On Climate Change Research Measurements from NPOESS: Letter Report

Committee on Earth Studies, National Research Council

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Space Studies Board

On Climate Change Research Measurements from NPOESS

On May 27, 1998, Space Studies Board Chair Claude R. Canizares and Committee on Earth Studies Chair Mark Abbott sent the following letter report to Dr. Ghassem Asrar, associate administrator for NASA's Office of Earth Science, and Mr. Robert S. Winokur, director of NOAA's National Environmental Satellite, Data, and Information Service.

The Committee on Earth Studies would like to share with you some early results from our study, "Integration of Research and Operational Satellite Systems." The committee has met four times thus far concerning this topic. The first meeting included briefings by John McElroy, Jerry Mahlman, and others who provided a scientific and historical context for the research and operational Earth-observing missions. In addition, the committee heard reports on the status and plans of NASA/Office of Earth Science (OES) and on the National Polar-orbiting Operational Environmental Satellite System (NPOESS). The committee also heard from the Polar-orbiting Operational Environmental Satellite (POES) and Geostationary Operational Environmental Satellite (GOES) program offices as well as from NOAA and NASA on plans for advanced geostationary platforms.

At the end of the first meeting, the committee decided an appropriate study strategy would be to evaluate specific satellite-derived long-term data series that have important applications to Earth science. Particular emphasis was placed on climate research, given the unique potential of NPOESS. At its second and third meetings, the committee examined several such data sets, including sea surface temperature, atmospheric ozone and aerosols, sea surface elevation, global temperature, terrestrial vegetation, clouds, Earth's radiation budget, and ocean winds. For each time series, the committee explored issues related to sensor performance and calibration, data access, and data consistency. The fourth meeting continued these discussions with a specific focus on how to leverage the NPOESS satellites to better meet key data needs for the climate research community. The committee was also briefed by Berrien Moore, Eric Barron, and Tom Karl on related studies that are under way within the National Research Council's Board on Sustainable Development and Board on Atmospheric Sciences and Climate.

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At this point, the committee is now prepared to discuss its initial impressions on issues related to the development and application of NPOESS.

The committee wishes to thank you and your staffs for their considerable help in this initial phase, and we look forward to continuing our strong relationship with you. Please feel free to contact us at any time if you wish to discuss any of these issues in more detail.

On Climate Change ResearchMeasurements from NPOESS

Interactions Between Research and Operational Earth Observation Systems: Initial Steps

General Issues

The current schedule for NPOESS shows that specific instrument concepts will be selected for most of the major sensors in the next 2 years. During this time period, NASA will be completing its mission planning for the second series of Earth Observing System (EOS) missions. Recommendations by the Committee may have a significant impact on the planning process. Therefore, if the recommendations of the Committee on Earth Studies are to be useful in the planning process, it is urgent that they be forwarded at this time, and the committee has chosen this abbreviated format to achieve that purpose.

There is a clear distinction between measurements related to climate monitoring and those related to understanding climate variability and processes. In the first case, the variables used to document climate change require a high level of accuracy, precision, and consistency, and traceability over time. In the second case, the requirements are somewhat less stringent though no less important. Although some variables can fall into both categories, it is useful to recall the distinction between them, particularly as we begin to move toward the use of operational satellite systems for climate studies.

It is clear to the Committee on Earth Studies that NASA, through its Earth Science Enterprise (ESE), and NOAA, through its operational environmental satellite programs, fulfill important roles in Earth system research. As noted in the report to the NPOESS Integrated Program Office (the Mahlman and Karl report—NOAA, 1997), climate research (both monitoring studies and studies of climate-related processes) must build on both the long-term stability provided by an observing system such as NPOESS and the flexibility provided by programs within NASA/ESE.

No single approach will work; instead, we must have the capability to collect long time series of science-quality, integrated data sets to study both climate change

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and climate-related processes and the flexibility to take advantage of new science and new technology.

The European Meteorological Satellite platform, METOP-3, is a critical component of the NPOESS program and illustrates the kind of coordinated international missions that will be needed as we move toward a global observing strategy. The committee is strongly supportive of these efforts, while recognizing that there are potential programmatic risks that may need to be overcome.

One of the hurdles in achieving the goals of an integrated climate observing system is the lack of a clear federal charter to either NASA or NOAA for the requisite work. The committee notes that the NPOESS program is currently aimed at addressing short-term operational requirements associated with NOAA (and DOD) needs for weather-related information and weather prediction, whereas NASA's EOS and associated programs in the ESE are focused primarily on scientific research without operational constraints. As long-term climate monitoring and climate research do not fall under the purview of either agency, it has been difficult to obtain the necessary budget authority to meet these needs.

Ranking of Climate Observables

Numerous scientific committees have identified and described the variables that should be included in any climate observing system. However, many of these attempts have not separated the measurements needed to document global change from the measurements needed for understanding specific processes. It has also been difficult to prioritizerank these variables in a manner based on scientific understanding.

The committee has begun to discuss with other National Research Council committees appropriate the idea of an workshop optimization study (or perhaps conducted as a series of workshops) to characterize satellite-based climate measurements in terms of their maturity, stability, and sensitivity to gaps. Thworkshop e study would support a systems engineering approach by evaluating measurement quality (including spatial and temporal resolution, calibration requirements, and the effect of measurement errors) and its impact on climate models and predictions. Such knowledge could then be used to rank the various observables in much the same way that observables are ranked in the area of weather prediction. The committee recognizes that the present state of climate research will make this a difficult task, but now is the time to start this study.

This This process would result in a set of defensible requirements that could be used to evaluate in part how present EOS climate measurement research and monitoring requirements could be met through a combination of research and operational sensor systems. Ctransitioned to the operational NPOESS.onsideration of the complementary in situ measurements is also essential in this effort. This optimization process should act as a reference point to evaluate the overall balance of an integrated observing strategy.

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This workshop study approach must be broadly based, and the committee recommends that it include both modelers and satellite remote sensing experts. It would provide a firm basis from which to evaluate various trade-offs in sensor design and performance while also establishing a method for evaluating new operational requirements for climate observing systems. The workshop optimization study does not need to be limited solely to polar-orbiting missions, but may include missons that use geostationary, low-inclination, or other orbits as well.

The Committee on Earth Studies will begin working with other appropriate NRC committees to define the workshop study in more detail and begin the organization process. The committee recognizes that considerable planning will be necessary in advance of any study. The purpose is not to restructure the plans for NPOESS and EOS, but instead to provide a framework for building a climate observing system—one built on the foundation that already exists. The committee hope towill wwork closely with the NASA's Office of Earth Science (OES) and the NPOESS Integrated Program Office (IPO) throughout this process.

Actions for NOAA and NASA

NPOESS

The NPOESS program presents enormous opportunities for climate research. The committee acknowledges the importance of the program's primary focus, which is short-term environmental predictions and assessment. However, the committee believes that there may be relatively inexpensivesmall changes in mission architecture, sensor performance, and operations that would greatly enhance the use of the NPOESS satellites for climate research and prediction, particularly in cooperation with NASA.. Such changes will require involvement by the science community throughout the development and operations of NPOESS, as opposed to involvement limited to the program's initial design phases.

The committee recommends that NOAA and the NPOESS IPO address the needs for climate research by:

- *Ensuring that a knowledgeable climate advocate participates in the continuing design and implementation of NPOESS.* An expanded role for NASA in the IPO may meet the need for this advocate for climate research.
- *Ranking the measurements identified by the workshop optimization study and establishing a science team for each of the high-priority measurements that have analogs in NPOESS.* These measurement-focused teams would provide input on only the climate-related aspects of these data sets and would examine the entire end-to-end system from this vantage point. The committee recommends that these teams be established as soon as possible after the optimization study is completed.
- *Examining critically its approach and its interactions with EOS.* The

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present schedule for NPOESS sensor acquisition and development may limit the opportunities to learn from pre-NPOESS missions such as AM-1 and PM-1, as well as from polar-orbiting operational environmental satellite missions such as NOAA-N'.

The committee envisions one science team for each climate-critical variable. Below, it lists some issues that the teams should consider. This list is not comprehensive, but merely shows the scope of the activities.

- *Flexibility in the NPOESS program: Current plans include weight and power growth allowances to enable testing of new sensor concepts and designs on the NPOESS platforms.* The committee strongly supports this approach as it will provide opportunities for new measurements as well as a mechanism for cross-validation between different sensor designs. Other approaches to enhance flexibility might be the use of sensor designs that can be easily upgraded, or the use of small satellites as part of the operational observing system, or for technology demonstration. Particular attention must be made to the "risk reduction" strategy and its ability to influence the implementation of NPOESS.
- *Replenishment strategies: Gaps in the data record could seriously reduce the utility of the NPOESS operational datasets for climate studies and for monitoring climate change.* The committee recommends that the IPO consider strategies to reduce the impact of gaps in the data record, including strategies for overlap and/or replenishment of NPOESS sensors.
- *Instrument/platform design: The present plan is to use maintain on-board propellant to maintain a fixed the orbitequator-crossing times of for the NPOESS satellites.* This is a significant improvement for the application of NPOESS measurements to climate research. However, in addition, an overall system architecture failure analysis of the sensors and satellite bus should be performed to identify whether there are small changes that might be made to increase system redundancy and reliability. The results of the committee's optimization study should also be considered for developing specific strategies for monitoring instrument stability.
- *Data processing and distribution: It is essential that the complete archive of raw sensor observations be maintained and organized in a manner to facilitate reprocessing.* This archive must include information related to sensor design, construction, testing, and operations in order to build a consistent time series. Early planning will enhance the ability of the global change community to use these data sets for research.

Although the science teams would focus initially on NPOESS sensor systems, they should not be constrained to the polar-orbiting missions. In particular, geostationary platforms have many advantages for some types of climate research, and the science teams should also consider these and other orbits as part of the observing strategy.

ESE

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The Earth System Science Pathfinder (ESSP) approach is emerging as the model that NASA will use to select and develop future missions as part of the Earth Observing System. In addition to the present approach for ESSP, the committee believes that future EOS missions must also focus on the following objectives:

- Improving NPOESS sensors through the use of new technology or new approaches;
- Filling gaps in critical data sets between NPOESS and the first set of EOS missions; and
- Continuing observations of critical variables that will not be measured (or not measured with sufficient quality) by NPOESS. As with the NPOESS measurements, the committee thinks that the workshop optimization study described above can help identify and prioritizerank the critical variables.

The Operational Satellite Improvement Program (OSIP), which was operated by NASA until the early 1980s, may serve as a model for the interaction between the research satellite programs developed by NASA and the operational satellite programs developed by NPOESS. OSIP had its roots in scientific research and technology development to develop and test new sensor concepts in the context of weather forecasting. A similar process may be possible in the area of climate research and monitoring.

In addition to its support of NASA missions, the Research and Analysis (R&A) program within the Earth Science Enterprise should provide a solid scientific basis for analysis and reprocessing of NPOESS and geostationary satellite data sets. As noted in the Mahlman and Karl report (NOAA, 1997), long time series require continued analysis and reworking to identify errors and to improve data quality. Such reprocessing efforts also may require more stable funding beyond the traditional 3-year funding cycle. Experience with reprocessing and analysis of long time series of satellite data (such as the NASA Pathfinder program) has shown that while ongoing review is necessary, a typical 3-year research grant is not sufficient to accomplish this complex set of tasks.

The R&A program should continue to support improved algorithms for climate research. This includes forging partnerships with other agencies to maintain the global ground-based validation networks that are essential for climate monitoring through the use of satellite-based measurements. It also includes support for physically based algorithms and algorithms based on multiple sensors (as opposed to algorithms based on empirical relationships). In some cases, long time series can be developed serendipitously by combining measurements from a variety of sensors and missions—such research should be encouraged.

Climate Research and Monitoring

The committee recommends that NOAA and NASA establish an active,

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coordinated management structure that will focus on the needs for both climate research and climate monitoring. Although there are existing agency linkages, there needs to be a particular focus on long-term measurements for climate research that is accompanied by a stronger, continuing science involvement. The committee is concerned that neither NASA nor NOAA has clear leadership or responsibility for climate-related measurements. If we are to achieve an integrated system that can both monitor climate change and be used to study climate processes, then there must be a strong advocate for these science requirements. The committee recommends that in coordination with NASA/OES the IPO immediately extend its responsibilities to include the potential climate research and monitoring capabilities of the NPOESS satellites. This will enable a systemwide view of both NOAA and NASA missions in the context of an integrated climate-observing system.

While the present schedule for NPOESS includes opportunities for inserting new technology, as well as risk reduction through the flight of pre-NPOESS sensors, the strategy could be improved through better coordination with NASA's EOS program. For example, the committee is concerned that the test flight of a new atmospheric sounder will may occur shortly before a final decision is made on the specifics of the planned NPOESS sounder. This will leave limited time in which to evaluate the pre-NPOESS sensor. Similarly, the committee is concerned that decisions regarding measurements of vector winds over the ocean using passive microwave radiometry may be made without the benefit of a thorough analysis because of constrained schedules. These potential problems arise in large part because the long-lead-time activities of NPOESS may lock in particular technologies far in advance of actual deployment in space. In contrast, NASA's EOS missions are moving toward a much more rapid accommodation of science and technology infusion. Overall coordination of these two activities could lead to a better balance between needed operational continuity and technology infusion.

The scheduled launch of the second AM series of EOS satellites in 2004 will result in sensor concepts being selected during the next 2 years. Currently, NASA's plans for continuity with AM-1 are based in part on expectations for NPOESS. However, to realize the scientific goals established by NASA for EOS, there must be extensive coordination between NASA/OES and the NPOESS IPO. This must include coordination not only at the management level, but also at the scientific level as well. The committee recommends that NASA and NOAA establish a science advisory group that will ensure that the two programs remain integrated to meet the scientific needs of climate research (including studies of climate change as well as climate processes). Such a group will also ensure that they the programs can respond in a coordinated manner to changes in science, technology, or budgets.

Next Steps for the Committee on Earth Studies

Over the next year, the Committee on Earth Studies will continue its investigation of issues related to the integration of operational and research satellite systems. The committee will continue its analysis of existing long time series of satellite

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measurements as well as the needs of data assimilation models that rely on satellite data. In addition, it will study how various mission architectures, including geostationary systems and small satellites, might be used and how they would affect sampling strategies. The committee also intends to study the present status of physically based algorithms, especially those that rely on multiple sensors. Calibration and validation are essential components of Earth systems science, and the committee will investigate both the on-board and ground-based strategies that are needed. Lastly, the committee will work with other appropriate NRC committees in the area of data systems to better understand how they may be optimized to support reprocessing of long time series for climate research.

Reference

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