

Review of the
Climate Observations and Analysis Program,
NOAA
Climate Working Group (CWG)
April 11-13, 2007
At NOAA's National Climatic Data Center
5/20/07

1. Introduction

Under the CWG, a working group of the Science Advisory Board of NOAA, a review was performed of the Climate Observations and Analysis (COA) program 11-13 April 2007. The review team is listed in Appendix 5. The terms of reference for the review were to:

- Conduct a non-advocate review of the COA program of the Climate Goal
- Meet with COA program representatives for a thorough on-site brief and review in April
- Conduct other site reviews, as needed, in April and May.
- Complete report by September 15 for submission to CWG where it will be discussed at Fall 2007 meeting on Oct 10-11 (tentative).
- Provide initial feedback to COA program manager and Climate Goal lead by early May to have an influence on NOAA FY10-14 program development.

The nature of the review was developed and the plans expanded jointly between the NOAA Program Office and COA, and the Chair of the review panel, as given in Appendix 3. Appendix 1 provides the agenda for the meeting, and it outlines the Panels that were set up and the NOAA panel members. Appendix 2 provides general background information. Appendix 4 provides the guidance for the panels and the presentations. The report has two main parts, the first provides the overall commentary and review, and the second provides a more detailed commentary on the eight topics presented in the panels that make up components of COA. Acronyms are listed in Appendix 6.

2. Findings

The Climate Working Group (CWG) review of the NOAA Climate Mission Goal's Climate Observations and Analysis (COA) Program learned that there is considerable excellent work going on in NOAA which is contributing to the COA program. The various activities identified with the COA program are providing many valuable climate observational products and services to the nation that should be continued. In particular, the essential work of collecting observations and creating climate records, assuring their quality and documenting and making them accessible to the climate research, applications research, and decision-making communities is of great importance and should receive a high priority within the NOAA Climate Goal. However, the review panel also identified several overarching strategic issues that affect the management of the COA Program and the NOAA Climate Goal in general. These include the need for a shared vision that (i) provides a coherent, integrated structure for COA activities and services, in essence a strategic plan; (ii) improves the functioning of the NOAA internal process that integrates program planning, budget formulation and execution, and processes used to determine priorities when requested and appropriated budgets differ; (iii) advances the approach to engaging partners from the external communities in COA and Climate efforts; and (iv) furthers the integration of the many efforts under COA with one another and other activities under the Climate Goal. One way forward in the longer term may be to note that VADM Lautenbacher has recently called for a National Climate Service, and the

Panel suggests that if such a Service were a distinct line of NOAA then it would ease many of the perceived management difficulties.

Strategic Plan

COA is a collection of activities that fall under the label of “climate observations and analysis. The program was not developed with a particular objective, so that it lacks an overall coherent theme and a strategic plan. There needs to be a clearer overall framework. The panel believes that development of such a strategic plan would not only help to promote the program to NOAA, Commerce, and the Congress, and help define and demonstrate its essential nature, but it would also provide a means of helping NOAA management prioritize and make decisions. By making this comment the Panel does not intend to demean the many excellent coherent projects within NCDC or other parts of NOAA. Indeed, a programmatic thrust is evident, which the panel suggests will facilitate the preparation of the plan. However, there are elements that are less critical and there are other critical elements that are absent. A strategic plan should help establish priorities and identify new areas for investment.

The foremost key issue then, is how the many parts of COA fit together and make a whole. The Panel finds that COA requires a strategic plan that includes aspects of implementation and provides a blueprint for integration of the various parts of COA. This strategic plan needs to guide adoption of more of a system approach that more fully involves the relevant NOAA line offices and the outside community from planning to execution and operations. One possible model for this strategic plan would be to adapt some of the concepts from what Trenberth, Karl and Spence (2002) called the full “climate observing system” but which might be better termed the “**climate information system**”. The system must include all the parts that were detailed in the various panels: the observations (that satisfy the climate observing principles); a performance tracking system; the ingest, archival, stewardship of and access to data, including data management and integration; the analysis and reanalysis of the observations and derivation of products, especially including Climate Data Records (CDRs); assessment of what has happened and why (attribution); initialization of predictions; and responsiveness to users. This then provides concepts to guide planning, operations and setting priorities, and thus to help make decisions.

The process of developing such a strategic plan would likely be a learning process and could be as important as the plan itself. The Panel recognizes that a large level of effort is required to develop such a plan, and notes that, while this plan should be developed by the COA Program Manager (Tom Karl), he would likely need to recruit a team to help.

One example of the application of such a plan for priority setting comes from the crisis brought on by the Nunn-McCurdy certification in June 2006 that de-manifested a number of vital climate observing instruments from NPOESS. It is critical that ongoing efforts to sustain continuity in many records continue, and this must remain a major priority; however, contingency plans for the inevitable gaps in the climate record must be developed as well. The Panel suggests that it is actually likely that a gap will occur even if the efforts to get the instruments into space are realized (such as from a vital instrument failure). For some measurements, such as solar irradiance, such a gap is disastrous for the climate record. For other measurements, it may be possible to bridge such gaps with *in situ* measurements. Such measurements must, then, be of sufficient quality, accuracy and sampling that they can act as a transfer standard. One possibility is the proposed reference radiosonde network, in its full regalia, with multiple measurements consolidated at the sites (such as temperature, ozone, radiation, and water vapor). Consolidation of the multiple networks could provide savings in staff and locations so that additional costs for this network are not prohibitive. But if this were deemed the way to help bridge gaps, then it should become clear that implementing this network should be a much higher priority. [Currently it has been proposed for funding as a separate item and it is not funded].

More generally, COA needs to develop a clear and consistent vision for the role of satellite data in climate services. The issues of satellite data assimilation, relationships and dependencies on other parts of NOAA, and the long-term relationship between NASA and NOAA also need to be addressed.

As another example, the Panel heard about a lot of excellent work on climate observations, but relatively little about assimilation and analysis, the “A” in COA. In part this seems to be because the analysis is primarily carried out by a different group in a different line of NOAA. An example is in the area where otherwise excellent comprehensive management is taking place because the planning and execution are in the same group, namely the area of ocean observations. However, the synthesis of these observations and strong links to data assimilation and production of analyses and error fields are missing. Having that link would also enable observing system experiments that can aid the design of the observing network. Again, a system approach and a more strategic view of the entire program are required.

Planning and execution

The program appears to be severely hampered by the cross-NOAA nature of its management and the planning and execution of the program plan. Of particular concern in this context is the fact that while efforts may be made to develop NOAA-wide programs and plans, authority for implementation of individual activities rests with individual line organizations. This inherently constrains the authority of a manager charged with responsibility for a particular component program like COA. In addition, the Panel is very concerned about the inherent conflicts of interest that arise when the program manager of COA is also the Director of NCDC. We think Tom is doing an amazing job (in reality two jobs) under the circumstances.

The Panel is concerned about the severe limitations to the timeliness and effectiveness of the COA program that are imposed by NOAA’s planning, budgeting and execution methodology (PPBES) and the NOAA matrix management process. Based on our knowledge of this process, it appears to lack flexibility in implementation by disconnecting the planning process from the execution of the program, and it limits what managers can do and their ability to manage. There appears to be insufficient authority and control of resources, as well as some lack of clarity as to responsibility when something goes wrong and in the setting and carrying out of priorities.

An example highlighting the difficulties is in the vital area of reanalysis, in this case atmospheric or coupled reanalysis, where the preparation of the observations and datasets is based in NCDC (NESDIS), the modeling, assimilation and reanalyses themselves are in NCEP (NWS), and the main expertise in evaluating and using the products is in ESRL (OAR). Further complicating the reanalysis area is its overlap between the COA and the Climate Predictions and Projections (CPP) program. The panel received the impression that in the execution phase, in particular, funds are allocated in an inflexible and somewhat arbitrary manner, and the Climate Program Office loses the ability to control resources and ensure coordination, including the much needed involvement of the outside community. This is especially a problem when resources are inadequate and less than planned for. The basic infrastructure for such a project is lacking and no individual is in charge.

It is also evident that the COA Program depends on a number of observing systems that are planned and budgeted for in the context of other Mission Goals (most notably Weather and Water) as well as the satellite missions in the Mission Support Goal, without a clear mechanism for climate requirements to factor into decisions about priorities and resources. The panel also heard about requirements that the Climate Goal address/accommodate some significant infrastructure investments with benefits that far exceed the Climate Program (Mission Goal) itself (e.g., CLASS, GEO-IDE).

Were these activities all coordinated and planned as part of the climate information system as an integral part of the proposed climate service, many of these difficulties would be overcome, as authority and responsibility would become clear.

Engaging partners

Another overarching issue that arose throughout the COA Review was the need for a broadly-understood and transparent priority-setting process that effectively engages Climate Program partners in and out of NOAA. This is particularly important when the leadership for the Climate Goal and its constituent Programs reside within individual NOAA line organizations. The panel notes the excellent outreach workshops with users, and that user needs are sought and considered when changes are implemented. However, the COA Review highlighted the importance of effectively engaging a variety of partners to the success of the COA program element and the NOAA Climate Goal more broadly, from planning to execution. Such partnerships should include:

- International, regional, national and local observing systems and programs;
- Universities and other partners in the extramural research agencies;
- Agency partners in a number of other agencies;
- Regional partners including, most notably, the Regional Climate Centers, State Climatologists, RISA programs and IOOS Regional Associations among others; and
- The private sector active in climate research, monitoring and services.

A key part of the strategic plan should be how COA plans to engage and take advantage of expertise and interest in the outside community. Hence it became apparent that there is a need to upgrade and invigorate the extramural grants program and especially to include calls related to reanalysis and attribution. The grants program can benefit NOAA, as extramural research should help operations, just as operational or routine activities (such as improved datasets) can aid research. The Panel recommends that NOAA set a fixed fraction of program funds that are committed to peer-reviewed extramural funding, and that they make every effort to ensure that this funding commitment be maintained. Another way to invigorate the program is to include a visitor and postdoc program so that connections to internal personnel are fostered. This also often provides an inroad into recruiting new qualified staff.

The COA review highlighted the importance of a variety of sustained mechanisms for user engagement and feedback to help guide program design, priorities and implementation.

3. Panels

Panel 1 *Data Ingest, Access, and Archive (and “Storage” CLASS CONOPS)*

Moderator: Peter Cornillon, Jim Kinter

The activities being undertaken by the NOAA Climate Observations and Analysis (COA) program in the areas of data ingest, access and archive, which will be broadly referred to herein as data management activities, are providing valuable services to the climate research community and users of climate services from NOAA. Of particular note is the rapid growth of usage of the NOAA Operational Model Archive and Distribution System (NOMADS), which has been cited in a National Academy of Sciences report as a service that should be maintained and expanded.

Overarching finding: The leadership of the data management activity, which is critical to the success of COA, should be clearly defined to provide more appropriate levels of direction, prioritization, and integration of activities, to more systematically identify opportunities and risks, and to raise the needed funds in the budget process. Furthermore, these activities should focus explicitly on the needs of COA as opposed to being required to address the broader needs of NOAA.

The remainder of this section is organized into critical observations and findings.

Observations

1. The goal of this program element is to provide access to and stewardship of the nation’s resource of global climate and weather related data and information. The data management activities being undertaken are critical to, and are making significant progress toward, this goal. The National Climatic Data Center (NCDC), as primary repository of U.S. climate data takes the lead in this activity, annually taking in ~150,000 paper records, and multiple petabytes of electronic data from satellites, radar, and *in situ* measurements as well as numerical models.
2. Distributed data access is critical to expanding and leveraging data services through a service-oriented architecture.
3. A number of important tasks are being undertaken as part of the data management capability, but there are also a number of worthwhile tasks that are not being undertaken, due to a lack of funding or because it is not clear who is responsible. Ultimately, the COA Program Manager (Tom Karl) is responsible for COA data management, but the panel gained the impression that the architect (Ken MacDonald) of the Group on Earth Observations (GEO) Integrated Data Environment (IDE) project is viewed as responsible for execution. Furthermore, it appears that, within COA, data management and data system integration are viewed as synonymous. This is resulting in important COA data management activities being overlooked (Item 6 below).
4. Funding is in place for many of the data management systems as well as for CLASS, at least in part, but there is little to no funding for GEO-IDE, the integration effort. Data integration is an essential component of many climate analyses. Given the critical and increasing need for a high level of data management integration, the fact that this part of the program element relies on modest, incremental funding is short-sighted and a potential source of trouble.
5. Responsibility for GEO-IDE and CLASS is NOAA-wide but the responsibility for funding comes from COA. It is not clear what mechanisms are in place to make sure that broad NOAA data integration needs do not swamp the COA climate data management needs.
6. There are non-integration data management functions within COA that are not being addressed as part of the data management activity; e.g., institutionalizing the upgrading and reprocessing of datasets is a critical component that will contribute to the success of reanalysis (issue raised by COA Review Panel 3, Analysis, including Reanalysis, OSSE, OSE and Related Research).

Another example is the provenance work that Bruce Barkstrom is doing.

7. It is not clear who the climate-specific users of COA archives are, which makes defining data management needs for climate problematic.
8. Interoperability is an issue across several domains, including within the NOAA Climate goal, intra-NOAA with respect to other Goals, with respect to other U.S. Federal agencies, with respect to the academic community, with respect to the user/stakeholder community, and with respect to international activities.
9. Adherence to data and metadata standards is viewed as a critical factor contributing to the success of COA data management; however, it is not clear how COA will ensure adoption and usage of common standards.
10. The need for access via the Open Geospatial Consortium (OGC) protocols is increasing substantially.
11. Although OPeNDAP and the OGC protocols handle the syntax part of access pretty well, especially OPeNDAP, neither handles semantics very well, and accordingly semantics is a big issue that has received little attention.
12. Data sharing is a sociology problem - NCDC is used to being a "center" with full control over data, software and everything, but a distributed model means that other institutions are involved. It is not clear how "operational" assurance will be provided in a distributed model?

Findings

1. If GEO-IDE is the solution to integration/interoperability problems, then there needs to be top-level recognition in NOAA that GEO-IDE is important and GEO-IDE should be prioritized as such, i.e., from the COA perspective, it should be stated that integration is required to accomplish the Climate Goal.
2. Given the importance of data integration: The panel endorses the notion of a NOAA group, the Data Management Integration Team (DMIT), operating as part of GEO-IDE to address access, standards and other relevant data management issues. From the COA perspective, this group should work closely with existing climate groups. The adoption of standards, at least for metadata, needs to be done soon so that those collecting data need to know what standards to follow.
3. It would appear that GEO-IDE and CLASS should be elevated to a higher level within NOAA than the COA program within the Climate Goal. For example, these projects could be made a NOAA infrastructure mission (or whatever the cross cutting infrastructure missions are called).
4. There is a strong need to link GEO-IDE and CLASS. If GEO-IDE is the coordination activity for the NOAA Climate Goal cyber-infrastructure interoperability element, these two systems should, at a minimum, be linked. Alternatively, CLASS should be integrated into an organization in which GEO-IDE provides the lead. Our understanding is that there is a meeting of the Data Archive and Access Working Group (DAARWG) in Chicago this month (May?) that will examine CLASS and GEO-IDE, and a further review by DAARWG would be beneficial.
5. The group of climate users needs to be clearly identified and prioritized, so that the climate data access/management requirements can be identified specifically for *this (these)* group(s). For example, one might place the climate scientist addressing long term climate changes in the highest priority group while weather concerns, whose only use of climatologies is to characterize a given storm to the public, might be put in a lower priority group. Or one might not! In either case, such a prioritization is critical when addressing funding shortfalls in the data management part of COA.
6. Addressing the interoperability issues raised in item 8 above is complicated by the fact that interoperability for climate studies is required not only with groups outside of the Climate Program in NOAA but also with groups external to NOAA. There are several options for ensuring that common standards required for interoperability are adopted. NOAA can:
 - a. Take the lead and/or work with other agencies.

- b. Work within NOAA to achieve standardization.
- c. Build the capability into GEO-IDE to augment metadata after the fact (via the service-oriented architecture) allowing for the inclusion of important data sets developed by non-NOAA organizations into a standard-homogeneous environment.
- d. Build metadata/standard crosswalks.

Each of these must be carefully considered both from a NOAA perspective and from a COA perspective.

- 7. Provision of products and services for the OGC-oriented community should be a priority, but not at the expense of users who rely on products and services that are provided through the long-established, more flexible services capable of handling three- and four-dimensional data types.
- 8. A special effort must be made with regard to semantics.
- 9. Steps should be taken to determine how best to provide "operational" assurance in the distributed data management model.

Panel 2 *In-situ Observing Systems and Data Management including Stewardship*

Moderator: B. Weller, Rit Carbone

On the observations side, a suite of blue-water ocean, atmosphere, and Arctic observations were presented. These NOAA COA observations form the core of the global climate observing system and as such are essential. The elements in and near the U.S. also are the heart of the U.S. climate observing system. Much of this work is responsive to and benefits from the oversight of national and international groups such as the international AOPC (Atmospheric Observations Panel for Climate) and OOPC (Ocean Observations Panel for Climate), both under GCOS, and Mike Johnson's COSC (Climate Observing Systems Council). Seeing the sweep of observations from continental U.S. out across the global oceans, one thing that stuck out was the lack of linkages with or inclusion of the regional coastal ocean observing efforts going on under NOS and NWS.

The blue water ocean observing effort has a multiyear strategy for investment and is evolving a system-oriented approach. This represents good progress in our view, though we find the lack of the funding necessary to keep on track with the ocean observations to be a major disappointment. A systems approach to the atmospheric observing was not evident and may not be as easily built. Many of the atmospheric observing elements are heritage systems put in place for weather observations. We encourage, however, the evolution of an integrative strategy for the atmospheric observations. As part of that strategy, attention must be paid to what makes the atmospheric observations climate quality and subsequently to the need for atmospheric observations to adhere to the principles for climate observations. Thus overlapping old and new systems is needed. The notion of sparse but high quality 'reference' networks on land and in the ocean is a good one to sustain climate quality observations and provide reliable reference points.

In both the ocean and the atmosphere the emphasis is apparently on the physical climate. We note that great benefit would derive from better integration of these observing systems with those doing biological and chemical observations. These benefits come from scientific relationships as well as potential logistical savings. We note several areas of opportunity that need to be considered. NOAA COA has inherited several surface energy balance observing elements on land. The capability to do surface radiation at sea has matured and new NSF-funded buoys will push it further; COA should consider moving toward producing global surface radiation, and surface energy balance fields. Another opportunity will come when the NSF investment in IPY observations is completed; so the question arises as to whether COA should take over some new Arctic observations? Should COA reach across Line Offices to collaborate, for example, on use of DART buoys for climate observations?

The annual *State of the Climate* report in *BAMS* is acknowledged as a significant effort with positive impact. We suggest that the effort with time move toward increasing integration across sub-elements and across the air-sea interface. For example, by discussing upper ocean heat content anomalies together with surface flux anomalies, their consistency could be assessed. This takes more effort and time, and a negative consequence of this might be to delay publication of the *State of the Climate* report.

However, a general comment is that there was not much discussion of the analysis part of observations and analysis. Analyses can play an important role in judging the efficacy of observing systems and thus in setting priorities for observing, so we encourage growth in the integrative and analytical part of this effort. As the *State of the Climate* report is now quite long, should it evolve into two parts, one observations based, and one related more to analysis, attribution and assessment?

We hope that such work would help make the case for more funding. The observing system is in stasis, held back by lack of funding. Funding increases are needed to move forward. At the same time there

must be procedures, consistent with climate observing principles, to decommission elements not performing as needed. The phasing out of broadcast mode XBTs is one example of such a decommissioning. In addition, while the notion of sparse reference networks is sound, such an approach may not address needs for higher spatial resolution. Without analysis and joint dialogs with efforts on modeling and attribution, the need for high spatial resolution in climate observations is unclear. Partnering with other agencies and observing networks may fill in some gaps and is important given financial constraints on climate observations.

Part of the effort required to demonstrate value of observations is good data management (ease of access, metadata, cataloging). We were unsure of the level of effort in this area, also about the extent of partnering with producers of products, with modeling, and with assessment activities. These efforts, along with development of a clear process for evolution, integration, and assessment of efficacy are needed and should be aided by the establishment of a Project Office for Climate Observations, which we see as a good step.

Panel 3 *Analysis including Reanalysis, OSSEs, OSEs, and related Research*

Moderator: Kevin Trenberth, Phil Arkin

This is an essential integrating activity for COA. On the atmospheric side, observations are analyzed routinely for weather forecasting purposes. The resulting set of operational analyses includes effects from changes arising from changes in the model and data streams. There is no attempt to homogenize the analyses in any way. Reanalysis overcomes some of the problems and has the potential to provide a comprehensive climate data record as a set of physically consistent fields. To date this goal has not been achieved because of the constantly changing observing system, although a much improved and more consistent set of fields has proven useful for many purposes. On the ocean side, operational analyses are now becoming available, and problems in the data streams are being identified, suggesting that reanalysis would be beneficial. Advancing data assimilation methods also mean that newer analyses can take better advantage of the observations and produce improved quality products.

Essential components of the “reanalyses” activities then include:

- 1) The development of the input data. This includes reprocessing of various individual datasets, such as satellite radiances; recovering lost or missing data; correcting data; and assembling disparate datasets ranging from composition of the atmosphere, changes in the sun, sea surface temperatures, surface vegetation and soil moisture, snow cover, and so on; as well as all of the variables to be analyzed.
- 2) The development of the data assimilation system and model.
- 3) The development of “bias correction” procedures to handle changes in data. This typically includes running the system forward without and then with the new data stream, and determining how various fields change and whether bias corrections should be applied. It amounts to a series of small observing system experiments (OSEs) that also provide a commentary on the utility of various observations.
- 4) The development of an archival and data management and access system.
- 5) A team of users to evaluate the products as they are generated and to provide feedback to the reanalyses.
- 6) A more formal set of OSEs and Observing System Simulation Experiments (OSSEs) to help guide the development and operation of the observing system.
- 7) A post processing of the data to generate sets of products and diagnostics for more general use, and appropriate archiving and dissemination activities.
- 8) Learning lessons from previous reanalyses including data deficiencies and bias correction problems.

Inherently, reanalysis activities involve several different lines in NOAA, including NCDC (NESDIS) on the data side, NCEP (NWS) on the modeling side, and ESRL (OAR) on the analysis and evaluation side. There is also considerable overlap between COA activities and CPP activities, which is accentuated by reanalysis.

These different activities have largely been recognized in the planning stage, but seem to disintegrate in the current execution stage, especially when less than required resources are forthcoming. It highlights the shortcomings of the internal NOAA process and the matrix management of the project, as no one is sufficiently in charge, with the ability to control the resources in the various NOAA lines. In the planned activity, insufficient attention has been given to seeking advice and developing an advisory team, learning lessons from previous and ongoing reanalyses (notably the current NASA MERRA reanalyses), upgrading the input data, developing a grants program component to recruit users to help exploit and evaluate the products, and especially developing a detailed plan with goals and objectives that can help determine the success or otherwise of the project.

One clear symptom of this lack of coordination was the fact that each sub-activity presented its own summary of coordinating activities. NOAA badly needs some sort of overall planning and coordination of analysis/reanalysis and allied activities, and that coordination and planning must incorporate other national efforts and the relevant international community. The specifics of coordination listed by each element are unsatisfying principally because the one that should have come first for each – ensuring that they fit into the broader NOAA plan – is missing. The needs of some communities have not been sought or recognized (such as the chemical and aerosol communities, the polar (especially Arctic) community, and the climate change community). While regional reanalyses may be necessary for some purposes, no regional analysis can possibly succeed without a good global analysis for context. Whether some reanalyses should be less than comprehensive and carried out to meet specific goals, such as those related to seasonal or extended range prediction, is a decision that should be made deliberately. Gil Compo's efforts have been very successful in encouraging lots of productive effort from data providers around the world and this is to be applauded.

There is no clear sense of broader issues or of an overall strategic vision and approach. An implementation plan that identifies critical paths and activities and permits priority-setting is greatly needed. The presentation and discussion made clear two things: reanalysis and allied activities are vital to COA and the Climate Goal, and there is insufficient effective coordination and planning across the topic within NOAA. In fact, reanalysis is the “poster child” for how matrix management can negatively impact an important component of the enterprise. A strategic, system approach is required. The first step to ensuring that NOAA and the nation have the climate analysis products that are necessary to permit successful climate monitoring, research, nowcasting, prediction and applications is to develop the plans and coordinating infrastructure that are needed. And the first step to accomplishing that is to specify whose job it is to make that happen.

Panel 4 *Climate Services and Product Development (half of the hourglass)*

Moderator: Dave Robinson, Kelly Redmond

As part of the national climate services infrastructure, NOAA's COA Program is responsible for the development and delivery of a vast array of climate products to diverse communities of users. For a service to be truly rendered, someone must be helped. This is often accomplished through the preparation, distribution and interpretation of products. To use a mathematical analogy, a "product" can be viewed as any function of one or more data sets. The most basic product is thus the data themselves, and range upward in complexity from value added data sets, analyses of past and present climate information, and on to predictions and projections of the forthcoming climate state. They span spatial scales from global to point, and temporal resolutions from minutes to decades. Products are served to user communities in near real time or from information archived long ago. A single point observation may be all a user requires, however others might need large satellite or radar files or model output from ensemble runs. Users span orders of magnitude in sophistication and technical capability, and range from grade school students to small businesses to county and state government to large regional and national organizations. User needs revolve around making a better decision about some issue of interest with a climate component (NRC, *A Climate Services Vision*, 2001), and the role of climate information can range from incidental to crucial. The audience for climate services, and thus for COA, encompasses those marginally or episodically engaged with climate (tens of millions) to those with intense interest such as those in the climate research community (hundreds or thousands). This clientele includes a large number of external end-users, as well as a variety of important intermediaries within the structure. Formed around a substantial public investment, national climate services must cater to this entire spectrum in an equitable manner, in order to maintain the sustained support that is needed.

A well-organized COA program that puts users first must have mechanisms to understand user needs and incorporate these into products and services, and, for end-to-end usefulness, must have active and effective feedback loops. This latter capability lies partly within NOAA, but more importantly much of it also resides in its many partners. NOAA and its partners need stronger relationships for each of them to succeed. [This aspect is developed further by Panel 5]. NOAA has developed a number of exceedingly useful products, many of which are used extensively, and myriad means of delivering products to users. However, they have yet to achieve a system that meets the goal of a unified program. This must be accomplished in an environment that more fully emphasizes user needs. A clear and consistent vision of the multitude of user communities must be better understood and subsequently maintained. Users must be engaged with all facets of product development and delivery. NOAA personnel must know their users; acknowledging that they fall into a number of classes. A seamless suite of meteorological to climatological products will best suit the majority of users. Users do not differentiate between operations and research. Nor do they distinguish between climate and weather, though within NOAA a climate niche needs to be better identified in order to sustain the COA program. Means of obtaining user feedback are a must in order to ensure the success of product and service programs.

Careful thought must be given to how user feedback is solicited and obtained. Certain biases are built in to this process. The annual user workshop helps considerably in addressing these issues. However, only certain classes of users can afford to travel to constituent workshops held at or near major NOAA facilities. Nearly always these locations are determined by their convenience to NOAA rather than to the user. Ironically and paradoxically, governmental entities are increasingly constrained by privacy considerations in their ability to acquire the detailed feedback necessary for them to function better. Security considerations, as well, have led to increasing physical isolation of and distancing of government labs from ordinary citizens. NOAA's many regional, state, and private partners are in many cases better positioned to obtain such criticisms and commentary, stationed as they are out near the "front lines" of

day-to-day interaction with all sectors of society. The resources needed to foster improved interactions between NOAA and these partners are well worth the payoff.

The principal unifying theme among users at every level is the expectation that NOAA will insure that quality climate observations are obtained of important elements for extended periods at a sufficient spatial density. Many first-time users assume this as an article of faith, and are surprised to discover the real story. When the stringent implications arising from the crucial requirement of long-term homogeneity are factored in (the main separation between “weather” and “climate” observations), this strong mandate for data stewardship is universally seen as a fundamental responsibility of government. This ethos needs to permeate through all of NOAA, and especially those operational entities (NWS is foremost) that supply the raw material of observations to the climate sector. Currently, this is not the case. COA has a much better appreciation of this key issue, and as the principal point of interaction with the various suppliers of data, it needs to be vigilant and unrelenting in making this case, which is surprisingly often not understood. Climate makes no such distinctions across these time and space scales, and the various administrative organizations and line offices within NOAA attempting to understand and monitor and predict climate, should take a cue from COA. A large organization needs structure and boundaries, but no matter how they are formulated, climate will always span them all, and porosity and communication across all such human walls is a necessity for this subject.

Products must be developed within a research to sustained operational environment. One example of such an endeavor is the Applied Research Center operated through NCDC and supported by CCDD funding. While this has proved to be a rather successful program, the operative word “sustained” remains a perennial concern for this and other efforts of its kind. Sustaining such efforts require substantial resources, something that has been difficult for NOAA to obtain. A more unified and visible system might result in more support for these endeavors. This could include an individual or office dedicated to executing research to operations. Prioritization of products is also an ongoing reality, and one that must be better met within NOAA. Currently lacking is a well developed means of soliciting new products and retiring those not deemed useful. Also, adaptation strategies must be incorporated in recognition of eventual changes in user demands or priorities. All of this can best be achieved by not losing sight of the customer, considering them as “partners”. Their feedback must be better solicited, and partners must better share in development and maintenance responsibilities as opportunities arise. NOAA must become more adept at entraining these partners. Certain parts of NOAA are much better at this than others. This is an art that takes years of sustained commitment to accomplish, and spending much time outside of comfort zones, and out of one’s own familiar surroundings. Even within NOAA there is room for better interaction and exchange of data and products. This must be addressed in concert with the aforementioned partnering, and a number of questions must be considered. Are there too many products? Are products functioning the way they should be? Is there too much redundancy? Are there adequate strategies to work with regulators, FEMA, engineering committees, etc?

It warrants repeating that there are many excellent products being produced within the NOAA COA program. So, too, are there many creative and successful means of displaying and delivering products to user communities, particularly via the World Wide Web. However, as with the production side of the equation, climate services are often accomplished in a piece-meal manner. To be fully successful, NOAA must endeavor to develop a unified service program that focuses on the discovery and delivery of the optimal product(s) to the end user or translator (intermediary between those serving the product and the ultimate user). It is essential to recognize that these individuals may not know exactly what they want or all that is available to fulfill their needs. Thus, intelligent guidance is a necessity, and this may include interacting with a human assistant. Web portals that provide access to products at various levels of user sophistication must be developed and maintained. The gray area as to how far NOAA should develop services, and for that matter, products, arises here. NOAA must work with other entities, including, for

instance, other federal and state agencies, state climate offices, and the private sector to determine mutually beneficial distributions of responsibilities; in the process never losing site of the user. Such climate service endeavors have begun, but clearly need more attention and resources.

A theme of stewardship should accompany the provision of climate products and services, and must be pervasive with respect to the underlying data. This ties in directly with the emphases on “end-to-end” and “sustainability” stated previously. There appears to be a growing appreciation of the need for a mindset of stewardship within NOAA (and especially within COA); visible through support of Academy studies to define principles for the development of satellite CDRs, and the archiving, stewardship and access of environmental data. Also, there is the recent formulation of the DAARWG. However, considerable additional efforts are required. There is still not a widespread and automatically accepted notion that operational records (such as ASOS) should also become CDRs. As another instance, NOAA does not place great enough emphasis on metadata (and it is not alone in this), typically because other things are considered more urgent. The development of standards and documentation priorities for metadata, and methods for access, are time consuming in themselves, and lead to yet other work, often seen as detracting from actually making the observations. Vetting questions from users regarding products is likely the best means of getting at what needs better documentation.

We are encouraged to see increasing attention within NOAA being given to climate products and services, and note many successful efforts in these regards. However work remains. To have the most responsive and successful climate products and services program, NOAA must strive further to encourage creativity while maintaining a reasonably structured system. A culture of stewardship (for data, products and service functions) must be fostered, encouraged, and inculcated. The readings used by an operational forecaster for the current one-hour nowcast should also be viewed as part of the long-term legacy to posterity. This might be structured around drivers, such as: 1) global atmosphere/oceans and climate change, or 2) regional water resource issues, or 3) local decision makers. Whatever the case may be, NOAA must continually aim toward meeting the needs of the vast array of user communities that increasingly rely upon high-quality climate products and services. A major point of distinction here is that the uses and users for climate data are largely in the future, some not even imagined or born yet, and their needs are the responsibility of our generation.

Panel 5 User Communities (the other half of the hourglass)

Moderator: Lee Branscome, Ken Kunkel

A key question addressed by this panel is “Who are the users and what is their value to COA?” The spectrum of users of climate products and services is very broad, reflecting the complexity and extent of the impacts of climate on society and the environment. These users include the disciplinary experts, highly sophisticated decision-makers in climate-sensitive business and government sectors, private sector climatologists, educators, design engineers, students, and private individuals, to name just a few. A portion of the users can be more accurately described as the “partner community”. Many such “users” make observations, are engaged in data management, and develop and provide climate products and services to a wide variety of end users in the private and public sectors.

NOAA/COA has done a great job, considering their limited resources and the exploding demand for climate data and services, whether for basic research or for applications. The widespread and rapidly expanding use of COA data indicates that COA has met many of the needs of user communities. The quality and reliability of COA data supports many diverse applications and even the emergence of entirely new climate-based products, such as weather derivatives. The COA commitment to data quality and to engagement with users has led to significant improvements over time in data access and product quality and quantity. The continually-growing list of datasets and products available via the web supports an increasing volume and efficiency of data usage. New datasets (e.g., those coming out of the CDMP) and observing networks (e.g., CRN) are expanding the suite of potential applications.

The expanding usage within the context of limited resources has created some obvious stresses. In order to realize its full potential in this environment, COA needs to recognize who the partners are, the value of the partners, and then engage those partners in an effort to achieve common goals. COA attempts to do this in a number of ways that have considerable merit, including the outreach through the annual users’ workshops. However, the nature of current interactions with this community is highly varied; while NCDC manages the Regional Climate Centers and has established formal mechanisms, interactions with other partners, such as the State Climatologists, RISAs, and private sector climatologists are not systematic and tend to occur opportunistically. See Panel 4 section for more on this topic, and how NOAA might benefit from expanded interactions with regional partners.

It appears to us that there is considerable potential to improve the dissemination of societally-beneficial information through an expanded engagement with the partner community. Given its limited resources, it is essential that COA leverage the resources and abilities of its partners, whether formal or informal, public or private. COA's partners are capable of performing basic and applied research, and developing new products and services based on high-quality COA data and analyses, for the benefit of science and society. Such efforts broaden the value of COA activities and products, without requiring extensive commitment of COA resources. For example, the private sector may have more flexibility than COA to develop new products and services and can grow as needed to respond to specific interests and needs for climate services. To a lesser extent, the same capability exists within universities and regional/state/local institutions. COA should not try to take on all areas of climate research and applications, but instead should rely on its partners to help carry the load. First and foremost, COA needs to make sure it does its core mission well so that climate science and services will thrive through the cooperative efforts of COA and its partners.

Some ways in which partners can/do contribute to COA’s main objectives:

- Identifying and addressing data gaps because they (i) use and quality-check the observations themselves and, in some cases, (ii) manage their own local observing systems (mesonets). In this sense, they can help NOAA ensure the long-term integrity of the observing system and associated data archives, while complementing the global and national observing systems with more localized components.
- Developing and providing products and services to end-users, based on data products generated within COA. Partners also assist other users in the discoverability and interpretation of COA products and services (see also Panel 4 discussion on partners). Thus, the partners enhance and expand COA's efforts to be relevant and beneficial to the nation's economy and welfare.
- Interacting with the full spectrum of users of climate data and information, thereby developing an increased understanding on how COA and its partners can best contribute to the welfare of our society and the environment.

How can user needs be identified and met by COA?

- An efficient way of finding and engaging partners is through a problem/issue-focused approach (e.g., water resource management, disaster management, coastal planning) – as opposed to a broad, “shotgun” approach to search for and engage users. Focusing on problems helps to define both the types of products and the key partners. Those problems are becoming more focused on adaptation.
- Make more effort to engage with professional and scientific organizations (e.g., AMS, ASCE) to determine needs of large groups of users
- More systematic engagement with partners, who can provide connections to, and feedback from, the broad spectrum of users of climate products and services

What are the concerns of the users/partners?

Within the context of a generally successful program, the Panel has identified issues that prevent the realization of the full potential of the program to meet the needs of the full spectrum of users. COA needs to ensure that it is performing its core missions in making relevant climate observations, successfully managing that data, and performing valuable analyses of the climate system. While COA has had considerable success improving access to data, many users are concerned about the robustness of the observational networks, the availability of metadata and documentation, and the lack of a clear decision-making and prioritization process within COA with respect to the development of new products and services. Users/partners are concerned that COA has not effectively integrated its programs so that opportunities are being missed and the main objectives are not being met. COA could do a much better job in encouraging and guiding collaboration across its many elements within the NOAA Climate Program. COA needs to leverage its limited resources by working with its partners, who are engaged in many of the same primary activities. COA/NOAA needs to identify what only it can do and do that well with its limited resources, particularly where its partners/users are critically dependent on it. COA also needs to recognize that its partners/users can particularly provide regional and sector-specific products and services, so that COA does not need to replicate those capabilities (see below for examples) and can instead focus primarily on broader, more global projects and on providing products and services that are directed to large, national, and diverse user groups.

NOAA should take a comprehensive approach to the development of region- and sector-specific research and applications that effectively integrates the data stewardship, product development and user engagement efforts of COA with those conducted in the context of other NOAA Climate Program components most notably Regional Decision Support. In addition, as discussed in the context of Panel 4,

it is essential that planning for and implementation of user engagement, product development and new information services involve critical partners such as the Regional Climate Centers, State Climatologists, RISAs and the private sector. To be more specific, COA should probably foster region- and sector-specific research and applications elsewhere. An entire structure in the public and private sectors has developed around NOAA/COA to do such work. COA should instead be proactive in advocating and encouraging partners to carry the load on the regional and sector work. The view of the Panel is that COA should continue to focus on national and global analyses and products, such as the reanalysis program and products that support national/global seasonal predictions and longer term projections. Useful sector-specific applications developed by COA include national probabilistic analyses of wind gusts (for building code and design purposes), freezing rain (for ice loads), and extreme rainfall (for water management, building design). In addition, responsiveness of COA to industry wide or sectoral issues is highly appropriate (examples include requests from the Home Builders Association on weather and climate impact on housing construction, or impacts of climate on transportation for the Federal Aviation Administration). However, highly specialized analyses may be more appropriately performed elsewhere, for instance weather and climate effects on individual building projects, energy and weather derivative tools, or regional coastal erosion and inundation studies (many regional and local agencies and private companies are doing this already). If COA has identified an interest or need in some regional or sector specific problem, it should engage its partners to do the research and develop the services, primarily at their expense, while COA provides the high-quality CDRs. In practice, NCDC already takes this approach in some cases, even in the national-level risk analyses like the 3-second wind gust map developed in cooperation with the ASCE.

As demands for new climate analyses and products increase, it will be particularly important for COA (and NOAA generally) to support and facilitate the development of highly-specialized, sector-specific analyses and tailored products by the private sector. Similarly COA should work closely with regional partners such as RCCs, RISAs and the emerging NOAA regional teams to provide support the development of data products and services that address region-specific information needs in areas such as water resources and coastal hazards.

The NRC *Fair Weather Report* on weather services (which has now been applied more broadly across NOAA, including climate services), concluded that NWS should not have a rigidly defined role in the weather services enterprises. But public agencies need to understand what their role is, otherwise there will be no continuity across the agency or when leadership changes occur. Furthermore, there will be no guidance for determining what activities should take priority over others, particularly in a tight budget environment. For instance, this problem was anticipated by the National Council of Industrial Meteorologists in its white paper on this subject, www.ncim.org/pdfs/NCIM_White_Paper.pdf. In a similar vein, COA should understand and advertise its role.

Panel 6 *Detection, & Attribution*

Moderator: Jonathan Overpeck, Graeme Stephens

This is an essential integrating activity for COA and the broader climate enterprise within NOAA. The central goal is to understand the causes of observed climate variability and change, including the uncertainties, and to be able to 1) use this understanding to improve model realism and forecast skill and 2) communicate this understanding to users of climate knowledge and the public in general. However, it appears to be a fairly new activity that lacks coordination across NOAA.

Any attribution activity is fundamentally about the science of climate predictability, including the predictability of models of climate variability (e.g., ENSO, seasonal variability, etc.), as well as long-term climate change. Indeed, understanding and attributing what has just happened would seem to be a prerequisite to making the next climate prediction. Attribution is thus of fundamental importance to NOAA, and not just to COA.

Although there is growing coordination between lines in NOAA, and good partnership building with other agencies (i.e., DOE) and the university research community, this is quite recent and much more is needed. NOAA has played a leadership role in attribution related to climate change, and thus in both CCSP and IPCC activities. There have been early successes, just as there has been experiences that highlight the formidable challenges in building the needed science, modeling and communication foundations for an eventual “attribution service.” But criticism arose from the failure to recognize or acknowledge the role of climate change on hurricanes in parts of NOAA.

The vision of a formal NOAA “attribution service” is commendable and of potential great importance for NOAA and the nation. It is a worthy goal to explain why climate has varied and changed, as well as to explain to the significance of such variation and change to the public. Moreover, such an effort might also serve as a tool for advocating more science and research support through emphasis of what is not known. It is critical, however, that NOAA proceed carefully as they think of a formal attribution service.

Issues

- The nation, public, and media clearly require that NOAA take a leadership role in helping them understand the contexts, causes and significance of on-going climate changes and extremes.
- NOAA CPC also has an existing, and urgent need, for regular climate assessments aimed at helping to improve model realism and forecast skill. However, CPC seems out of touch with issues and research in NCDC and GFDL.
- NOAA is not considering the full breadth of users and what they need, especially at regional scale. A major effort is needed to understand the user community and what they need. This effort must engage the users in a sustained manner. An improved and sustained dialog with users will also help educate users on the nature of climate science and what future developments are feasible.
- NOAA has spoken with multiple voices, sometimes at odds with the community (for instance on hurricanes, noted above). This is a serious problem that must be worked out in a way that promotes open and transparent scientific discourse, but that also does not confuse the public. One component to success is clear articulation of uncertainties.
- NOAA scientists, like those across the broader community, need to be able to talk freely about climate attribution as individual scientists. However, the national and regional user communities require NOAA to speak as the credible, reliable lead climate agency it is.

- The issues, science and communication are presently not well coordinated within NOAA, nor at the community-wide levels. High-levels of coordination are needed for success. NOAA has both the opportunity and responsibility to lead, but clearly cannot do the job by themselves.
- A bottom-line is that NOAA needs to speak on climate attribution issues, and must do so in a way that maintains agency credibility and reliability
- Another bottom-line, however, is that the science of attribution is still not that well developed, nor likely sufficient to support an operational “attribution service.” Extreme care should be taken to stay within the science.

Findings

- 1) The panel suggests that NOAA is not yet ready for an attribution service, but that they are ready for a more organized and better-funded climate attribution program. Hence, an attribution service is a worthy goal.
- 2) NOAA has to weigh in on climate change and extremes, and what we can say about them. NOAA needs to stay within the science and be careful. An expanded climate attribution program would help NOAA be more effective in meeting this objective.
 - *** Note that Panel consensus was not reached here. Some COA Review Panel Members were quite concerned that NOAA might be moving too fast, and that NOAA credibility and reliability could be compromised if this operational “attribution service” was developed too quickly. Other Panel Members were more sympathetic to the urgent (e.g., to meet CPC’s operational forecasting needs) needs for a regular and expanding attribution program. Also, NOAA is, by default, the agency that needs to make statements about attribution related to on-going climate change and climate extremes. Extreme caution is likely warranted in any case, as are much improved coordination and a careful articulation of uncertainties in all attribution statements.***
 - *** Deeper issues of accountability also loom – many Panel Members expressed grave concerns about producing an authoritative source of attribution information that might have serious legal implications.***
- 3) The NOAA climate attribution program should work across NOAA climate program goals: COA, Climate Forcing, Climate Predictions and Projections, and (noting that regional users/stakeholders are perhaps the most important “customers”) Regional Decision Support.
- 4) The Panel suggests the development of a strategic implementation plan for a NOAA climate attribution program. Given the highly timely nature of the issue, NOAA is urged to develop this plan as quickly as possible. The CWG would be happy to help in the development.
- 5) The Panel suggests that the strategic plan focus on three issues: Coordination, Research, and Communication.

A. Coordination

A *coordination structure* should be set up for the NOAA climate attribution program. This structure should involve and facilitate, to the extent possible, activities across NOAA, with other agencies, the broader climate attribution community (both national and international) and the regions where users are located (i.e., users of regional climate attribution information).

To facilitate coordination at the regional scale, there should be more formal and sustained interactions with RCCs, RISAs, State Climatologists and WSFO’s.

As noted above, it should be recognized that a diversity of views within and outside NOAA exist and should be fostered, but that having a NOAA-wide consensus view may also be worthwhile. Coordination is needed for both research and communication – these should be closely linked, e.g., by a top-level climate attribution coordination committee that includes strong representation from outside NOAA.

B. Research

Climate attribution science will see many improvements in the years to come, and the path forward for NOAA clearly needs to include a strong focus on enhanced/expanded research. Enhanced funding is needed and should be allocated to:

- significantly expanded computer resources for ensemble simulations, and simulations that have sufficient resolution for regional-scale climate attribution (e.g., droughts, hurricanes, floods, etc.).
- funding for in-house (e.g., ESRL, CPC, GFDL and NCDC) NOAA research is needed
- a substantial amount of climate attribution research is done by scientists outside NOAA. To be successful, NOAA needs a strong peer-review grants program in climate attribution. One possibility is for NOAA to build on, and expand on, its current CCDD program and collaboration with DOE. Continued further interagency leverage is encouraged. The integration of paleoclimate science has been successful (e.g., featured in the IPCC), and is applauded.

Attribution may take two stages. For instance one stage entails running models to determine the extent to which recent conditions could have been predicted given the observed SSTs, soil moisture and other “forcings” of the atmosphere. Then the second step is to say why the SSTs and soil moisture etc. are the way they are. As models have become better, climate events that could not be attributed in the past now can be. Models are still far from perfect and are likely to underestimate what can actually be attributed. Individual researchers may be far ahead of consensus. Accordingly, both steps should take account of shortcomings of models and often empirical (statistical etc) evidence can be more compelling. At CPC there has been an undue emphasis on ENSO that needs to be broadened – to the global tropics and then to be truly global – and global change research at GFDL and NCDC needs to be more recognized. Any committee or consensus view is likely to be conservative, and therefore NOAA should seek ways to ensure that it is relevant in this area.

C. Communication

NOAA needs to be very deliberate and careful in meeting the public (etc.) demand for attribution information and understanding. Extra care should be taken to stay within the bounds of sound science, and to recognize uncertainty and the need for further research where appropriate.

Strict scheduling of NOAA climate attribution statements should be implemented with care and only where this can be done within the bounds of strong science. The Panel felt that it would be premature to implement strict scheduling at this time except in specific cases where operational requirements must be met (e.g., with CPC forecast evaluation). Moreover, user perspectives must be factored into what constitutes timely assessment; otherwise assessments may be of limited use.

A committee – made up of NOAA and non-NOAA experts in climate attribution, as well as user-oriented scientists – needs to guide and provide oversight that NOAA represents the community consensus on what we can and cannot say about climate attribution. This committee could be a sub-committee of the above-mentioned NOAA climate attribution coordination committee. NOAA might

be well-served by committee involvement in discussing individual public statements, just as a committee is involved in the production of individual drought monitor releases. A few mistakes can seriously damage NOAA credibility.

Panel 7 *Understanding the State of the Climate (including data assimilation) and Monitoring*

Moderator: Tony Busalacchi, Judy Curry

Although the title of this panel was “Understanding the State of the Climate (including data assimilation) and Monitoring” most of the presentation centered on “Describing the State of the Climate” in the form of the *Annual State of the Climate* report published in BAMS. The contributions to the Climate Report are largely by a single author, and there is no extensive peer review. To avoid idiosyncrasies of individual authors, a team approach and more extensive external peer review may be warranted. A competing view point stated that it was more important to get the document out quickly, which implies a smaller group of authors and little review. There was considerable discussion regarding the observations that go into the report and the progress that has been made to include an increasing number of Essential Climate Variables (ECVs), as defined by GCOS. However, beyond ECVs, the process for determining what new observations to include is somewhat ad hoc. The Review team emphasized the importance of the Report expanding towards a synthesis and integration of climate observations. In this regard, calculation of derived variables (such as upper ocean heat content) would be a valuable supplement to the Report. As there was very little discussion of data assimilation by this panel, future editions of the Report would benefit from the consideration of data assimilation/reanalysis products. (In fact the review panel was disappointed by the overall lack of data assimilation activity in this element, e.g., land data assimilation or ocean state estimation.) It was also suggested that each Report be accompanied by a DVD containing the data depicted in the report. Consistent with earlier discussions regarding the need for a communication strategy in response to extreme climatic events, it was felt that the *Annual State of the Climate* report could play an essential role in such a strategy.

With respect to essential climate variables, much progress has been made in recent years to winnow the list. The "list" now has official heritage in GCOS, GEOSS and other international groups. Nonetheless, against the backdrop of presently available funds, a list of 42 Essential Climate Variables may not be affordable. It was unclear if the goal of obtaining all 42 ECVs by 2015 was attainable. The review team thought it important for COA to do a good job on the most essential variables, as some variables are more essential than others! For example, sea surface temperature (one of the most mature variables) is still a work in progress and can be improved. Yet, not every variable needs to be monitored globally and long term. Retrieval of some climate variables can be accomplished in process studies and using more limited spatiotemporal data. Hence, does NOAA have a process for prioritizing their investments in the climate observing system and its evolution? This was another example of the strong need for data assimilation in this element as a way of addressing observing system design and dealing with questions pertaining to redundancy.

The above comments are consistent with suggestion in Panel 2 and again raise the question of whether the *State of the Climate* report should it evolve into two parts, one observations based, and one related more to analysis, attribution and assessment?

Panel 8 *Space-based Observing Systems and related Data Stewardship*

Moderator: Mark Abbott, Michael Prather

This part of COA appears to the review team to have multiple identities. Part one is stewardship of core climate data, primarily the surface-based station data. This is an activity that NCDC is noted for and has been able to sustain, but primarily as an archive and not in an active recalibrating, reprocessing role. Part two is bringing new data, particularly satellite data, into an active facility that can regularly evaluate, re-analyze, and if necessary reprocess the CDRs. In this review we consider the stewardship responsibility to cover all CDRs, not just the satellite data; however, maintaining CDRs from space-based observation in the future is most challenging and requires a new vision and new resources within NOAA.

Vision

In the past, NCDC primarily served as a repository for satellite and other data as the World Data Center. In recent years, its role has greatly expanded to include the whole range of services associated with Scientific Data Stewardship (SDS). These include data rescue, reprocessing, and the development of CDRs. In particular, the development of quantified temporal and spatial error fields is a key part of the CDR process along with homogeneous errors as well as reduction of these errors. This goes far beyond the repository function and is essential for the success of COA and the Climate Goal. The next step will be to combine these data into a coherent picture of climate system variability and change, and then assimilate these satellite data sets into global models as part of an overall strategy related to reanalysis (panel 3).

Context

COA has made good progress down this path, but there are several continuing and emerging issues that must be considered as COA formulates its strategy.

The broad range of satellite activities is scattered across many elements of NOAA, but it was difficult for the panel to gain the larger view that is necessary to develop a clear strategic and cross-cutting plan. Observing requirements, SDS, data analyses, assimilation, and utilization need to be placed within this larger context.

Satellite data must be viewed as part of a larger comprehensive effort that includes pre-launch characterization of the sensors, validation and vicarious calibration activities that include a wide range of non-satellite data, algorithm development and testing, data analyses, and reprocessing. COA's efforts in regards to SDS and operational CDR production clearly recognize the importance of these activities, but the challenge is that the responsibility (and budget) is parsed among several other elements in NOAA. COA should not bear the financial burden alone as many of these activities will benefit other NOAA programs and elements. Engaging these other NOAA partners remains a challenge and, at times, an obstacle to a successful SDS process.

The NRC Decadal Survey (DS) stated that the nation's Earth remote sensing capabilities are in danger of collapse. Restructuring of NPOESS in the face of severe cost overruns, descoping of GOES-R, and the dramatic reductions in NASA's Earth remote sensing budget are the most obvious evidence of this collapse. COA is focusing its efforts on sensors that have been dropped from NPOESS and GOES-R or on looming gaps in critical data records. Although these efforts should be maintained, there also has to be a recognition that 1) many of the sensors on NPOESS will not be up to the task for climate services; 2) gaps are inevitable; and 3) new capabilities must continue to be evaluated. In regards to the first issue, it still appears that the short-term forecasting mission for NOAA trumps the climate mission, and that any

climate requirements must find a short-term forecasting “partner” to have any hope of being considered in the design/budget process. If NOAA is to be the “lead” agency for climate, and it is, this attitude *must* change throughout the agency. Regarding gaps, COA must assume that there is no realistic way to avoid gaps in many critical data sets, given that many of the existing sensors are well over their planned lifetimes and the time it takes to develop and launch any new missions that are not on either the NASA or NOAA manifest. Innovative strategies (multiple sensors, international partners, etc.) must be considered, although they may not be optimal. Lastly, NASA continues to have new observing capabilities in orbit, and COA must begin to evaluate these systems as part of an evolving observing system for climate. For example, CLOUDSAT may offer important new capabilities for cloud-related CDRs that are a weak point in the NOAA list, and COA should begin to consider how such a system might be developed into an operational capability.

The list of Essential Climate Variables (ECVs) plays a critical role in COA's decision-making process, yet this list appears to be accepted from the GCOS recommendations without much analysis. The Panel suggests that a critical look at the GCOS assumptions and thus whether the same priority should apply for NOAA. For instance, in developing the ECVs GCOS made certain assumptions about the requirement for a past record. The ECVs may not be optimal and are constantly shifting based on scientific progress. For example, if we focus on space-based ECV, the aerosol-cloud requirements for climate are critical for understanding climate forcing (as compared with perfluorocarbons), and yet these are not being met by any current or proposed sensors. A further complication for ECV lies in the prioritization program being developed to balance both "societal benefits" and "science questions." While this is important to do, the transparency of this process is critical since the inherent uncertainty in the parameters can probably be changed to alter the "benefit" of an ECV.

The transition from NASA to NOAA continues to be a complex and sometimes difficult process. Although the relationship between the two agencies and their programs has improved over the past year, there remain serious obstacles. There still is not a clear, shared “programmatic pathway” whereby NASA scientific and technical capabilities can be evaluated and ranked in terms of their potential contribution to the NOAA operational mission. Such a pathway will require continuing engagement between NASA and NOAA, rather than sporadic efforts such as the annual report on research-to-operations that is developed for Congress. It requires realistic assessments of future budgets and future requirements as well as an open process to prioritize transition capabilities. Attention will also need to be paid to develop sustainable observing capabilities; that is, operations and maintenance (O&M) costs will need to be kept at a level that is affordable by NOAA. Lastly, the culture and capabilities of NOAA must continue to expand so that they are more on par with those of NASA. For example, NASA spent nearly an order of magnitude more on validation of each EOS sensor than NOAA plans to spend on each NPOESS sensor. The obvious danger is that NPOESS data will not be able to produce CDRs. Effective partnerships likely demand that each partner be roughly in balance in terms of their expertise and level of commitment.

Implementation

COA needs to develop a clear and consistent vision for the role of satellite data in climate services. Significant progress has been made, but there remain some critical gaps. In particular, the issues of satellite data assimilation, relationships and dependencies on other parts of NOAA, and the long-term relationship between NASA and NOAA need to be addressed as well. The Climate Program as a whole still does not have a clear path in influencing the outcomes of satellite requirements as they are developed by NESDIS. This includes the issues of validation as well as satellite sensor performance. Climate requirements still often take a back seat to those of short-term forecasting. Moreover, the costs of many climate requirements should be shared among other NOAA goals because there are often significant

overlaps. The SDS process is moving in a positive direction, and its engagement with the external community is a model for other Climate Program components.

COA should continue to actively engage both the NASA and NOAA satellite programs to ensure that climate requirements are considered, to develop innovative strategies to address likely gaps in critical data records, and to assess new measurement capabilities for possible incorporation into the sustained observing system. For example, the NOAA-NASA team that engaged OSTP and OMB with the NPOESS re-manifest white paper is an excellent example of what will be needed. At this point, COA is primarily focusing on reinstating sensors that were dropped during the Nunn-McCurdy Recertification process, but there remain serious issues with sensors that were retained (e.g., ocean color by VIIRS) as well as with new capabilities that have been developed by NASA (e.g., cloud properties from CLOUDSAT). COA should move from a reactive mode to a proactive mode. This requires that NOAA (and COA) expand its in-house capabilities in both science and technology to be more on par with those of NASA.

As many NRC studies have noted, NOAA is unique in its ability to step up to the notion of SDS as well as in sustained, climate capable observing systems. However, there will need to be significant changes within NOAA (e.g., recognition of the balance between climate and short-term forecasting, the need for cross-discipline balance, and the importance of societal benefits as well as scientific understanding) as well as in its budget. A more effective partnership must continue to be developed and to mature between NASA and NOAA, with a shared vision and a clear understanding of roles and responsibilities. Lastly, sustained observing and information systems must pay particular attention to O&M costs. This is an area where technical innovation may play an important role.

Appendix 1.

AGENDA
Climate Working Group (CWG)
COA Program Review
April 11-13, 2007
NOAA's National Climatic Data Center
Federal Building, Room 400, Asheville, NC

Day 1 – Wednesday, April 11

- 8:00 Executive Session: Climate Working Group and COA Review Team** (Tony Busalacchi)
- 8:30 **Welcome and Meeting Logistics** --- Tom Karl
- 8:45 **Goal of COA Review** --- Chet Koblinsky (CPO)/Kevin Trenberth (Chair, COA Review Team)
- 9:10 **Overview of COA Program** --- Tom Karl (Q&A discussion at the end of Overview)
- 10:40 Break
- 10:55 **Overview of NCDC** --- Tom Karl
- 11:15 **Panel 1 Discussion: *Data Ingest, Access, and Archive (and "Storage" CLASS CONOPS)***
Moderator: Peter Cornillon (Member of DAARWG)
Panelists: Chair- Glenn Rutledge (NCDC), Steve Del Greco (NCDC), Neal Lott (NCDC), David Urbanski (NCDC), John Bates (NCDC), Rick Vizbulis (NESDIS/OSD), Steve Hankin (OAR), Ken McDonald (NESDIS/OSD), David McGuirk (NCDC)
- 12:30 Working Lunch
- 1:00 **Panel 2 Discussion: *In-situ Observing Systems and Data Management including Stewardship***
Moderator: B. Weller (CWG member)
Panelists: Chair-Mike Johnson (OAR/OCO), (Co-Chairs - Dave Easterling and Howard Diamond, NCDC), Kathy Crane (OAR/OCO), Ellsworth Dutton (OAR/ESRL), Steve Hankin (NOSC-DMC/DMIT)
- 2:45 CWG Members - NCDC "Walk About" and talk with NCDC personnel in work spaces
- 3:30 **Panel 3 Discussion: *Analysis including Reanalysis, OSSEs, OSEs, and related Research***
Moderator: Kevin Trenberth (Chair, COA Review Team)
Panelists: Chair-Robin Webb (OAR/ESRL), Chris Miller (OAR), Kathy Crane (OAR/OCO), Stephen Lord (NWS/NCEP), Dave Easterling (NOAA, NCDC), John Bates (NCDC), Don Anderson (NASA), Russ Vose (NCDC)
- 4:45 Climate Assessments --- Tom Karl
- 5:00 **Executive Session: Climate Working Group and COA Review Team**
- 7:30 Informal Discussions @ Barley's Taproom**

DAY 2 – Thursday, April 12

- 8:30 **Panel 4 Discussion:** *Climate Services and Product Development (half of the hourglass)*
Moderator: Dave Robinson (CWG member)
Panelists: (Chair-Russ Vose, NCDC), Chris Miller (OAR), Randy Dole (OAR/ESRL), Arun Kumar (NWS/CPC), Mike Brewer (NWS/CSD), Neal Lott (NCDC), Dave Easterling (NCDC), Steve Del Greco (NCDC)
- 10:15 Break
- 10:30 **Panel 5 Discussion:** *User Communities (the other half of the hourglass)*
Moderator: Lee Branscome (Special invitee)
Panelists: (Chair-Eileen Shea, NCDC), Greg Carbone (U of SC), Dave Goodrich (WMO), David G Brandon NWS/CO River Forecast Off), Tim Owen (NCDC), Ken Hubbard (HP RCC), Paul Knight (AASC), Nancy Beller-Simms (CPO)
- 11:45 Working Lunch
- 12:15 **Panel 6 Discussion:** *Detection, & Attribution*
Moderator: Jonathan Overpeck (CWG member)
Panelists: Chair-Dave Easterling (NCDC), Randy Dole (OAR/ESRL), Marty Hoerling (OAR/ESRL), Robin Webb (OAR/ESRL), Arun Kumar (NWS/CPC), Jay Lawrimore,(NCDC)
- 1:30 **Panel 7 Discussion:** *Understanding the State of the Climate (including data assimilation) and Monitoring*
Moderator: Tony Busalachi (CWG member)
Panelists: Chair-Jay Lawrimore (NCDC), Ken Casey (NESDIS/NODC), Stephen Lord (NWS/NCEP; phone), John Bates (NCDC), David M. Anderson (NCDC)
- 2:45 Break
- 3:00 **New Opportunities:** General Discussions lead off --- Tom Karl
What's missing and what needs more emphasis?
- 4:30 **Executive Session: Climate Working Group and Review Panel– membership discussions and other issues. (Tony Busalacchi; Kevin Trenberth)**

7:00P - **Advanced Discussions @ Local Restaurant**

Day 3 – Friday, April 13

- 8:30 **Panel 8 Discussion:** *Space-based Observing Systems and related Data Stewardship*
Moderator: Mark Abbott (Special Invitee)
Panelists: Chair-Jeff Privette (NCDC), John Bates (NCDC), Mitch Goldberg (NESDIS, STAR), Bruce Barkstrom (NCDC).
- 9:30 Break
- 9:45 **Executive Session: Climate Working Group and COA Review Team** (led by Kevin Trenberth)
- 11:00 **Executive Session:** Brief from COA Review Team to CWG and Climate Goal Leadership
- 12:30 **Meeting Adjourns**

Appendix 2

BACKGROUND Areas of Consideration

Accomplishment:

What have been the major accomplishments of the COA program over the past 6 years?

Strategy:

Does each of the capabilities (observing systems, data management, analyses) of the COA program have a clear strategy, schedule/road map, and implementation plan?

Are they aligned with the strategies & requirements of COA and the Climate Goal?

Are the COA capabilities integrated within COA?

Is the COA strategy effective, should changes be considered?

Is NOAA's COA program adequate in atmospheric observations, ocean observations, Arctic, land based measurements, data management and analyses?

Requirements:

Are the requirements and mandates that must be met by COA clear?

Are the requirements of other programs within the Climate Goal for COA clear?

Specifically, evaluate and validate the Climate requirements for GOES-R and NPOESS in their current configurations.

Priorities:

Are the priorities of the COA clear in terms of how it would address the use of new resources or divest or delay in the presence of reductions?

Challenges:

What are the major challenges and shortfalls of the COA program? How should the program address these shortfalls? In an increasing, level or decreasing budget scenario?

Integration:

How well does COA respond to requirements from other climate programs within and outside NOAA?

How well is COA aligned to leverage off and help those programs?

Are COA observations, data management and analyses activities well integrated and used?

Does COA sufficiently leverage the capabilities in other programs within NOAA, other agencies or international entities?

Execution:

Are the performance measures for COA activities realistic, useful, and appropriate for level of resources provided?

Does COA make effective use of the resources provided?

Is the execution of COA activities aligned with its requirements and strategy?

Do NOAA line organizations respond effectively to the needs of COA?

Grants:

Does the COA grant programs meet the needs of the Climate Goal and COA?

Does COA make effective use of grants and contracts to utilize the expertise of the external community?

Cooperative Institutes:

Are cooperative institutes used effectively in COA and how could they be more useful?

Advisory:

Are advisory groups used effectively in COA?

International:

What are the strengths and weaknesses of COA's international collaborations? Does COA use of international coordination organizations, such as WMO, WCRP, IOC, GCOS, GEOSS, JCOMM, effectively?

National:

What are strengths and weaknesses of COA's interactions with national and regional organizations, such as CCSP, CENR, NRC, US agencies, state climatologists, RCCs, etc.?

Service:

What are the strengths and weaknesses of COA provided climate services?
Is the coordination between national and regional centers effective?
Are stakeholder requirements clear?

Transition:

Does COA have effective programs to transition research accomplishments into operations?

Users:

What are the strengths and weaknesses in COA's responsiveness to user needs from a broad set of external users, e.g., academia, the private sector, and government?

NOAA's unique contribution

Unique Contribution (from CWG Oct 2006 review)

In this program element especially, the NOAA Climate Program would benefit from a clearer articulation of NOAA's unique contribution to the broad, national investment in...

NASA/NOAA transition

Describe how the NASA/NOAA transition works within this program...How does NOAA take advantage of NASA, NSF or DoE R&D

Priorities:

How are priorities determined

Emerging issues:

How are emerging issues identified? And addressed?

Appendix 3

COA Program Broad Range of Overview Questions to be Considered/Addressed

- 1) What is COA?
 - a. *Is there an advisory group?*
 - i. *Is it appropriately used, aligned with CWG, and functioning?*
- 2) What is its goal and strategy for accomplishing it?
 - a. *Is there an implementation plan and how adequate is it?*
- 3) What are its major accomplishments over the past 5 years?
 - a. *Comment on merit, balance, gaps.*
- 4) What are the requirements of COA from NOAA and the nation?
 - a. *Are they clear and attainable?*
- 5) What are its challenges, issues and concerns for this program?
 - a. *Are there plans for addressing these?*
 - b. *How about NOAA support?*
- 6) Are the resources adequate and used wisely?
 - a. *Are there plans and contingencies for budget cuts?*
 - b. *Are there plans for expansion and new endeavors, should more funds become available?*
 - c. *Are priorities clear and appropriate?*
- 7) What are the linkages with other programs: within the U.S. and internationally?
 - a. *Are these appropriate?*
 - b. *Is the research to operations transition functional?*
 - c. *In particular is the NASA to NOAA handoff on data and data management, and satellite missions working?*
- 8) How are user needs considered?
 - a. *Is the current user set representative of national or international needs?*
 - b. *Are user needs being adequately assessed?*
- 9) What are the performance metrics?
 - a. *Is COA performing according to the metrics and are the metrics appropriate?*
- 10) What is the grants program and what has it achieved?
 - a. *Is the grants program a useful complement to achieving the goals?*
- 11) Should NOAA consider a reorganization of the COA program?
 - a. *Separate Research and Development from operations?*
 - b. *Separate into new programs:*
 - i. *R&D: Climate State Observations (Atmosphere, Arctic, Oceans).*
 - ii. *Operations: Climate Monitoring and Services (Monitoring, Data Management, Predictions, Service delivery)*

Appendix 4

PANEL DISCUSSION QUESTIONS TO BE ADDRESSED BY CHAIR & CO-CHAIRS IN 20 MINUTE OVERVIEW

Panel members address these and other questions in Q&A with CWG and invited Guests

A. Questions for All Panels to Consider:

1) What are the most significant pressures changing demand for NOAA Applications?

Possible Response: Understanding our vulnerability to climate and enabling resilience in a changing climate

2) How do last year's priorities need to be adjusted to respond to these pressures?

Possible Response: Priority needs to be increased on helping to identify thresholds and change points that nonlinearly impact various sectors of society and ecosystems. Priorities related to increased physical understanding must go hand in hand with understanding the risk of non-linear impacts in a changing climate.

3) What questions do we need to answer in Planning to address the changing priorities?

Possible Response: How will climate change affect the efficiency of the US economy and the global ecosystems we depend upon?

B. Questions for Each Individual Panel to address/consider:

Panel 1 *Data Ingest, Access, and Archive (and "Storage" CLASS CONOPS)*

How do the existing observing systems move data to the Archive Storage?

How do customers get access to data?

What are the interagency linkages and leveraging?

What is the grand strategy?

What are the major obstacles to success (and what defines successful), and how can they be overcome?

Panel 2 *In-situ Observing Systems and Data Management including Stewardship*

What are the primary observation systems?

What is the state of evolution of the observing system?

Who are the users and what are the requirements?

Who ensures data quality?

How does implementation affect planning?

What are the mid- and long-term plans?

What are the major obstacles to success (and what defines successful) and how will they be overcome?

Panel 3 *Analysis including Reanalysis, OSSEs, OSEs, and related Research*

What interagency and international coordination is occurring

How is NOAA leveraging its capability?

What is the strategy for success (and what defines success)?

What are the current activities?

What are the obstacles to achieving success and how will they be overcome?

Panel 4 *Climate Services and Product Development (half of the hourglass)*

What is the basis for developing new products?

Who is responsible for maintaining and documenting new products?

What is the role of research to operations in new product development?

How are user requirements addressed?

Panel 5 *User Communities (the other half of the hourglass)*

How are user requirements factored into climate services?

How do regional, local, national, and international requirements get addressed?

What is the role of major climate assessments in terms of defining decision makers needs?

How do user requirements work their way into NOAA products and services?

What is working well and what isn't?

What is a successful climate service and how do we get their?

Panel 6 *Detection, & Attribution*

How does NOAA currently develop detection and attribution statements?

How timely are these statements?

Is it possible to develop this into a routine service?

If so, what can be done to develop this into a routine service?

How can or does NOAA leverage its partners?

Panel 7 *Understanding the State of the Climate (including data assimilation) and Monitoring*

What is the goal of this effort and how do we measure success?

What our capabilities?

What do we produce now?

What is our strategy for filling any gaps?

Panel 8 *Space-based Observing Systems and related Data Stewardship*

What is NOAA's role in space observing and related data stewardship in Climate and what are NOAA's expectations?

What is the current status of NOAA/NASA activities related to Nunn-McCurdy and NRC Decadal Survey?

What role can (should) COA or the Climate Goal play in the satellite observing system?

How are we working to overcome current obstacles to success?

How does the interagency "process" factor into the Climate Goal (including research to operations)?

What are the impediments and solution to developing climate data records?

Chair: Kevin Trenberth

CWG members:

1. Tony Busalacchi (ocean)
2. Graeme Stephens (clouds, satellite obs)
3. Rit Carbone (radar, precipitation)
4. Judy Curry (Arctic, surface fluxes, hurricanes)
5. Bob Weller (Ocean obs)
6. Dave Robinson (State networks and user, state climatologists and regional needs)
7. Jon Overpeck (regional, RISA/RCC, paleo)
8. Mike Prather (atmospheric chemistry)

External members:

9. Phil Arkin (reanalysis, precipitation)
10. Kelly Redmond (State, regional, ground networks)
11. Jim Kinter (model data)
12. Mark Abbott (general, data management, CLASS)
13. Peter Cornellan (ocean obs, data management systems, CLASS)
14. Ken Kunkel (precipitation, extremes)
15. Lee Branscomb (user)

AASC	American Association of State Climatologists
AMS	American Meteorological Society
AOPC	Atmospheric Observations Panel for Climate
ASCE	American Society of Civil Engineers
ASOS	Automated Surface Observing System
BAMS	Bulletin of the American Meteorological Society
CCDD	Climate Change Data and Detection Program of NOAA/CPO
CCSP	Climate Change Science Program U.S.
CDMP NOAA	Climate Data Modernization Program
CDR	Climate Data Record
CENR	Committee on Environment and Natural Resources Research (CENR) of the National Science and Technology Council (NSTC)
CF	Climate Forcing program of the NOAA Climate Goal
CLASS	Comprehensive Large Array-data Stewardship System of NOAA/NESDIS
CLOUDSAT	Satellite mission on clouds of NASA
COA	Climate Observations and Analysis Program of the NOAA Climate Goal
CONOPS	Concepts of Operations
COSC	Climate Observing Systems Council
CPC	Climate Prediction Center of NOAA/NWS NOAA
CPO	Climate Program Office NOAA
CPP	Climate Predictions and Projections program of the NOAA Climate Goal
CRN	Climate Reference Network of NOAA/NESDIS
CSD	Climate Services Division NOAA/NWS
CWG	Climate Working Group of the NOAA Science Advisory Board
DAARWG	Data Archiving and Access Requirements Working Group of the SAB
DART	Deep Ocean Assessment and Reporting of Tsunamis Project of the NOAA National Data Buoy Center
DMC	Data Management Committee NOAA
DMIT	Data Management Integration Team NOAA
DOE	U.S. Department of Energy
DS	Decadal Survey of the National Research Council
ECV	Essential Climate Variable
EMC	Environmental Modeling Center NOAA/NWS/NCEP
ENSO	El Niño-Southern Oscillation
EOS	Earth Observing System NASA
ESRL	Earth System Research Laboratory NOAA
GCOS	Global Climate Observing System
GEO-IDE	Group on Earth Observations - Integrated Data Environment
GEOSS	Global Earth Observation System of Systems
GFDL	Geophysical Fluid Dynamics Laboratory NOAA
GOES-R	Geostationary Operational Environmental Satellite
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOOS	Integrated Ocean Observing System
IPCC	Intergovernmental Panel on Climate Change
IPY	International Polar Year
JCOMMM	Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology
MERRA	Modern Era Retrospective-analysis for Research and Applications NASA

NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center NOAA/NESDIS
NCEP	National Centers for Environmental Prediction NOAA/NWS
NESDIS	Environmental Satellite, Data, and Information Service NOAA
NOAA	National Oceanic and Atmospheric Administration
NOMADS	NOAA Operational Model Archive and Distribution System
NOS	National Ocean Service NOAA
NOSC	Observing Systems Council NOAA
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NRC	National Research Council
NSF	National Science Foundation
NWS	National Weather Service NOAA
O&M	Operations and Maintenance
OAR	Office of Oceanic and Atmospheric Research NOAA
OCO	Office of Climate Observations NOAA
OGC	Open Geospatial Consortium
OMB	Office of Management and Budget of the Executive Office of the President of the United States
OOPC	Ocean Observations Panel for Climate
OPeNDAP	Open-source Project for a Network Data Access Protocol
OSD	Office of Systems Development NOAA
OSE	Observing System Experiment
OSSE	Observing System Simulation Experiment
OSTP	Office of Science and Technology Policy U.S.
R&D	Research and Development
RCC	Regional Climate Center of NOAA
RDS	Regional Decision Support program of the NOAA Climate Goal
RISA	Regional Integrated Sciences and Assessments of NOAA/CPO
SAB	Science Advisory Board NOAA
SDS	Scientific Data Stewardship
SST	Sea Surface Temperature
U.S.-GEO	U.S.-Global Earth Observation System
VIIRS	Visible/Infrared Imager/Radiometer Suite, NPOESS instrument
WCRP	World Climate Research Program of the United Nations
WMO	World Meteorological Organization of the United Nations
WSFO	NWS Forecast Office
XBT	Expendable Bathythermograph