

**Statement of
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National Research Council of the National Academies**

**Testimony for the
Subcommittee on Space and Aeronautics
Committee on Science and Technology
U.S. House of Representatives**

June 28, 2007

Mr. Chairman, Ranking Minority Member Calvert, and members of the subcommittee: I appreciate the opportunity to provide this testimony on *NASA's Earth Science and Applications Programs: Fiscal Year 2008 Budget Request and Issues.* My name is Eric Barron, and I am Dean of the Jackson School of Geosciences at the University of Texas at Austin. I was also the Chair of the Climate Variability and Change Panel, which was one of the key components of the National Research Council (NRC)'s Committee on Earth Science and Applications from Space: A Community Assessment and Strategy for the Future.

Our most basic objective is to simultaneously protect life and property, promote economic vitality, and enable environmental stewardship. Regardless of our views on climate change, we all recognize that this objective is a balancing act. It is impossible to have billions of people on a planet and not have an environmental impact. Impact is also clearly associated with individual, regional and national levels of consumption. We also know that nations that have the strongest economies are the ones who are the most capable of adapting to change or mitigating its adverse consequences. Finding the optimum balance is enormously challenging and is in itself a subject of great debate. However, it becomes impossible if we lack sufficient knowledge of how the Earth operates. We need a commitment in two key areas if we are to achieve this most basic objective. First, we need to know how the components of the Earth are changing in response to human activity and natural forces. Second, we need to continue to improve our ability to "anticipate" or predict the future on a variety of time scales. If current climate projections are correct, climate change over the next ten to twenty years will have highly noticeable impacts on society and the demand on climate scientists will begin to broaden substantially. Impacts on agriculture, water resources, human health, and ecosystems are likely to drive a public demand for climate knowledge that is both sector (agriculture, health, water, etc.) and regionally dependent. It will be our ability to anticipate or forecast all of these elements in the future, and then to take appropriate action on these predictions with full understanding of their uncertainties, that can enable

us to simultaneously protect life and property, promote economic vitality, enable environmental stewardship, and help assess a broad range of policy options for decision-makers.

This view yields six key tenets that should define the observation systems of the future:

- (1) Sustained multi-decadal, global measurements and data management of quantities that are key to understanding the state of the climate and the changes taking place are crucial.
- (2) Climate change research, including the observational system, will be increasingly tied directly toward understanding the processes and interactions needed to improve our predictive capabilities and resolve the probabilities associated with different outcomes.
- (3) Evaluation and assessment of model capability will increasingly be the focus of future measurement activities. Demonstrating model capability is likely to be a driver for developing and evolving observation systems and field campaigns.
- (4) The link between climate research and societal benefit will require a much greater emphasis on higher spatial resolutions in climate predictions, observations, and assessments.
- (5) The “family” of climate observing and forecasting products will continue to grow, involving innovative research into societal connections with energy, agriculture, water, human health, and a host of other areas, creating new public and private partnerships.
- (6) The demand to understand the connection between climate and specific impacts on natural and human systems will require a more comprehensive approach to environmental observation and modeling in order to integrate the multiple stresses that influence human and natural systems (i.e. climate, land use, and other human stressors such as pollutants).

The importance of climate information is clear. As economic impact from climate change grows there will likely be both a change in research emphasis and a demand for much greater investment in climate research. Yet, the NASA investment in climate research and observation is in serious decline. We will enter the next decade with an observing system that is substantially less capable than we had at the start of the 21st century.

The specific questions provided by the Subcommittee help elucidate this issue and I am pleased to answer them to the best of my ability.

- (1) What is NASA’s contribution to the U.S. Climate Science Research Program in terms of percentage of overall expenditures and percentage of sensors dedicated to studying Earth’s Climate? What fraction of the world’s effort on climate change research does NASA’s contribution represent?**

At the start of the U.S. Global Change Research Program, considerable effort was invested in labeling the contributions of each federal agency to the components of global change research including climate. Further, this analysis identified contributions to the

observing and modeling components of the investment in climate research. In 1992, NASA contributions were approximately 70% of the total USGCRP budget, with more than a third of the total USGCRP budget focused on climate and hydrology observations provided by NASA (about 400 million dollars of a total budget of 1,185 million). A decade later, growth in NASA investments in USGCRP kept pace with the growth in the total budget, and also kept pace in terms of the investment in climate research. In the FY08 request, NASA's investment is about 60% of the total Climate Change Science Program (CCSP) and the total CCSP budget request is about 6.5% above the 2002 USGCRP budget (figures not adjusted for inflation). The full set of segmented disciplinary topics within the USGCRP set of cross-cuts is combined into one CCSP budget. More telling is an analysis of the out-year budgets with their associated numbers of missions and instruments. Even with the extension of some current missions beyond their nominal life times, by 2010 the U.S. will have a 35% decrease in the number of operating sensors and instruments on NASA spacecraft. By 2015, the number will have decreased by more than 50%. In real dollars, NASA Earth Sciences has declined by more than a half a billion dollars since the 2002 USGCRP budget.

The total international investment in climate science is difficult to confirm with certainty by the science community, but NASA has always been the international leader in Earth observations. The decrease in research, missions, and numbers of instruments is a real loss of capability. The baton is not being passed to international partners, it is simply being dropped.

(2) What are your perspectives on the FY2008 budget request for NASA's Earth Science Program and how well does it position NASA to contribute to the U.S. priorities and plans for climate and related research?

The modest increase in the FY2008 budget request for NASA's Earth Science Program is the first sign that the steady erosion of capability and the lack of a credible program of observations beyond the end of this decade is reversing. However, the FY2008 budget and its out-year projections are simply inadequate. Under current funding and projections, the U.S. will have significant gaps in the long-term observation record, making it more difficult to separate natural and human contributions to climate change and making it more difficult to assess how the Earth is changing. Debates on issues such as the relative importance of solar versus greenhouse causes of warming will continue rather than be solved definitively. Under current funding and projections, the key areas of uncertainty in climate models will very likely continue to languish. Most certainly, the areas of investigation that couple climate change to societally-important areas such as water, health, and food security will be delayed. Stated frankly, our capabilities to address critical questions in climate change in service to society will experience a dramatic decline if the NASA out-year projections are realized.

(3) Which missions and observations recommended in the National Academies Earth science decadal survey are most critical for advancing our understanding of climate change and any mitigation and adaptation strategies? What

uncertainties in our understanding of change would the observations from those missions help reduce?

In my opinion, a decadal survey in the Earth sciences produced a decade ago would have focused on innovation built upon a robust global observing system. Such a survey would likely have focused on new technologies and new capabilities that would have extended our abilities to address difficult variables, improve the quality of our observations, and demonstrate an increase in forecasting capability. Certainly, we would have debated how to balance the notion of entraining new technologies while still preserving continuity of the observations. Likely, we would have debated the best mechanisms to bring the same “discipline of forecasting” that has resulted in dramatic improvements in weather forecasting to a much broader family of variables of interest to our society. In contrast, the Decadal Survey rarely considered the frontiers that we know are in the realm of the possible. This is not a critique of the Decadal Survey. It is a fact that the NRC effort sought primarily to ensure a reasonable and robust set of observations within a tractable budget, where “tractable” is defined as only restoring the budget to its level in 2001 in terms of real dollars, while ensuring that the most critical needs were addressed.

For climate studies, the list provided in the National Academies Earth Science Decadal Survey is a base set. It is prioritized in time, taking into account the existing instrumentation and international partners, but each element is critical and the list is not sufficient to solve all of the major uncertainties in forecasting the future. It maintains the most basic needs and adds only those missions which are clearly the most crucial priorities in a set of many critical observations. The request for climate research reveals the level of constraint applied within the Decadal Survey.

First, we must have a sufficient set of sustained multi-decadal, global measurements of key variables in order to understand how the Earth is changing, to understand the roles of various natural and human forcing factors, and to assess climate models. Stripped to its fundamentals, the climate is first affected by the long-term balance between incoming and outgoing energy. Both the long-term records of total solar input and the Earth’s energy budget are in jeopardy. Other variables that define the state of the atmosphere and ocean and provide a foundation for both weather forecasting and climate are equally critical. These include such fundamental observations as temperature and water vapor soundings, the distribution of snow and ice, ozone profiles, and surface winds. The de-scoping of NPOESS involved each of these key climate variables. Without the Decadal Survey recommendations we do not address these most basic needs of the climate sciences.

Second, current observations and models raise particular concerns about the mass balance and even the stability of the large ice caps. In terms of our capabilities to assess how the Earth system is changing, the ice sheets represent one of the most significant areas of uncertainty and one of the most significant areas in terms of potential societal impact. The Decadal Survey places a high priority on determining ice sheet volume, sea ice thickness, ice sheet surface velocities, and improved estimates of the sensitivity of the ice sheets to climate change.

Third, the Decadal Survey calls for a focus on the two areas that are considered to be the most limiting in terms of our ability to improve climate model predictions. The first area is aerosol-cloud forcing. Aerosol climate forcing is similar in magnitude to carbon dioxide forcing, but the uncertainty is estimated to be substantially larger. The impact of aerosols on cloud formation amplifies their importance to the climate system. The Decadal Survey also calls for a focus on measuring ocean circulation, ocean heat storage and ocean climate forcing. Again, the problems are fundamental, involving the measurement of sea level, the importance of how rapidly heat is being mixed into the oceans, and improvements in our ability to simulate the ocean circulation.

We are more than capable of providing the observations needed to address the specific topics above. Importantly, the climate chapter of the Decadal Survey also calls for us to address much more challenging problems by bringing innovative approaches to the fore and challenging our ability to return to the cutting-edge of Earth observing. The accurate measurement of the surface fluxes of energy, water and momentum at the Earth's surface, and an improved ability to examine atmospheric convection (which governs the transport of heat, water vapor, trace gases, and aerosols and defines cloud formation) would substantially advance our ability to predict the future and to understand critical problems such as sea level variations and changes in the distribution and character of precipitation. Missions dedicated to these two important topics are not a part of the priority set from the Decadal Survey.

(4) What role, if any, do NASA's Earth science research and related programs play in validating the accuracy of climate measurements collected from Earth observing satellites and in developing predictive capabilities for climate change and its effects?

The decline in capability is not restricted to missions and instruments. The decline in the observation budget is matched by a significant decline in the Research and Analysis budget in the Earth Sciences. Sub-orbital and land-based studies increase our ability to assess and validate climate measurements. A comprehensive approach to the analysis, distribution and stewardship of observations broadens the base of applications and entrains a broader set of disciplines and a higher level of expertise directed toward increasing our confidence in Earth observations, expanding their value, and improving predictive capabilities.

The loss of capability has the potential to be long-term and particularly costly because of its timing. The lack of missions, the reduced level of opportunities, the lack of innovation, and the weakness in the Research and Analysis budgets are likely to result in a reduction in student interest, and most clearly in the training of graduate students and post-doctoral researchers. This loss of opportunity, with its potential impact on attracting the next generation of scientists and engineers who design sensor systems and analyze data, matches a time in which a substantial fraction of the NASA Earth sciences workforce is able to retire. The FY2008 and out year budgets have the potential to create

significant weakness in the capability of the workforce at the same time that society is demanding an increased emphasis on understanding climate and its impacts.

(5) What are your perspectives, as an individual researcher, on international collaborations in the Earth sciences, and what value would international collaborations offer in advancing the recommended missions in the decadal survey?

In my opinion, the statements on international collaboration provided in the Decadal Survey are sound. International collaborations have a number of benefits including a reduction in cost and a potential reduction in the likelihood of gaps in key data sets. In addition, collaboration can increase the number of science users and bring a broader array of technologies to bear on a specific problem. NASA has demonstrated success in developing such partnerships, with TOPEX/Poseidon and RADARSAT-1 as good examples. Moreover, it is now relatively common for flight agencies to offer announcements of opportunity to the international science community as the agencies attempt to maximize the payoff of each flight project.

However, joint ventures must still be considered with care, particularly for climate data sets. As noted in the Decadal Survey climate chapter, instruments built by one partner may not be designed to the exact requirements of another partner. Although two missions may utilize the same type of instrument – for example an altimeter – and therefore sound like they are duplicative, the differences in design may allow one to resolve ocean eddies and improve our knowledge of the ocean circulation while the other may not achieve this objective. Technology transfer restrictions may also prevent the exchange of important technical details about the instruments. Restrictions on access to data and software vary from country to country, as do approaches to calibration and validation. Joint ventures between government flight agencies and commercial partners can result in serious complications with data cost, availability, and distribution. Missions can also be terminated or significantly altered by host countries, resulting in a greater impact if the other partners had counted on the international partner to provide a key observation or synergistic measurement.

International partnerships should only be fostered where synergy between instrument capabilities and the science requirements is strong, where there is free and easy access to data, and where there is transparency in the process of analyzing data such that analysis algorithms are freely available.

The Decadal Survey includes many examples where priorities were altered based on knowledge of missions proposed by international partners. A case in point is the cloud-aerosol mission (ACE) proposed by the Decadal Survey which, despite its importance in addressing areas of uncertainty in climate models, was placed in phase 2 (2013-2016) because of cloud and aerosol information that would become available from international sources (GCOM-C and EarthCARE).

End Note

An improved ability to predict climate change will allow us to be good stewards of this planet. But few seem to recognize that our ability to better predict the future has benefit far beyond addressing the consequences of increased levels of greenhouse gases. The potential societal benefits are substantial. For example, even modest improvement in seasonal to interannual predictions have the potential for significant societal benefit in agriculture, energy, water, and weather-related management. The Decadal Survey presents a vision that recognizes that the demand for knowledge of climate change and variability will increase. The risk in failing to provide this information is high. However, our ability to serve society through increased observing capability and improved model prediction is far greater than a single issue, even though the issue of climate change is of enormous significance. An improvement in our ability to anticipate the future increases our capability to utilize this knowledge to both limit adverse outcomes and maximize benefits to society.