**Testimony of Jack D. Fellows, Ph.D.**
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**Select Committee on Energy Independence and Global Warming**
**"Investing in the Future: R&D needs to meet America's Energy and Climate Challenges"**
**10 September 2008**

Mr. Chairman and Members of the Select Committee:

Thank you for the opportunity to testify before your Committee on this important topic.

I am Jack Fellows, Vice President of the University Corporation for Atmospheric Research, a non-profit consortium of over 70 universities involved in weather and climate research and applications. I joined UCAR in 1997 after overseeing many of the federal weather and climate related agencies and interagency programs for many years in the Office of Management and Budget But today, I'm summarizing a *transition document* that provides program, management, and budget recommendations to the next administration and Congress on R&D needs to meet our nation's energy and climate change challenges – and more specifically how to make our nation more resilient to severe weather and climate change (floods, tornadoes, hurricanes, drought, sea level rise, etc.).

Our 50 states are battered by billions of dollars in weather and climate related damages and losses each year and it isn't fully clear how these impacts will change as the climate changes. The threats associated with extreme weather and climate change are substantial and adapting to climate change will be crucial to economic and social stability, in particular making future water, food and energy supplies reliable and sustainable. Our concern is that our nation is not prepared to adapt to climate change and related severe weather. Decision makers need local and regional scale information, but our models are hampered by the lack of research, observations, and computing at this scale.

The *transition document* is entitled *Advice to the New Administration and Congress: Actions to Make Our Nation Resilient to Severe Weather and Climate Change* and was produced by the following organizations:

- University Corporation for Atmospheric Research
- Weather Coalition
- American Meteorological Society
- American Geophysical Union
- Consortium of Universities for the Advancement of Hydrologic Science
- National Association of State Universities and Land-Grant Colleges
- Consortium for Ocean Leadership
- Alliance for Earth Observations

These organizations represent thousands of experts in the public, private, and academic weather and climate enterprise and they have undertaken this task for a variety of economic, public health and safety, and national security issues that are highlighted in *transition document*. These partners are also collecting nominations for key weather and climate leadership positions in the next administration and will provide those nominations as the transition progresses.

At this Committee's 31 July 2008 hearing entitled, "Renewing America's Future: Energy Visions of Tomorrow, Today", my respected colleague, Dr. Aristides Patrinos, stated, "Our nation and the world stand at an important crossroads. Decisions we make during the next few years will affect the trajectory

of human civilization well into the next century." Dr. Patrinos outlined the world's increasing demand and reliance on oil from unstable parts of the world, the alarming increase in global atmospheric concentrations of carbon dioxide, and the 2007 Intergovernmental Panel on Climate Change's conclusions that warming of our climate system is unequivocal, as evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.

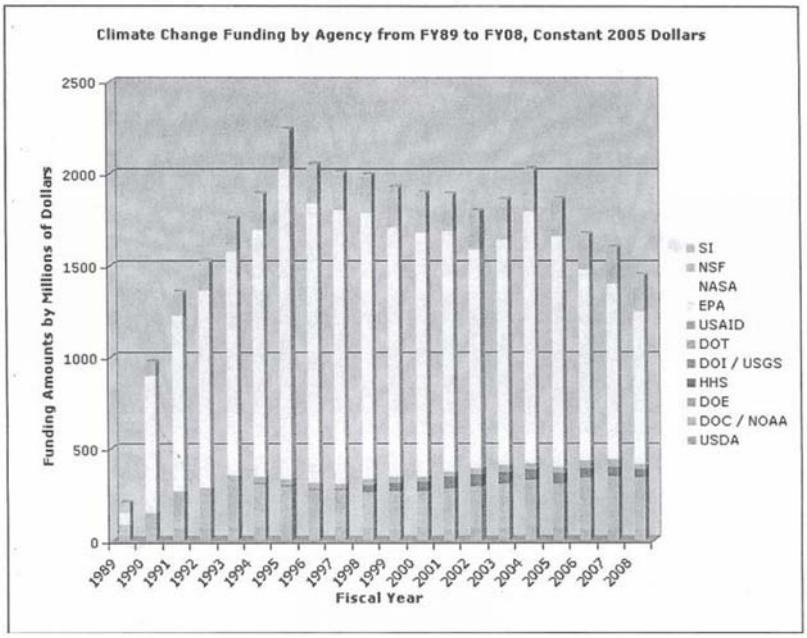
Our organizations share this concern that our nation is standing at a defining moment in human history. We believe that having the science and policy tools to make our nation more resilient to weather and climate hazards must be a critical component of our country's energy and climate strategy. Many of our weather and climate research and operations programs have suffered through years of declining budgets at the very time we need improved weather and climate tools and information to: (1) help local and regional decision makers, (2) support the implementation of carbon emission reduction proposals (e.g., cap-and-trade), and (3) help build a prosperous carbon-free economy (e.g., wind and solar forecasting). In the mean time, local and regional decision makers are moving forward with inadequate information and in the face of substantial climate impacts and adaptation feedback uncertainties — feedbacks that may prove very costly to civilization (e.g., polar ice melting faster than expected, massive carbon release in a warming Arctic, hurricane intensity forecasting shortfalls like Hurricane Gustav, etc.).

The hearing questions provided to me by the Select Committee are addressed thoroughly in the *transition document*, which can found at www.ucar.edu/td. I'm also submitting that document and its program, management, and budget recommendations as the balance of my testimony after the following brief responses to the hearing questions:

1. What is the current investment in the Earth observations and climate modeling in the United States? How does this compare with past funding? How does this compare with funding in other countries?

   **Response:** Unfortunately, there isn't a centralized inventory of Earth observations and climate modeling programs in our country, so reliable estimate are very difficult to find. Having this type of Federal-wide inventory and coordination is a major recommendation of the *transition document*. In the absence of such a complete inventory, the Climate Change Science Program (which grew out of the U.S. Global Change Research Program) provides the best estimate we have today, although it does not include all the pieces (e.g., operational weather budgets in NOAA). That said, we hope the 13 agencies involved in CCSP will have a budget around $1.9 billion in 2009 and beyond (see the budget recommendations in the *transition document*). The graph entitled "History of

History of USGCRP/CCSP Funding



USGCRP/CCSP Funding" shows how this funding has changed over time. Currently, we are roughly back to the levels of funding when the USGCRP was initiated in the early 1990s. So, the funding gains have largely been lost over the past decade and this has happened for a variety of reasons. I'm not familiar with the current Earth observation and climate modeling funding in other countries. In the past, it has been roughly equivalent to the U.S. investment.

2. In your view, what investments are needed going forward to meet our energy and climate challenges? **Response:** The transition document makes the following recommendations to help make our nation resilient to severe weather and climate change:
   a. **Observations.** Fully fund the satellite and ground-based observations recommended by the National Research Council.
   b. **Computing.** Greatly increase the computer power available for weather and climate research and operations.
   c. **Research and Modeling.** Support weather and climate research and modeling to advance our understanding of these events and their impacts on society.
   d. **Societal Relevance.** Support education, training, and communication efforts on how to use the weather and climate tools and information to the maximum benefit of society.
   e. **Leadership and Management.** Implement effective leadership, management, and evaluation approaches to ensure that these investments are done in the best interest of the nation.

   These recommendations are based on community documents (e.g., National Research Council) and will require an investment of roughly $9 billion between 2010-2014 to implement. Please see the *transition document* for more details on these investments, in particularly the budget table and budget explanations in the *Budget Estimates* section of the *transition document*.

3. What, if any, new policies are needed to support and optimize this investment? **Response:** Leadership will be a key ingredient to support and optimize these investments. That is why the *transition document* partners are collecting nominations for key weather and climate related position in the next administration. The document makes a broad range of leadership and management policy recommendations to ensure that these investments are made wisely and effectively. Many of the authors of the *transition document* have been extensively involved in trying to focus and coordinate these activities and fully understand what is needed to implement these recommendations. Please see the transition document's *Recommendation 5 (Leadership and Management)* section for our policy recommendations on how to support and optimize these investment, including a set of proven policy and management tools that have not be available for roughly the last decade.

4. What is the role of America's universities in supporting and providing Earth observations and climate modeling? How can the government and private industries work with universities to maximize return for investments in these areas? **Response:** As you will read in the *transition document*, implementing the document's recommendations will require the involvement of all sectors of the weather and climate enterprise (private, public, and academic) and these respective roles are outlined throughout the document.

## Advice to the New Administration and Congress: Actions to make our Nation resilient to severe weather and climate change

*"Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability."* — *National Research Council, 2007*

**Executive Summary.** Our organizations represent thousands of experts in the public, private, and academic weather and climate enterprise and we fully agree with the National Research Council position above (see "Sponsoring Organizations" on the last page). Over the past year, our organizations have developed this document to help guide the transition to the next Administration and Congress. This document provides recommendations and budget estimates for what is needed to make our nation more resilient to severe weather and climate change. We have undertaken this task for the following reasons:

1. Our health, safety, economy, environment, transportation systems, and national security continue to be battered by billions of dollars in weather-related damages and losses each year.
2. Mayors, governors, and local decision makers trying to plan for climate change and related weather changes need help—they are not waiting for the federal carbon emission reduction debates to conclude.
3. Implementing carbon emission reductions (e.g., cap-and-trade, carbon tax, etc.) or moving to a prosperous carbon-free economy will be inhibited by the lack of weather and climate tools and information (e.g., carbon monitoring, forecasts for green industries, etc.).
4. Substantial uncertainties remain over climate impacts and adaptation feedbacks—feedbacks that may prove very costly to civilization (e.g., the release of carbon frozen in a warming Arctic that will dwarf the human carbon contribution to the atmosphere).
5. Science is key to understanding these impacts, but funding for weather and climate research and operations has been flat or declining for years due to the budget debates in Washington.

Understanding these regional and local climate and severe weather impacts and having the science and policy tools to make our nation more resilient to these hazards must be a high priority for our country. To achieve this goal, the next Administration and Congress must:

1. **Observations.** Fully fund the Earth observing system from satellite and ground-based instruments as recommended by the National Research Council.
2. **Computing.** Greatly increase the computer power available for weather and climate research, predictions, and related applications.
3. **Research and Modeling.** Support a broad fundamental and applied research program in Earth sciences and related fields to advance present understanding of weather and climate and their impacts on society.
4. **Societal Relevance.** Support education, training, and communication efforts to use the observations, models, and application tools for the maximum benefit of society.
5. **Leadership and Management.** Implement effective leadership, management, and evaluation approaches to ensure that these investments are done in the best interest of the nation.

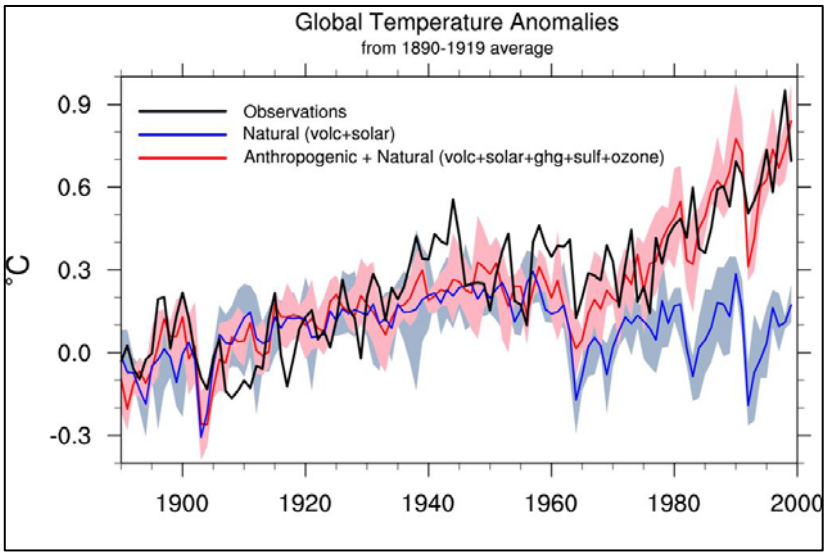
This document is intended to provide the next Administration and Congress with the information needed to understand this challenge our nation is facing. Implementing these recommendations over the

next five years will cost roughly $9 billion beyond what our nation is planning to invest in this area between 2010 and 2014 and will require the involvement of all sectors of the weather and climate enterprise (private, public, and academic). Our goal is to provide this document to transition teams and other interested parties to help guide them in this important area of weather and climate. Below you will find the needed details on how to best implement these recommendations, including specific management actions and budget estimates. We are collecting nominations for key weather and climate leaders to be provided to the next Administration.

**Economic, Security, and Societal Impacts of Weather and Climate on Our Nation.** More than 75 percent of natural disasters around the world are triggered directly or indirectly by weather and climate. Each year, our nation sustains billions of dollars in weather-related damages associated with hurricanes, tornadoes, forest fires, flooding, heavy snows, and drought. All 50 states are affected, and many of these events will be exacerbated by climate change. Hurricane Katrina, the multiple year droughts in the southeastern and southwestern United States, the 2007 and 2008 California wildfires, the record number of tornadoes in 2008, and the 2008 Midwest floods all show the devastating impacts on our nation's people and economy. These events have caused $100s of billions in losses and disrupted millions of lives.

With more than a quarter of the U.S. gross national product (over $2 trillion) sensitive to weather and climate, these events substantially impact our national health, safety, economy, environment, transportation systems, and military readiness. While the threats associated with extreme weather and climate change are substantial, adaptation measures will provide crucial economic stability, for example by making future water, food, and energy supplies reliable and sustainable. We want to both help the decision makers facing these challenges (practical applications) and fully understand the process and uncertainties associated with these changes (basic knowledge).

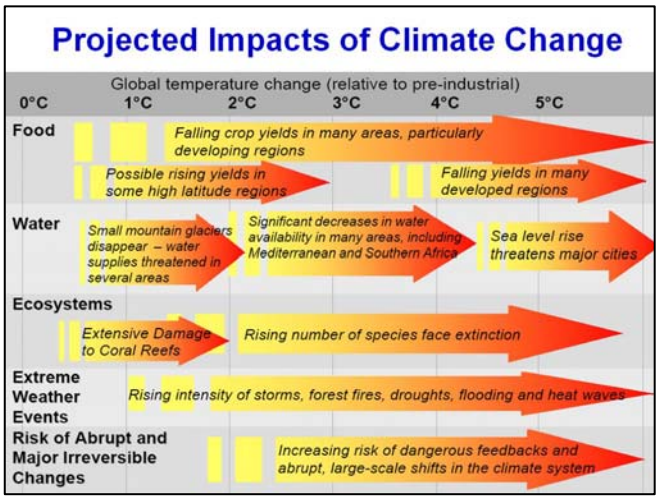
**How are the Climate and Weather Changing?** Greenhouse gases such as carbon dioxide are beneficial to life on Earth. They have kept our planet within a reasonable temperature range for thousands of years. However, rapid increases in greenhouse gases can produce a new, warmer climate that can be challenging to life in many ways. Indeed, both greenhouse gases and temperatures are currently increasing at alarming rates. It is clear from models and observations that without greenhouse emissions from human activities we cannot fully explain the dramatic temperature increases since the 1960s. This is demonstrated in the Global Temperature Anomalies graph produced by the NCAR/DOE Parallel Climate Model and presented in a



2004 paper by Meehl et. al. in the Journal of Climate (Vol. 17 3721-3727). The black line represents actual observations; the blue line represents model output with only natural forcing; and the red line represents model output with natural and human forcing. This graph is based on a model that clearly reproduces the historical climate quite well. Similar analyses are being produced by hundreds of scientists around the world. These scientists get together every four years to examine the state-of-knowledge of climate science and its relevance to society and policy through the Intergovernmental Panel on Climate Change (IPCC). The IPCC shared the 2007 Nobel Peace Prize for its work. This level of warming is becoming evident in dramatic ways, for example in the retreat of the Upsala glacier in Argentina between 1928 and 2004 shown in these images taken by Dr. Lonnie Thompson from Ohio State University.

Upsala glacier in the Andes, Argentina

As will be described in more detail below, we are being hampered in our efforts to understand the impacts of these changes by lack of political leadership and needed resources for science, observation, and computing. That said, the IPCC and the U.S. Climate Change Science Program have attempted to evaluate what the impacts of various temperature changes might be on key human resources (food, water, ecosystems, extreme weather events, etc.—see Projected Impacts box). We need better answers to these impact questions and we need them soon. For more details on understanding climate change, see the NRC report entitled *Understanding and Responding to Climate Change 2008 Edition* (http://dels.nas.edu/dels/rpt_briefs/climate_change_2008_final.pdf)




The 2007 IPCC report documents how humans are contributing to climate change and notes that we are already committed to a significant level of climate change over the next few decades regardless of our near-term mitigation strategies (e.g., controlling greenhouse gas emissions). In addition, a recent scientific report concludes that climate change and global warming will almost certainly lead to more extreme weather and climate events (http://www.climatescience.gov/Library/sap/sap3-3/final-report/default.htm ):

- Abnormally hot days and nights, along with heat waves, are very likely to become more common.
- Cold nights are very likely to become less common.
- Sea ice extent is expected to continue to decrease and may even disappear in the Arctic Ocean in summer in coming decades.
- Precipitation, on average, is likely to be less frequent but more intense.
- Droughts are likely to become more frequent and severe in some regions.
- Hurricanes will likely have increased precipitation and wind.

- The strongest cold-season storms in the Atlantic and Pacific are likely to produce stronger winds and higher extreme waves.

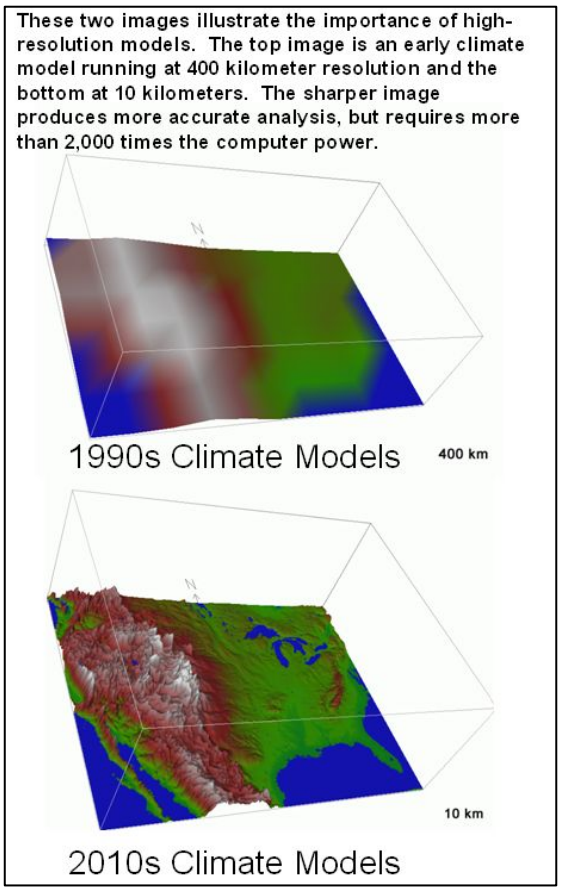
Even the national security community is expressing concerns about these matters. On June 25, 2008, before a joint hearing involving the House Permanent Committee on Intelligence and the House Select Committee on Energy Independence and Global Warming, the chairman of the National Intelligence Council said,

> *From a national security perspective, climate change has the potential to affect lives (for example, through food and water shortages, increased health problems including the spread of disease, and increased potential for conflict), property (for example through ground subsidence, flooding, coastal erosion, and extreme weather events), and other security interests. The United States depends on a smooth-functioning international system ensuring the flow of trade and market access to critical raw materials such as oil and gas, and security for its allies and partners. Climate change and climate change policies could affect all of these—domestic stability in a number of key states, the opening of new sea lanes and access to raw materials, and the global economy more broadly—with significant geopolitical consequences.*

**Build on the strengths of the weather and climate enterprise.** We must have a 21st century program of Earth observations, science, and information to guide policy choices and to determine whether these choices are having the desired effects. Building on advances in observing systems and forecasting skills over the past three decades, government, industry, and policy makers at all levels can potentially implement much more effective strategies to deal with weather and climate challenges. But we are faced with significant hurdles to achieve that objective, including:

- Federal law requires the President to develop a coordinated national policy on global climate change. Yet, coordination of federal weather and climate activities remains inadequate. A recent National Research Council evaluation of the U.S. Climate Change Science Program concluded that while our ability to predict climate change has improved, our understanding of the impacts on society is "relatively immature" (see the NRC *Understanding and Responding to Climate Change 2008 Edition* report).

- Policy debates and emerging legislative initiatives are calling for global change research that is more relevant to decision makers. However, creating integrated atmosphere-ocean-land predictions that are relevant to local and regional decision making is hampered by the lack of key Earth observations, computer resources, and ways to merge science output with management tools in water, agriculture, transportation, and other sectors. There has been an erosion of key observational and science programs at NASA, NOAA, and NSF at precisely the time when they are most needed. In addition, these science programs will be crucial in developing and monitoring the success of current and



These two images illustrate the importance of high-resolution models. The top image is an early climate model running at 400 kilometer resolution and the bottom at 10 kilometers. The sharper image produces more accurate analysis, but requires more than 2,000 times the computer power.

proposed climate policy initiatives, such as carbon cap-and-trade systems or a carbon tax.

- We are particularly disappointed with the outcome of the Fiscal Year 2008 federal budget and the outlook for Fiscal Year 2009. In the years when we need to be making substantial progress understanding the processes underlying climate change and severe weather and how we might mitigate or adapt to these changes, Congress and the Administration have produced omnibus budgets that substantially cut these programs. Those reductions occurred even though Congress and the Administration had proposed substantial increases for these programs in individual appropriations bills. Partisan politics should not prevent scientific progress and the training of the next generation of leaders in this important area given how rapidly things are changing around the world. For example, reductions of Arctic sea ice are occurring faster than climate models predict, and we don't really understand why. Some models are predicting an ice-free Arctic Ocean in the 2030s, and we don't fully understand how this influences other related impacts that may occur in this same time frame (e.g., the release of vast amounts of carbon and methane frozen into melting tundra).

**Recommendation Implementation.** To implement the recommendations above will require three critical ingredients: (1) strong leadership, (2) effective management, and (3) adequate and wisely invested resources. The rest of this document will provide guidance on these three areas for each of our recommendations.

- **Recommendation 1 (Observations): Fully fund the Earth observing system from satellite and ground-based instruments as recommended by the National Research Council (NRC).** Observations from both space and the ground are key to monitoring climate and weather variables and developing climate and weather models. These observations will be essential in monitoring the progress and success of any carbon emission reduction initiative (e.g., cap-and-trade). The NRC has produced two community documents that the next Congress and Administration should strongly support (see budget estimates for this recommendations below):
  - **Space.** The study entitled *Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond* (http://books.nap.edu/catalog.php?record_id=11820)
  - recommends that: "*The U.S. government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth-observing systems and restore its leadership in Earth science and applications.*" This report is often referred to as the Earth sciences "Decadal Survey." This community report prioritizes the needed satellite observations for the foreseeable future, including seventeen that must be undertaken if we hope to understand and monitor critical environmental issues related to climate change and severe weather.
  - **Ground.** An NRC study, entitled *Observing Weather and Climate From the Ground Up, A Nationwide Network of Networks* will recommend a national public-private partnership to renew our strategic investment in ground-based, storm-scale observing systems that are crucial to the prediction of extreme weather, the health and safety of our citizenry, and the impacts of local climate and climate variability. This report is scheduled to be released by the NRC in September–October 2008 and we anticipate will include budget estimates for ground-based observing systems that are essential to severe weather prediction and modeling (e.g., radar technologies).

- **Recommendation 2 (Computing): Greatly increase the computer power available for weather and climate research, predictions, and related applications.** As mentioned above, current

climate models do a reasonable job of providing useful information at the global level, but most climate change and severe weather impacts will be managed at local and regional levels (e.g., public health and safety, water and ecosystem management, energy production and use, food production, transportation services, recreation opportunities, military readiness). To provide this level of information will require a better understanding of local and regional user needs and computer models that perform effectively at this scale (i.e., 10 kilometer versus today's 100 kilometer). There are computers today that can perform at this level (petascale computers), but the climate community does not have enough access to them to meet the demand of modeling climate at these local and regional scales. Such high-resolution computers and model codes can also be used for severe weather to improve forecast for hurricane intensity and landfall, tornadoes, and winter storms, which continue to put many thousands of American lives at risk each year. NASA, NSF, NOAA, and DOE are all involved in climate modeling and the coordination of these efforts must be improved (Recommendations 5). See budget estimates for this recommendation below.

- **Recommendation 3 (Research and Modeling): Support a broad fundamental and applied research program in Earth sciences and related fields to advance present understanding of weather and climate and their impacts on society.** To support all of these recommendations will require the next Administration and the Congress to provide adequate resources for key federal agency weather and climate programs. Most of the proposed climate and energy policy legislation, like the Lieberman-Warner Climate Security Act of 2008 (S.3036), will require these key science programs to implement and evaluate progress. We don't start from zero—the U.S. Global Change Research Program (USGCRP) and the Climate Change Science Program (CCSP) provide a substantial base of funding to work from. See budget estimates for this recommendation below.

- **Recommendation 4 (Societal Relevance): Support education, training, and communications efforts to use the observations, models, and application tools for the maximum benefit of society.** We need to support programs that teach children at an early age to collect, analyze, and apply data to pressing environmental problems in a way that will help develop the next generation of environmental leaders. We also need to equip emergency managers and other public and private officials with the needed tools and information to make local and regional decisions. Years ago, a national climate assessment was undertaken to establish and better understand these partnerships between users, researchers, and providers. This national assessment should be reinvigorated. The process could begin with a national dialog led by the American Meteorology Society and University Corporation for Atmospheric Research to help define the goals of the assessment. That dialog could be one national meeting or several regional meetings, but should involve all stakeholders—scientists, political leaders, and users and providers of weather and climate information. See budget estimates for this recommendation below.

- **Recommendation 5 (Leadership and Management): Implement effective leadership, management, and evaluation approaches to ensure that these investments are done in the best interest of the nation.** Our recommendations are not just about funding—equally important will be key leaders and effective management to implement these programs:
  - **Leadership.** Strong, qualified leaders must be appointed to top policy positions. Most important, an experienced and knowledgeable leader coordinating the overall federal effort should report directly to the President. This leader will need to understand that all sectors of the research and operational weather and climate enterprise (public, private, and academic) are needed to address these issues. Similarly, it will be vital for the new leaders in all the involved agencies to understand weather and climate issues and support a CCSP/USGCRP-like interagency process (see Management below). Our organizations have collected nominations

for key weather and climate leadership positions and stand ready to provide them to the new Administration and Congress. With respect to our Earth observation recommendations, the United States has played a significant leadership role in developing the Global Earth Observing System of Systems though the international Group on Earth Observations or GEO (http://www.earthobservations.org/geoss.shtml). International cooperation on these critical global observations is extremely important, and U.S. leaders must continue to be involved and lead in the GEO process.

- **Management.** The Executive Branch offices and federal agencies must take more leadership in coordinating weather and climate programs, including OMB, OSTP, NOAA, NASA, NSF, USDA, DOE, DOI, DOT, and EPA. The USGCRP (www.usgcrp.gov) has existed since the late 1980s and has made substantial progress on understanding Earth processes and coordinating the federal agency efforts in this area. This multi-agency effort worked best in the years when there was a strong partnership between the research agencies and OMB/OSTP that supported an effective, integrated program and budget approval process. **We are recommending that the next Administration and the Congress adopt the very best management tools from the USGCRP/CCSP's history and create CCSP Version 2.0:**
    1. The leader of this effort should report to the President and at a level equivalent to an economic or national security advisor. The leader must have an effective staff, enough of a budget to influence the agency programs in key priority areas, the ability to get outside advice from the broad weather and climate enterprise, and an open and transparent manner of conducting business.
    2. OMB/OSTP and agency leaders should be selected to support this critical interagency process and OMB/OSTP staff should be given the authority, resources, and time to support it. OMB, in particular, should examine how it is structured to ensure that the involved agencies are overseen in an effective, integrated fashion. In the past, differences between key OMB leaders have eroded the effectiveness of this interagency process.
    3. OMB/OSTP should implement an annual integrated weather and climate program and budget review and submit an integrated program plan and budget to the Congress as part of the President's budget.
    4. These programs should be considered national priorities and protected from internal agency budget cuts and tradeoffs. This should be implemented via the normal OMB budget development and passback process.
    5. The U.S. Global Change Research Program Act of 1990 may need to be updated to reflect a greater focus on adaptation and to ensure that the critical management approaches mentioned above are followed.
    6. Other related management issues:
        - **The Role of OSTP.** The Woodrow Wilson International Center for Scholars recently produced a report entitled *OSTP 2.0* that outlines the key role the President's science advisor should play in this area and how proven interagency management and review mechanisms should be applied (http://wilsoncenter.org/news/docs/OSTP%20Paper1.pdf). We support the recommendations in *OSTP 2.0*. There are many people in our organizations who played key roles in these past interagency efforts and can provide additional guidance on their effective implementation.
        - **An Earth System Agency.** The USGCRP interagency process that worked so effectively in the 1990s can clearly be reimplemented today with the right leadership. However, there have also been proposals to create a national climate service or an

Earth system science agency (e.g., combining NOAA and the USGS—http://www.sciencemag.org/cgi/content/full/321/5885/44) or make changes to the interagency process (e.g., S.2037, S.2355, H.R.906, etc.). There are many options that should be examined (e.g., run within an agency, led by an agency, led by an interagency federation, run by a non-profit with federal sponsorship, etc.) These are bold and creative ideas that have strong merit and should be seriously considered—provided they don't divert attention from the real problem of consistent underfunding of these weather and climate research and operational programs. Our community has provided feedback on the merits and shortcomings of these proposals and would welcome the opportunity to provide this input to the new Administration and Congress.

- **Research to Operations Transitions.** For years, the hope has been that NASA and NOAA would develop a comprehensive strategy to transition research satellites into operational NOAA weather and climate satellites. To date, this has not happened effectively for a variety of reasons, including budget constraints and agency mission differences. The issue is too important to leave to chance or agency culture. Leaders must be chosen for these agencies who will support these important transition issues or, perhaps, the functions need to be folded into the Earth System Agency mentioned above.
- **Climate Models and Computing.** We do not support a single climate modeling or climate computation center. Our nation has four key climate modeling groups (NSF's National Center for Atmospheric Research, NOAA's Geophysical Fluid Dynamics Lab, NASA's Goddard Institute for Space Studies, and DOE lab contributions to both climate modeling and computing). These groups serve distinctly different communities and purposes (e.g., NCAR serves the broad university community and GFDL works with NOAA on application activities). Our nation has been well served by having several groups because: (1) history shows that an average across several models outperforms a single model, (2) competition between groups spawns creative innovation, (3) modeling groups can take very different and equally important approaches, and (4) having multiple models and entry points permits more people to participate in model development. Today, it takes roughly $20 million per year to support a cutting-edge climate modeling group (that sum does not include observations or computing). All these groups will need access to computational resources that can be "tuned" and dedicated to very specific climate modeling efforts. Some groups will continue to develop critical high-resolution global climate models, while others will work at "nesting" advanced weather models into climate models to provide very specific local and regional information about climate change. Some efforts will be for research and others will have an operational focus. All of these approaches are extremely important, but will have very different computational needs and environments. A general petascale computational center designed for all scientific disciplines will not effectively support a national climate modeling effort. We strongly recommend that the national climate/weather computation and modeling effort be coordinated and managed within the CCSP Version 2.0 management principles and that the management structure include a mechanism to provide guidance from the climate modeling and user communities.

- **Evaluation.** We must have mechanisms to evaluate whether we are making progress toward creating and using knowledge that can help society adapt to climate change and severe weather. Congress should vigorously exercise its oversight responsibilities to assist in the implementation

of these and other policy recommendations. We also call for the establishment of a presidential committee that will advise, assess, and report on progress toward the recommendations mentioned above and on their impacts with respect to national policy. This high-level advisory committee should include representatives from across the weather and climate enterprise, including the public, private, and academic sectors.

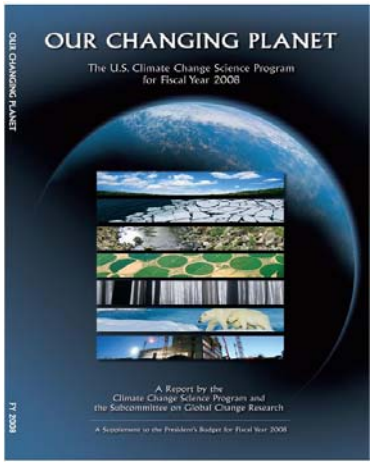
**Budget Estimates.** Below you will find our best estimate and explanations for what it will cost to implement our recommendations. These estimates are based on several key community documents:

1. The Decadal Study and Ground-based Study mentioned above,
2. The US Climate Change Science Program's FY 2008 report entitled *Our Changing Planet* (www.usgcrp.gov/usgcrp/Library/ocp2008), and
3. The *Ocean Blueprint for the 21st Century* (www.oceancommission.gov).

Implementing these recommendations over the next five years will cost roughly $9 billion beyond what our nation is planning to invest in this area between 2010 and 2014. Given the substantial impact severe weather and climate change are projected to have on our nation, we believe these are critical investments toward better local and regional information and a nation that is more resilient to severe weather and climate change impacts. Some of these investments could be paid for by the "climate funds" being created in various climate and energy policy legislation (e.g., from the auction of carbon offsets) and some of them can be supported by reprioritizing efforts in the U.S. Climate Change Science Program. New leaders will need to review these estimates and determine the next level of needed detail and prioritizing. We can provide additional details on any of these estimates.

| Weather & Climate Transition Budget ($ in Millions) | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2010-2014 Totals |
|---|---|---|---|---|---|---|---|---|---|---|
| Continue CCSP Base Funding | 1,692 | 1,822 | 1,837 | 1,910 | 1,910 | 1,910 | 1,910 | 1,910 | 1,910 | **9,550** |
| Provide Critical CCSP Increment | 0 | 0 | 0 | 0 | 143 | 267 | 397 | 536 | 682 | **2,026** |
| Fund the NRC Decadal Survey | 0 | 0 | 0 | 0 | 272 | 596 | 975 | 1,038 | 803 | **3,684** |
| Fund the NRC Ground-based Study | 0 | 0 | 0 | 0 | TBD | TBD | TBD | TBD | TBD | **TBD** |
| Restore Climate Sensors to NPOESS/GOES-R | 0 | 0 | 0 | 74 | 92 | 181 | 227 | 258 | 333 | **1,091** |
| Upgrade Climate/Weather Supercomputing | 0 | 0 | 0 | 0 | 75 | 100 | 150 | 200 | 200 | **725** |
| Fund the NOAA Integrated Ocean Observing System | 0 | 0 | 0 | 21 | 138 | 260 | 385 | 480 | 500 | **1,763** |
| Fund the NSF Ocean Observation Initiative | 0 | 0 | 0 | 0 | 31 | 80 | 90 | 95 | 30 | **326** |
| Restore National Flood Warning/Forecasting Capabilities | 0 | 0 | 0 | 20 | 25 | 35 | 40 | 55 | 80 | **255** |
| **Subtotal** | **1,692** | **1,822** | **1,837** | **2,025** | **2,686** | **3,428** | **4,175** | **4,572** | **4,538** | **19,400** |
| **2010-2014 Needed Increment** | **0** | **0** | **0** | **0** | **661** | **1,403** | **2,150** | **2,547** | **2,513** | **9,275** |

Our estimates are based on the following imperatives:

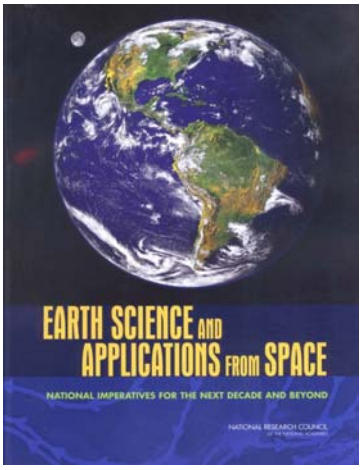



1. **Operational Weather Budgets.** Agency funds that aren't traditionally part of the CCSP, but are critical to weather and climate research and operations, must be continued (e.g., much of NOAA's operational weather budget is not part of the CCSP).

2. **Continue CCSP Base Funding and Provide Critical CCSP Increments.** The CCSP (which was built upon the USGCRP) has been a critically important interagency research and assessment program since the early 1990s, and *Our Changing Planet* provides budget estimates for the 13 federal agencies involved in the CCSP. We expect the funding for the CCSP to be roughly $1,910 million in 2009. This base funding must be continued, but the increments are

needed to undertake a broad range of unfunded activities, including the development of a national climate service, critical national weather and climate modeling efforts, moving toward helping local and regional decision makers, and much more. We also believe that an enhanced CCSP interagency management process as mentioned above is critical. These investments are needed to implement Recommendations 3, 4, and 5. The CCSP goals during this period are:

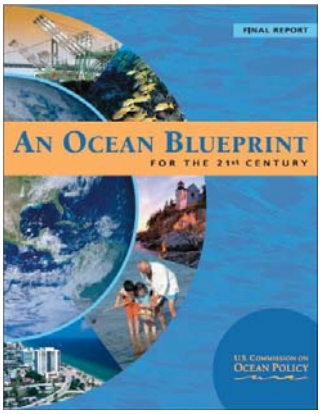
a. Improve knowledge of the Earth past/present climate.
b. Improve quantification of climate forces.
c. Reduce uncertainty in climate projections.
d. Understand the sensitivity and adaptability of different natural/managed/human systems to climate change.
e. Explore abilities to manage risk and opportunities of climate change.




3. **Fund the Decadal Survey and Ground-based Study Recommendations.** The Decadal Survey recommends and prioritizes 17 satellite missions that need to be flown in the 2009–2020 timeframe to adequately capture our planet's vital signs. Our budget estimates include the missions proposed for the 2010–2014 time period that are not included in the CCSP. The Ground-based Study will be released in September–October 2008. Our document will be updated to reflect those key recommendations and budget estimates once they are available. While we can't predict the study's recommendations, we anticipate that they will include new radar and other technologies that are critical to severe weather and climate monitoring. These investments are needed to implement Recommendation 1.

4. **Restore the climate related sensors on NPOESS and GOES-R satellites.** The climate-related sensors were dropped from the NPOESS and GOES-R operational satellites due to budget overruns and were not part of the CCSP funding. These estimates include the resources to put these sensors back on these important operational satellites. These investments are needed to implement Recommendation 1.

5. **Upgrade Climate and Weather Supercomputing.** One of the biggest constraints to providing local and regional decision makers with critical information to make our nation more resilient to the impacts of severe weather and climate has been the lack of dedicated supercomputers to run finer-resolution weather and climate models. These are our best estimates of what could be responsibly spent given expected constraints in computing technologies, software tools, and human resources. These funds should be invested in NSF, NOAA, NASA, and DOE; should be reviewed in the CCSP Version 2.0 interagency process to ensure they are focused on key research and operational areas; and be consistent with the climate modeling management recommendations mentioned above. These investments are needed to implement Recommendation 2.




6. **Fund the NOAA Integrated Ocean Observing System and NSF Ocean Observatories Initiative.** These two important initiatives are not included in the current CCSP and are highly recommended by the *Ocean Blueprint for the 21st Century* to make progress on ocean observations that are key to both weather and climate. These investments are needed to

implement Recommendation 1.

7. **Restore the National Flood Warning/Forecasting Capabilities.** Our nation's water programs have been underfunded for years, which has undermined our ability to issue flood and water quality warnings. Water will be a critical issue in the future as ecosystems are stressed by population growth, economic fluctuations, land use changes, and the impact of climate change. These issues were highlighted recently in a letter from over 30 public and private water associations (http://www.icwp.org/cms/gages/StreamgageLtr2HouseFeb2008.pdf). These investments are needed to implement Recommendation 1.

**Sponsoring Organizations**

This document was developed by the organizations below and we welcome others to join in this effort. This document can be found at: www.ucar.edu/td

- **University Corporation for Atmospheric Research** is a consortium of 71 universities located in Boulder, Colorado. http://www.ucar.edu/td Contact: Jack Fellows jfellows@ucar.edu
- **Weather Coalition** is an industry and academia group involved in advancing U.S. weather observation, prediction, and warning capabilities. www.weathercoalition.org. Contact: John Snow jsnow@ou.edu or Ray Ban RBan@weather.com
- **American Meteorological Society** is a scientific and professional organization dedicated to advancing the atmospheric and related sciences, technologies, applications, and services for the benefit of society. www.ametsoc.org Contact: Keith Seitter kseitter@ametsoc.org
- **American Geophysical Union** is a geophysical scientific association. www.agu.org Contact: Eugene Bierly EBierly@agu.org
- **Consortium of Universities for the Advancement of Hydrologic Science** is a consortium of over 100 universities involved in hydrologic sciences. http://www.cuahsi.org Contact: Richard Hooper rhooper@cuahsi.org
- **National Association of State Universities and Land-Grant Colleges** is nonprofit association of public research universities with member campuses in all 50 states and the U.S. territories. http://www.nasulgc.org Contact: Wendy Fink WFink@nasulgc.org
- **Consortium for Ocean Leadership** is a nonprofit consortium of 95 public and private ocean research education institutions, aquaria and industry with the mission to advance research, education and sound ocean policy. http://oceanleadership.org Contact: Kevin Wheeler kwheeler@oceanleadership.org
- **Alliance for Earth Observations** includes industry, academic, and non-governmental organizations working together to promote the understanding and use of Earth observations of societal and economic benefit. www.strategies.org. Contact: Nancy Colleton nancy_colleton@strategies.org