EXTERNAL REVIEW OF THE

COOPERATIVE INSTITUTE FOR CLIMATE SCIENCE

PRINCETON UNIVERSITY (CICS-P)

PRINCETON, NEW JERSEY

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I. Introduction

An external review of the research, education, and outreach programs of the Cooperative Institute for Climate Science at the Princeton University (CICS-P) was conducted on November 3-4, 2011 at Princeton University. Guidelines for conducting the review were provided by the Cooperative Institute Program staff of the Office of Oceanic and Atmospheric Research (OAR) within the National Oceanic and Atmospheric Administration (NOAA). The review was conducted under the auspices of the NOAA Science Advisory Board (SAB) and, therefore, is subject to the requirements of the Federal Advisory Committee Act (FACA).

A previous external review of the CICS-P program on behalf of NOAA's Science Advisory Board took place on January 18-19, 2006. While the current NOAA/SAB ranking system was not in place, a reading of that review strongly indicates that this program would have had an "outstanding" ranking under the current evaluation system. That review included six recommendations and suggestions that were responded to by CICS-P on July 18, 2007, with additional comments provided on October 12, 2011. Our Review Panel felt that CICS-P either fully responded to recommendations and suggestions or provided a reasonable response.

Our Review Panel concluded that CICS-P is a successful and productive enterprise providing significant contributions to science and NOAA's science, and clearly serves the needs of NOAA. Strong institutional support exists. The Review Panel was impressed by the quality and number of publications produced by CICS-P, the value of CICS-P for training graduate students and mentoring postdoctoral scientists, and the key role CICS-P has played in the development of the Earth System Model at NOAA's Geophysical Fluid Dynamics Laboratory (GFDL).

The Review Panel identified 10 findings and 13 recommendations which are elaborated in the body of this report and listed in Appendix I. A list of the Review Panel members is provided in Appendix II. The Review Panel on-site agenda is provided in Appendix III.

II. Overview of CICS-P

Although CICS-P was established in October 2003, it is the product of a highly successful collaboration between Princeton University and GFDL stretching back to 1967. The goal has been to produce oceanic, atmospheric and now Earth system models; to perform research in climate, biogeochemical cycling, and related areas; and to educate graduate students and mentor postdoctoral research scholars. Over 92 graduate students and 241 postdoctoral scientists have passed through the program since its inception, plus 23 current postdoctoral and visiting scientists. With NOAA support, over 90 students have successfully completed a Ph.D. degree, most of whom have been advised by GFDL scientists who have a faculty affiliation at Princeton University. A great many of these students and postdoctoral scientists have gone on to leadership positions in NOAA and across the nation. The primary instrument that has delineated the relationships between NOAA/GFDL and Princeton University is the original memorandum of understanding signed in 1967.

The **mission** of CICS-P is to focus the core scientific competencies of Princeton University on answering key questions related to the sciences of climate change and Earth System Modeling, and so provide an effective bridge between the two institutions.

The overall **vision** of CICS-P is to: *be the world leader in understanding and predicting climate and the environment - integrating physical, chemical, biological, technological, economic and social dimensions- and in educating the next generations to deal with the increasing complexity and importance of these issues*.

CICS-P is thus built upon the strengths of two outstanding institutions and the ties between them: Princeton University in biogeochemistry, ecology, physical oceanography, paleoclimatology, computer science, hydrology, climate change mitigation technology, economics and policy, and GFDL in numerical modeling of the atmosphere, oceans, weather and climate. CICS-P carries out research that, when combined with the ongoing activities at GFDL, is intended to produce

the best and most comprehensive models and a holistic understanding of the Earth system, and, therefore, enable NOAA to deliver a new generation of products to decision makers.

The Scientific Themes of CICS-P are**:**

(1) Earth System Modeling Development and Analysis **-** Develop and improve models that simulate and aid the understanding of the present climate and Earth system, and that can be used to predict changes in the state of the climate and Earth system.

(2) Data Assimilation **-** Develop capabilities to assimilate both physical and biogeochemical observations to produce an estimate of the current environmental state for use in Earth system modeling and the prediction of the future state of the climate.

(3) Earth System Modeling Applications **-** Use Earth system models to study the processes associated with long term climate change and variability, and to make predictions of the future state of the Earth system.

III. Strategic Plan

As noted in NOAA's Next Generation Strategic Plan, December 2010, research underpins the science-based mission of NOAA, and a priority for that research is to develop an Earth system model using our scientifically-based understanding of the system and its components. Such a model can then be used to further study the Earth system and to provide forecasts and assessments of the climate and the processes that constitute and affect it. A major goal of CICS-P is to aid in the construction, development, and use of such an Earth system model. A component of this is to perform research that provides the knowledge base for such model construction and informed use.

In order to continue to address the nation's critical scientific needs it is important to attract, retain, and develop competencies at all levels within NOAA, and to maintain a strong scientific workforce in the nation as a whole. To this end, CICS-P, through the Atmospheric and Oceanic Science (AOS) Program of Princeton University, plans to continue its highly successful graduate program. The graduate program provides both academic training, leading to a Ph.D. degree, and the opportunity to work closely with NOAA scientists, and, therefore, to obtain hands-on training in areas relevant to NOAA research activities. CICS-P will also continue to provide a postdoctoral and visiting scientist program that enables young and established scientists to participate in NOAA research.

The main goals of this cooperative institute are as follows:

1. To aid in the development of GFDL's Earth System Model by providing expertise in its constituent components, particularly in ocean modeling and parameterizations, ocean biogeochemical cycling and ecology, land modeling and hydrology, the interactions

within and among the various components of the Earth system, and the computational infrastructure that binds all the components together in a model.

2. To use the Earth System Model and its component parts to address problems in climate variability and change on decadal and longer timescales. This includes using the model and observational data to assess the state of the Earth system and to provide projections of the future state of the system.
3. To support senior scientists in the cooperative institute in performing long-term research on components of the Earth System Model and other topics and in providing opportunities for graduate students and postdoctoral scientists to be mentored and participate in this research. CICS-P research currently supported by NOAA includes:
    - Studies of ocean mixing and its role in the general circulation
    - Development and use of a new generation of numerical ocean models
    - Development of land ice models
    - Development of software infrastructure for global models
    - Development and use of new models of land and the terrestrial carbon budget
    - Fundamental research in ocean/atmosphere/climate dynamics
4. To bring new ideas into GFDL that involve model development or the use of models and that compliment ongoing Earth System Model research.
5. To educate and train future generations of scientists for NOAA and the nation as a whole, by providing access to a graduate degree program and a postdoctoral and visiting scientist program that provides academic training and a hands-on opportunities to work with NOAA scientists at a NOAA facility.

Success of CICS-P is judged by three criteria: (1) the contribution of ongoing CICS-P research to NOAA's and, specifically, GFDL's mission; (2) the publication of scientific results in refereed journals; and (3) the success of CICS-P postdoctoral scientists and graduate students in obtaining research, faculty, public policy, or other positions in this field upon completion of their stay at Princeton University.

Finding – In terms of research in the three primary science themes, excellent progress has been made in area ***(1)*** Earth system modeling and analysis and area ***(3)***, Earth system model applications. Although there is some high quality on data analysis and carbon cycle inversions, work inarea ***(2)***data assimilation ***(2)*** is generally less developed. From discussions with senior scientists in CICS-P and GFDL, this asymmetry has developed in part from a commitment within CICS-P to focus on critical GFDL needs in areas ***(1)*** and ***(3)***.

> **Recommendation 1** – Given the very high quality of the scientific activity that has occurred during the review period, the review committee does not recommend a redistribution of resources among the different science themes. The committee does recommend, however, that NOAA program officers consider developing a mechanism

enabling modification of the science themes over the 10 year time span of the cooperative agreement.

Finding – CICS-P creates a vibrant partnership between GFDL and Princeton that is crucial for recruiting high quality climate scientists for GFDL. More generally, many of the graduate students and postdoctoral scholars trained through CICS-P have moved into university faculty and government leadership positions in climate science.

> **Recommendation 2** – We recommend CICS-P maintain its commitment to supporting and creating a rich intellectual and supportive funding environment for postdoctoral scholars and graduate students.

Finding – CICS-P is highly sensitive to year to year changes in NOAA's budget. Fluctuations in CICS-P funding through GFDL are amplified because of many fixed GFDL costs associated with government employees, computer contracts, and other aspects of the budget that are difficult to modify from one year to the next. Because CICS-P senior staffs, postdoctoral scholars and graduate students are Princeton employees without long-term contracts, the CICS-P component of the GFDL budget is vulnerable during a budget downturn. While this issue likely affects other cooperative institutes, at GFDL this vulnerability compromises its ability to retain senior CICS-P staff that develop and maintain the Earth System Model while also recruiting and training the next generation of climate science leaders. Senior staff can be extremely difficult to replace when funding levels are restored. Many senior staff supported by CICS-P have, for example, contributed significantly to the development of land surface, carbon cycle, and the ice sheet model components. In the opinion of this review committee, continued reductions in funding to CICS-P are likely to severely compromise GFDL's ability to contribute a state-of-the-science Earth system model for the Intergovernmental Panel on Climate Change (IPCC) 6th assessment.

> **Recommendation 3 –** Establish policies to provide GFDL with more flexibility in managing its internal and CICS-P budgets during periods of significant cutbacks.

> **Recommendation 4 -** CICS-P and GFDL should work together to protect senior CICS-P staff appointments when funding levels drop because of their crucial role in Earth System Model development.

> **Recommendation 5** – Encourage NOAA management to continue to view cooperative institutes as valuable and integral parts of NOAA's resources and to be proactive in protecting high-performing CIs such as CICS-P during tough budget periods.

IV. Science Review

Science in all three Themes (Section II) was presented to the Review Panel in both oral and poster presentations. Due to time constraints, however, only a fraction of the total science was

presented. The supporting materials provided to the Review Panel provided a more extensive review. However, again, even that provided only a partial review of CICS-P's scientific accomplishments.

Overall, the Review Panel feels the science performed by CICS-P is outstanding in regard to both quality and quantity and breadth and depth. The science presented fell under two main categories: 1) Earth System Modeling and Analysis and 2) Earth System Modeling Applications. CICS-P, with GFDL, is clearly among the top groups worldwide in regard to development and use of its global model. A critical area of uncertainty, with regard to global climate prediction, is an understanding of the dynamics of ice sheets. CICS-P is playing an active role here. The institute is also exploring the use of isopyncal, as well as z-coordinates and enhancements in efficiency and resolution in the Earth System Model, and focusing on key aspects of the atmosphere (e.g., aerosols), land (e.g., forests), and oceans (e.g., biogeochemistry). Applications of this Model include investigations of climate variability and change and their attribution to natural and human causes, ocean circulation and mixing (e.g., its use in analysis of the Deepwater Horizon spill in the Gulf of Mexico), and smaller scales (e.g., regional climate and mesoscale eddies). Collectively, these comprise valuable contributions to NOAA's mission.

The consistently high productivity of CICS-P is manifest in its peer-reviewed publications (22 in 07/08-04/09, 55 in 04/09-04/10, and 61 in 04/10-04/11, see table below). The venues vary from Biogeosciences, the American Naturalist, and Ocean Modeling to the Journal of Geophysical Research and Nature, all respected journals with high impact. The following table displays the publication record of CICS-P and GFDL from 2008 through 2010 (This information was provided to the Review Panel by CICS-P).

Publications	*CICS-P Publications (Report Year)	Total GFDL Publications (Calendar Year)	**GFDL Publications with Princeton co-authors
2008	22	103	48 (47%)
2009	55	107	42 (39%)
2010	61	139	68 (49%)
Totals	**138**	**349**	**158 (45%)**

*Peer – Reviewed

**This includes non-CICS-P supported scientists

Equally important evidence of the value of CICS-P to NOAA's mission is its contribution to IPCC assessments. Finally, CICS-P supports NOAA's mission by contributing to the education and training of its workforce; through it graduate student and postdoctoral programs.

CICS-P has achieved partial success with respect to its vision statement. While it is a world leader in understanding and predicting climate and the environment, its efforts to study interactions between different components of the Earth system have focused almost exclusively on the natural sciences, including physics, chemistry, and biology.

CICS-P has enabled, for example, the development of the state-of-the-science Earth System Model with a fully coupled carbon cycle at GFDL. The simulations from this Earth System Model used in the IPCC 5th Assessment are an important contribution to climate science by NOAA. CICS-P has made tremendous progress in integrating physical, chemical, and biological interactions within this model. Integration of social, including economic, dimensions within the model, however, is in its infancy. Further, few Earth system application projects within CICS-P (Task III projects) have targeted economic interactions with the physical, chemical, and biological Earth System Model elements (area 3 of CICS-P).

With respect to fulfilling the goals described by the vision statement in these areas, there is exciting potential over the next five years to develop within CICS-P an initiative that draws upon other efforts ongoing within the Princeton Environmental Institute. CICS-P will ultimately need to make progress in this area in order for GFDL to continue to lead Earth System Model development over the next two decades.

Capability in this area is crucial for GFDL to effectively address key elements of NOAA's next generation strategic plan related to climate adaptation and mitigation. Currently, GFDL relies on external organizations such as the IPCC for the development of future scenarios that provide boundary conditions for model simulations. These include, for example, trajectories of fossil fuel and aerosol emissions and changes in land cover. In the opinion of this review committee, NOAA needs to be able to develop its own mitigation scenarios that are fully integrated within an Earth System Model. This will be essential for effective exploration of different policy options and climate treaty configurations designed to stabilize greenhouse gas levels and climate. CICS-P and GFDL are poised to play a key role in this exciting scientific frontier.

Finding – Progress towards the CICS-P vision statement has not been evenly balanced.

> **Recommendation 6 –** Increase efforts to integrate technological and social, including economic, dimensions within Earth System modeling activities.

Finding – The research of CICS-P is of consistent high quality and quantity and directly supports NOAA's mission. CICS-P role in the development and application of the Earth System Model, in particular, is critical to NOAA's mission and its contribution to the IPCC assessments.

> **Recommendation 7** – The Review Panel recommends continuation of existing research. It is critical that funding be continued for CICS-P contribution to the Earth System Model, particularly in light of overall budget constraints within NOAA and, in particular, GFDL.

V. Education and Outreach

CICS-P participates in a number of education and outreach activities. The following six subsections briefly summarize these activities for the review period. This information was provided to the Review Panel by CICS-P.

The AOS Graduate Program

The most significant educational program supported by CICS-P is the AOS Graduate Program. This is an autonomous, Ph.D. granting program at Princeton University, typically with a standing body of 12 to 18 graduate students. The AOS program is a collaboration between Princeton University and GFDL enabled and financed by CICS-P. A unique attribute of the AOS Program is the composition of its faculty, which contains both Princeton University employees and government employees who have been granted faculty status by the University. Currently, eight GFDL employees and two CICS-P-supported scientists are faculty members of the AOS Program.

CICS-P provides financial support for many of the students in the AOS program. Thus, the program provides outstanding opportunities for graduate students to get both a strong academic training at a leading university and a 'hands-on' opportunity to participate in NOAA research activities and to work with GFDL scientists. We believe that the Program provides an unmatched opportunity to train future generations of scientists and NOAA employees.

Over 90 students have graduated from the AOS Program, and CICS-P has also provided support for students in other departments in the University. Graduate alumni include professors at the Courant Institute, California Institute of Technology, University of Michigan, UC Los Angeles, McGill University, a former Dean at the University of Washington, and NOAA scientists at GFDL, the Pacific Marine and Environmental Laboratory, and Earth System Research Laboratory.

The Postdoctoral and Visiting Scientist Program

The postdoctoral and visiting scientist program within CICS-P provides another outstanding opportunity for training scholars in areas relevant to NOAA's present and future needs and for scientists from other institutions to visit Princeton and GFDL to work closely with NOAA scientists. Typically, the program will support postdoctoral scientists to work at CICS-P for a two year period and more senior visitors for shorter visits. Over 240 scientists have passed through the program since its inception, many of whom, like the graduate students, have gone on to leading positions in NOAA and elsewhere.

Summer Institute in Weather and Climate

CICS-P continued its collaboration with a Princeton University professional development institute for New Jersey teachers, during the summers of 2008, 2009 and 2010. This well-

established summer program, QUEST, is led by Princeton University's Teacher Preparation Program. A one week Weather and Climate unit for teachers of students in second through eighth grades, held during the summer, offers a wide range of inquiry-based experiences through which the teachers explored the fundamentals of weather, the Earth's climate, and the interaction of land, ocean, and atmosphere. Ten teachers participated in the Weather and Climate unit, representing seven different school districts. Teachers serving underrepresented students in urban districts comprised 40 percent of the participating districts.

Coral Workshop

Through CICS-P, the NOAA Coral Reef Conservation Program sponsored a "Coral Vulnerability Workshop" from August 30-September 1, 2010 at Princeton University. The ultimate products of this project will be a globally extensive suite of downscaled reef-level projections of the effects of climate change and acidification that will help identify coral reefs and regions that may be more susceptible/resistant and vulnerable/resilient to climate change and acidification. This effort will supply a key consideration in the design and management of marine protected areas. From an outreach perspective, another goal of the workshop was to identify scientific meetings that would appropriately link the resultant model findings with reef managers who can make use of this information for conservation efforts. We plan to continue these outreach efforts as the project matures and the analyses are complete.

Fundamental Problems in Climate Science Spring School

In conjunction with the Princeton Center for Theoretical Science (PCTS), a spring school on 'Fundamental Problems in Climate Science' was held on Princeton University's main campus in May 2009, for a ten day period. The school brought together about half a dozen invited distinguished speakers and about 40 students and postdoctoral scholars from other universities, in addition to local participants. The speakers each gave two or three lectures on some aspect of climate dynamics. In addition, there were more informal discussions and round tables.

Applying IPCC-Class Models of Global Warming to Fisheries Prediction Workshop

CICS-P sponsored the workshop "Applying IPCC-Class Models of Global Warming to Fisheries Prediction" from June 15-17, 2009 at Princeton University. From an outreach perspective, a goal of this workshop was to promote a greater shared understanding of the key challenges faced by climate and living marine resource scientists studying climate change and its potential impacts. Such an understanding is critical for the development of new and innovative applications of IPCC-class climate models in assessing the impacts of climate change and variability on living marine resources. Over 50 scientists attended this workshop. In addition, a manuscript providing a detailed synthesis of the workshop entitled "On the use of IPCC-class models to assess the impact of climate on living marine resources" has been produced. This will be submitted for peer review by the end of April 2010.

Findings – The representation of women within the AOS Ph.D. program has increased over time. This is an important achievement. The commitment by CICS-P to gender balance should be maintained over the next five year funding cycle. Although the overall number of Ph.D. students within the AOS Ph.D. program is small, thus making it difficult to statistically quantify trends, the review committee felt that U.S. minorities were underrepresented.

> **Recommendation 8** – Existing pipelines for entraining underrepresented minority undergraduate students into the sciences both at Princeton and nationally need to be more effectively used to increase the representation of underrepresented minorities within the AOS Ph.D. program. This might be achieved by entraining undergraduate students through summer research programs and targeted Ph.D. recruiting efforts.

Finding – CICS-P postdoctoral scholars and graduate students spend most of their time focused on research activities needed to advance our understanding of the Earth System. From our discussions with the Ph.D. students, many were not sure about the most effective ways to communicate their recent science findings with the media or public. For graduate students, there is an option available to explore climate policy implications of their work by applying for a Ph.D. dissertation enhancement program at the Woodrow Wilson School. This option is used by some but not all of the AOS Ph.D. students.

> **Recommendation 9** – CICS-P may consider developing a more formal approach for teaching Ph.D. students and postdoctoral scholars how to communicate their science effectively with journalists; their representatives in local, state, and federal government; and the public. In the opinion of the review committee, many of the exciting science findings supported by CICS-P would be of high interest to these groups, and would increase the visibility of the GFDL- Princeton partnership supported through CICS-P. This could be achieved by a seminar or workshop, similar to the one developed by the Leopold Institute. NOAA's Sea Grant Outreach/Engagement/Extension/Education experts could assist.

> **Recommendation 10** – It is recommended that each PI report on the outreach activities conducted by personnel funded by each project.

VI. Science Management

CICS-P's three science management tasks are summarized below with the University context within which they fit. This structure is based on similar arrangements at other NOAA cooperative institute. It accommodates innovative scientific research within the academic institute while fostering strong collaboration and the exchange of ideas with GFDL. It also simplifies the administrative management and oversight of the Institute's diverse research activities.

Task I: Administration This task covers the administrative functions of the Institute, including support for the Institute Director and his administrative assistant. As chief administrator of the Institute, the Director is responsible for managing the budget and issuing the Institutes' annual technical reports. The Director also provides scientific leadership for the institute by coordinating research activities, with the guidance from the Executive Committee, setting research priorities, and fostering collaboration between NOAA and CICS-P scientists. The Director and Associate Director maintain links with other NOAA cooperative institutes and represents CICS-P at their periodic meetings. The administrative assistant helps the Director in his administrative responsibilities. The AOS Program and Princeton Environmental Institute provide other technical, financial and administrative assistance.

The Director of CICS-P will be a faculty member or senior research scientist with strong links to the AOS Program, GFDL, and the Princeton Environmental Institute, and who is responsible for ensuring that CICS-P is achieving its goals. PI driven research projects funded under the CICS-P agreement may have independent PI's.

An *Executive Committee,* consisting of a subset of the CICS-P Fellows and GFDL senior scientists advises the Director and Associate Director on the development of basic scientific themes for projects as well as the preparation of proposals and allocation of resources. This committee consists of the Director, Associate Director, faculty members from the AOS Program, and the Director and faculty members from the Princeton Climate Center.

The budget for Task I activities provides support for the core administrative activities of CICS-P. The present base-funding request provides support for 6 months of administrative assistant time to help in administering the Institute and partial support for the Director and Associate Director. The AOS program and PRINCETON ENVIRONMENTAL INSTITUTE share in the administrative costs by providing additional funds to cover partial administrative support. Princeton University waives the indirect cost recovery (normally 61%) on the entire Task I budget.

In addition to salaries, the Task I budget covers funds for the Director and the administrative assistant(s) to attend the annual NOAA cooperative institute meeting. Funding for computer equipment to facilitate the management of the Institute, office supplies, and for the cost of publishing CICS-P reports is also included.

Task II: Cooperative Research This task provides for scientists and students who are employed by Princeton University but normally located at GFDL or Sayre Hall. CICS-P scientists, typically are postdoctoral fellows, visiting scholars, or research staff and scholars, employed by CICS-P to enhance the technical and scientific expertise at GFDL required to execute collaborative CICS-P projects or to address needs that require specific expertise not available at GFDL. Postdoctoral fellows constitute the bulk of the Research Program and are normally supported for one or two years. Visiting scholars, who are established scientists with positions

elsewhere, may be appointed to the Program for periods from a few days to one year. Short-term visitors are normally supported with travel funds, whereas long-term visitors are afforded an appropriate University position. Finally, 38% of Task II funds support scientists on a continuing basis, following consultation with the GFDL Director.

This task also supports a program for advanced graduate students that support Ph.D. research consistent with the CICS-P themes and under the mentorship of GFDL. The Princeton AOS Program typically has an enrollment of 12 to 18 graduate students engaged in research and study toward a Ph.D. degree. If the focus of a student's research is deemed relevant to the scientific objectives of the Research Program and NOAA, such students are offered positions as Assistants-in-Research in the Cooperative Research Program.

The AOS Program is the platform for carrying out the education and cooperative research project tasks and for involvement of GFDL staff in educational and research activities. The AOS Program is an autonomous program within the Geosciences Department, with a Director appointed by the Dean of Faculty, currently Jorge Sarmiento.

The Task II budget provides support for salaries and benefits for approximately 20 scientists that are Princeton University employees but work at GFDL, providing specialized scientific support for CICS-P related projects. Of these scientists, five to six will be at the senior rank. We also anticipate that some will be filled through visiting scholar positions. Travel support is provided for attending conferences and meetings and for relocation costs for new hires. Support for supplies, photocopying, software license agreements, and publications is also included. The Task II budget also provides funding to support about 10 graduate students to enhance the Princeton-GFDL collaboration through Ph.D. research, which is relevant to the CICS-P themes. Minimal costs for travel to workshops, supplies, and photocopying are budgeted. Finally, Task II provides ongoing funding and projected new funding of subcontracts required to carry out the proposed research themes of CICS-P. Indirect costs for Task II are currently at a reduced rate of 29.6% (Princeton's full indirect cost rate is 61%). Tuition is cost-shared with Princeton University and is exempt from indirect costs.

Task III: Individual Projects This task encompasses the bulk of individual and collaborative PI research at Princeton that is supported by grants from NOAA (including GFDL) and is aligned with the themes of CICS-P. Funding for new projects is normally obtained by submitting proposals for consideration to various NOAA funding bodies, subjected to a formal review process and, if successful, funded at a negotiated level. While projects listed under this task may or may not include collaboration of NOAA/GFDL scientists, they will all address research goals mutual to NOAA and Princeton. CICS-P facilitates the exchange of ideas between Princeton University scientists and those from NOAA. PRINCETON ENVIRONMENTAL INSTITUTE is the locus of interdepartmental PI-driven research projects within the cooperative institute, under the name of the Princeton Climate Center (PCC). The head of the PCC is Jorge Sarmiento.

Finding – The management of CICS-P has made more resources available for individual scientific projects (Task III) by redirecting a portion of the funding provided for administration (Task I). This reallocation of resources has been made possible by an efficient administrative structure, including in-kind contributions of administrative support by Princeton University. This resource allocation decision is commendable and has provided benefits to NOAA in the form of greater scientific output.

> **Recommendation 11** – Continue to seek administrative efficiencies that will allow optimal use of resources. Efficient management will be especially important in a more constrained budget environment.

Finding – CICS-P has been effectively managed, but the Review Panel noted that CICS-P does not have an explicit succession plan for its senior management.

> **Recommendation 12** – Develop a succession plan for senior management. Such plan need not identify specific successors for the current Director and Associate Director, but rather identify a process by which they would be selected with input from the CICS-P Executive Committee, CICS-P External Advisory Board, and other appropriate sources.

Finding – A substantial increase in female participation in CICS-P has occurred since the last review. During the period from April 1, 2010-March 31, 2011, 40% of the individuals supported by CICS-P were female, up from 22% during the last review cycle. We commend CICS-P for their significant improvement in gender balance in their program.

> **Recommendation 13** – Build on this effort and continue to expand the diversity of CICS-P personnel, including all underrepresented demographic groups.

VII. Summary and Conclusions

In summary, after a thorough review of the research, management, education and outreach programs of the Cooperative Institute for Climate Services (CICS-P) at the Princeton University on November 3-4, 2011, the Review Panel was impressed with the quality and performance of this cooperative institute. As the Director of GFDL told us, he could not accomplish his laboratories goals without the strength and performance of CICS-P. While we, the Review Panel, provided nine Findings/Recommendations, these are primarily items to further strengthen CICS-P.

The Review Panel unanimously agreed that CICS-P should be continued at Princeton and we ranked CICS-P's performance as "Outstanding", based on the guidelines provided by NOAA OAR's program office.

Appendix I:

List of Report Findings and Recommendations

Finding – In terms of research in the three primary science themes, excellent progress has been made in area ***(1)*** Earth system modeling and analysis and area ***(3)***, Earth system model applications. Although there is some high quality on data analysis and carbon cycle inversions, work in the area of data assimilation ***(2)*** is generally less developed. From discussions with senior scientists in CICS-P and GFDL, this asymmetry has developed in part from a commitment within CICS-P to focus on critical GFDL needs in areas ***(1)*** and ***(3)***.

> **Recommendation 1** – Given the very high quality of the scientific activity that has occurred during the review period, the review committee does not recommend a redistribution of resources among the different science themes. The committee does recommend, however, that NOAA program officers consider developing a mechanism enabling modification of the science themes over the 10 year time span of the cooperative agreement.

Finding – CICS-P creates a vibrant partnership between GFDL and Princeton that is crucial for recruiting high quality climate scientists for GFDL. More generally, many of the graduate students and postdocs trained through CICS-P have moved into university faculty and government leadership positions in climate science.

> **Recommendation 2** – We recommend CICS-P maintain its commitment to supporting and creating a rich intellectual and supportive funding environment for postdoctoral scholars and graduate students.

Finding – CICS-P is highly sensitive to year to year changes in NOAA's budget. Fluctuations in CICS-P funding through GFDL are amplified because of many fixed GFDL costs associated with government employees, computer contracts, and other aspects of the budget that are difficult to modify from one year to the next. Because CICS-P senior staffs, postdoctoral scholars and graduate students are Princeton employees without long-term contracts, the CICS-P component of the GFDL budget is vulnerable during a budget downturn. While this issue likely affects other cooperative institutes, at GFDL this vulnerability compromises its ability to retain senior CICS-P staff that develop and maintain the Earth System Model while also recruiting and training the next generation of climate science leaders. Senior staff can be extremely difficult to replace when funding levels are restored. Many senior staff supported by CICS-P have, for

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> **Recommendation 3 –** Establish policies to provide GFDL with more flexibility in managing its internal and CICS-P budgets during periods of significant cutbacks.
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> **Recommendation 4 -** CICS-P and GFDL should work together to protect senior CICS-P staff appointments when funding levels drop because of their crucial role in Earth System Model development.
>
> **Recommendation 5** – Encourage NOAA management to continue to view cooperative institutes as valuable and integral parts of NOAA's resources and to be proactive in protecting high-performing CIs such as CICS-P during tough budget periods.

Finding – Progress towards the CICS-P vision statement has not been evenly balanced.

> **Recommendation 6 –** Increase efforts to integrate technological and social, including economic, dimensions within Earth System modeling activities.

Finding – The research of CICS-P is of consistent high quality and quantity and directly supports NOAA's mission. CICS-P role in the development and application of the Earth System Model, in particular, is critical to NOAA's mission and its contribution to the IPCC assessments.

> **Recommendation 7** – The Review Panel recommends continuation of existing research. It is critical that funding be continued for CICS-P contribution to the Earth System Model, particularly in light of overall budget constraints within NOAA and, in particular, GFDL.

Findings – The representation of women within the AOS Ph.D. program has increased over time. This is an important achievement. The commitment by CICS-P to gender balance should be maintained over the next five year funding cycle. Although the overall number of Ph.D. students within the AOS Ph.D. program is small, thus making it difficult to statistically quantify trends, the review committee felt that U.S. minorities were underrepresented.

> **Recommendation 8** – Existing pipelines for entraining underrepresented minority undergraduate students into the sciences both at Princeton and nationally need to be more effectively used to increase the representation of underrepresented minorities within the AOS Ph.D. program. This might be achieved by entraining undergraduate students through summer research programs and targeted Ph.D. recruiting efforts.

Finding – CICS-P postdoctoral scholars and graduate students spend most of their time focused on research activities needed to advance our understanding of the Earth System. From our discussions with the Ph.D. students, many were not sure about the most effective ways to communicate their recent science findings with the media or public. For graduate students, there is an option available to explore climate policy implications of their work by applying for a Ph.D. dissertation enhancement program at the Woodrow Wilson School. This option is used by some but not all of the AOS Ph.D. students.

> **Recommendation 9** – CICS-P may consider developing a more formal approach for teaching Ph.D. students and postdoctoral scholars how to communicate their science effectively with journalists; their representatives in local, state, and federal government; and the public. In the opinion of the review committee, many of the exciting science findings supported by CICS-P would be of high interest to these groups, and would increase the visibility of the GFDL- Princeton partnership supported through CICS-P. This could be achieved by a seminar or workshop, similar to the one developed by the Leopold Institute. NOAA's Sea Grant Outreach/Engagement/Extension/Education experts could assist.

> **Recommendation 10** – It is recommended that each PI report on the outreach activities conducted by personnel funded by each project.

Finding – The management of CICS-P has made more resources available for individual scientific projects (Task III) by redirecting a portion of the funding provided for administration (Task I). This reallocation of resources has been made possible by an efficient administrative structure, including in-kind contributions of administrative support by Princeton University personnel. This resource allocation decision is commendable and has provided benefits to NOAA in the form of greater scientific output.

> **Recommendation 11** – Continue to seek administrative efficiencies that will allow optimal use of resources. Efficient management will be especially important in a more constrained budget environment.

Finding – CICS-P has been effectively managed, but the Review Panel noted that CICS-P does not have an explicit succession plan for its senior management.

> **Recommendation 12** – Develop a succession plan for senior management. Such plan need not identify specific successors for the current Director and Associate Director, but rather identify a process by which they would be selected with input from the CICS-P Executive Committee, CICS-P External Advisory Board, and other appropriate sources.

Finding – A substantial increase in female participation in CICS-P has occurred since the last review. During the period from April 1, 2010-March 31, 2011, 40% of the individuals supported

by CICS-P were female, up from 22% during the last review cycle. We commend CICS-P for their significant improvement in gender balance in their program.

> **Recommendation 13** – Build on this effort and continue to expand the diversity of CICS-P personnel, including all underrepresented demographic groups.

Appendix II:

Science Advisory Board Selected CICS-P Reviewers

[1] Frank Kudrna, Ph.D., M.B.A, Chairperson (Member of NOAA's Science Advisory Board) Chief Executive Officer
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Dr. Frank Kudrna is President and Chief Executive Officer of Kudrna & Associates, Ltd. The firm provides diversified consulting engineering services in the areas civil engineering to industrial, commercial and institutional clients including municipal, state and federal agencies. In addition to his work at Kudrna & Associates, Ltd., Dr. Kudrna has served as the Director of the Illinois Division of Water Resources where he coordinated the water resource activities of the State of Illinois and chaired the Governor's State Water Plan Task Force. He holds a B.S. in Engineering and graduate degrees from the Illinois Institute of Technology (M.S. and Ph.D. in City and Regional Planning) and the University of Chicago (M.B.A.). Dr. Kudrna is active in several professional societies including the National Society of Professional Engineers and the American Society of Civil Engineers where he is a Fellow. Dr. Kudrna is currently a member of NOAA's Science Advisory Board.

[2] Anthony Broccoli, Ph.D.
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Dr. Anthony Broccoli is a Professor in the Department of Environmental Sciences at Rutgers University. Dr. Broccoli's research interest is climate dynamics, with particular emphasis on the simulation of past climates and climate change. At Rutgers University, he serves as Director of the Center for Environmental Prediction, Director of the Climate and Environmental Change Initiative, and Associate Chair of the Department of Environmental Sciences. Dr. Broccoli is presently the Chief Editor of the Journal of Climate and serves on the New Jersey Department of Environmental Protection Science Advisory Board, chairing its Standing Committee on Climate and Atmospheric Science. Prior to joining the faculty at Rutgers, he spent 21 years at the National Oceanic and Atmospheric Administration's Geophysical Fluid Dynamics Laboratory as a Research Associate, Senior Research Associate, and Research Meteorologist. He received a M.S. in meteorology (1979) and Ph.D. in environmental sciences (1998) from Rutgers University. 3

[3] James T. Randerson, Ph.D.
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Dr. James T. Randerson is a Professor in the Department of Earth System Science at the University of California, Irvine. Dr. Randerson studies the global carbon cycle using models and remote sensing measurements of the land surface and atmospheric trace gases. Current research themes in his laboratory include climate-carbon cycle feedbacks, land use change, and assessments of the role of fire in the Earth System. He has conducted field work in Alaska and Siberia to assess fire effects on ecosystem processes, atmospheric composition, and climate. He is a member of the science team for National Aeronautics and Space Administration's (NASA's) Orbiting Carbon Observatory and co-chair of the biogeochemistry working group of the Community Earth System Model. In 2005 Randerson was the recipient of the James B. Macelwane Medal awarded by the American Geophysical Union. He received a Ph.D. in biological sciences (1998) and a B.S. in chemistry (1992) from Stanford University. He conducted postdoctoral work at University of California, Berkeley and University of Alaska. He is a Fellow of the American Geophysical Union.

[4] David W. Fahey, PhD

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Dr. David W. Fahey is a research physicist in NOAA's Earth System Research Laboratory in Boulder, Colorado, USA. He joined the Laboratory after receiving advanced degrees in physics from the University of Wisconsin and the University of Missouri. His principal research interest is the measurements of trace gases and aerosols in the troposphere and lower stratosphere using instruments on board research aircraft. His current projects address water vapor in the lower stratosphere and the role of black carbon aerosol in climate. Dr. Fahey has served as a Principal Investigator and Project Scientist for a number of airborne sampling missions with NASA's research manned and unmanned aircraft and as a participant in several international scientific assessments of ozone depletion and climate. He is an author of the 2007 climate science assessment of the Intergovernmental Panel on Climate Change (IPCC), which shared the 2007 Nobel Peace Prize, and the 1999 IPCC Special Report on Aviation and Climate. He has received the U. S. Department of Commerce Silver and Bronze Medals for Meritorious Federal 4 Service, the American Meteorological Society Henry G. Houghton Award, and is a Fellow of the American Geophysical Union.

[5] Dave Checkley, Ph.D. (*Ex-Officio,* Cooperative Institute Representative)

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Dr. Checkley has Bachelor's Degrees (Oceanography and Zoology) from the University of Washington in 1970 and a PhD in Biological Oceanography from the Scripps Institution of Oceanography (SIO) in 1978. Dr. Checkley is a Professor of Oceanography at SIO where he teaches graduate courses in biological oceanography, fisheries oceanography, and pelagic ecology. Dr. Checkley carries out research on the effects of climate on plankton and fish, the effects ocean acidification on fish, and the role of zooplankton and other particles in the biological pump. He also develops instruments for observing plankton and particles. He is Editor-in-Chief of Fisheries Oceanography, was co-Chair of the Small Pelagic Fish and Climate

Change program of international GLOBEC, and is Director of the Cooperative Institute for Marine Ecosystems and Climate.

Appendix III:

Review Agenda
Cooperative Institute for Climate Science
Friend Center Convocation Room, Main Campus

Thursday, November 3, 2011

8:00 – 8:45	**Breakfast at hotel/Review Panel Executive Session**
8:45 – 9:00	**Travel to Princeton Main Campus** University Van to pick-up and drop-off
9:00 – 9:15	**Welcome –** A. J. Stewart Smith, Dean for Research
9:15 – 9:45	**CICS-P Introduction and Overview** Jorge Sarmiento, CICS-P Director
9:45 – 10:45	**Role of CICS-P:** Geoffrey Vallis – AOS (Cooperative Program/Students) V. Ramaswamy – GFDL Director Steve Pacala – Princeton Environmental Institute Director
10:45 – 11:00	**Coffee Break**
11:00 – 12:00	**CICS-P Science Presentations:** Sonya Legg – **Ocean mixing: process studies and climate model parameterizations** Alistair Adcroft – **Projections of underwater oil plumes from *Deepwater Horizon*** Charlie Stock - **Interactions between climate and marine ecosystems**
12:00 – 1:00	**Lunch**

1:00 – 2:00	**CICS-P Science Presentations:** James Smith – **The Climatology of Extreme Rainfall and Flooding from Landfalling Tropical Cyclones** Olga Sergienko – **Ice sheets as a part of the climate system** David Medvigy – **Seasonal variability in forest leaf area and its consequences for terrestrial carbon budgets**
2:00 – 3:00	**Discussion with Senior Researchers:** Leo Donner, Steve Garner, Gabriel Lau, Robert Hallberg, Larry Horowitz and Tom Delworth (GFDL); Sonya Legg (AOS)
3:00 – 3:30	**Coffee Break**
3:30 – 4:30	**Discussion with Postdocs and Graduate Students:** *Graduate Students:* Andrew Ballinger, Amanda O'Rourke, Ilissa Ocko, Joe Majkut, Spencer Hill *Researchers:* Claudie Beaulieu, Martin Jucker, Sarah Kapnick Rym Msadek, David Paynter, Olga Sergienko, Allison Smith
4:30 – 5:30	**Poster Session** *Graduate Students:* Andrew Ballinger, Amanda O'Rourke, Ilissa Ocko, Sam Potter, He Wang, June Yeung, Joe Majkut *Researchers:* Alistair Adcroft, V. Balaji, Claudie Beaulieu, Massimo Bollasina, Jan-Huey Chen, Takeshi Doi, Yalin Fan, Lucas Harris, Mehmet Ilicak, Su-Jong Jeong, Martin Jucker, Sonya Legg, Meiyun Lin, Angelique Melet, Caroline Muller, David Paynter, Olga Sergienko, Elena Shevliakova, Allison Smith
5:30 – 6:30	**Executive Session (breakout for reviewers)**
6:30 – 8:30	**Dinner with Executive Committee and Senior Leaders:** Jorge Sarmiento, Geoff Vallis, V. Ramaswamy, Steve Pacala, James Smith, Brian Gross, A. J. Stewart Smith, CICS-P Reviewers and NOAA Managers 7

Friday, November 4, 2011

8:00 – 8:40	**Breakfast at hotel**
8:45 – 9:00	**Travel to Forrestal Campus**
9:00 – 9:45	**Tour of GFDL/AOS**
9:45 – 10:00	**Break**
10:00 – 11:00	**Executive Session with CICS-P:**

	Jorge Sarmiento and Geoff Vallis
11:00 – 12:00	**Executive Session with NOAA**
12:00 – 1:00	**Lunch**
1:00 – 4:00	**Review Panel Executive Session (conference room)**
4:00	**Debrief**