to anchor the projection of future climate in a better understanding of the recent past. The central goal of this effort was the execution of coupled model integration of the last millennium using best estimates of past solar and volcanic forcing. A proposal was put together that laid out a plan for research and an emphasis in funding early career investigators (including graduate students) was included. The project featured research into the climate dynamics of global and regional phenomena in preparation for the long integration. The

subjects of these investigations were North American Droughts, the past and future of the hydroclimate of sub-Saharan Africa, the past and future of Arctic climate, troposphere-stratosphere interactions, and the response of the tropical Pacific to Solar and Volcanic forcing during the Holocene. In parallel testing of proxy reconstruction methods have been conducted to provide verification data for the future millennium simulation. Funding for the LDEO portion of the research was provided by GFDL. The project is entering its third year and despite a break in the funding we are continuing the collaboration by moving into the stage of setting up the millennium model integrations as a joint CICAR-GFDL effort.

- *CICAR Drought Applications Initiative:* The exciting CICAR research on the history and physical understanding of North American Droughts came at a time when the US West is suffering from a protracted drought that began at the end of the 20th century. On the national stage Western State Governors called for action on the subject of predicting and mitigating the drought impact and increasing the availability of research based data for decision makers. The idea of a National Integrated Drought Information System (NIDIS) was launched, and in 2006 received Congressional support. At the CICAR Executive Board meeting in the fall of 2005, a stimulating discussion helped identify this topic as an opportunity for developing a research-to-applications project within CICAR. In response to this Board recommendation, CICAR Director called for an Advisory Board meeting to discuss how to respond. The Committee proposed facilitating a meeting between Columbia social science investigators and their physical science counterparts as a first stage for arriving at an integrated CICAR program. A sub-committee organized a University-wide workshop where participants from the IRI, CIESIN, and CRED (see Section 1f) got together with CICAR climate scientists to learn about each other's drought related research. The Workshop identified the broader Columbia's strengths and outlined the possibilities for contribution to NIDIS. The Workshop was followed by a brainstorming session in a smaller group of investigators and areas of opportunity were defined and narrowed down. As we enter our fourth budget year we are continuing the discussion towards preparing a proposal to NOAA on a CICAR contribution to NIDIS.

d. Strategy for New Starts

A large part of CICAR's new starts (under Task III) are supported by the NOAA competitive funding process in which PIs respond to funding opportunities announced by NOAA program offices such as the CPO. With the move in NOAA to base most of the extramural funding on competition, this might be the only avenue for new starts available in the future. This does not mean however that the Institute's research portfolio will be based only on "opportunistic" funding. As described above in previous sub-sections, CICAR seeks to identify its strengths and build them to meet the future needs of climate research. The process involves understanding and contributing to the identification of the future needs through close involvement of our scientists in a national discussion. Seeking excellence in scientific research in key climate research areas and achieving national and

international recognition in these achievements is a goal we share with many of our colleagues in other universities and research institutions. In this way we participate in the ongoing discussion and feedback between the funding agencies and the academic community and in fact help shape future priorities.

In some past cases CICAR worked outside the competitive process. In some cases CICAR PIs were able to obtain short time funding to address and develop unique and new opportunities because of specific strengths. This is done by directly negotiating with a NOAA partner or with the CPO to clearly identify the goals and time limits of the project. In this way CICAR was able to obtain limited funds to support sending students to a summer school for special training (SOLAS) and to grant scholarships to students in the Columbia Masters in Climate and Society Program. The support from GFDL for the "Climate of the Last Millennium" project described in Section 4c above was also funded in this way by GFDL with the goal of spurring collaboration and moving both institutes into a new research direction.

e. Resources for New Opportunities

CICAR has limited resources for new opportunities built into its administrative budget and by pooling resources across individual sub-projects. In this way we can hold lecture to feature new research directions and workshops to introduce and discuss new research areas. This approach was taken in the two cases highlighted in Section 4c.

As indicated in section 4d above we were able to negotiate with NOAA partial funding for new starts (the case of the educational program on Climate and Society). As new research and education develop they can attract more robust funding from NOAA and from other Federal and private sources.

CICAR also relies on several University sources available for developing new research opportunities. Four such sources are the Lamont and Earth Institute postdoctoral programs, the LDEO Climate Center, and the Columbia University's Initiative in Science and Engineering (ISE).

- The LDEO and Earth Institute postdoctoral fellowship programs hold annual competition open to young scientists worldwide. These programs are open to candidates with research plans consistent with CICAR Themes. CICAR is represented on the respective selection committees by one of its PIs and candidates with climate science and climate applications interests are often selected. These candidates tend to work under the mentorship of CICAR PIs. CICAR has in the past assisted these programs in increasing their hiring capacity by partially supporting appropriate candidates.
- The Climate Center provides small grants (normally $5K) for stimulating new research directions.
- The ISE provides larger sums of money for new research initiatives (such funding for a two year startup project was recently obtained for a proposal featuring collaboration between climate scientists and statisticians to explore the application of new methodology for research into climate variability and change).

f. Institute Demographic Structure

As of itself CICAR has no employees. Its investigators and administrators are all Columbia University employees that receive NOAA funds in processes described above. The Tables below, taken from our 2005 and 2006 annual reports, display breakdowns of employees that obtain more than 50% of their annual salary from NOAA by rank and function and academic education. There are changes in this distribution from year to year due to changes in funding. Normal termination of some Task III projects and their replacement by new ones also affects the personnel structure.

Personnel Information Table July 1, 2004 – June 30, 2005
The Cooperative Institute for Climate Applications and Research

Category	Number	H.S.	B.A.	B.S.	M.A.	M.S.	Ph.D.
Research Scientist	5						5
Postdoctoral Fellow	2						2
Research Support Staff	8				1	4	3
Administrative	5	1	0	3	0	1	0
TOTAL Support > 50%	20	1	0	3	1	5	10
Undergraduate	0	0	0				
Graduate	11		5	4		2	
Total Support < 50%	45						
@ GFDL	0						
Obtained NOAA Employment	2						2

Personnel Information Table July 1, 2005 – June 30, 2006 The Cooperative Institute for Climate Applications and Research							
Category	**Number**	**H.S.**	**B.A.**	**B.S.**	**M.A.**	**M.S.**	**Ph.D.**
Research Scientist	**3**						3
Postdoctoral Fellow							
Research Support Staff	**6**				1	5	
Administrative	**2**			1		1	
TOTAL Support > 50%	**11**			1	1	6	3
Undergraduate	**1**	1					
Graduate	**6**			5		1	
Total Support < 50%	**39**						
@ GFDL	**0**						
Obtained NOAA Employment	**0**						

g. What is provided for Human Resource Development

As indicated above CICAR has no Institute employees. Columbia University HR and its representation on the LDEO campus (which is a part of Lamont Administration) fulfill all the traditional human resource functions for the investigators and administrators of CICAR. These functions are well defined by the University. Their description is available on the LDEO and Columbia web sites and is provided to all employees on the day of their recruitment. In addition the HR offices provide consultation by interview, phone, or e-mail to address any special request. Columbia University employees can participate in University training and continuing education programs often at no cost to the employee.

The main HR development concern in CICAR is the preparation of the scientific workforce of the future. In particular the development of a workforce concerned with NOAA-relevant science and with potential to work as NOAA employees or on NOAA project when they develop their independent careers. One tier in this development process is the interaction with students. The other is the mentorship of postdoctoral scientists.

CICAR's resources for achieving such goals are limited. Our administrative budget sets aside funds for a summer undergraduate internship, provided as part of the Lamont summer internship competition (see Section3b above). CICAR also supports visiting scientists that lecture on CICAR related topics and sponsors workshops on CICAR related science with an intention of exposing the graduate community on campus to these topics. Limited resources for postdoctoral research scientists are based on the availability of funding through the GFDL-CICAR collaborative project.

Other resources are made possible through individual PI projects (normally obtained by responding to competitive funding opportunities). The latter are limited in duration (usually 3 years) and have to be justified by the PIs in their proposals to NOAA.

A crucial element in CICAR's HR development effort is the CICAR PI. Many of the PIs participate in the University education process or work with undergraduate, graduate students, and postdocs on their research projects. This interaction often exposes the young investigators to NOAA related science and lead to their involvement in the actual research at no cost to NOAA.

h. What is the State of the Financial Health of the Institute

CICAR funding can be divided into two parts:

- Administrative support – provided by NOAA as part of the CICAR Cooperative Agreement, for the duration of the Agreement. This sum of money, $100K (adjusted slightly each year to reflect changes in LDEO salary scales), is matched by Columbia University (LDEO) as part of the Agreement. Together this budget provides for part of the Director's salary and full support for CICAR Administrator's salary and supports the funding needed for CICAR Office operations (technical web assistance, publications, and travel). From this budget we have set aside a modest amount for support for a summer undergraduate student internship and for a small visitors program.
- Research and Education funding – supports all research and educational activities featured by the Institute. This funding comes from NOAA as sub-awards (amendments to the CICAR funding portfolio) and is tied to individual PI projects. Many of these projects have a 3-year duration and their support is provided by NOAA CPO as part of the competitive extramural research program and is contingent on Federal funding availability. CICAR also features projects that were granted by NOAA (CPO and GFDL) on the basis of recognition of our Institute special capabilities. Here too the grants are contingent on Federal funding availability and its continuation from year to year is not guaranteed by contract.

In the 2003 CICAR proposal we provided a projected budget Task-by-Task ceilings under which all the funding amendments are provided. CICAR has not exceeded these ceilings.

The task of identifying imbalances and assessing the need for budget adjustment is part of the strategic research planning process performed by CICAR through working internally with the Advisory Committee and externally with the Executive Board and our NOAA partners. These imbalances are identified by looking at the Institute as a whole and the balance of projects within Themes and Tasks. On an individual project level it is assumed that the PIs worked to strike a balance between their own scientific goals and the funding confines provided by NOAA.

Looking back at the CICAR's three years of operation few imbalances stand out. These can be summarized by Theme and Task:

- *By Theme*: CICAR would like to see robust growth under Theme III: Climate Applications Research. Under this Theme, we were able to obtain funding for education purposes (which we define as related to Task III). This support has however been intermittent (this is addressed more fully below). That said, CICAR's goal is also to create robust funding growth in this area for projects that provide actual climate applications for decision makers, a goal that is well within the capabilities of the Institute. We made continual attempts to achieve such funding through individual PI competition for the NOAA extramural funding pool. To date such efforts were only partially successful. Last budget year we launched an attempt to address growth under Theme III in a more centralized approach. Identifying the subject of North American drought research are a targeted growth area we have began laying out a CICAR strategy for creating a focused activity on the subject. Our first step to identify existing physical and social science research activities under this area within Columbia University was the North America Drought Workshop (described under Section 4c). As an outcome of the Workshop we identified strengths in the area of applications research within the University and planned to pursue those by presenting them to our Executive Board and then with NOAA to seek the necessary funding in FY07.
- *By Task*: Here we would like to see more robust commitment to Education (Task IV). First on our list is to pursue guaranteed funding for graduate students and postdoctoral scientists. Such plan was laid out in our 2003 proposal. We envisioned a NOAA commitment that could cover a small number of graduate and postdoctoral (CICAR) fellowships granted on a competitive basis to applicants that conduct research addressing CICAR mission and Themes. We were successful in obtaining support for such program in our budget years II and III from GFDL resources. This project has the additional goal of stimulating GFDL-CICAR collaboration and got off to an excellent start (see above Section 4d). However, the funding was terminated this year because of NOAA budget constraints. Providing robust support for education to Cooperative Institute has been on the agenda of the CI body's discussion with the NOAA Cooperative Institute Program Office. Tentative ideas exist to provide each institute with additional Task I funding, based on a proportion of the overall Institute's funding portfolio) to guarantee education support. CI directors continue to raise this issue with NOAA in their annual meetings with NOAA representatives and general communication with the Cooperative Institute Program Office.

A Budget Table summarizing the three years of CICAR operation is provided below. The Table shows CICAR project balance. The number in red (negative) is based on the difference between projections and availability of funding in support for education projects.

CICAR Projects - Account Balance as of June 30, 2006					
Project	**Actual Budget**	**Expenditures**	**Balance**	**Task**	**Theme**
Task I: Administrative	**$313,978**	**$257,729**	**$55,350**	**1**	
Task III Theme 1	**$3,987,858**	**$3,738,319**	**$405,400**	**3**	**1**
Task III Theme 2	**$3,082,626**	**$2,148,104**	**$921,012**	**3**	**2**
Task IV: Theme 3	**$109,999**	**$201,752**	**– $91,753**	**4**	**3**
Total	**$7,494,461**	**$6,345,904**	**$1,290,009**		

i. How does the Institute intend to work to achieve its financial goals?

The discussion in Section 4h above includes comments on our plans to addresses our plan to accomplish our financial goals. It builds on our ability to utilize our governance structure to identify the University's strengths in underdeveloped CICAR areas, communicating these to NOAA and seek support. In addition we have started to work with LDEO Development Office to identify non-governmental funding opportunities that can be used to enhance the resources available for research in underdeveloped areas. Finally, we are pursuing the strengthening the interaction within the University between CICAR and synergetic institutes or centers that are funded by other resources (Federal and non-Federal), particularly in areas where CICAR research is underdeveloped. Examples are our Drought Initiative where we laid the foundation for interaction between CICAR physical science research and the application research in CIESIN and CRED, which is funded by other Federal agencies. Such synergy, will lead to development in the direction of increased climate applications research in the University.

j. Issues in Interaction with NOAA

It should be evident from the answers to previous questions that over the three years of operation CICAR developed an outstanding interaction with GFDL in research partnership and in mutual planning for the future of climate research. It is our hope that the more fledgling collaborations that now exist with ESRL, NCDC, and PMEL will grow as well.

Last year an issue critical to CICAR developed in our relationship with NOAA. The problem is a decision made by the CPO to fund new (FY 06) individual PI projects, submitted under the open competition as individual grants and not as CICAR amendments. This diminishes the importance of our institute within the University as a

single point of contact with NOAA. It hurts our ability to provide a unified strategic dimension to our research. NOAA is aware of this problem (which also affects several other Institutes) and we hope to work together to its resolution.

k. Issues in Interaction with the University

As part of the university's research administration hierarchy CICAR is well integrated within the system and interaction is largely seamless. The LDEO director is extremely supportive and well involved in CICAR matters. His role as the Chair of the CICAR Executive Board facilitates a direct communication with our NOAA sponsors and partners. Columbia University Executive Vice President for Research is also a member of our Executive Board and is keenly interested in our research agenda. As CICAR moves to increase its applications Theme, our exposure on the main Columbia Campus (LDEO resides on a separate one) increases.

CICAR administrative support from LDEO and Columbia Administration Offices is to the most part excellent. We are looking toward imminent developments in internal University communication procedures on matters related to grants processing to further improve our interactions.