Scientific Data Stewardship (SDS) Implementation Plan

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Executive Summary

The United States climate and global change program is at a critical juncture. NASA's Earth observing system is starting to wind down, the Department of Commerce has been named lead agency for the US climate research, and the next generation of the NOAA operational satellites is being built. It is clear that NOAA's operational satellites will play a critical role in the long-term monitoring of climate, climate change, and applied climatology. The white paper (Lawler, 2004) prepared for an ongoing national academies study concludes that the United States climate program has diffuse objectives and the lack of priorities that have left it "marginalized and politically expendable."

The Scientific Data Stewardship (SDS) plan responds to these challenges. Based upon lessons learned over the past decade, NOAA proposes an operational program to convert research results to operations while maintaining the high quality needed for a variety of climate applications. This will be accomplished by developing and implementing a new and innovative cost estimation model that will provide strict accountability for all products and services. By using the latest advances in information technology, the SDS program will allow for an affordable, sustained climate program that will enhance society's ability to plan for and respond to variability and change.

As much as $4 trillion of the nation’s $10 trillion economy is affected by weather and climate events each year. Industries such as transportation, energy, and agriculture rely on accurate climate and weather information and predictions. Improved seasonal to interannual climate forecasts have become increasingly important to predict periods of drought or intense storm activity such as hurricanes - occurrences of which can significantly affect the economy. Global climate change looms as a mounting concern to the nations of the world. High quality Climate Data Records of the atmosphere, oceans, and land surface are needed for:

- Applied Climatology – provide a variety of decision makers with place-based information of known high quality for use in industry, water resources, the energy sector, agriculture, fisheries and other sectors of the economy
- Climate Monitoring - provide decision makers with reliable information on the state of the Earth’s climate.
- Climate Change - enable researchers to achieve an improved understanding of climate variability and change

1. Introduction

This document presents a Plan for a Scientific Data Stewardship (SDS) Program to create high-quality, operational long-term data sets of climate conditions - Climate Data Records - from satellite and supporting ground-based observations. The SDS Program will ensure that the observations are processed, archived, and distributed to users in a manner that is scientifically defensible for monitoring, diagnosing, understanding, predicting, modeling, and assessing climate variation and change. It will apply a newly developed cost accounting model, implemented as part of the Federal enterprise architecture, to demonstrate the benefit versus cost of the development, implementation, operational production and sustained validation of the CDRs. The Plan will be executed by NOAA, its partner agencies, and the external community. The Plan responds to the overarching recommendation of the NRC's Committee on Climate Data Records from NOAA Operational Satellites (NRC, 2004):

> ***NOAA should embrace its new mandate to understand climate variability and change by asserting national leadership for satellite-based Climate Data Record generation, applying new approaches to generate and manage satellite Climate Data Records, developing new community relationships, and ensuring long-term consistency and continuity for a satellite Climate Data Record generation program.***

This report is a response by NOAA to the overarching recommendation as well as the six supporting recommendations and the key elements of successful climate data record generation programs contained in the NRC document. The report is organized into four sections; an introductory section, a section that summarizes the NRC study and the response of NOAA to each recommendation, a section outlining the principal parties that should be involved, and a section on the organizational, generation, and sustainable elements of NOAA's proposed SDS program. In addition, we will provide the NRC panel with several additional documents related to the SDS program.

1.1 Background

NOAA's vision is "to move NOAA into the 21st century scientifically and operationally, in the same interrelated manner as the environment that we observe and forecast, while recognizing the link between our global economy and our planet's environment."

Specifically, NOAA will apply its vision to the NOAA mission to understand and predict changes in the earth's environment and conserve and manage coastal and marine resources to meet our nation's economic, social, and environmental needs.

To fulfill its mission, NOAA has defined four interrelated goals within its Strategic Plan:[1]

- Protect, restore, and manage the use of coastal and ocean resources through ecosystem-based management
- Understand climate variability and change to enhance society's ability to plan and respond
- Serve society's needs for weather and water information
- Support the nation's commerce with information for safe, efficient, and environmentally sound transportation

It is noteworthy that climate science has been elevated to a high priority goal within NOAA. This plan for Scientific Data Stewardship will directly aid NOAA in fulfilling the mission goal: Understanding Climate Variability and Change to Enhance Society's Ability to Plan and Respond. This goal's measurable outcomes and strategies are shown in Table 1-1.

The NOAA Climate Program manages new and existing climate activities that cut across all NOAA line offices. Climate research and products are developed to support national, regional, and local users both within and external to NOAA. This program is also a key component in implementing the Climate Change Science Program. The NOAA Climate Program acts as the interface between both national interagency and intra-agency planning efforts. NOAA's activities, which focus both on near-term deliverables and longer research, will be integrated and managed for performance by the Climate Program.

The National Environmental Satellite, Data and Information Service (NESDIS), an organization in NOAA, maintains the world's largest archive of climate-related data and information spanning the ice age to the space age. NESDIS operates the nation's civil operational satellite observing system of Polar-orbiting (POES) and Geostationary (GOES) satellites, which provides essential data for understanding climate variability and change. NESDIS processes these observations as well as those of other Earth observing satellites. NESDIS is also currently developing and implementing the U.S. Climate Reference Network (USCRN) to provide reference quality in-situ data for temperature and precipitation monitoring. Data and information from these observing systems are used along with other climate-related NOAA and non-NOAA observing system data to construct long-term records regarding local, regional, national, and global climate variability and change.

Table 1-1. NOAA Strategic Goal to Understand Climate Variability and Change

[1] *New Priorities for the 21st Century, NOAA's Strategic Plan for FY 2003-2008 and Beyond*. March 2003.

Goal: Understanding Climate Variability and Change to Enhance Society's Ability to Plan and Respond		
Measurable Outcomes	**Strategies**	
• Increased use and effectiveness of climate observations to improve long-range climate, weather, and water predictions. • Increased use and effectiveness of climate information for decision makers and managers. • Increased use of the knowledge of how climate variability and change affect commerce.	• **Monitor and Observe:** Invest in high-quality, long-term climate observations and encourage other national and international investments to provide a comprehensive observing system in support of climate assessments and forecasts. • **Understand and Describe:** Increase understanding of the dynamics and impacts of coupled atmosphere/ocean/land systems by working with national and international partners to conduct research on climate variability and change.	• **Assess and Predict:** Provide decision makers with reliable, objective information, by improving the skill and accuracy of intraseasonal and interannual climate forecasts and regional, national, and international assessments and projections. • **Engage, Advise, & Inform:** Help customers effectively use climate information to enhance public health and safety; support environmental, economic, and community planning; maximize potential benefits; and minimize the impacts of climate variability.

NOAA manages the nation's civil operational environmental satellite system. NOAA also has statutory responsibility for long-term archiving of the nation's environmental data. Increasingly, this responsibility is expanding to provide information on the health of the environment in real-time to both national and international users, and to respond to growing demands for stable long-term climate records derived from satellite observations. In order to meet these needs, NOAA must provide a framework to ensure that satellite climate data are processed, archived, and distributed to users in a manner that is scientifically defensible for monitoring, diagnosing, understanding, predicting, modeling, and assessing climate variation and change.

As concern for understanding climate change and variation has grown, it has become apparent that the somewhat *ad hoc* nature of adapting observations originally intended for weather prediction to climate study is not sufficient to produce reliable findings and draw reasonable conclusions. While real-time operational products from NOAA's space and ground-based environmental observing systems meet the goals for short-term environmental forecasting and stewardship, they have not generally become authoritative long-term records for a number of reasons. For example, the archive of operational products is not reprocessed when scientific algorithms are improved; therefore small artificial discontinuities in the record will likely coincide with algorithm improvements and hence the record cannot be used for detecting small changes in climate.

NOAA's acceptance of its role and responsibilities for providing quality climate data is reflected in NOAA's Strategic Plan for FY2003 – FY 2008 and Beyond, "New Priorities for the 21st Century":

> "To enable society to better respond to changing climate conditions, NOAA, working with national and international partners, will employ an end-to-end system comprised of integrated observations of key atmospheric, oceanic, and terrestrial variables; a scientific understanding of past climate variations and present atmospheric, oceanic, and land-surface processes that influence climate; application of this improved understanding to create more reliable climate predictions on all time scales; and service delivery methods that continuously assess and respond to user needs with the most reliable information possible."

NOAA recognizes that the development of quality climate data records is key, and that a strong program focus on the development, retention, and distribution of climate data records will be necessary to meet the needs of researchers and decision makers. NOAA also realizes that it cannot go it alone; NOAA will partner with other federal agencies and engage the external community to create a vibrant national program, as recommended in NRC (2004).

The SDS program will be comprised of both centralized and the decentralized approaches to manage the generation and distribution of satellite derived as well as integrated CDR's to ensure cost-effective and efficient utilization of existing human and institutional expertise and resources. Operational production of critical CDR's and related services will include the acquisition, processing, distribution, archiving, and management of calibrated, navigated fundamental CDR's as well as selected thematic CDR's and their metadata. Specialized higher level CDR's, as well as supporting research, will be produced in a distributed system in collaboration with Federated partners.

> Fundamental CDRs (FCDRs) are sensor data (e.g., calibrated radiances, brightness temperatures, radar backscatter) that have been improved and quality-controlled over time, together with the ancillary data used to calibrate them.

> Thematic CDRs (TCDRs) are geophysical variables derived from the FCDRs, specific to various disciplines, and often generated by blending satellite observations, in-situ data, and model output.

1.2 Climate Data Users and Applications

1.2.1 Climate Data Users

Users of climate data include organizations both within and outside of NOAA. Some of the primary user communities include:

- Business, industry, agriculture, and water resource managers
- The general public
- Federal government agencies with environmental stewardship, disaster planning, national defense, homeland security, and land use responsibilities (EPA, NOAA, FEMA, DOD, DOI)
- State and local officials responsible for disaster planning and natural resource

protection

- International governments and organizations
- NOAA, NASA, other agency and academic researchers

1.2.2 Uses of Climate Data

Simply put, climate data users seek information to:

- Apply understanding of the processes controlling climate thus providing critical information to decision makers in agriculture, industries, water resources and all levels of government
- Monitor the climate - Assess the current state of climate
- Climate change - Assess changes in climate, predict future climate variations and change, verify climate models

Climate change and variation occur over a range of time scales and therefore climate data must be collected over a time series in order to be able to detect and understand these changes. The concepts of climate change and variability include both short-term and long-term components. The short-term component (generally called *climate variability*) includes seasonal changes, multiyear extended periods of wet and dry conditions (prolonged periods of above normal hurricane activity, excessive rainfall or drought) and the periodic cyclical changes through wet and dry conditions that occur generally within a 20-year time frame related to long-term fluctuations in sea surface temperature across ocean basins. Such changes may be related to global events, but effects at the regional level (e.g. the West Coast of the United States) may differ from the response in some other region (the East Coast). The long-term component (generally called *climate change*) refers to more or less permanent changes that occur over a longer period and have global implications. The result is an overall trend that has impacts throughout the world. These include phenomena such as increased concentrations of carbon dioxide in the atmosphere and changes to the ozone layer.

Public and private sector decision makers need to consider the effects of *climate variability* in planning and making day to day decisions concerning operations, maintenance, and activity scheduling. They also need to consider *climate change* for long-term planning, design and construction of infrastructure, as well as associated needs to protect natural resources, lives and property.

Both climate change and variability are occurring simultaneously, so that effects are additive and cumulative over time. To provide maximum flexibility, climate data need to be observed and collected over a range of temporal and spatial scales not generally used for weather prediction. Generally, three time scales apply and differ in their accuracy requirements; two-week to seasonal, seasonal to interannual, and decadal.

1.3. Why now

The importance of understanding and predicting climate variation and change has escalated significantly in the last decade. Several converging events drive the development of a Scientific Data Stewardship program at this time.

- In 2001, in response to a request from the White House, The National Academies' National Research Council (NRC) (2001) recommended several research priorities to reduce uncertainties in climate science. One key recommendation was to "ensure the existence of a long-term monitoring system that provides a more definitive observational foundation to evaluate decadal-to century-scale changes."

- In 2002, President George W. Bush announced the formation of the Climate Change Science Program (CCSP) to focus federal research on climate by integrating the activities of the established U.S. Global Change Research Program (USGCRP) and the new Climate Change Research Initiative (CCRI). Observations and Monitoring are a key component of the CCSP Strategic Plan (2003): the Plan addresses the following question:

  > How can we provide active stewardship for an observation system that will document the evolving state of the climate system, allow for improved understanding of its changes, and contribute to improved predictive capability for society?

- NOAA's mission for the next century includes a bold new mandate to "understand climate variability and change to enhance society's ability to plan and respond" as one of four central goals. One of the strategies for achieving this goal is **Monitor and Observe:** Invest in high-quality, long-term climate observations and encourage other national and international investments to provide a comprehensive observing system in support of climate assessments and forecasts.

- NASA is nearing completion of the deployment of the Earth Observing System (EOS) and is now considering an appropriate strategy for follow-on exploratory and systematic missions. Over the next decade, new observing capabilities established by NASA will transition a number of environmental parameters from research-oriented programs to operationally oriented ones. These new operational satellite programs include the National Polar-orbiting Operational Environmental Satellite System (NPOESS) and the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) METOP in 2006 These follow-ons to the current generation of civil and military meteorological satellites will monitor global environmental conditions and collect and disseminate data related to weather, atmosphere, oceans, land and near-space environment. The climate community is depending on the NPOESS and METOP series to provide much of the data required to monitor the climate system.

- In 2003, high level representatives of 31 countries met in Washington, DC at the Earth Observations Summit and initiated a 10-year program to develop an international, comprehensive, coordinated and sustained Earth observation system. A major motivating factor for this international initiative is concern about climate variability and change.

- The report of the NRC's Committee on Climate Data Records from NOAA Operational Satellites (NRC, 2004) discussed in more detail below and in the following section.

- The National Academies' Space Sciences Board study, which will be carried out over a two-year period and organized in a manner similar to other NRC "decadal surveys," seeks to establish plans and priorities within the sub-disciplines of the Earth sciences as well as an integrated vision and plan for the Earth sciences as a whole. It will also consider Earth observations requirements for research and for a range of applications with direct links to societal objectives.

1.4 Engaging the National Research Council

To generate the best possible plan for creating climate-quality data, NOAA asked the National Academies to assist in developing a plan for creating Climate Data Records (CDRs) from satellites that monitor environmental conditions. In response, The National Academies formed the Committee on Creating Climate Data Records from NOAA Operational Satellites and charged it with providing a comprehensive and practical evaluation of the NOAA CDR plan, including conclusions and recommendations. In Phase I of its study, the Committee conducted an information gathering workshop, collected additional information via a questionnaire, and prepared a report (NRC, 2004) that outlines a range of different approaches and strategies for generating CDRs and identifies key attributes common to successful CDR generation programs. NOAA has prepared this plan using the Academy report to provide guiding principles. In Phase II of the Academy study, the Committee will provide specific comments on this plan.

2. Summary of the National Research Council Study

NOAA engaged the NRC to assist it as it designs its plan to create high-quality long-term data sets of global climate conditions from satellite and supporting ground-based observations. The Statement of Task under which the NRC operated is shown in Box 2-1. To carry out its work the NRC organized a committee of 13 experts in the creation, use, and maintenance of Climate Data Records. The Committee met several times, conducted an information-gathering workshop, and issued its Interim Report on Climate Data Records from Environmental Satellites (NRC, 2004). This Interim Report builds on the wealth of information available, giving specific attention to creating CDRs useful to NOAA's new climate mandate, and providing practical advice to help NOAA create CDRs from operational satellite data that are:

- responsive to the needs of the climate science community as well as policy makers and other stakeholders
- utilize the best scientific practices in the creation of CDRs, and
- properly archived and disseminated to the user community.

In this section, we summarize the main findings and recommendations of the NRC report; these recommendations form the fundamental principles for the Integrated Global Climatology Program (SDS) plan presented in the following section.

2.1 Past Studies of Note

(This section extracted directly from NRC, 2004)

Concern over the future availability of satellite-based climate-quality data led the National Research Council and several other bodies to issue reports on ensuring the climate record from satellites (e.g., NRC, 1999a,b; NRC, 2000a,b,c,d,e; NOAA, 2001; GCOS, 2003). In addition to highlighting the need for climate data records, many of the reports recommend steps for the long-term creation and preservation of climate data from the NPOESS and the NPOESS Preparatory Project (NPP). Although NPOESS and NPP were originally envisioned for serving civilian and defense needs for environmental data, the climate community quickly realized that these platforms also will be the primary information sources for any satellite CDRs in the coming decades. The committee viewed these reports as stepping-stones for this project; NRC (1999a) outlined the state of the observing system relative to the USGCRP and discussed several elements of a climate observing system, while NRC (1999b) assessed the adequacy of the climate observing system and endorsed the now well-known ten climate monitoring principles. NRC (2000b) provided a short overview for creating and maintaining climate data specifically for NPP and NPOESS, and NRC (2000a,c) outlined in greater detail the science, design, and implementation of a potential program for creating climate quality data for NPOESS. NRC (2000d) examined atmospheric temperature trends near the surface and in the lower to mid-troposphere to reconcile disagreements in the observed trends. NRC (2000e) builds upon the recommendations from NRC (2000d) and discusses

BOX 2-1
STATEMENT OF TASK

The ad hoc committee charged to conduct this study will assist the National Oceanic and Atmospheric Administration-National Environmental Satellite, Data, and Information Service (NOAA-NESDIS) as it designs a plan to create climate data records (CDRs) from existing and new instruments aboard NOAA satellites for understanding, monitoring, and predicting climate variations and changes. The committee will provide input to the plan by summarizing major needs for and uses of climate data records, examining different approaches and strategies for generating climate data records, and identifying key attributes of CDRs that have proven useful. NOAA would then use this information as guidance to develop its plan for producing CDRs from operational satellites. Once the plan is drafted, the committee will review the draft Climate Data Records Plan to ensure that it is sound, comprehensive, and includes mechanisms for continued user involvement, and it will recommend improvements to ensure that CDRs are processed according to established scientific methods and packaged in forms that are useful for real-time assessments and predictions of climate as well as retrospective analyses, re-analyses, and reprocessing efforts.

In phase I, the committee will organize and host a workshop to facilitate discussion of a NOAA white paper that will outline its preliminary ideas on satellite data utilization for climate applications, and it will write an interim report that:

- Summarizes major needs for and uses of climate data records,
- Examines different approaches and strategies for generating CDRs, and
- Identifies key attributes of examples of successful attempts to create high quality CDRs from satellite data.

Questions to be addressed in the workshop and by the committee include:

- How does a CDR become a community standard (i.e., established as legitimate)?
- How can NOAA ensure that the CDRs are responsive to user needs?
- What are the key attributes of successful CDR generation programs?
- What are the advantages and disadvantages of different models or strategies for producing CDRs, such as using partnerships among government, academia, and the private sector, different blends of space-based and in-situ data (e.g., all space-based versus some balance), or other approaches?
- How can NOAA learn from present and past efforts such as the NOAA/NASA Pathfinders, EOSDIS, etc.? What are the successes and failures, and how do we emulate the successes or avoid the pitfalls?

Phase 2 will begin when NOAA provides the committee with a draft of its Climate Data Records Plan (estimated to be approximately 3 months after delivery of the interim report).

strategies for NOAA to develop long-term monitoring capability of upper air temperature CDRs; as such, NRC (2000e) is particularly relevant for NOAA to refer to in addition to this report. NOAA (2001) was written by the NOAA Science Advisory Board, and this report suggested creation of a new programmatic start for climate monitoring within NOAA, including but not limited to satellites. The GCOS (2003) report examined the state of the global climate observing system and suggested various methods to address perceived inadequacies.

2.2 Findings: Summary of Lessons Learned

The NRC committee reviewed "case histories" of a number of climate data sets that had received acceptance by the wider scientific community. The intention was to gather lessons learned from these past experiences to provide guidance for future activities in creating CDRs. The committee developed a set of lessons learned that represented the combined wisdom in all of the earlier projects:

1. **CDRs must be accepted by the community**. This is the most fundamental characteristic of a CDR. This acceptance is evaluated after a period of community use to correct unforeseen problems, identify new applications, and apply algorithm improvements. .
2. **Long term funding for CDR production is required**. This is a need common to all CDR activities and it is clear that without stable funding support it is impossible for a CDR to be created or sustained long enough to be of value. Historically this funding has come from a variety of sources but of the federal agencies NASA and NOAA have been active at funding these types of data analysis activities.
3. **Science advisory review provides critical oversight**. Without science input it is difficult to create and/or identify a CDR and to maintain its production and utilization.
4. **User workshops allow broad community input**. One method for generating user input is by initiating workshops.
5. **Long-term trends are often unreliable due to input changes, calibration errors, algorithm evolution, and instrument changes**. Again science guidance is needed to assess errors in long-term time series and correct or compensate for physical changes in long time series.
6. **CDR stewardship is needed throughout the entire process**. A critical requirement is that the science overview and involvement is end-to-end and that oversight will be needed continuously for the duration of the period that the CDR is generated and maintained.
7. **Reprocessing/reanalysis is an on-going activity**. The development of a CDR is often an evolutionary process and repeated reprocessing of the entire input data set is often necessary. The CDR algorithm will change over time as measurement hardware and software and understanding of the measurement process evolve.
8. **Raw data must be archived.** The reprocessing requirement for satellite data means that the raw satellite data must be archived for future reprocessing.

9. **Multiple, independent processing efforts can provide important insights into the CDR.** Multiple efforts provide information on the precision of a CDR, and biases based on one processing method may not be obvious without comparison to other, independent methods.
10. **Data management and oversight are critical components of a successful program**. CDR data sets need to be managed in a way that allows easy, meaningful access by users of varying technical sophistication. Web access could include browse images, read software, subsetting tools, and online plotting
11. **Validation and overlap of successive satellite missions is critical for developing consistent CDRs over time**. Satellite measurements are by their very nature "remote" and thus *in situ* observations are needed to validate remotely sensed data and monitor sensor degradation, while overlap is needed to reduce satellite biases
12. **Orbital and instrument decay need correction for consistent long-term CDRs**. Another source of change that requires *in situ* validation measurements is caused by orbital and instrument degradation decay, which changes the atmospheric path length for each measurement, the Sun-Earth sampling geometry, and/or introduces aliasing of the diurnal cycle.

The committee referred to the first four as organizational elements, the next seven as generation elements, and the final three as sustaining elements.

The Committee defined two types of Climate Data Records: Fundamental CDRs and Thematic CDRs. Fundamental CDRs (FCDRs) are sensor data (e.g., calibrated radiances, brightness temperatures, radar backscatter) that have been improved and quality-controlled over time, together with the ancillary data used to calibrate them. Thematic CDRs (TCDRs) are geophysical variables derived from the FCDRs, specific to various disciplines, and often generated by blending satellite observations, in-situ data, and model output.

High quality FCDRs - or sensor data - are not only essential to the generation of valid Thematic CDRs, but can form a useful record of changes in the climate system on their own. In essence they represent a vertically integrated record of the surface and atmospheric variables to which they are sensitive. And, in fact, more and more sensor data, rather than the geophysical variables derived from them, are being assimilated directly into weather prediction models. Reanalysis projects, which provide time series of climatic states based on decadal runs of a data assimilating numerical weather prediction, also use much sensor data directly.

TCDRs are the traditional Climate Data Records and will continue to serve as markers of climate variability and change in their own right as well as input and verification data for climate models and reanalysis.

2.3 Conclusions and Recommendations

2.3.1 Key Recommendation

The major recommendation of the NRC Committee is that NOAA should take the national lead in a program to generate satellite-based Climate Data Records.

OVERARCHING RECOMMENDATION

NOAA should embrace its new mandate to understand climate variability and change by asserting national leadership for satellite-based Climate Data Record generation, applying new approaches to generate and manage satellite Climate Data Records, developing new community relationships, and ensuring long-term consistency and continuity for a satellite Climate Data Record generation program.

NOAA already is well-established as a national leader in weather services, and NOAA also provides leadership for weather-based satellite data. However, NOAA’s climate mandate is a new function and NOAA will need to embrace and be proactive in providing leadership for climate data in order to fulfill their mandate. In particular, a successful CDR generation program requires a long-term commitment and efforts above and beyond NOAA’s traditional role in weather forecasting. The task and the structures being proposed for NOAA in this report are considerably more complex, costly, and demanding than those currently in place. Without the highest level of commitment within the agency to institute and fund these changes, there is considerable concern in the science community that the CDR agenda as described in the report will not succeed.

NOAA Response

NOAA welcomes the recommendations of the NRC Panel regarding its thoughtful comments on a program to generate satellite-based Climate Data Records. NOAA has been developing plans in this area for several years and these efforts are now bearing fruit. The wider community may not be aware of some of these efforts. We summarize our response to the NRC recommendations here but provide further details in the following chapters and in additional documentation.

NOAA is creating a new program element to specifically address the need for asserting national leadership for satellite-based CDR generation called Scientific Data Stewardship (SDS). This program will be responsible for the generation of CDRs and associated activities.. The data management services associated with the SDS program will be handled by NOAA’s Comprehensive Large-Array data Stewardship System or CLASS.

NOAA’s National Data Centers (NNDCs) are major archives that maintain, process, and distribute retrospective environmental and geospatial data. The Centers provide long-term stewardship for most of NOAA's environmental and geospatial data and a broad range of user services. The Centers serve as Agency Record Centers subject to NARA-accepted archive standards. NOAA National Data Centers may be composed of two or more archive facilities linked together through a computerized wide area network. There are three NNDCs: the National Climatic Data Center (NCDC), the National Oceanographic Data Center (NODC), and the National Geophysical Data Center (NGDC).

In response to these data product and service challenges, the NNDCs have placed renewed emphasis on their archive and access systems for large volumes satellite data sets (the Comprehensive Large-Array data Stewardship System or CLASS) and has created a new program element to specifically address the need for asserting national leadership for satellite-based CDR generation called Scientific Data Stewardship (SDS). Both CLASS and SDS are programs within the NNDCs, but with active participation with other NOAA offices, centers, and laboratories.

Overview of Scientific Data Stewardship - SDS

The overall goal of SDS is to create high-quality, long-term data sets of global climate conditions - Climate Data Records - from satellite and supporting ground-based observations and to ensure that the observations are processed, archived, and distributed to users in a manner that is scientifically defensible for monitoring, diagnosing, understanding, predicting, modeling, and assessing climate variation and change.

The concept of scientific stewardship within NOAA means providing the data and information services necessary to answer global change science questions of the highest priority, both now and in the future. High quality, long-term records are needed to address important monitoring and prediction issues. The NOAA in-situ observations, such as surface temperature and precipitation, have long been subjected to extensive scrutiny, quality control, adjustment, and analysis. These steps created the confidence in the quality of these data used by decision makers. Similar stewardship functions are required for all the NOAA observations. Then, long-term records from all the NOAA observing systems will reveal their respective maximum potential usefulness regarding a range of critical environmental monitoring and prediction issues, such as atmospheric and oceanic climate change, terrestrial change detection in response to climate changes, space and solar variability, and ecosystem and coastal management.

There are five fundamental principles associated with the NOAA Scientific Data Stewardship Program:

- *Ensure Observing System Quality*. Provide real-time monitoring of climate-scale biases for the global suite of satellite, airborne, and in-situ (atmospheric and ocean) observing systems by monitoring the observing system’s performance. Subtle spatial and temporal biases can contribute to serious data quality problems. Automated Network Monitoring to discover these biases as soon as possible are the first line of defense, before the data becomes part of the long-term historical records. Programs to seek out existing biases in the historical records provide the second level of monitoring necessary for improving the climate data records. Time dependent and other biases can be minimized or eliminated through efficient and effective early processing and periodic reprocessing leading to improving and maintaining the quality of the observing systems.

- *Develop a Climate Processing System*. Provide the necessary algorithms to ensure that understanding of key climate processes can be derived from space-based systems and the fusion of space-based and in-situ systems. The best possible scientific understanding of critical climate and global change issues can only be reached when many opinions and perspectives are explored. Essential to this end is an active program that engages the research community, establishes partnerships with industry, and facilitates interactions with local, regional, and national governments, agencies, and institutions.
- *Provide Basic IT Support*. Technology now provides the capabilities to implement, maintain, and access the most comprehensive and highest possible quality historical data and information records, critical to the support of effective analysis and prediction activities. A dynamic and flexible strategic plan for the efficient use of IT resources will support rapid adaptation to evolutionary and revolutionary IT changes (e.g., new sensors, telecommunications, storage, commercial-off-the-shelf software, and interoperable hardware). The creation of long-term, contiguous, and quality data records requires the commitment of resources to accomplish these tasks.
- *Document Earth System Variability*. Documenting the Earth's integrated climate system, variability, and change on global, regional, and local scales depends on creating, using, and maintaining the highest quality climate databases and deriving the best historical perspective from these records. This will optimize data and information services in order to responsive. Success will be achieved by establishing end-to-end accountability for establishing long-term, scientifically valid, and consistent records for global change studies. This will ensure that our data and information are available to the maximum number of users.
- *Enable and Facilitate Future Research*. Climate and global change is a long-term societal imperative. Questions and answers often take many years into focus due to the nature of the "feedback" and "forcing" systems influencing the global and regional climate systems. This aspect of stewardship encompasses providing the quality climate observations over years and decades, recurring basic information technology hardware and software improvements, and improved models, that can guarantee the preservation of and access to the data, information, and gained knowledge for future generations of scientists and policy makers. Today the Internet, NGI, and the emerging grid technology will provide the access for today and the near future. Newly developed data sets will be used to update scenarios and assessments, and identify and respond to emerging questions that the scientific community is expected to answer.

The implementation of scientific stewardship has begun and covers not only the archiving plans for all the various satellite and in-situ data sources through CLASS, but it also involves applications with a number of groups and activities as outlined in section 4.

Scientific data stewardship, with an emphasis upon satellite data and information, is a new era in data management consisting of an integrated suite of functions to preserve and exploit the full scientific value of environmental data and information entrusted to NOAA. These functions provide effective observing system design, careful monitoring of observing systems performance for use in long-term applications, improved quality control, generation of authoritative long-term quality data and records, assessments on the state of the environment, and archive and access to data, metadata, products, and services. Successful implementation of scientific stewardship will ensure maximum use and public benefit of environmental data and information, now and in the future.

Overview of the Comprehensive Large-Array data Stewardship System - CLASS

CLASS will build upon systems already in place to implement an architecture for an integrated, national environmental data access and archive system to support a comprehensive data management strategy. The goals of CLASS are as follows:

1. Give any potential customer access to all large-array NOAA (and some selected non-NOAA) data through a single portal.
2. Eliminate the need to continue creating "stovepipe" systems for each new type of data, while, as much as possible, using already refined portions/modules of existing legacy systems.
3. Describe a cost-effective architecture that can primarily handle large array-data sets, but is also capable of handling smaller data sets as well.
4. Support the reprocessing of any or all datasets managed by CLASS.

The development of CLASS is expected to be a long-term, evolutionary process, as current and new campaigns are incorporated into the CLASS architecture.
CLASS supports the NESDIS mission to acquire, archive, and disseminate environmental data. NESDIS has been acquiring these data for more than 30 years, from a variety of in situ and remote sensing observing systems operated by NOAA and from a number of its partners. NESDIS foresees significant growth in both the data volume and the user population for these data, and has therefore initiated this effort to evolve current technologies to meet future needs.

NOAA's National Data Centers and their world-wide clientele of customers look to CLASS as the primary NOAA information technology infrastructure project in which all current and future large array environmental data sets will reside. CLASS provides permanent, secure storage and safe, efficient access between the Data Centers and the customers. The initial objective for CLASS is to support specifically the following campaigns:

- NOAA and Department of Defense Polar-orbiting Operational Environmental Satellites (POES) and Defense Meteorological Satellite Program (DMSP)
- NOAA Geostationary-orbiting Operational Environmental Satellites (GOES)
- National Aeronautics and Space Administration (NASA) Earth Observing System (EOS) Moderate-resolution Imaging Spectrometer (MODIS)
- National Polar-orbiting Operational Environmental Satellite System (NPOESS)
- The NPOESS Preparatory Program (NPP)
- EUMETSAT Meteorological Operational Satellite (Metop) Program
- NOAA NEXt generation weather RADAR (NEXRAD) Program
- NCEP NWP Model Datasets

CLASS is currently not a goal-wide program but is in the Climate Goal. Although it is recognized that CLASS serves the needs of all NOAA customers, the requirements of the Climate Goal take priority, In particular, CLASS must be able to ingest, archive and provide access to long-term satellite climate data records produced from these large-array data sources, both existing and those to be defined in the future.

NOAA has recently prepared an update of the CLASS Archive and Access requirements document. Although it is not the purview of this NRC committee to conduct an extensive review of the CLASS program, we do invite informal comments by the committee, particularly pertaining to the CLASS support of archive and access to CDRs and reprocessing.

As part of its commitment to serve the Nation, NOAA is focused on developing an integrated global environmental observation and data management system. As one of the first steps toward this goal, NOAA established the NOAA Observing System Council (NOSC) in May 2003. NOSC is the principal advisory body to the NOAA Executive Council for earth observation and data management activities and the principal coordinating body for NOAA to the White House Committee on Environment and Natural Resources Subcommittee on Earth Observations in developing a comprehensive, coordinated and sustained Earth observation system. The NOAA Data Stewardship Committee (originally the NESDIS Data Archive Board) was established under NOSC to provide clear guidance for managing NOAA data stewardship and to provide the NOSC with the information it needs to integrate data stewardship with the NOAA Observing Systems Architecture and into the NOAA data management enterprise.

The ARWG was established under the Data Archive Board (a NESDIS Line Office structure now defunct) to ensure that science requirements and other user applications are clearly defined with respect to NOAA's archive, access, and reprocessing stewardship activities. The ARWG serves as a clearinghouse for requirement planning in support of the science objectives related to archive, access, and reprocessing. Requirements are defined, validated and then presented for review and approval. The process for review and approval is being finalized since the Data Archive Board is no longer functioning. We are working with both the NOSC Data Stewardship Committee and the Climate Goal team to establish a new process. The ARWG provides advice and assistance to facilitate the definition and implementation of a NOAA stewardship architecture that balances the needs of users for a dynamic and flexible system and the needs of developers for structure and continuity.

Terms of reference

- To ensure that CLASS and other stewardship activities are responsive to the goals of the NOAA strategic plan
- To provide for effective use of stewardship activities by ensuring that mechanisms are in place to engage the user community in decisions concerning what data and products are to be included in or excluded from the NOAA National Data Center archives
- To periodically review the contents of the NOAA National Data Center archives for disposition in conjunction with NARA guidelines and data center record retention and disposition schedules.

- To provide requirements and prioritization for preserving and maintaining the basic storage of and access to critical large array-data, other NOAA National Data Center critical data sets and derived products and their documentation, including verifying their quality and compliance with federal standards
- To establish requirements for the information technology aspects for implementation of scientific data stewardship
- To provide a long-term vision to incorporate other NOAA data holdings into a system of archive, access, and scientific data stewardship

The relationship between the ARWG and the other responsible parties within CLASS is illustrated in Figure 1 below.

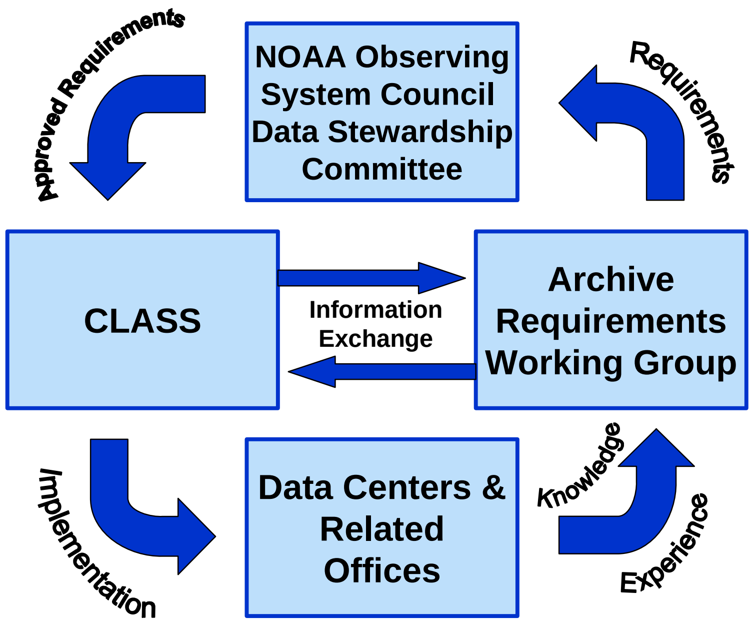

Figure 1. CLASS Project responsibilities (proposed to Data Stewardship Committee)

2.3.2 Supporting Recommendations

The Committee made six supporting recommendations on the organizational and management structure for a credible, high quality CDR program.

Recommendation 1: NOAA should utilize an organizational structure where a high-level Leadership Council within NOAA receives advice from an Advisory Council that provides input to the process on behalf of the climate research community and other stakeholders. The Advisory Council should be supported by instrument and science teams responsible for overseeing the generation of Climate Data Records.

NOAA Response

NOAA agrees with this recommendation and proposes an organizational structure within the new NOAA matrix management structure that will ensure input from a variety of stakeholders in climate community (see section 4.4)

Recommendation 2: NOAA should build their satellite-based Climate Data Record generation program based on lessons learned from previous attempts, which point out several unique characteristics of satellite Climate Data Records, including the need for continuing calibration, validation, and algorithm refinements, all leading to periodic reprocessing and reanalysis to improve error quantification and reduce uncertainties.

NOAA Response

NOAA is actively working with NASA and other NOAA programs that have engaged the community in previous attempts to generate satellite-based climate data records. With regard to NASA, we are working with the NASA science program to evaluate the successes there and the EOSDIS program to understand the details of the processing system. Similarly, NOAA's climate change data and detection program element within the office of global programs has supported principal investigators to generate satellite-based climate data records for some years. NESDIS' Office of Research and Applications has considerable experience in the development of algorithms and the generation of satellite derived climate data sets. The SDS program manager will coordinate with NOAA's climate change data and detection program element and NESDIS' Office of Research and Applications to evaluate lessons learned and to consider possible research to operations transition.

Recommendation 3: NOAA should define satellite Climate Data Record stewardship policies and procedures that ensure data records and documentation are easily accessible for the current generation and permanently preserved for future generations.

NOAA Response

NOAA believes that adopting several of the recent standards for archive and metadata will go a long way towards achieving this recommendation. The International Organization for Standardization (ISO) has encouraged the development of standards in support of the long-term preservation of digital information obtained from observations of the terrestrial and space environments. ISO has requested the Consultative Committee for Space Data Systems (CCSDS) Panel 2 to coordinate the development of those standards.

The initial effort has been the development of a Reference Model for an Open Archival Information System (OAIS, CCSDS 650.0-B-1). The OAIS Reference Model has been extensively reviewed and, pending some editorial updates, has been approved as an ISO Standard and as a CCSDS Recommendation. Additional information on the OAIS Reference Model is available at http://www.ccsds.org/documents/650x0b1.pdf.

The organization and operation of CLASS and SDS will follow the OAIS Reference Model with respect to archive issues.

Understanding complex environmental problems demands data from many observing systems. In order to be useful, these data need to be extensively documented so that they can be effectively used by a variety of users. Long-term preservation imposes the additional requirement that the documentation must be sufficiently detailed to allow the data to be successfully used even after all personnel with first hand experience have left the observing program. Both CLASS and SDS will be required to follow the Federal Geographic Data Committee (FGDC) and the National Spatial Data Infrastructure (NSDI) metadata standards and the forthcoming ISO 19115 standard for metadata.

Recommendation 4: NOAA should develop new community relationships by engaging a broader academic community, other government agencies, and the private sector for the development and continuing stewardship of satellite Climate Data Records.

NOAA response

NOAA's scientific data stewardship program will be the primary mechanism for engaging a broader academic community and the private sector. Within NOAA, a new Division has been established within the National Climatic Data Center (NCDC), called the Remote Sensing Applications Division (RSAD), in order to create a focal point for the use of satellite and radar remote sensing in climate applications. The NOAA Office of Research and Applications (ORA; soon to become the Center for Satellite Applications and Research) has also reorganized it's Satellite Meteorology and Climatology Division to include a special focus on satellite climate applications. These two divisions (RSAD and ORA) will lead NOAA's effort in the creation of satellite climate data records.

In addition, Joint Center for Satellite Data Assimilation (JCSDA), the multi-agency collaborative center for improving the use of data assimilation, is managed by the Office of Research and Applications. The JCSDA is expected to contribute tools for the creation of climate data records e.g radiative transfer models (See Section 3.5) and analysis techniques. The JCSDA also provides an established forum to help initiate collaboration with the broader community.

NOAA will partner with NASA, DoE, and NSF to develop a coordinated multi-agency program for the development and continued stewardship of CDRs. It will also explore cooperative opportunities with climate user agencies such as USGS, DoA, EPA.

Recommendation 5: NOAA should consider the existing US multiagency organizations for implementation of the Climate Data Record program, rather than devising a new structure. The most appropriate organization is the Climate Change Science Program.

NOAA's scientific data stewardship program is an element within the observation and analysis subgoal of NOAA's climate goal team. This hierarchical structure provides a direct reporting mechanism to the climate change science program, and hence, two other agencies. We believe, however, that there are specific programs within other agencies that provide unique opportunities for collaboration with NOAA's scientific data stewardship program. It may be fruitful to work with these programs directly and to then vet plans for direct collaboration through the CCSP Observations Core Approach. In addition, the interagency working group on earth observations (IWGEO) should also be considered as in other mechanism for interagency coordination and collaboration.

Recommendation 6: NOAA should pursue appropriate financial and human resources to sustain a multi-decadal program focused on satellite Climate Data Records.

NOAA’s CLASS program is a specific line item in the current NOAA budget and SDS is in the budget beginning in FY06. Details on these budgets will be provided to the Panel.

SECTION 3. Pathways Forward – Building Blocks for Partnerships in the NOAA Scientific Data Stewardship Program

As noted in the NRC report, the new emphasis on climate within NOAA's mission will require an increased focus on partnerships. This is particularly important in the development, analysis, reanalysis and research of CDRs. Creating a program to develop, produce, archive and disseminate CDRs will require a large investment of resources and expertise. NOAA cannot do this alone. Fortunately, NOAA's plan to create CDRs is of interest to several national and international programs.

In its report the NRC recommended:

> "To maximize the effect of NOAA's finite resources, it should develop partnerships with other groups whose goals relate, in least in part, to those of NOAA. Moreover, in developing a CDR plan and taking on its stewardship role, it is crucial for NOAA to take a proactive leadership role in international and interagency partnerships and leverage the limited funding available to support this type of effort. This will require an open and collaborative environment with full participation from the national interagency and international climate science community."

Taking this advice to heart, NOAA will, as a fundamental aspect of its CDR plan, establish cooperative partnership arrangements with other agencies and groups that share similar goals. This section describes activities of several programs within and outside of NOAA that have the potential to form the basis for significant partnerships in the NOAA CDR program. Effective management of these partnerships will require an innovative governing structure through the NOAA Climate Program to ensure all parties are represented and to engage the broader research community and the proposed structure needed is described in Chapter 4.

3.1. Related NOAA Activities

3.1.1. Climate Mission Goal

NOAA-wide planning for climate has gained impetus from the formation of the U.S. Climate Change Science Program (CCSP) and the related U.S. Climate Change Science Plan and by the formation of the NOAA Climate Program. The NOAA Climate Program has been tasked to oversee and integrate existing and new climate activities across all NOAA line offices. The Program functions in a matrix management framework, where organizational goals describe climate research and services throughout all six NOAA Line Offices. There are five sub-goals within the NOAA Climate program as described below.

Observations and Analysis

Observations (atmospheric/ocean including Arctic), Data Stewardship, and Analysis of the Climate System taken together increase the value and utility of observations, improves the performance of models, and reduces the uncertainty of predictions. Observations are the foundation for research critical to understanding earth's climate system, improving climate predictions, and monitoring current climate. Data Stewardship includes: acquisition and quality control; archival and access for research, business, and government users. Quality data records support capabilities for ongoing analysis leading to economic and environmental forecasts and timely analyses and assessments of present and past climate. Within NOAA's budgeting process, the Scientific Data Stewardship (SDS) Program resides within this sub-goal as does NOAA's archive and access system for large-array data, the Comprehensive Large-Array data Stewardship System (CLASS). It is the SDS program that has the overall responsibility for the production of climate data records (CDRs). The SDS program dovetails with the CLASS program which will provide the archive and access for customers of CDRs as well as the IT infrastructure for production and reprocessing of CDRs. These activities are essential to formulating policies and plans that will impact on the Nation's economy, environment, and society. The program is a fundamental component of GEO and CCSP.

Forcings

This component addresses the information needs associated with the atmospheric components whose changes in atmospheric abundance drive changes the climate system. Global climate models (in component 3) must include changes in climate forcing in order to predict how climate will be impacted from policy choices. The Climate Forcing program will: (1) monitor and understand changes of greenhouse gases, including water vapor, and the ability of the oceans and terrestrial biosphere to sequester carbon dioxide (with emphasis on North America), provide decision support for U.S. carbon management, (2) study the atmospheric chemical processes that produce aerosol particles, to improve our inadequate knowledge of their radiative climate forcing properties, and (3) study atmospheric chemical processes that produce and remove tropospheric ozone and other non-CO2 greenhouse gases, broadening the suite of non-carbon options available for policy decisions.

Predictions and Projections

This program will provide the nation with a seamless suite of forecasts (e.g. outlooks and projections) on intraseasonal, seasonal, interannual and multi-decadal timescales to facilitate management of risks and opportunities of climate variability and change and their environmental impacts. The environment includes not only the atmosphere, the ocean, and land but ultimately biogeochemical processes on land and in the ocean, ecosystems, atmospheric chemistry and air quality, hydrology, and the lower food chain. Spatial and temporal resolutions and accuracy will evolve, balancing user requirements with technical feasibility.

Ecosystems

Existing related NOAA programs will be integrated into a national Climate and Ecosystems program that will provide resource managers the knowledge and tools to adapt to the consequences of climate change to marine and coastal ecosystems. Because every marine ecosystem, coastal estuary, and coastal wetland cannot be individually monitored and assessed, only critically important ecosystems will be selected for long-term, climate-integrated, biological assessments. Local- and regional-scale place-based demonstration projects will be conducted to link NOAA climate information with NOAA resource management information to predict the status of marine and coastal living resources in future climates. These projects will be located in the fisheries-rich ecosystems of the North Pacific (Gulf of Alaska and California Current), the estuaries of the southeastern United States and Gulf of Mexico vulnerable to sea-level rise and changing rates of freshwater delivery, and coral reef ecosystems of Hawaii.

Regional Decision Support

Regional Decision Support represents the NOAA Climate Program's main interaction with users of climate information and forecasts at the local up to national levels. The program helps NOAA identify and serve the nation's needs for climate information to support decision making through an integrated program of: research on decision maker needs, transitioning the results, and operationally producing and delivering local and regional climate services. This program leverages cross line office activities as well as key NOAA partners to fulfill its goals.

3.1.2. Mission Support Goal

Strong, effective, and efficient support activities are necessary for NOAA to achieve its mission goals. NOAA facilities, ships, aircraft, environmental satellites, data-processing systems, computing and communication systems, financial and administrative offices, and its approach to management provide the foundation of support for all NOAA programs.

NOAA ships, aircraft and environmental satellites are the backbone of the global earth observing system and provide many critical mission support services. To keep this capability strong and current with its mission goals, this goal will ensure that NOAA has adequate access to safe and efficient ships and aircraft through the use of both NOAA platforms and those of other agency, academic, and commercial partners. NOAA will work with academia and partners in the public and private sectors to ensure that future satellite systems are designed, developed, and operated with the latest technology. In addition, safe and adequate facilities and state-of-the-art information technology are essential to the improvement of NOAA's operations and service delivery.

Satellite Services

One of the strategies to support NOAA's mission is to use applied research to ensure the quality, reliability, and accuracy of current and future satellite products and services. Principal contributors to this effort are the NESDIS Office of Satellite Data Processing and Distribution (OSDPD) and The NESDIS Office of Research and Applications (ORA). OSDPD manages and directs the operation of the central ground facilities which ingest, process, and distribute environmental satellite data and derived products to domestic and foreign users. ORA provide leadership, guidance, and direction for NESDIS research, development, and applications activities with respect to satellites, satellite data, and the development of new/improved algorithms for processing satellite data into operational products. One of ORA's roles is to assist with the development cross platform and sensor continuity issues regarding the use of satellite data. In this regard, ORA will play an important role in supporting the development of climate data records.

Polar Satellite Acquisition

The Next Polar Orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project (NPP) is a joint NASA-Integrated Program Office instrument risk reduction project. It is designed to function as a bridge between the NASA EOS program and NPOESS for the development of the following sensors:

- Advanced Technology Microwave Sounder (ATMS)
- Cross-track Infrared Sounder (CrIS)
- Ozone Mapping and Profiler Suite (OMPS)
- Visible/Infrared Imager Radiometer Suite (VIIRS)

Its mission is to demonstrate advanced technology for atmospheric sounding, providing continuing observations pertinent to global change after EOS-PM (Terra) and EOS-AM (Aqua) reach the end of their missions. It will supply data on atmospheric and sea surface temperatures, humidity soundings, land and ocean biological productivity, and cloud and aerosol properties.

NPOESS is a low Earth orbit spacecraft remote sensing platform, hosting up to 14 sensors. It will acquire meteorological, environmental, and associated data, including information on cloud imagery, atmospheric profiles of temperature and moisture, and other specialized meteorological, terrestrial, oceanographic, climatic, and solar-geophysical data. It will also provide support to a international search and rescue mission.

Geostationary Satellite Acquisition

GOES satellites provide continuous reliable operational, environmental and storm warning systems to protect life and property from a geo-synchronous orbit at an altitude of approximately 35,800 km. They provide a constant vigil for the atmospheric "triggers" for severe weather conditions such as tornadoes, flash floods, hailstorms, and hurricanes. When these conditions develop, these satellites are able to monitor storm development and track storm movements. GOES satellite imagery is also used to estimate rainfall during thunderstorms and hurricanes for flash flood warnings, as well as estimate snowfall accumulations and overall extent of snow cover. Such data help meteorologists issue winter storm warnings and spring snowmelt advisories. Satellite sensors also detect ice fields and map the movements of sea and lake ice, and monitor the space environment around the satellite. In 2012, a new generation of GOES satellites (GOES-R) will provide VIIRS and CrIS capabilities in geostationary orbit and will allow climate monitoring at higher temporal resolutions.

3.1.3. Cross-cutting Priority of Integrating Global Environmental Observation and Data Management

NOAA is striving to make its core priorities more relevant and effective to support its mission goals. As a result, it has selected several essential activities where corporate policy and guidance can assure that its goals coordinate in important areas. Each of these cross-cutting priorities is guided by a NOAA council, which is responsible for developing agency-wide policies and procedures in that area. Most important for CDRs is the cross-cutting priority of Integrating Global Environmental Observations and Data Management.

Earth Observations are intrinsic to NOAA's mission. NOAA depends on an observing system for virtually every activity – from fundamental research and discovery to long-range operational forecasting to short-term warnings of immediate hazards to day-to-day regulatory decisions. An integrated Earth observation and data management system will enable NOAA's resources to be applied more efficiently and effectively by reducing duplication, improving coverage, and providing networks to disseminate information when and where it is needed around the world. Through participation and leadership in national and international global data collection and reporting efforts, such as the Global Earth Observing Systems of Systems (GEOSS) and other important observing groups and efforts, NOAA can further integrate its observing systems, data, and quality control with efforts of other nations to guarantee the best quality and coverage of Earth observing data.

3.1.4. Extramural Research

The NOAA Office of Global Programs (OGP) sponsors scientific research aimed at understanding climate variability and its predictability. Through studies in these areas, researchers contribute to improved predictions and assessments of climate variability over a continuum of timescales from season to season, year to year, and over the course of a decade and beyond.

The OGP Climate Change Data and Detection program element ensures that the data needed to understand the climate system is available for analysis. The data and resultant products extend the existing long-term climate record and serve as essential input to predictive models. In addition, Climate Change Data and Detection (CCDD) provides support for documenting variations in climate on time scales ranging from less than one year to periods of 100 years and longer. It also provides support for the analysis of observed climate variations and changes to identify causes that are consistent with Earth's long-term climate history.

Several grants funded under CCDD support development and production of CDRs, some of which could be considered pseudo-operational. The NOAA CDR Program will support evaluation and review of these activities to determine which should be transitioned from research to operations and provided with long-term support.

3.2. NASA EOS Program

It is clear that the National Aeronautics and Space Administration (NASA) must be a key partner in the NOAA CDR Program. NASA, through its Earth Observing System (EOS), has a wealth of experience in development and production of CDRs and related data systems. Furthermore, NOAA and NASA share a long history of cooperative activities related to CDRs, including the NOAA/NASA Pathfinder program, joint support for development of datasets for CCDD, and shared support for the Joint Center for Satellite Data Assimilation (described in section 6 below).

EOS is the centerpiece of NASA's Earth Science Enterprise. It is composed of a series of satellites, a science component, and a data system supporting a coordinated series of polar-orbiting and low inclination satellites for long-term global observations of the land surface, biosphere, solid Earth, atmosphere, and oceans. NOAA has entered into a Memorandum of Understanding with NASA for long-term archival and access to EOS data.

3.2.1. NASA EOS Spacecraft and instruments

The spacecraft for EOS consist of several missions, each carrying multiple instruments. Two spacecraft, Terra, and Aqua, are of particular interest since some of the instruments they carry will be transitioned to operational use on NPOESS. The most significant is MODIS (Moderate-resolution Imaging Spectroradiometer), which improves upon the heritage of the NOAA Advanced Very High Resolution Radiometer (AVHRR) and will be further improved to VIIRS (Visible/Infrared Imager/Radiometer Suite) on NPOESS.

3.2.2. The EOS Science Component

The EOS Project Science Office serves as the primary day-to-day interface between the Earth science community and the Earth Science Systems Program Office and EOS Projects at Goddard Space Flight Center, Langley Research Center, and Jet Propulsion Laboratory; and works to define and represent the EOS scientific requirements and to provide related scientific insight and guidance. The Senior Project Scientist works closely with the EOS personnel at NASA Headquarters to ensure that scientific and related programmatic requirements are appropriately implemented by the EOS Project.

Science Teams

NASA has aimed to accomplish the objectives of the EOS Science Program through Interdisciplinary Science (IDS) and Instrument Science teams. The IDS teams will use EOS instrument data to develop and refine integrated Earth system models to help in understanding the Earth as a system. The IDS teams' investigations cross research discipline boundaries by addressing more than one science objective. The Instrument Science teams define the scientific requirements for EOS instruments, and generate the algorithms that will process data from the instruments into useful products. The teams selected represent organizations such as NASA, universities, and other U.S. and foreign government agencies.

Through its experience with EOS NASA has demonstrated the advantages of developing close working relationships among members of the science community and those directly involved with a particular instrument and its data system. Several groups have recommended that NOAA learn from this experience and create science teams for its satellite instruments, their associated climate data records (CDRs), and the long-term archive.

In its report *Ensuring the Climate Record from the NPP and NPOESS Meteorological Satellites*, the Committee on Earth Studies of the NRC stated that

> "Competitively chosen science working teams for the NPOESS Preparatory Project would have a number of benefits because they would do the following:
>
> - Facilitate early science efforts (e.g. on prototype systems and/or synthetic datasets) that could contribute directly to engineering and systems analyses.

- Optimize algorithms through competition (e.g. retrieval algorithms, extrapolations, etc.)
- Provide a conduit to the user community.
- Provide timely notice to the research community, which would rapidly expand the user base.
- Exploit the science perspective for system refinements (i.e. for follow-on missions), validation, and error detection."

3.2.3. EOSDIS (EOS Data and Information System)

EOSDIS manages data from NASA's Earth science research satellites and field measurement programs, providing data archiving, distribution, and information management services. It commands and controls EOS satellites and instruments, and generates useful products from orbital observations. EOSDIS also supports generation of data sets made by assimilation of satellite and observations into global climate models. EOSDIS is a distributed system with many interconnected nodes (Science Investigator-led Processing Systems and Distributed Active Archive Centers) with specific responsibilities for production, archival and distribution of Earth science data products.

3.2.4. NASA and NOAA EOSDIS interactions

In 1998, NASA and NOAA sponsored a workshop to develop guiding principles for long-term maintenance of EOS data and for assessing lessons learned from current and past experience. The results of the workshop were published as *Global Change Science Requirements for Long-term Archiving, Report of the Workshop,* October 28-30, 1998. Scientists at the workshop decided that the Long-term Archiving program should be:

"A continuing program for the preservation and responsive supply of reliable and comprehensive data, products and information on the Earth system for use in building new knowledge to guide public policy and business decisions."

The workshop concluded that the following elements are essential for the success of the Long-Term Archiving program:

1) Scientists must be involved in all aspects of the program
2) The program must preserve key long-term data and information, including the definitive version of Level 1 data and derived products, any other data sets or products needed to interpret and use them, and any other data sets needed for calibration and validation.
3) The program must establish a process for deciding which products to include within or exclude from the long-term archive, and this process must be driven by science priorities and scientific assessments.
4) The program must ensure that data sets and products are accompanied by complete, comprehensive, and accurate documentation. The documentation should be subject to peer review to ensure it is complete and suitable for use by scientists who are not experts with that data set or product.
5) The program must verify the integrity and quality of data and derived products and associated documentation as it is ingested into the archive.

6) The program must be capable of ingesting data and/or derived products and their documentation from research environments.
7) The program must develop and maintain a multi-year data migration plan and must perform integrity checks on archive media between data migrations.
8) The program must exercise data to produce new products and/or new versions of old products.
9) The program must provide next and subsequent generations of scientists with appropriate access to, and facilitate their use of, the archived data and products.
10) The program must provide data and information services that are responsive to needs of its users.

A successful program for long-term archival of EOS data can only be achieved if:

- Existing long-term archiving activities for atmospheric and oceanographic data and products are coordinated and elevated to the status of a distinct program with a dedicated budget
- The present scope of archiving is extended to include NASA EOS and related NASA atmospheric and oceanographic data and products, NPOESS data and products, and fully effective handling of NOAA GOES and NEXRAD data sets.
- It fosters dedicated conservation of the nation's Earth science data and information resources and builds an effective and vigorous partnership between data managers and scientists.

As the CLASS and SDS programs have gained support and grown over the past several years, it is now possible for NOAA to enter into a conversation with NASA about the mechanics and scientific steps that would be needed to be accomplished to ensure that not only the data, but the scientific information content, of EOS data be preserved in the NOAA long-term archive. Preliminary contacts have been made between the NASA DAAC managers and the NOAA CLASS and SDS programs. They have tentatively agreed to a meeting on how they might set up a long-term archival process for early in CY2005 with additional follow on meetings to involve the scientific community.

3.3. National Science Foundation - NSF

NSF through the National Center for Atmospheric Research (NCAR) and its grants and contracts program is a major player in the CCSP. NSF global change research programs support research and related activities that advance fundamental understanding of dynamic physical, biological, and socioeconomic systems as well as interactions among those systems. In addition to research on Earth system processes and the consequences of changes in those systems, NSF programs facilitate data acquisition and data management activities necessary for basic research on global change, promote the enhancement of modeling designed to improve representation of Earth system interactions, and develop advanced analytic methods to facilitate fundamental research. NSF also supports fundamental research on the general processes used by governments and other organizations to identify and evaluate different types of policies for mitigation, adaptation, and other responses to changing global environmental conditions. The SDS program will collaborate and coordinate with NSF on activities of mutual interest. One area of mutual interest is the Constellation Observing System for Meteorology, Ionosphere and Climate (COSMIC) mission

NSF led the way in demonstrating the viability of global positioning system (GPS) radio occultation (RO) soundings by sponsoring the GPS for Meteorology (GPS/MET) mission in 1995. The scientific basis for GPSRO is an adaptation of the limb sounding technique which was developed by the Jet Propulsion Laboratory (JPL) and Stanford University in the late 1960s to study planetary atmospheres. Following the success of GPS/MET, NSF and NCAR have been instrumental in the planning and coordination of the COSMIC mission, a joint U.S.-Taiwan project. Its goal is to gain inexpensive vertical profiles of temperature and moisture across the globe with high spatial and temporal resolution. This will be done by intercepting GPS signals with satellite-based GPSRO receivers and inferring the deviations in each signal's straight-line path caused by temperature and moisture gradients.

COSMIC not only promises great value for weather, climate, and space weather research and forecasting, but also geodesy and gravity research and other applications. The COSMIC high vertical and lower horizontal resolution measurement will complement the high horizontal and lower vertical resolution measurements of existing and planned U.S. meteorological satellites (GOES and POES). Data assimilation schemes are being developed by the JSCDA in close collaboration with NCAR to effectively integrate the COSMIC data into existing operational weather forecasting models. COSMIC will also complement a variety of related GPS missions, including OERSTED, SUNSAT, CHAMP, SAC-C, and GRACE. The SDS program will establish and make available to the public temperature and moisture CDRs from COSMIC, and also use these CDRS to validate and intercompare with other temperature and moisture records.

3.4. DOE ARM

The Atmospheric Radiation Measurement (ARM) Program is the largest global change research program supported by the U.S. Department of Energy (DOE). It was created to help resolve scientific uncertainties related to global climate change, with a specific focus on the crucial role of clouds and their influence on radiative feedback processes in the atmosphere. The primary goal of the ARM Program is to improve the treatment of cloud and radiation physics in global climate models in order to improve the climate simulation capabilities of these models. ARM's scientists research a broad range of issues that span remote sensing, physical process investigation and modeling on all scales. ARM's site operators focus on obtaining continuous field measurements and providing data products to promote the advancement of climate models.

Through the ARM Program, DOE has funded the development of several highly instrumented ground stations for studying cloud formation processes and their influence on radiative transfer, and for measuring other parameters that determine the radiative properties of the atmosphere. This scientific infrastructure, and resultant data archive, is a valuable national and international asset for advancing scientific knowledge of Earth systems. To provide more research capability for the global scientific community, ARM's field research sites are now being made available for use by scientists worldwide through the ARM Climate Research Facility (ACRF). The ACRF has enormous potential to contribute to a wide range of interdisciplinary science in areas such as hydrology, ecology, and weather forecasting. The ACRF Science Board reviews proposals for use of the ACRF and makes recommendations on scientific field campaigns to be conducted at the fixed and mobile ACRF sites.

An example of a current ACRF project is the NASA-sponsored validation activity for the Atmospheric Infrared Sounder (AIRS) instrument. The DOE ARM sites provide very accurate atmospheric profiles of temperature and water profile, plus surface observations.

This information is used routinely to validate AIRS radiances, via radiative transfer calculations, and the AIRS derived atmospheric profiles and surface parameters. The AIRS validation activity involves the use of different water vapor profiling radiosonde and Raman lidar systems. This example of collaboration between DOE, NASA, and NOAA demonstrates the value of interagency collaboration to further scientific advancements related to global climate change. The SDS program will use the DOE ARM site observations to help validate CDRs generated from satellite observations.

3.5. Joint Center for Satellite Data Assimilation (JCSDA)

JCSDA, initially a partnership between NOAA and NASA, has been expanded to include DoD, and is addressing the development of common algorithms that will be used by all NPOESS customers. The goal of JCSDA is to make better use of all sources of satellite data in operations including preparing for, assimilating, and using data from NPOESS sensors. This will ensure that operational users are ready and eager to use NPOESS data on day one of its availability.

The mission of the JCSDA is to accelerate and improve the quantitative use of research and operational satellite data in weather and climate prediction models. Its goals are to:

- Reduce from two years to one year the average time for operational implementation of new satellite technology
- Increase uses of current satellite data in NWP models
- Advance the common NWP models and data assimilation infrastructure
- Assess the impacts of data from advanced satellite sensors on weather and climate predictions

JCSDA has resulted in committed partnership among NOAA Line Offices (NOAA’s National Weather Service, NOAA Research, and NOAA Satellites and Information), DOD (US Air Force and US Navy), NASA, and the academic community. This has lead to incorporation of EOS AIRS data into NWS models; upgraded communications lines between NASA and NOAA in order to move data to operations processing centers at NOAA; and improved computing capacity.

Because of the leadership role that the JCSDA plays in advancing satellite assimilation techniques, we anticipate that it will naturally also have a lead role in the next round of

U.S. climate re-analysis. SDS will play a key role in ensuring that quality assurance and quality assessment for fundamental climate data records also will serve the needs for re-analysis. Futhermore, the tools/algorithms developed by the JCSDA for the preparation and assimilation of satellite observations and products can be used to support future modeling re-analysis efforts.

3.6. Academia

As noted in the NRC report, academic partners have conducted climate research through several Cooperative Institutes and grants funded by NOAA programs. NOAA's Cooperative Institutes, collectively, have the breadth of knowledge and in-depth skills necessary to support CDR development by contributing: a) scientific expertise; b) in-situ data useful for CDR development and validation; c) their data processing and computing infrastructure; and d) the graduate students and post docs who gain CDR experience and thus build NOAA's capacity in this area. In particular, the Satellite Climate Studies Branch (SCSB) performs research to exploit the capabilities of Earth observing satellites to obtain measurements on regional and global scales for regional and global climate variability studies.

3.7. World Climate Research Program (WCRP) and the Global Climate Observing System (GCOS)

The WCRP currently products both FCDRs and TCDRs primarily through programs under the Global Energy and Water Cycle Experiment (GEWEX) Radiation Panel (GRP). The GRP is responsible of the oversight of most of the large international efforts that use global satellite data sets in studies of the global water cycle, including water vapor, clouds, and precipitation, and efforts to produce observational data sets of the Earth's radiation budget, including the surface radiation and turbulent fluxes and radiative impact of aerosols. NOAA plays an important role in the International Satellite Cloud Climatology (ISCCP) and the Global Precipitation Climatology Project (GPCP) and we anticipate NOAA's role in GRP will continue and expand.

The Global Climate Observing System (GCOS) was established in 1992 to ensure that the observations and information needed to address climate-related issues are obtained and made available to all potential users. It is co-sponsored by the World Meteorological Organization (WMO), the Intergovernmental Oceanographic Commission (IOC) of UNESCO, the United Nations Environment Program (UNEP) and the International Council for Science (ICSU). GCOS is intended to be a long-term, user-driven operational system capable of providing the comprehensive observations required for monitoring the climate system, for detecting and attributing climate change, for assessing the impacts of climate variability and change, and for supporting research toward improved understanding, modeling and prediction of the climate system. It addresses the total climate system including physical, chemical and biological properties, and atmospheric, oceanic, hydrologic, cryospheric and terrestrial processes.

3.8. Cooperation with Interagency Working Group on Earth Observations (IWGEO)

During the Earth Observation Summit of July 31, 2003, the intergovernmental ad hoc Group on Earth Observations (GEO) was formed to develop a 10-year plan for implementing an integrated Earth Observation System. Subsequently, the Interagency Working Group on Earth Observations (IWGEO) was formed to develop a 10-year plan for implementing the United States' components of the integrated Earth Observation System.

The IWGEO comprises representatives from 15 member agencies within the federal government: DHS, DOC, DOE, DOT, EPA, HHS, NASA, DOD, NSF, OSTP, Smithsonian, State, USDA, USGS, and USAID. IWGEO was structured to mirror the GEO: along with an executive secretariat and a planning and integration team. IWGEO contains architecture, data utilization, user requirements and outreach, capacity building, and international cooperation teams.

The NOAA CDR program will work closely with the IWGEO teams, particularly the data utilization and user requirements and outreach teams to ensure CDRs are responsive to the requirements of the various user communities.

3.9. Conclusion

It is clear that NOAA must depend upon partnerships for the development, analysis, reanalysis and research of CDRs. Figure 1 illustrates the breath of possible partnerships that the SDS Program will explore with the wide range of expertise in the climate community. Effective management of these partnerships will require an innovative governing structure to ensure all parties are represented and to engage the broader research community. This structure is described in the next chapter.

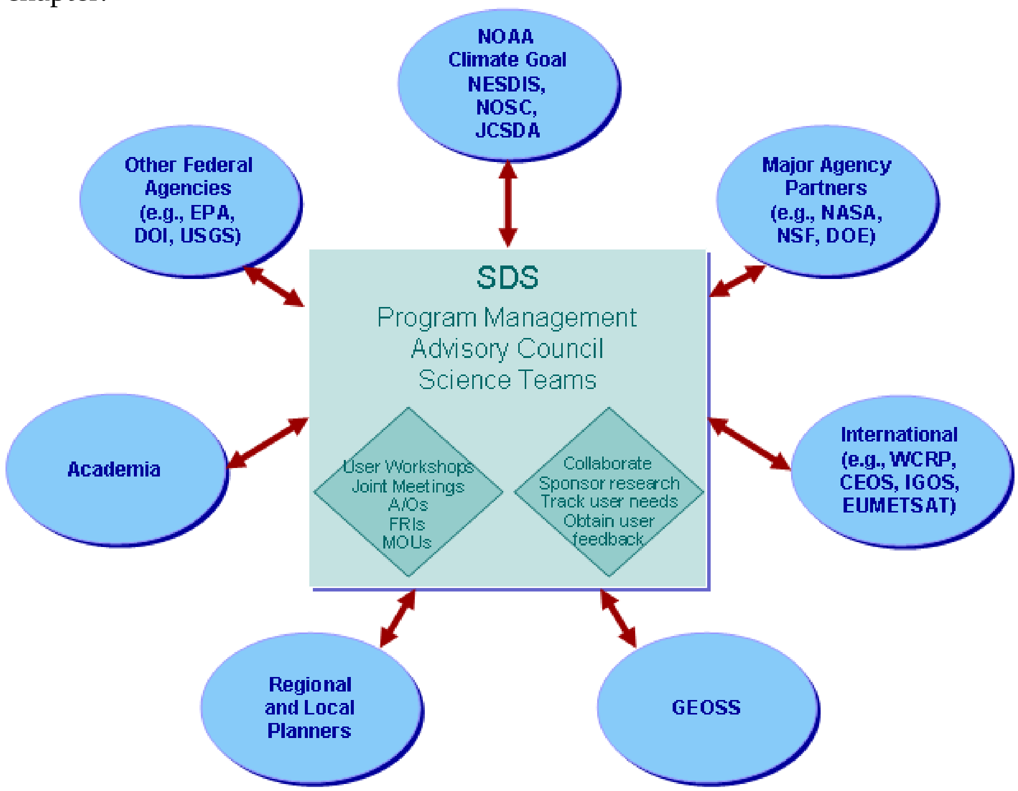

Figure 1. Schematic of SDS possible Partnerships

4. Implementation Plan for a Scientific Data Stewardship Program

4.1 Vision and Goals

The Vision of the of the Scientific Data Stewardship Program is: *A climate science community empowered with the high-quality satellite and supporting ground based climate data records needed to enhance society's ability to plan and respond by providing a detailed framework for federal investments in this area.*

Realizing this Vision will provide the nation with the observational data needed to reliably provide climate applications, climate monitoring, and to assess and predict global climate variations and change to a wide variety of sectors. Partnerships will be a key to the SDS program and will also be a key to the U.S. Climate Change Science Program.

Benefits of realizing the SDS Vision include:

- Applied climatology using SDS CDR's will bring practical benefits to numerous sectors of the U.S. economy. In particular, major advances in land remote sensing have occurred in the last decade as a result of research using NASA's Earth observing system data. These applications of advanced remote sensing satellite observations are recent and hence are not reflected in NOAA's planning for NPOESS environmental data records. Data sets for vegetation science, management, and applications will be a primary focus for the SDS applied climatology operations. Other applications will be in industrial climatology, bioclimatology, and marine resources climatology.

- Use of the SDS Climate Data Records in climate monitoring will permit earlier detection of any changes that may be occurring in the Earth's climate. Earlier detection means that necessary actions to reduce, mitigate, or adapt to any climate change can be implemented before the problem becomes more acute, and therefore, more difficult to manage. Just as early detection of disease in humans facilitates successful treatment, early detection of climate change will accelerate effective solutions.

- The SDS CDRs for climate change will provide exacting checks on climate model simulations, enabling evaluation of their accuracies and limitations. These results can then be used to determine the reliability of the model projections of future climate change. The checks of the models against SDS CDRs will also permit discovery of weak points in the models and focus effort on fixing them. Reanalysis will be improved with the assimilation of the high quality SDS CDRs, thus providing increasingly more reliable and physically consistent estimates of the regional distribution of climate change. Research performed with the SDS CDRs will contribute to increased understanding of the processes that control climate. Increased understanding of these processes is the foundation for improving climate models.

The more sophisticated, more capable, and higher data volume instruments of NPP and NPOESS pose additional opportunities and challenges. SDS will develop and implement the science for creating seamless CDRs extending from the POES era (going back to the 1960s for some climate variables) through the NPP and NPOESS time frames. The SDS will also exploit the new capabilities of NPP and NPOESS to improve the CDRs and to add additional high priority CDRs to the observational data base.

4.2. Pathways to Critical Climate Products and Services

The U.S. climate program is in a period of transition. As the program has started to mature and, to some extent as a result of its success, the program is being asked to provide a broader suite of products and services to users and to measure societal benefits. From the outset of the Climate and Global Change Program, now the CCSP, the primary pathway to users and societal benefits has been that illustrated by the top line of the flow chart below. In this pathway (Figure 4.1), observations are primarily used to generate new understanding, this new understanding leads to improved modeling of the climate systems and then this improved modeling leads to the societal benefits. The results of this pathway have been mixed with some notable successes, such as improved understanding and modeling of El Niño, but also some failures, such as continuing large regional disparities in the impacts of global warming on the water cycle.

As the records from satellite remote sensing have grown longer and new applications, particularly with respect to the land surface, have gained credibility, new pathways to critical climate products and services have opened. These pathways are applied climatology and climate monitoring, both of which have been somewhat underappreciated as modeling has eclipsed these more traditional uses of observations in climate applications. Improved climate monitoring, the bottom pathway illustrated below, is possible using remote sensing and blended in situ remote sensing data is improving due to the longer records and continued work with the data sets. Applied climatology is defined as the scientific analysis of climatic data in light of useful application for an operational purpose. Operational in this sense does not simply describe the production of the data sets, but also entails the application of the data to specialized endeavors such as agricultural climatology, industrial climatology, bioclimatology, etc. This pathway, illustrated in the middle layer of the diagram below, is becoming an increasingly important use of remote sensing data, particularly for NOAA as an operational agency.

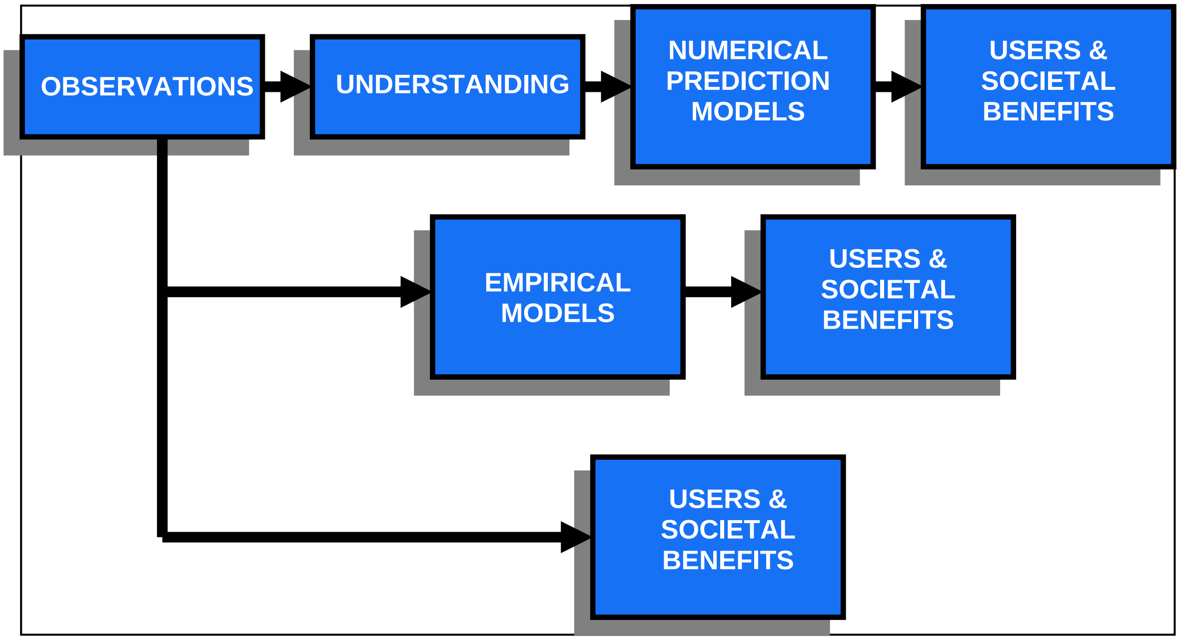

Figure 4.1. Pathways from observations to users and societal benefits.

4.3. Research to Operations Cycles and Transitions for CDRs

The research to operations life cycle may be thought of as two iterative and cyclical processes (Figure 4.2). Too often these cyclical processes do not overlap and/or those involved in each individual cycle do not recognize the required roles of the other cycle. In addition, no process for a transition has been formally established. These cycles must by examined for each parameter with a focus on a prioritization of parameters that occurs jointly as a responsibility of the NOAA Goal teams and the NOAA Observing System Architecture (NOSA). Parameters will be prioritized based upon a return on investment strategy including cost, schedule risk and impact. The iterative process of both research and operations must be evolutionary and must focus on the why, what, and when of specific deliverables. In the following discussion we focus on the specific processes of research, operations, and the transition from one to the other while maintaining quality. After that, we propose the organizational structure required to implement these processes but emphasizing that the organization is not the end. The evolving process of ensuring societal benefits to end users is the ultimate goal and performance measure.

4.3.1. Research

The iterative cycle of climate research within NOAA begins with user requirements as identified by the NOAA goal teams and delineated in the climate observation requirements process. The following steps then are outlined, but pilot studies will help to further clarify the process:

- Observing system scoping – perform trade space studies on how to implement an integrated observing system blending multi-platform data to meet accurately and efficiently design trade space studies

- Observations requirements – identify and validate with users climate observation requirements using the observing system scoping results
- Observing systems – procure and deploy integrated observing systems to meet the climate requirements
- Research and development products and services – conduct needed research and development using the observing systems to satisfy user requirements
- Evaluation – conduct internal and external peer review of the research and development results to decide to 1) stop the effort if it is not likely to meet user requirements, 2) continue the research if there is progress but requirements are not met, 3) transition to operations if the method is making sufficient progress to meet user requirements.
- Research to operations assessment from research perspective – perform complete assessment of all aspects of products and services that would need to be addressed for a successful transfer of the products and services to operations including continued involvement of the research development community

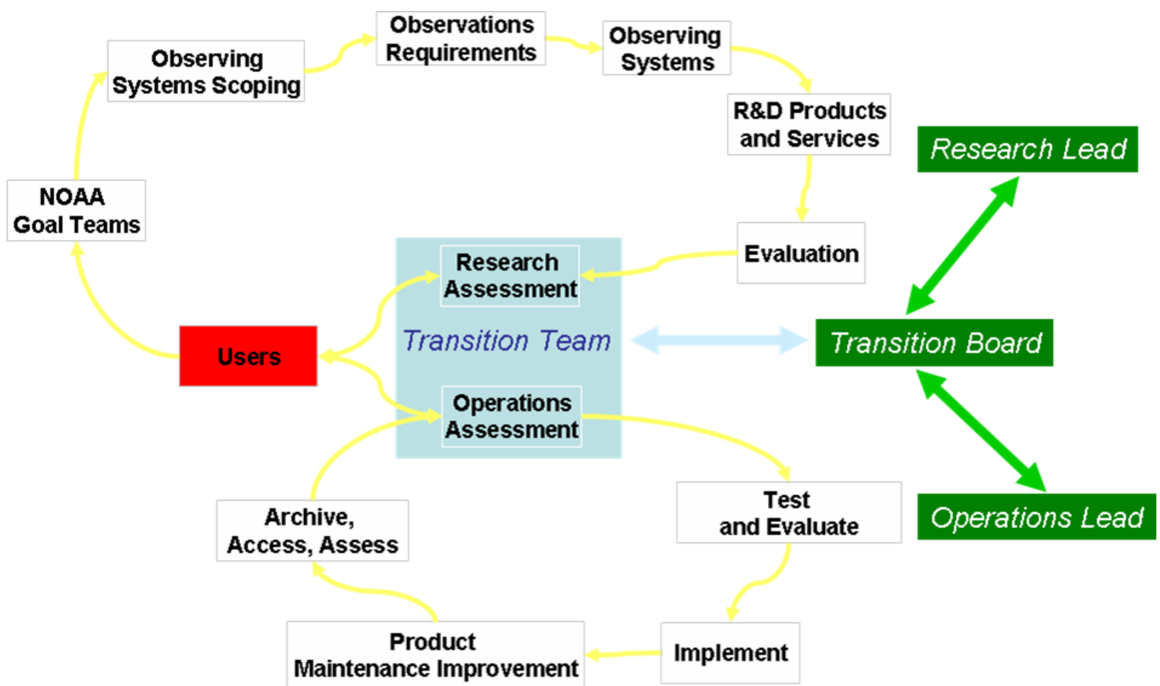

Figure 4.2. Iterative cycles of research, operations and research-to-operations transitions.

4.3.2. Operations

We have begun, with our NASA EOS colleagues, to develop a rigorous cost estimation strategy straw man that, when further developed, will provide a blueprint for accurately estimating steps needed and long-term cost for processing and reprocessing of operational CDRs to a given level of validation and confidence. These operations assessment steps include:

- *Designing the Data Products and Production Instances*
- *Estimating the Data Producer's Software Development Costs*
- *Specifying the Validation and Production Schedule*
- *Planning for Operational Production Problems*
- *Choosing Technology for Operational Production*
- *Calculating Capacity Profiles*
- *Calculating Investment Metrics*
- *Determining Performance Measures*

Concurrence is required by a transition team (described later) that takes into account the research side assessment and the operations side assessment in making a decision to perform the transition. Once that decision has been made, the iterative cycle to operations includes the following steps:

- Test and evaluate – the product or service will need to undergo an initial trial assessment

- Implement – transfer and update software and documentation, perform training, institute quality assurance, quality control, and configuration management

- Product maintenance and improvement – ensure transfers to new hardware and software systems as needed, perform minor adjustments to ensure efficient operations

- Archive, access, and assess – work with CLASS to assure easy and effective archival and access to data and metadata and periodically assess product quality

4.3.3. Transition teams and Partnerships

Planning for a transition from research to operations must occur at the outset of the observing systems scoping process. Transition teams will bridge, as well as include members from, the research and operations communities. Partnerships and observing systems that need to be considered in the research-to-operations transitions include:

NOAA and Partner Agencies: To create a truly integrated SDS Program, NOAA will take the lead in partnering with other agencies involved in the generation, validation, data management, and performance of research with CDRs.

In-situ data sets: Although the major source of data for the SDS will be space-based, the Program will also include in-situ data. Since satellite observations are based on remote sensing and are indirect, more direct in-situ observations are needed to support the satellite observations in the creation of Climate Data Records. High quality in-situ data sets are needed to validate satellite data sets. They are also required to generate blended data sets of satellite and in-situ observations such as those of the Global Precipitation Climatology

Project and the blended Sea Surface Temperature produced by NOAA's Climate Prediction Center within the National Weather Service (NWS) using satellite, buoy and ship data.

Science Oversight and Participation by the External Community: The SDS Program will utilize an external advisory council to provide oversight and feedback, and competitively selected Science Teams and Announcements of Opportunity to engage the extramural community in the activities of the Program.

International Collaboration: The SDS Program will actively participate in international data projects, in particular, those of the World Climate Research Program, collaborate with other satellite agencies in generating CDRs, and develop strong programmatic links to the GEOSS.

Mix of Centralized and Distributed Activities: NOAA will establish a centralized CDR processing center to transition mature CDRs from research to operations but some CDRs may also become operational within distributed centers provided criteria for operational support can be met by the distributed center. Distributed processing, data management, and research with the CDRs will be performed at the most appropriate capable institutions for CDRs that require additional maturity.

4.4 SDS Organizational Elements

The primary functions of the SDS organizational elements are to provide leadership, coordination and facilitation of the program. Although the iterative cycles of research and operations within the current NOAA organizational structure have been defined above, we currently find a research component with much experience in algorithm development and generation of CDRs but few operations and no mechanism from transfer from research to operations. Thus, the primary role of the organizational structure is to organize a SDS working group that will help identify and prioritize the near-term actions needed to insure an efficient research to operations track in NOAA. These high priority items should also be evaluated for their impact on helping NOAA transition from the current POES system, through EOS and METOP, to the NPOESS era. A schematic diagram for the organizational elements required to support this process is illustrated in figure 4.3.

4.2.1. NOAA Organization

The process outlined above dictates the organizational structure required for initial implementation of the SDS program. The exclusive NOAA elements are depicted in the green boxes:

- Scientific data stewardship program management will be responsible for leading and assisting with all aspects of research, climate data record production, and the transition of research into climate products. The SDS program leadership will consist of 3 members: 1) an overall program manager; 2) a research lead - the Chief of ORA's Satellite Meteorology and Climate Division (SMCD), and 3) an operations lead – the Chief of NCDC's Remote Sensing and Applications Division (RSAD). All three members will participate in the decision-making process with decisions made by consensus. Important decisions will be reviewed and require approval from higher levels within the NOAA organizational process. Implementation of the detailed processes for the supporting research, research to operations transition cycles, and operational climate product generation, as described above, is under the purview of the Scientific Data Stewardship program management personnel.

- The SDS program management will report to the respective Directors; the Director of ORA for the SDS research lead and the Director of NCDC for the operations lead. The program manager will report through the element lead for Observations and Analysis within the Climate Goal. The Director of ORA has additional research leadership through the NOAA Research Council and the Director of NCDC has additional operations leadership through the NOAA Observing Systems Council's Data Management Committee. In addition, the Director of NCDC is also currently the lead of the Observations and Analysis element within the Climate Goal team.

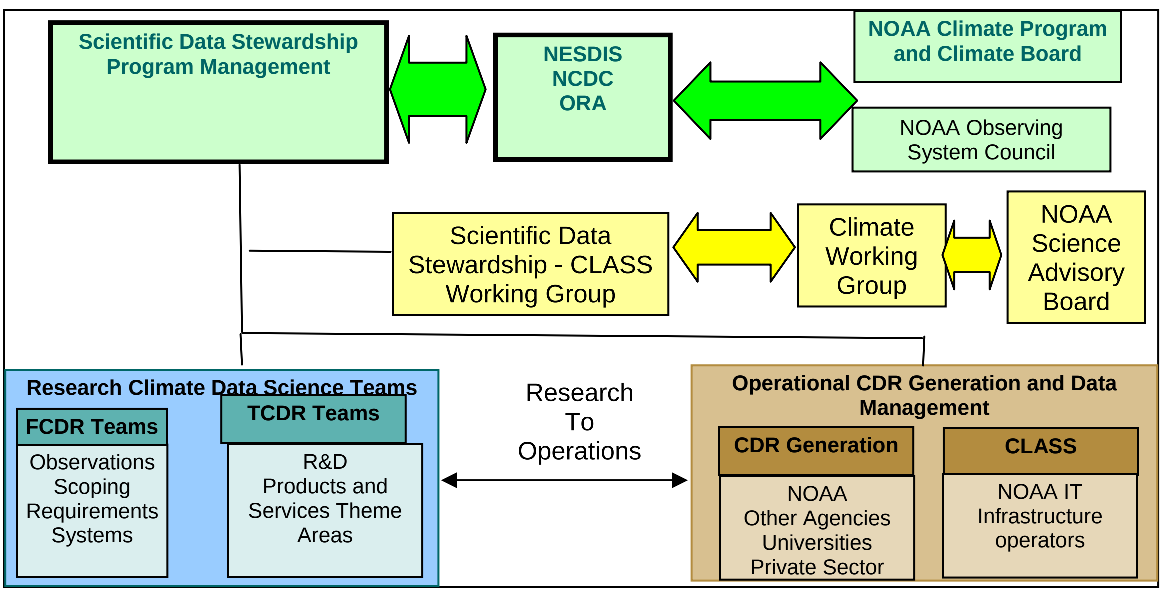

Figure 4.3. SDS organizational structure.

4.4.2. Research Climate Data Science Teams

Climate Data Science Teams will conduct a large part of the work of the SDS. The Science Teams will be competitively selected, with Partner Agencies adding additional members as required from its in-house staff. Proposals for Science Team participation will include the contribution of the proposer to the work activities of the Team (e.g., develop algorithm, validate data set, process data, apply data in climate models, analyses, etc.) based upon the iterative research to operations paradigm. Science team members may transition research climate algorithms and processing systems to operations and run them operationally under certain conditions.

Fundamental Climate Data Record (FCDR) Teams

The FCDR Teams will create high quality sensor data sets from the raw satellite observations. They will be organized according to the observation tasks within the research to operations cycles.

> Fundamental CDRs (FCDRs) are sensor data (e.g., calibrated radiances, brightness temperatures, radar backscatter) that have been improved and quality-controlled over time, together with the ancillary data used to calibrate them.

Responsibilities

- Perform real-time monitoring of the observing systems
- Determine best possible calibration and characterization of each instrument during its lifetime using on-board and vicarious calibration techniques and comparisons with NWP model analyses
- Account for any satellite drift or other artifacts in the sensor record
- Account for satellite to satellite instrument differences using overlapping observations
- Create a high-quality stable, seamless FCDR time series from a series of overlapping satellite observations
- Reprocess the FCDR time series as updated instrument information or improved techniques become available based upon cost/benefit analysis
- Subsampled, intercalibrated, integrated observations from suite of sensors both in situ and remote sensing

Membership

Team Members will include instrument specialists, calibration experts, spacecraft engineers, and representatives of the Thematic CDR Teams. It is anticipated that much of the expertise for these Teams will come from government specialists, but additional members will be competitively selected from the external community.

Thematic Climate Data Record (TCDR) Teams

The TCDR Teams create and validate all the climate variables derived from the FCDRs. They will follow the research to operations paradigm also and will be organized according to discipline areas:

- Applied Climatology
- Climate Monitoring
- Climate change Forcings and Feedbacks

> Thematic CDRs (TCDRs) are geophysical variables derived from the FCDRs, specific to various disciplines, and often generated by blending satellite observations, in-situ data, and model output.

Responsibilities

- Develop algorithms for generation of TCDRs from FCDRs
- Process near real-time TCDRs
- Validate TCDRs against ground truth and other satellite observations
- Reprocess the data set as updated instrument information or improved algorithms become available based upon cost benefit analysis
- Apply TCDRs in climate applications activities

Membership

TCDR Team Members will be selected in an open competition and will include specialists in algorithms, validation, and climate applications. The competition will be open to foreign scientists, but all expenses for foreign participation (except travel) will be borne by the scientist's institution. Additional Team Members will be appointed by the SDS Program and Partner Agencies from their government staff, including experts in data management.

4.4.3 Operational Generation Elements

FCDR and TCDR Generation

In most cases, the most appropriate site for FCDR generation will be the satellite operating agency. The satellite operator (NESDIS, NASA) procures and manages the satellite and its instruments, ingests the data stream, and monitors the observing system. It is ultimately responsible for the credibility of the basic observations: the FCDRs. Under the direction of the FCDR Team, the satellite agency will generate the FCDR data set.

TCDRs will be generated and reprocessed by TCDR Team Members at their respective government, university, or private sector institutions. Processing by science teams rather than data centers has been a successful innovation. As stated in NRC (2004): "A programmatic change in early 1998 transferred the responsibility for most EOS data processing from the DAACs (and the EOSDIS Core System) to EOS science instrument teams and their facilities. These teams included both scientists who generated data and scientists who used TCDRs. This transfer, accomplished through a call for proposals, was a major reason for the ultimate success and timely delivery of the EOS standard data products and accounted for the high degree of scientific community acceptance of these products."

FCDR and TCDR Data Management

FCDRs and TCDRs from NOAA satellite observations will be archived and managed at the NOAA Data Centers. Non-NOAA satellite FCDRS and TCDRs will be archived and managed at the NOAA Data Centers or the NASA DAACs, as determined by mutual agreement between the agencies.   The long-term archival responsibility for FCDRs and TCDRs is NOAA and a process will be developed for the transition of necessary CDRs from NASA to NOAA.

An operational center is required to ensure that critical climate products and services can continue independent of any particular investigator. This poses great challenges because it is often the care and continuous insight provided by dedicated investigators that leads to the highest quality products. On the other hand there are cases when an investigator has retired and their critical products could no longer be produced. Thus, the SDS Program must strive to meet several principles including 1) funding to keep principal investigators whose products have been transferred from research to operations involved with the ongoing quality control and quality assessment, 2) and open and responsive processing system at the operational Center, 3) free and open access to the product, metadata, and provenance, and 4) the eventual replacement of the principal investigator.

On an interagency level as well as an intra-agency level, the track record for transitioning climate research to operations is poor. The reasons for this are complex. The NOAA SDS program's most difficult challenge will be trying to change this situation. As noted by the national academies, "the new emphasis and importance of climate within NOAA's mission requires an increased focus on partnerships and new approaches as it relates to supporting extramural research". NOAA's existing extramural program, the Office Global Programs, has only limited experience in supporting satellite climate research and has no program for supporting extramural efforts in data management. NASA, on the other and, has supported of vigorous satellite climate research and data management extramural program for many years but no mechanism has been established to transfer the assets and results of this program to NOAA for operational implementation.

The SDS program will primarily focus on the production of operational climate data records and the transition of existing climate data record research to operations. This does not necessarily mean that all operational climate data records will be produced at a centralized site. Operational production can, and should, occur in a distributed manner. The distributed sites, however, must all adhere to common standards and have high-speed connectivity to CLASS. CLASS will also have IT for reprocessing of very large datasets. In fact for very large data volumes, the SDS Program will generate subsampled datasets as test beds for new algorithms. To maximize resources and reduce costs, the full resolution datasets will not be reprocessed until the CDR algorithms have been completely validated with the subsampled data. Generally, the subsampled datasets will be reprocessed by TCDR Team Members at their respective government, university, or private sector institutions

The SDS program will strictly adopt the Federal enterprise architecture which focuses on a business driven approach. Over the last 10 years, the climate research community has learned a great deal about the processing, validation, and generation of experimental climate data records from both operational and research satellites. These experiences have led to the first attempts to quantify the steps necessary to create operational climate data records using a cost estimation model. The SDS program will further quantify this cost estimation model and apply it to provide for a full implementation of the Federal enterprise architecture including: a performance reference model, a business reference model, a service complement reference model, a data reference model, and a technical reference model. All participants in the SDS program will be required to comply with this Federal enterprise architecture. This will allow for full accountability and a tracing through inputs, outputs, and outcomes.

4.4.4. Advisory Working Group for Scientific Data Stewardship and CLASS

A critical organizational element will be the empowering of an external working group for SDS-CLASS organized through NOAA's existing advisory mechanisms Figure 4.3; yellow boxes). NOAA's Science Advisory Board (SAB) is an officially-constituted Federal Advisory Committee Act (FACA). As needed, this board can empower non-FACA working groups to study specific issues ad hoc. Currently, there is a Climate Working Group to advise NOAA's Climate Goal. We will seek to another working group, to report up through the Climate Working Group, to specifically prepare independent advice on the SDS and CLASS programs and to work with SDS and CLASS program management on issues of mutual interest. We anticipate that this working group would meet approximately twice a year and prepare summaries of its findings and present them at meetings of the Climate Working Group. An alternative would to initially just have the Climate Working Group provide an independent evaluation of the SDS and CLASS programs. We will work with the existing Climate Working Group and SAB to determine the optimal external advisory structure.

4.5. Summary

We propose to implement a paradigm within NOAA and the U.S. Climate Program comprised of a iterative research and operations processes joined and interoperable using a formal transition process. We believe that these processes will incorporate the key elements of a successful CDR Program by incorporating organizational, generation, and sustaining characteristics in NOAA's operational mission.

References

GCOS, 2003, The Second Report on the Adequacy of the Global Observing Systems for Climate in Support of the UNFCCC, 85 pp., World Meteorological Organization – TD No. 1143, Geneva, Switzerland.

Lawler, A. 2004: Stormy forecast for climate science, *Science*, **305**, pp. 1094-1097.

National Research Council, 1999a, *Global Environmental change: Research Pathways for the Next Decade*, 616 pp., National Academy Press, Washington DC.

National Research Council, 1999b, *Adequacy of Climate Observing Systems*,66 pp., National Academy Press, Washington DC.

National Research Council, 2000a, *Issues in the Integration of Research and Operational Satellite Systems for Climate Research, I. Science and Design*, National Academy Press, Washington DC.

National Research Council, 2000b, *Ensuring the Climate Record from the NPP and NPOESS Meteorological Satellites*, 51 pp., National Academy Press, Washington DC.

National Research Council, 2000c, *Issues in the Integration of Research and Operational Satellite Systems for Climate Research, II. Implementation*, National Academy Press, Washington DC.

National Research Council, 2000d, *Reconciling Observations of Global Temperature Change*, 85 pp., National Academy Press, Washington DC.

National Research Council, 2000e, *Improving Atmospheric Temperature Monitoring Capabilities- Letter Report*, 18 pp., National Academy Press, Washington DC.

NOAA, 2001, *Final Report of the NOAA Science Advisory Board's Panel on Strategies for Climate Monitoring*, 27 pp. NOAA, Silver Spring, MA.

National Research Council, 2004, *Climate Data Records From Environmental Satellites: Interim Report*, 136 pp., National Academy Press, Washington DC.