

Climate Diagnostics Center

Response to Research Review team data requests
February 6, 2004

- 1) **Most recent laboratory evaluation** - provided separately in pdf format.
 - a. The most recent Climate Diagnostics Center (CDC) laboratory review was conducted in July 2001. The review was performed by an external panel, which then reported its findings to OAR management. The review panel members were: Dr. Eugene Rasmussen, University of Maryland (emeritus), chair, Professor David A. Randall, Colorado State University, Dr. Richard D. Rosen, Atmospheric and Environmental Research, Inc. (AER), and Dr. Louis W. Uccellini, NOAA NWS, NCEP Director.
 - b. In response to this review, CDC developed a five-year strategic plan for FY03-07, and numerous other actions were also taken in response to reviewer recommendations.

2) **Brief history and mission.**

History

The NOAA Climate Diagnostics Center was formed in 1993 through a Memorandum of Agreement (MOA) between the Office of Oceanic and Atmospheric Research (OAR) and the Office of Global Programs (OGP), with personnel derived from what had formerly been the Climate Research Division of the Climate Monitoring and Diagnostics Laboratory. The purpose of the OAR-OGP agreement was to establish a unique, focused center of expertise within NOAA to develop and apply diagnostic methods that would (i) aid in understanding the dominant processes influencing climate variability, and (ii) link observational analyses to model testing and evaluation. Under the terms of the MOA, CDC is managed as one of the OAR Research Laboratories.

Mission

The mission of CDC is to advance national capabilities to interpret the causes of observed climate variations, and to apply this knowledge to improve climate models and forecasts and develop new climate products that better serve the needs of the public and decision-makers.

CDC's mission directly supports NOAA Mission Goal 2: "Understand climate variability and change to enhance society's ability to plan and respond." To achieve its mission, CDC develops and applies a wide range of research methods, particularly emphasizing state-of-the-art diagnostic techniques, to elucidate fundamental processes governing climate phenomena such as droughts, floods, and the El Niño-Southern Oscillation, and to identify the causes of longer-term (decadal-to-centennial) climate variations. CDC also performs extensive intercomparisons between observational and climate model data, an activity vital to improving current climate models. The development of improved climate assessments and predictions enhances the Nation's economic and environmental security, and is a fundamental part of NOAA's mission. Diagnostic studies, for which CDC has exceptional breadth and expertise, vitally contribute to this process by linking basic observational and theoretical research to improvements in operational climate predictions and, ultimately, to the development of new climate products that better serve the needs of the public and decision-makers. By providing end-to-end links between research, operations, and users, CDC enables NOAA to rapidly transfer, quality-controlled, scientific advances into improvements in

NOAA climate products and services.

3) List major customers and describe what is being done for them.

- *NOAA-OAR GFDL*. CDC works with the GFDL in climate attribution and modeling research to diagnose climate model simulations and climate change projections to address key science questions for the Climate Change Science Plan (CCSP) and the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
- *NOAA-NWS Climate Prediction Center (CPC) and River Forecast Centers (RFCs)*. CDC works with CPC and individual RFCs on the development experimental intraseasonal to interannual forecasts and integrating research results into operational services to help achieve the NWS strategic goal to provide a seamless suite of forecast products ranging from minutes to years in advance.
- *NOAA-NESDIS National Climate Data Center (NCDC) and Regional Climate Centers (RCCs)*. CDC works cooperatively with NCDC to provide ongoing updates and improvements to (1) the widely used International Comprehensive Ocean-Atmosphere Data Set (I-COADS) of monthly summaries of surface ocean conditions at 2°x2° back to 1784, and (2) a serially complete dataset of daily temperature and precipitation station observations for the coterminous US.
- *Federal resource managers (USBR, USFS, USDA)*. CDC develops and provides experimental climate products and services to help plan for and mitigate the impacts and costs of climate variability and extreme events in the management of freshwater supply, floods, droughts, wildfire, and endangered species.
- *Major U.S. and international modeling centers (NCAR, NASA, ECMWF)*. CDC conducts collaborative climate research aimed at improving models and modeling methods for medium-range weather forecasts, seasonal- to-interannual climate predictions, and multidecadal climate projections, and developing new climate products.
- *Climate researchers at universities and other institutions*. CDC provides critical cyber-infrastructure to enable Internet access by the climate research community to NCEP/NCAR reanalysis products, web-based diagnostic and enhanced visualization tools, model data sets, and experimental climate monitoring and forecasts products.
- *State and Regional Entities* (State Climatologist Offices, State Drought Task Forces, Western Governors' Association). In support the missions of various public service providers, CDC provides NOAA-based expertise to diagnose and explain observed and evolving climate conditions, to develop experimental climate monitoring and forecasts, web-based diagnostic and enhanced visualization tools, and provide decision support resources.
- *Private sector* (energy, agriculture, and transportation). CDC provides Internet access to reanalysis products, web-based diagnostic and enhanced visualization tools, model data sets, and experimental climate monitoring and forecasts products for use by the public and private sectors to better manage risks and opportunities related to climate variability.

4.) Summary of CDC research being conducted (based on list of major requirements from the Program Baseline Assessments (PBA))

The Climate Diagnostics Center (CDC) supports NOAA Mission Goal 2: “Understand climate variability and change to enhance society’s ability to plan and respond” through a balance of applied and basic research. The core-funded activities at CDC are currently supplemented by a roughly equal amount of reimbursable funding obtained through peer-reviewed competitive grants (e.g., NOAA, NSF, NASA, DOE, DOD). These relatively

short term grant commitments support an additional 30 CIRES joint institute staff whose research address basic questions such as: *Are there limits of predictability for various aspects of the climate system? Are existing and proposed climate prediction approaches optimal, and what are the best practices for making predictions? And are there alternative pathways to achieve NOAA mission goals?* This significant component of reimbursable research at CDC contributes substantially to advancing the current understanding of climate variability and change, and strengthens the scientific foundation of applied research at CDC in support of all the NOAA Line Offices.

Climate Observations and Analysis

Subprogram: Understanding climate variability and change.

- a) CDC supports NOAA's "Understand and Describe" strategy to increase understanding of the dynamics and impacts of coupled atmosphere/ocean/land systems through research on climate variability and change. The delivery of regular and systematic explanations of the state of the climate with an emphasis on current and evolving conditions (climate variability, extremes, trends) is a NOAA and CCSP priority. The extent to which NOAA can provide scientifically-based explanations for recent and ongoing climate conditions will be vital to increasing the credibility and usefulness of NOAA's seasonal-to-interannual climate forecasts and climate change projections.
- b) The geographic scope of this research spans from addressing regional to national to global in terms of being able to explain observed climate trends, recent and evolving climate conditions, and to improve the skill and spatial resolution of seasonal forecasts.
- c) The timeframes of delivery of this research is 25% short term (0-2 years), 50% medium term (2-5 years), and 25% long term (greater than 5 years).

Recent research foci

- Collaborative work between CDC and CPC has shown that warm sea surface temperatures in the western tropical Pacific and Indian Oceans combined with persistent La Niña conditions over the period 1998-2002 contributed to wide-spread droughts in middle latitudes, including large portions of the United States, Mediterranean region and southwest Asia. This finding has contributed to the development of new NOAA capabilities for attributing causes of observed climate conditions, and to an improved scientific foundation for providing drought forecasts based on more than ENSO conditions and climate change projections. This information supports U.S. and international decision makers in areas such as risk management, energy and natural resources, agriculture, transportation and homeland security. For example, drought contributes to an estimated \$6-8 billion in average annual economic losses to the United States, and has profound social and economic impacts nationally and globally. Therefore, even modest improvements in drought forecasts carry enormous potential for societal and economic benefits.
- CDC research is providing new insights into the causes for 20th century regional climate trends. For example, collaborative research with the NCAR has shown that changes in North Atlantic/ European climate since 1950, including the drying in the Mediterranean region, were forced by long-term warming of tropical sea surface temperatures, primarily in the Indian Ocean and western Pacific. The public and policymakers benefit from these and other similar assessments because they help to explain current and evolving changes in climate, better understand uncertainties in climate change projections, and determine what will be necessary to estimate regional impacts of climate change. Research in this

area also supports national and international climate assessments and the development of a high-priority Climate Change Science Plan synthesis and assessment product.

- To enhance the use and usefulness of NOAA’s investment in paleoclimate research and data for risk assessments and resource management, CDC is developing tools to physically interpret paleoclimate data, place these data in a modern climate context, and characterize the time dependent uncertainties in paleoclimate reconstructions. Analyses of the long time series are being used to assess the stability of variability revealed in instrumental records and how well the instrumental record represents the full range of natural variability. Paleoclimate modeling research at CDC focuses on using global climate models to attribute paleoclimate extremes to known forcings, and thereby improve assessments for possible future extreme events and abrupt change.

Climate Predictions and Projections

Subprogram: Intraseasonal to interannual climate predictions.

- a) CDC supports NOAA’s “Assess and Predict” strategy aimed at improving intraseasonal to interannual climate forecasts. These forecasts support a wide range applications and help the public and regional and national resource managers to better anticipate and take actions for possible effects of climate variations. Improvements in NOAA’s seasonal to intraseasonal climate capabilities benefit taxpayers by contributing to better informed and more efficient resource management decisions in areas such as water resources, energy, agriculture and forestry (wildfires). Other payoffs include an improved ability to anticipate and respond to high-impact climate events (e.g., to a developing ENSO event), and to increase understanding and capabilities to project the regional impacts of climate events. These forecasts provide a scientific basis for government and resource managers to develop strategies to minimize potential vulnerabilities.
- b) The geographical scope of this research is global, but with a strong regional focus to meet user needs for increased regional specificity of skillful week-two forecasts of temperature and precipitation.
- c) The timeframes of delivery of this research is 25% short term (0-2 years), 50% medium term (2-5 years), and 25% long term (greater than 5 years).

Recent research foci

- CDC recently developed and implemented an experimental forecast product that substantially improves NOAA extended weather forecasts of surface temperatures and precipitation out to 6-10 days and week-two (days 8-14). CDC research on forecasts beyond short-range weather (≤ 2 days) and shorter than a season (called intra-seasonal forecasts) has greatly increased our understanding of how changes in tropical rainfall distributions affect the risks of heavy rainfall and flooding along the west coast of the United States. This work is being conducted in collaboration with ETL and CPC as part of a “Climate-Weather Connection” program to better understand how climate variations affect weather phenomena, especially high-impact events such as flooding or severe storm outbreaks. This research is helping to improve the CPC U.S. Hazards Assessment product. Forecasts for times from a week to a season in advance, are used by decision-makers in sectors such as agriculture, reservoir water management and energy planning, and provide guidance for emergency managers on upcoming potentially hazardous events. Benefits to the nation include increased lead-times for anticipating potential high impact weather and climate events and improved information for resource management decisions.

- CDC research provides seasonal forecast guidance products in support of operational seasonal-to-interannual forecasts generated by CPC. CDC scientists interact regularly with CPC forecasters, especially just prior to the issuance of the operational climate forecasts, and often provide experimental products to address specific forecast questions. The public and decision-makers in the agriculture, water and energy resources management sectors are primary users of seasonal forecasts. Improvements in this climate forecast capability benefit taxpayers by ensuring more informed and cost-effective resource management decisions.
- CDC pursues innovative research on climate variability that involves advancing understanding of random, probabilistic fluctuations in the earth climate system. CDC pioneered the use of probabilistic theory to illustrate the relationship between US seasonal climate extremes and ENSO, a framework now incorporated in operational categorical seasonal forecasts. CDC is spearheading the development and application of stochastic modeling architectures in order to maximize the usefulness of climate forecasts, especially accurate estimates of the uncertainty in predictions. Collectively, this research provides guidance to NOAA on what aspects of the climate system are predictable and if there are alternative prediction schemes that may be technically more viable than current practices.

Climate Information for Decisions: Research to Delivery

Subprogram: Climate Observations and Services – Regional Assessments and Education.

- a) CDC supports the NOAA Strategy “Engage, advise, and inform” aimed at working with users of climate information to increase applications and usefulness of NOAA’s climate information for health and safety, environmental, economic, and community planning, especially for freshwater supply, drought, wildfire management, water quality, and coastal impacts. CDC works extensively with a broad range of external customers to identify user priorities for future NOAA climate services. Expanded and more effective NOAA climate products will provide improved scientific information to better serve the needs of the public and decision makers, e.g., in proactive planning, impact mitigation and responses. These products are essential to developing and sustaining effective NOAA climate services. This activity contributes to a more rapid development and efficient transfer of research advances into NOAA operational products.
- b) The geographic scope of this research spans from addressing regional to national in terms of being able to provide climate products and services to better serve the public and decision makers in proactive planning, impact mitigation and responses, and cost reductions.
- c) The timeframes of delivery of this research is 30% short term (0-2 years), 40% medium term (2-5 years), and 30% long term (greater than 5 years).

Recent research foci

- CDC scientists have been working vigorously to develop new experimental climate products and decision support tools aimed at better meeting user needs in areas such as water supply, energy, agriculture and wildfire management. As part of this effort, CDC collaborates extensively with the NOAA Regional Integrated Science Assessments (RISAs) projects and NOAA Regional Climate Centers, especially the Western Water Assessment (WWA) and the Western Regional Climate Center (WRCC), to help identify current and prospective future uses of climate information.

- In cooperation with the NWS Climate Office, CDC also co-leads training workshops on *Climate Variability* to provide NWS field forecasters with the scientific background that they need to interpret NOAA climate products and to assist them in adapting national products to their region.
- CDC scientists also serve on an interagency core team in partnership with the Western Governors' Association (WGA) to develop plans for a National Integrated Drought Information System (NIDIS), providing the nation with a drought early warning system for the 21st century.
- Through its website, CDC provides a wide range of research and experimental products that are used extensively by both the public and private sectors. These efforts are all contributing to expanded and more effective NOAA climate services, more informed public and private sector decisions (such as anticipating and mitigating the impacts and costs of drought), and increased speed and efficiency in transferring results of NOAA research into real world services.

5) List four major accomplishments in the last five years.

1) *Advancing NOAA seasonal-interannual climate forecast capabilities.*

- Improved skill of climate forecasts and estimates of forecast uncertainties/predictability through increased understanding of the mechanisms that produce climate variations, and development and transfer of new forecast products into NOAA climate services.
- Experimental forecasts of ENSO and related climate responses developed at CDC are now routinely incorporated into NOAA-Climate Prediction Center (CPC) expert assessments and used in projecting SST variations and associated climate responses over the next few seasons.
- CDC provides to CPC real-time updates of diagnostic and experimental prediction products and guidance prior to the issuance of NOAA ENSO diagnostic discussions, monthly and seasonal climate outlooks, and drought monitor and outlooks.
- CDC documents the users, uses, and benefits of climate forecasts to inform NOAA of what worked, what did not work, and what results can be more broadly applied to meet user needs for decision support.

Users and benefits

NOAA seasonal-to-interannual climate forecasts and related products are used extensively by the public and a wide range of decision-makers, especially in agriculture, water and energy resources management. Improvements in NOAA's seasonal to interannual climate capabilities benefit taxpayers by contributing to better informed and more efficient resource management decisions. Other payoffs include an improved ability to anticipate and respond to high-impact climate events (e.g., to a developing ENSO event) and increased understanding and capabilities to project the regional impacts of climate events, which provide a sounder scientific basis for developing strategies to minimize potential vulnerabilities.

2) *Improving NOAA forecast capabilities within a season.*

- Development and implementation of an experimental reforecast product to improve Week 2 (forecast days 8-14) probabilistic surface temperature and precipitation forecasts.

- Improved ability to identify how changes in tropical rainfall distributions affect the risks of heavy rainfall along the US west coast.
- Improved understanding and assessments of predictability of extreme events (e.g., droughts, floods) contributing to improvements in the CPC U.S. “Hazards Assessment” product.
- An experimental reforecast product developed at CDC has resulted in a 2-4 day advance in lead time for medium-range forecasts, with the skill of the CDC 8-14 day experimental forecast product superior to the current CPC 6-10 day operational product for both temperatures and precipitation. The CDC experimental product will be transitioned to operational status at NWS/NCEP over the next year.
- Experimental CDC web-based tools have been developed for monitoring and predicting tropical Pacific rainfall variability on intraseasonal time scales (e.g., associated with the Madden-Julian Oscillation) for use by CPC and other operational and research centers throughout the world.

Users and benefits

Forecasts within a season support a wide range of decision-makers across public and private sectors, such as reservoir water management (e.g., to reduce flood risks) and energy planning. Through the hazards assessment product, this information also serves as long lead guidance for emergency managers. Research in this area also directly addresses a gap in NOAA forecast capabilities, and serves the NOAA NWS in achieving its strategic goal of providing a seamless suite of forecast products from minutes to years in advance. An important payoff is a more efficient and rapid transfer of research results into NWS operations. Benefits to the nation include increased lead-times for guidance on potential high impact weather and climate events to support improved planning and resource management decisions.

3) Increasing understanding of the links between decadal-to centennial climate variations and shorter-term climate variability, and implications for high-impact climate events.

- Improved understanding of the effects of the ocean’s role in forcing multi-year climate anomalies. Collaborative work between CDC and CPC has shown that warm sea surface temperatures in the western tropical Pacific and Indian Oceans combined with persistent La Niña conditions over the period 1998-2002, contributed to wide-spread drought in mid latitudes, including large portions of the U.S., Mediterranean, and southwest Asia.
- Enhanced understanding of the atmosphere-ocean coupling as a mechanism to explain the role of the tropics in Pacific decadal climate variability.
- Improvements in understanding the causes of major climate phenomena such as drought are leading to the development of new diagnostic or ‘climate attribution’ capabilities in NOAA, and also provide a scientific basis for developing drought forecasts.

Users and benefits

Public benefits will be achieved through an improved ability to explain observed climate events which lead to more reliable and useful climate prediction products. Such information is essential in supporting U.S. and international decisionmakers across a wide spectrum of public and private sectors (e.g., risk and emergency management, energy and natural resources, agriculture, transportation, homeland security). For example, the impact of the drought in 1988 is estimated to be on the order of \$40B in economic losses to the United States. Climate related extreme events have profound social and economic impacts

worldwide, so that even modest improvements in extreme event prediction capabilities carry enormous potential for economic and societal benefits.

4) Accelerating the expansion of NOAA climate services by developing, evaluating, and providing a broad range of experimental climate products, improving links between NOAA research, operations, and end users, and providing educational training for NWS field personnel.

- Developed, evaluated, and provided experimental climate products to address the needs of users (water supply, energy, agricultural, wildfire management, education).
- Collaborated with NOAA regional integrated science assessments in research on uses of climate information and the development of new operational and experimental climate products to better meet customer needs and promote the development and effectiveness of NOAA climate services.
- Developed experimental climate diagnostics and web-based analysis tools to provide information at spatial resolutions identified as needed by decisionmakers (e.g., regional, state, river basin, etc.).
- Supported NOAA climate services by co-leading with the NWS Climate Services Division an educational and training program on Climate Variability for NWS personnel.
- CDC provides access to a wide range of research and experimental products via its website, which is extensively used by the public and private sectors. For example, in the most recent month for which statistics are available, July 2003, CDC web pages were visited over 2 million times by over 120 thousand distinct users, with over 150 Gigabytes (GB) of data downloaded directly from the web site. Over the first seven months of the calendar year, the CDC website has averaged over 1.5 million accesses per month from nearly 110,000 distinct users, and about 130 GB of data downloaded directly from the site per month. In addition to the direct web transfers, over 1.6 Terabytes (TB) of climate data were downloaded from CDC via file transfer protocol (FTP) in July, with the monthly average this year being approximately 2 TB/month.
- CDC works with NWS regional offices, NESDIS Regional Climate Centers, and State Climatologist Offices to develop new climate products, such as new climate divisions that better represent patterns of climate variability in seasonal precipitation and temperatures, and develops climate analysis tools to improve access to information at resolutions that meet user-defined needs.
- CDC co-developed and co-leads a semi-annual “Training Workshop on Climate Variability” to familiarize NWS forecasters with NOAA climate forecasts and information products, and to provide them with capabilities to adapt and interpret the products for their region.
- CDC provides regular briefings of the regional implications seasonal climate outlooks and other experimental climate forecasts to the Colorado Water Availability Task Force and other user communities, such as water resource managers.
- CDC is part of a core team providing scientific expertise to the Western Governors’ Association in developing plans for a National Integrated Drought Information System.

Users and benefits

Broad public benefits will be derived from expanded and more effective uses of NOAA climate products and services, leading to better informed public and private sector decisions (e.g., proactive planning, impact mitigation and improved responses). This knowledge is essential to developing and sustaining effective NOAA climate services on both regional

and national scales. This work is also contributing to a more rapid and efficient transfer of research results into applications and NOAA services.

6) Summary of legal mandates for the work

- Weather Service Organic Act (15 U.S.C. 313 et seq.): “... the enhancement of the Nation’s economy....”
- National Climate Program Act (15 U.S.C. 2901 et seq.)
- Global Change Research Act (15 U.S.C. 2921 et seq.)
- Water Resources Planning Act (42 U.S.C. 1962-1962d-14)
- Cooperative Agreements/Reimbursement to further NOAA’s mission (15 U.S.C. 1525, 1540)
- OMB/OSTP Directives for FY 2004 and FY 2005
- Memorandum of Understanding between CDC and the NOAA/NWS Climate Prediction Center “to conduct collaborative efforts in order to advance NOAA's capabilities in climate monitoring and predictions.”
- National Weather Service Strategic Plan. *Development of a seamless suite of weather and climate products.*
- US Interagency Climate Change Science Plan (CCSP)
Goal 1: Improve knowledge of the Earth’s past and present climate and environment, including its natural variability, and improve *understanding* of the causes of observed variability and change.
CCSP Goal 5: Explore the uses and identify the limits of evolving knowledge to manage risks and opportunities related to climate variability and change.
CCSP Priority Synthesis Product: Reanalyses of historical climate data; implications for attribution of causes of observed change (NOAA co-lead).
CCSP Priority Synthesis Product: Climate extremes, including documentation of current extremes and prospects for improving projections (NOAA lead).
CCSP Priority Synthesis Product: Decision support experiments and evaluations using seasonal to interannual forecasts and observational data (NOAA lead).
- NOAA Annual Guidance Memorandum, 2003: Future Directions – *Expand Climate Services.*

7) EXCEL Spreadsheet – sent as separate file.

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