Climate Prediction Center

National Centers for Environmental Prediction • National Weather Service

National Oceanic and Atmospheric Administration

Reflections on 25 Years of Analysis, Diagnosis and Prediction 1979–2004

8-14 Day Outlook

Climate Diagnostics and Prediction Workshop

30-Day and 90-Day Seasonal Outlook

ENSO Advisory

Ozone Winter Summary

Drought Outlook

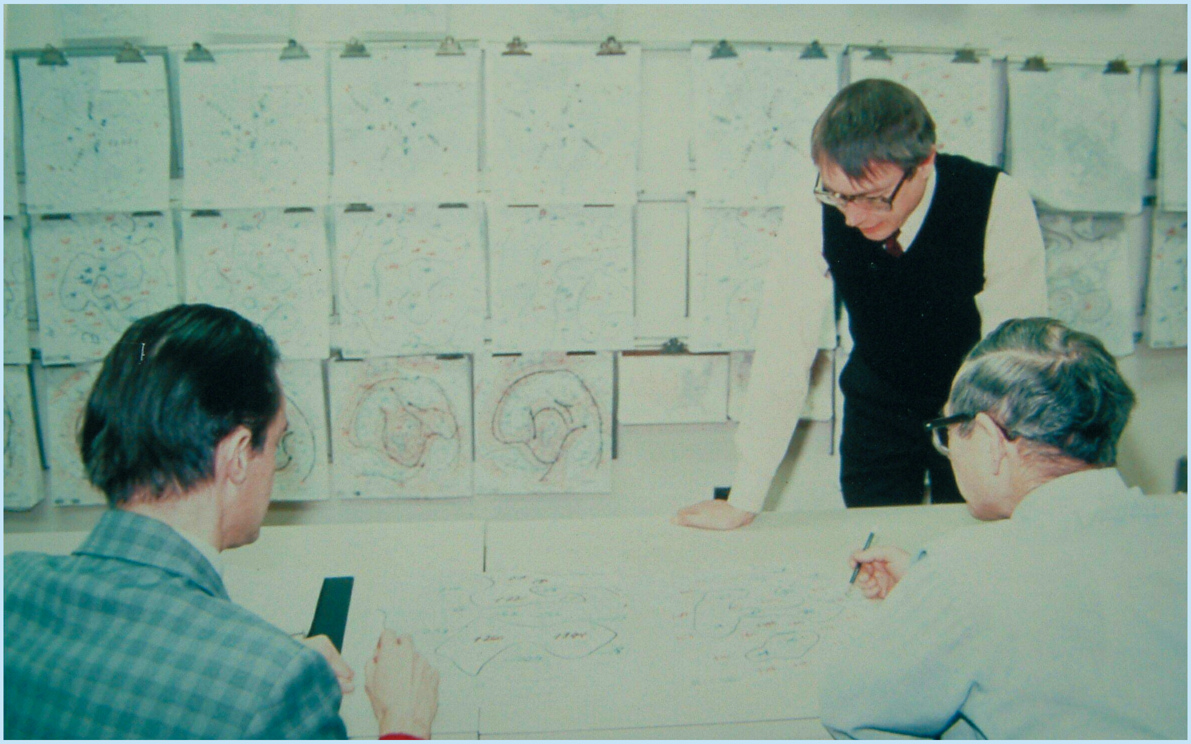
Drought Advisory

Monthly Climate Bulletin

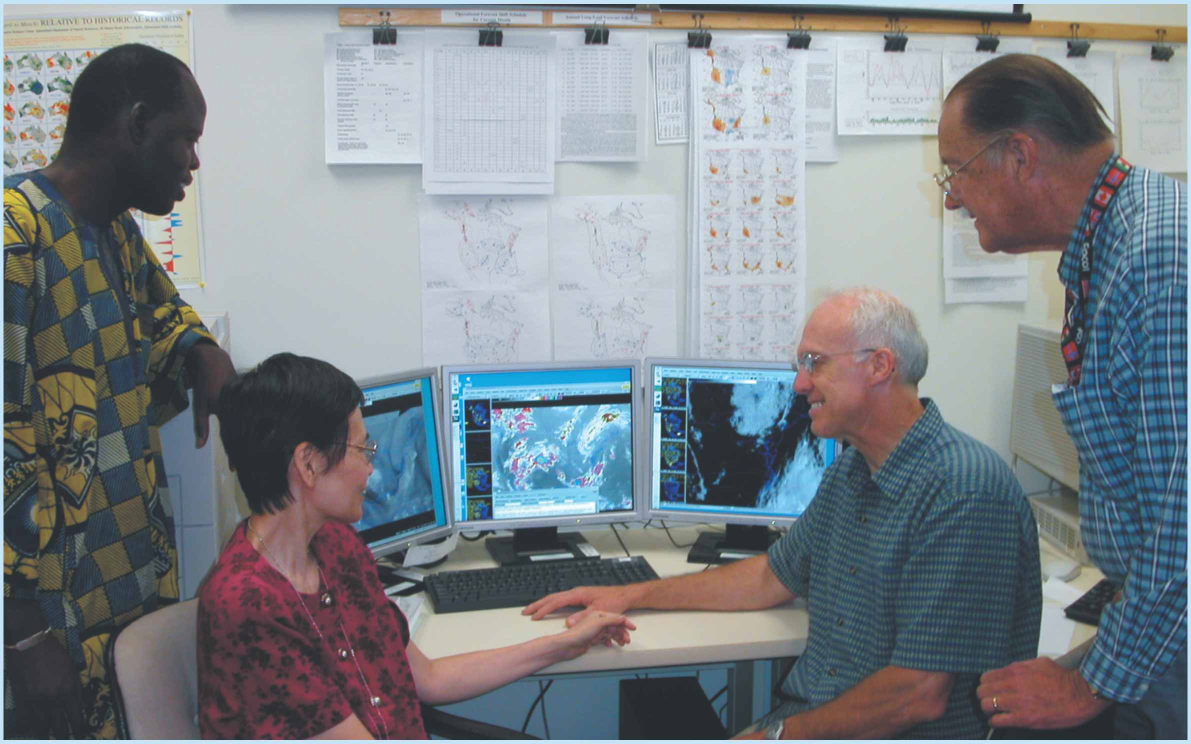
Seasonal Hurricane Outlook

UV Index Forecast

CDAS Reanalysis



The Climate Analysis Center's Jim Wagner, Don Gilman and Robert Dickson (left to right) prepare a medium-range forecast at the World Weather Building (ca.1980).



The Climate Prediction Center's Wassila Thiaw, Kingste Mo, Ed O'Lenic, and Jim Wagner (left to right) discuss the seasonal outlooks at the World Weather Building (July 2004).

CLIMATE PREDICTION CENTER

Reflections on 25 Years
of Analysis, Diagnosis, and Prediction

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CATALOGING DATA: Reflections on 25 Years of Analysis,
Diagnosis, and Prediction at the Climate Prediction Center, National Weather Service,
National Oceanic and Atmospheric Administration.
Robert W. Reeves and Daphne deJ. Gemmill, editors, 2004.

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Preface

THIS PUBLICATION IS INTENDED to provide an historical perspective on the creation of the Climate Prediction Center (CPC), which is one of seven Service Centers within NOAA's National Centers for Environmental Prediction (NCEP). The history is enriched by the "reflections" of the five Directors who have guided the Climate Analysis Center (CAC), which later became the CPC, over the past 25 years and have created an enterprise where scientific advances in the climate community are more rapidly infused into the operational product stream. Today, new and improved products are delivered to an increasingly diverse and sophisticated user community.

In the 1960s and 1970s, anomalous climate events caused economic reverberations around the world. By the mid-1970s, scientists, policy-makers, and users of climate information called for a collaborative effort to improve climate monitoring, diagnostics, and prediction. Early discussions stressed the need to develop climate indices that might assist the climate monitoring process and led to the concept of establishing a center to undertake and coordinate climate diagnostics and prediction. NOAA recognized this need and created the CAC in 1979.

The CAC consolidated NOAA's climate diagnostics and monitoring efforts and expanded on the earlier efforts of Jerome Namias' Extended Range Forecast Division in the National Weather Service. From these humble beginnings, the CAC expanded its focus from gathering, analyzing, monitoring, and diagnosing climate data and information to providing climate predictions on time scales out to thirteen months. With the reorganization of the National Meteorological Center (NMC) into the National Centers for Environmental Prediction (NCEP), led by NMC Director Dr. Ron McPherson, CAC became the Climate Prediction Center. In 1997 CPC's winter forecast, based on the likely impact of a strong El Niño brewing in the tropical Pacific Ocean, gained national attention and led to planning and actions by emergency responders and others throughout the U.S., saving many lives and millions of dollars in avoided property damage.

Since 1998, the National Weather Service (NWS) has embraced climate prediction as a major component of what has come to be called the "seamless suite" of forecast products ranging from minutes to seasons and even years in advance. John (Jack) J. Kelly, Jr., Brigadier General (USAF ret.), Deputy Undersecretary of Commerce for Oceans and Atmosphere, and NOAA's Assistant Administrator for the Weather Service from 1998 to January 2004 solidified the importance of climate in the NWS by incorporating "climate" in the NWS mission statement. A Climate Services Division was created at NWS headquarters, which works closely with CPC and the six Regions of the NWS to make climate an integral part of the product stream delivered by the NWS Regions through the 122 local Weather Forecast Offices located throughout the country.

Jack Kelly's participation on the "National Drought Policy Commission" led to the development of several new climate products, and his support for additional supercomputer funding has expanded the NWS capacity for climate model development, testing, and implementation. Brigadier General (USAF retired) David L. Johnson, NOAA's current Assistant Administrator for Weather Services continues to strengthen the role of climate in the NWS in collaboration with all NOAA line offices and through the NOAA "climate matrix." NCEP and CPC's research, developmental and operational partnerships have grown particularly strong with the National Environmental Satellite, Data and Information Service (NESDIS) and the Office of Oceanic and Atmospheric Research (OAR) including the NOAA Climate Office and Office of Global Programs, both led by Dr. Chet Koblinsky, and the OAR laboratories.

NCEP has embraced the seamless suite of products as a strategic foundation for improving its output stream, making this concept the basis for unifying a consistent set of guidance and forecasts created and delivered by all the NCEP Service Centers. A "collaborative" forecast approach, which involves the CPC, the OAR Climate Diagnostics Center, NCEP's Hydrometeorological Prediction Center, and forecast offices around the country, has been instituted to ensure consistent forecasts from Day 1 to Day 14, and from seasonal to interannual.

NCEP is also fostering partnership with other laboratories, universities, and research institutions around the world to improve the dynamical forecast process related to coupled atmosphere, ocean and land prediction models. In August 2004, a new Climate Forecast System (CFS), which couples the global ocean/atmosphere system, was implemented into the NCEP operational model suite. The development of the CFS was led by the Environmental Modeling Center and represents a major breakthrough in dynamic modeling of climate variability in the seasonal to interannual range. A major accomplishment of this system is the realistic simulation of ENSO events at various strengths over years to decades without drifting toward a large bias. The application of the GFS and the appropriation of $5M/year to support the climate component of the NWS supercomputer ensure the NWS will continue to support improving seasonal to interannual climate predictions for years to come.

The first 25 years of climate services provided by the CAC and CPC are a tribute to those who have contributed to improved understanding and prediction of climate from next week to next year. In this publication, the people involved in these formative years reflect on the challenges and successes in building a foundation for NOAA's climate services. The next 25 years will continue these efforts, with the CPC remaining a vibrant Service Center, built upon service-science linkages with the broad research community, delivering skillful and useful monthly to seasonal predictions to a diverse and increasingly sophisticated user community throughout the country.

—Louis W. Uccellini

Director, National Centers for Environmental Prediction

Origins
of a "diagnostics climate center"

By Robert W. Reeves and Daphne deJ. Gemmill

Full operation of the climate analysis center began in August 1979 when NOAA completed the Center's organizational structure. Where did the concept for a diagnostic climate center originate? Who were the key individuals? To what extent did concerns about long-term climate variability play a role in the Climate Prediction Center's birth? Our search for the origins took us back to the late 1960s and early 1970s.*

A number of short-term climate events, later linked to the 1972–1973 El Niño, had national and international economic consequences. These dramatic events reinforced the calls for action to improve understanding of the climate system and our ability to issue climate outlooks. Several climate events repeatedly cited in numerous reports and Congressional testimony were:

- A killing winter freeze followed by a severe summer heat wave in the U.S.
- Drought in the Soviet Union producing a 12-percent shortfall in their grain production in 1972, forcing the country to purchase grain abroad which in turn reduced world grain reserves and helped drive up food prices.
- Collapse of the Peruvian anchovy harvest in late 1972 and early 1973, related to fluctuations in the Pacific Ocean currents and atmospheric circulation, impacted world supplies of fertilizer, the soybean market, and prices of other protein feed stocks.
- The anomalously low precipitation in the U.S. Pacific Northwest during the winter of 1972–1973 depleted water reservoir storage by an amount equivalent to an amount of water required to generate more than 7 percent of the electric energy for the region.

*In researching the origins of CPC, the authors conducted personal interviews with individuals who were active during the 1970s. The editors also read numerous reports of Congressional hearings. See the acknowledgments section for a complete list of those interviewed. Don Gilman and Uwe Radok provided copies of some earlier planning documents.

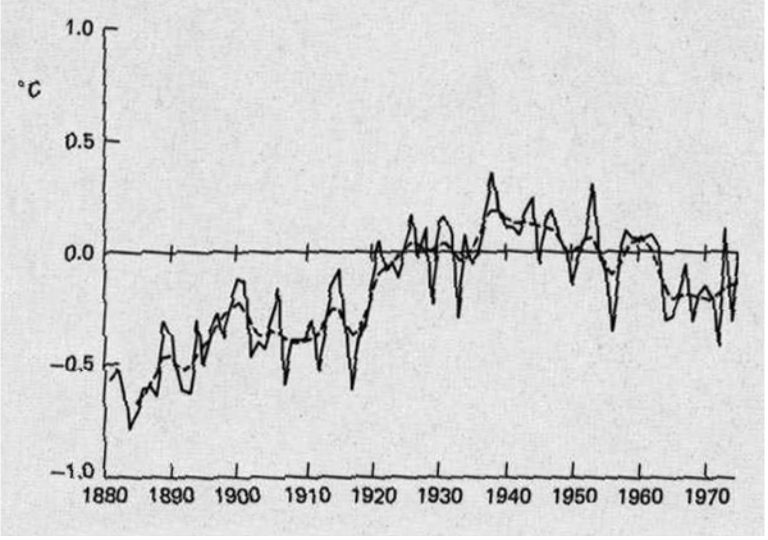


Figure 1. Northern hemisphere mean annual surface temperature variations in °C: deviations from the 1946–1960 mean, adapted from Jones and Wigley, 1980.

Interest in decadal to centennial timescales also contributed to the calls for action. The views on long-term climate trends, however, were split. Some scientists projected a warming trend and others focused on the gradual cooling as suggested by the global surface temperature record from the 1940s through the 1960s (Figure 1).

The cooling theory attracted the interests of many scientists, including glaciologists. In January 1972, geologists George Kukla of the Czechoslovakian Academy of Sciences and Robert Matthews of Brown University convened a working conference of top European and American investigators in Providence, Rhode Island, to discuss "The Present Interglacial, How and When Will It End?"

They summarized their results in *Science* (October 1972). Kukla had by this time accepted a visiting scientist position at the Lamont–Doherty Geological Observatory. In a rather bold move, they followed up their Science article with a letter to President Nixon calling for federal action based on the main conclusion of the conference:

> . . . a global deterioration of climate, by order of magnitude larger than any hitherto experienced by civilized mankind, is a very real possibility and indeed may be due very soon. The cooling has natural cause and falls within the rank of processes which produced the last ice age. This is a surprising result based largely on recent studies of deep sea sediments.

Kukla and Matthews concluded their letter with the following concern:

> It might also be useful for the Administration to take into account that the Soviet Union, with large scientific teams monitoring the climate change in Arctic and Siberia, may already be considering these aspects in its international moves.

The White House assigned the Kukla–Matthews letter to the State Department's Bureau of International Scientific and Technological Affairs and circulated it to the Interdepartmental Committee for Atmospheric Sciences (ICAS), for "review and appropriate action." The ICAS established an ad hoc Panel on the Present Interglacial to respond by September 30, 1973. (The formal publication date of the report was August 1974.)

The National Science Foundation (NSF) and National Oceanic and Atmospheric Administration (NOAA) sought the leadership role for the Federal Government. The NSF created the Office of Climate Dynamics in May 1974 under the leadership of Joseph O. Fletcher, with the assistance of Uwe Radok.

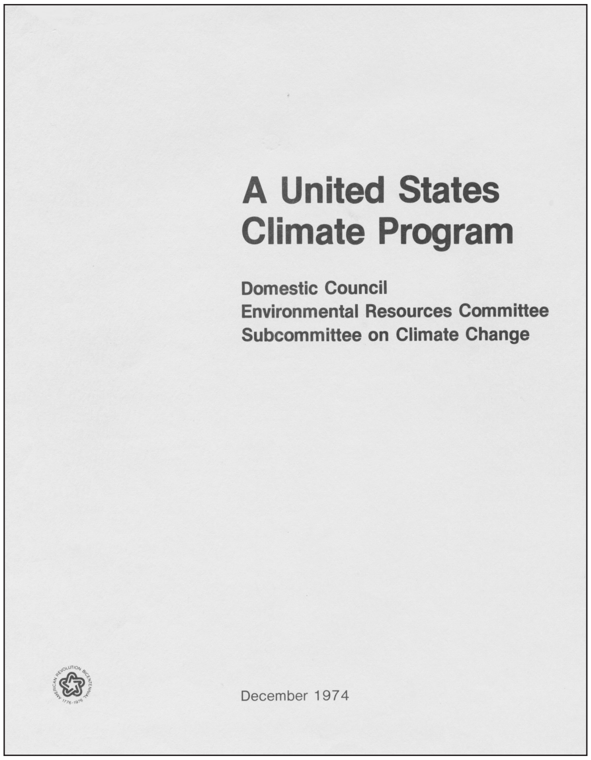
The ad hoc panel decided that the topic was of such importance that it should go beyond simply reporting findings to including recommendations. The report included a companion document that was a call for a national climate program to begin to address climate issues. Fletcher was instrumental in the companion report's preparation and had envisioned NSF in the lead.

On August 1, 1974, Rogers C.B. Morton, the chairman of the White House Environmental Resources Committee, wrote to Secretary of Commerce Frederick Dent:

> Changes in climate in recent years have resulted in unanticipated impacts on key national programs and policies. Concern has been expressed that recent changes may presage others. In order to assess the problem and to determine what concerted action ought to be undertaken, I have decided to establish a subcommittee on Climate Change.

The memorandum further requested the Department of Commerce to chair the subcommittee. Secretary Dent responded on August 16 and named Robert M. White, Administrator of NOAA, as chair of the subcommittee. John Townshend, White's Deputy, asked William Sprigg, who was in the office of the NOAA Assistant Administrator for Environment and Prediction, to convene a series of interagency meetings to assemble the "United States Climate Program." Sprigg recalled that during one of those meetings on climate data and indices, Barry Saltzman from Yale University proposed that a "focus or center" was needed where huge amounts of data can be assembled and analyzed. Sprigg stated that Saltzman's suggestion was included by the group as a recommendation to establish an analysis center—one of the earliest suggestions for a center. According to Norman Canfield, who joined NOAA headquarters in 1975 as Senior Climatologist, Sprigg was instrumental in the formation of the Climate Analysis Center because he organized the meetings that led to its formation (Canfield, personal communication).

In a related effort, Sprigg began assembling some of NOAA's concepts for such an interagency organization, including estimated computer costs in an undated, unpublished (probably 1974) document entitled *A Climate Diagnostics Center*. By late 1974 Don Gilman, at the request of Fred Shuman, both in NOAA's National Weather Service, had prepared a draft diagnostic center budget and personnel plan for 1976 and 1977 including 24 positions in 1976 with a budget of $1.4 million, increasing by 8 positions and $700,000 in 1977. A subsequent draft (12/30/74) by Gilman outlined three diagnostic center functions: data acquisition; data analysis and synthesis; and prediction.


A United States Climate Program

Domestic Council
Environmental Resources Committee
Subcommittee on Climate Change

December 1974

Figure 2. *A United States Climate Program Report* (1974) included a budget and plan for a proposed climate diagnostics center.

In December 1974, the interagency subcommittee produced their report *A United States Climate Program* (Figure 2), describing the needs for a climate program. An "action and milestone" in that report was to establish a climate diagnostics center in 1976.

In an article in *Inside CIRES* (September 1997), Uwe Radok reflected on the Brown University conference and mentioned the committee on the present interglacial and its "proposed national climate initiative which a new NSF Office of Climate Dynamics (OCD) started with a 'Climate Clinic' that brought together representatives of the major climate research groups at the National Center for Atmospheric Research (NCAR) in October 1974, and became the forerunner of annual Climate Diagnostic Workshops" (see page 45). Radok's invitation was issued in November for a December meeting in Boulder, Colorado. By that time, Joe Fletcher had left NSF to join NOAA at the Environmental Research Laboratories in Boulder. He convened the Clinic.

The Climate Clinic's proposed terms of reference stated, "The Climate Clinic represents a pilot experiment for a Diagnostic Climate Center." This was a clear indication that Joe Fletcher and Uwe Radok had also been developing the concept of a center.

Congressional action to create a national climate program was just beginning. In early 1975, Rep. Philip Hayes (D-IN) introduced H.R. 10013, the "National Climate Program Act of 1975" to establish a coordinated national program of climate research, monitoring, prediction, and contingency planning analysis. The bill gave the Department of Commerce the lead role. During the next four years numerous bills were introduced and committee hearings held.

Congress and most of the scientists and users of climate information who testified stated that the existing federal efforts in climate research, monitoring, and analysis were inadequate to meet existing and future needs of the nation. They also stated that the prospect for providing accurate monthly and seasonal forecasts was scientifically promising provided an accelerated program of basic and applied research was established and adequately funded. During an April 1977 House of Representatives hearing, a representative of the Agricultural Research Institute expressed dismay at the decline of the NOAA climate program and called for a separate division within the National Weather Service to address climate forecasting.

The official administration position was that legislation was not needed. The Office of Science and Technology Policy and the Office of Management and Budget tried with little success to rewrite the legislation in conference more in line with the administration's views. President Carter signed the National Climate Program Act on September 17, 1978.

After it became clear that NOAA would host any center for climate diagnostics, various NOAA line components sought the management lead. Interviews with those involved and Congressional testimony indicated that National Weather Service (NWS) management was cool to the idea of leading the new center. Ed Epstein, manager of the NOAA Climate Diagnostics Project, assigned management responsibility to the NWS in a July 1977 memorandum. A NOAA June 1978 memorandum administratively established the Climate Analysis Center. The following spring, NOAA added additional staff and functions. Full operations began in August 1979 when NOAA completed the organizational structure.

NOAA formed CAC, a unit of the National Meteorological Center (NMC, and later National Centers for Environmental Prediction) in response to the growing awareness of El Niño's impact on weather, the severe 1976–1977 winter, USSR's wheat-crop failure leading to the wheat deal, and Congressional pressure for progress in climate prediction. CAC combined in-house operations, research and development, and collaboration with outside entities through grants. The objectives were near-real-time climate monitoring, climate diagnostics, and prediction in support of agriculture, water resources, and energy.

Evolution of Climate Services

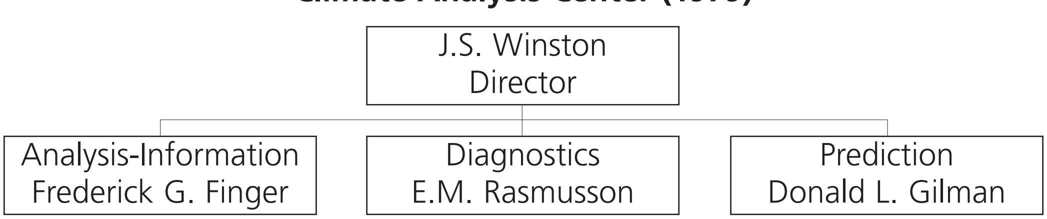
On June 4, 1978, the National Oceanic and Atmospheric Administration (NOAA) began the process of establishing a climate diagnostics center in the National Weather Service (NWS). This chapter describes the evolving administrative structure from the Climate Analysis Center (CAC) to the Climate Prediction Center (CPC) and gives the reflections of several branch chiefs and others from 1979 to the present on the major events, accomplishments, and progress made in the areas of analysis and information, monitoring and diagnostics, and prediction during CPC's first 25 years (see Major Milestones, pages 38–29).

Organizational Structure

The first step was to create the Climate Analysis Center (CAC) around the NWS Long Range Prediction Group. This group became the Prediction Branch. On April 12, 1979, NOAA officially transferred the Upper Air Branch (UAB) (with its focus on stratospheric analysis and research) from the National Meteorological Center's Development Division and staff who had been involved in global surface data processing, monitoring, to the new Center.

Because no existing NOAA unit had official responsibility for climate diagnostics, NOAA created the Diagnostics Branch by consolidating staff engaged in climate monitoring and diagnostics. By August 23, 1979, the last components of CAC were created when the Analysis and Information Branch, incorporating the UAB and Agricultural Weather Section, was established. The diagram below shows CAC's organizational structure and senior managers in 1979.

Climate Analysis Center (1979)



The Analysis and Information Branch became the largest branch with responsibilities for stratospheric analysis, global surface data, and a joint program with the U.S. Department of Agriculture to produce the *Weekly Weather* *and Crop Bulletin* (first published in 1872). In 1989 Jim Laver succeeded Fred Finger as branch chief. When Laver assumed the duties of Deputy Director, Alvin Miller became the branch chief in 1994.

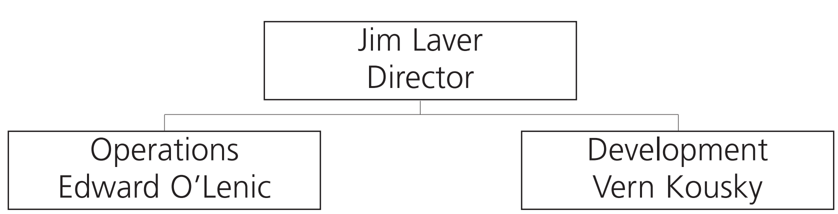
In 1994, the Analysis and Information Branch assumed responsibility for The African Desk as part of the National Centers for Environmental Prediction's (NCEP) international Desks. The African Desk supports U.S. international policy of building climate service capability in Africa, and NCEP international developmental programs of weather and seasonal climate forecasts and verifications.

The Diagnostics Branch conducted the bulk of the mission-directed research with the goal to diagnose climate variability to assist the prediction effort. Eugene Rasmusson was the first Diagnostic Branch chief, serving in that capacity from 1979 until his retirement from federal service in 1986. Phillip Arkin then directed the Branch until late 1989. Chester Ropelewski followed with the longest tenure to date from 1990 until 1997. In 1998 Vernon Kousky became Branch Chief and then Chief of the Development Branch after the 2003 reorganization.

The Prediction Branch was responsible for the seasonal temperature and precipitation outlook maps (30- and 90-days). In 1982, a major change was instituted when probability contours for the defined classes were added to the maps. In 1987 the Branch assumed responsibility for the medium-range (6–10 day) forecasts. Donald Gilman (1979–1989) was the first branch chief followed by Huug van den Dool (1990–1999). In 1999, Ed O'Lenic became Branch Chief and then Chief of the Operations Branch after the 2003 reorganization.

The original Branch structure remained intact until 2003. In recent years the prediction function had become increasingly emphasized. Management deemed the existing organizational structure out-of-date. The primary tasks are to develop the capabilities to predict climate and to deliver those predictions to the public and other users of climate information. The current configuration of a Development Branch and Operations Branch achieves those objectives. Generally, members of the former Diagnostics Branch and parts of the Analysis and Information Branch reside in the current Development Branch, while the other parts of Analysis and Information and Prediction Branches form the Operations Branch.

Climate Prediction Center (2004)



Analysis, Information, Data and Product Dissemination:

Reflections of Jim Laver, David Rodenhuis, Alvin Miller, Douglas LeComte, and Wassila Thiaw

The Analysis and Information Branch (AIB) consisted of four diverse components. The contingent at the U.S. Department of Agriculture Joint Agricultural Weather Facility (JAWF) (Haddock, Denny, Byrd, and later Flood, Llanso, McInturff, Williams, Bjerknes, LeComte, Stefanski, Morris, Rippey, Pugh, Luebehusen, Miskus, Savadel, and Wallace) worked to improve and issue climate outlooks to the agricultural community. The Information Monitoring Group focused on databases, quality control, and product dissemination (e.g., A. Thomas, Tinker, Patterson, Heddinghaus, Fulwood, Fleming, Miskus, Sabol, Harrison, Churchill, Bjerknes, Dionne, later Bergman, Logan, and others). The Stratospheric Group (Miller, Nagatani, Gelman, Long, Bowman, McInturff, Johnson, Kann, McCalla, Thomas, and others) focused on analysis of stratospheric conditions. In 1994, the Branch added the African Desk under Wassila Thiaw with activities centered on development of climate outlook products, operations, and training for African meteorologists. Another public-information program was the Regional Climate Centers (RCCs) with a budget of $2 to $3 million overseen by the Director and administered by Bob Bermowitz and Jim Laver from 1992–1997.

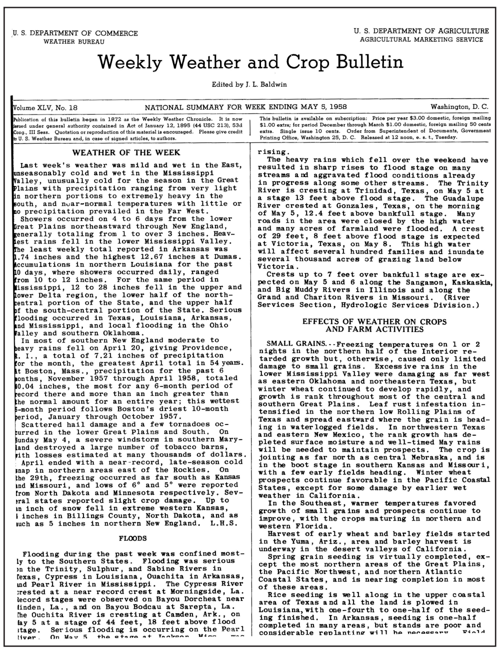
Two Defining Events

Sometimes the smallest events loom large in organizational development—a conference that asked users what products they could use, a drought that forced internal communications, and the acquisition of the Department of Commerce's first color copier.

The "Climate Analysis Center User Conference" (May 14–21, 1981) in Gettysburg, Pennsylvania, established the types of products that CAC should be producing. Fred Finger and Tom Heddinghaus were the organizers. The conference focused on energy, food and fiber, water resources, and climate research. Many users wanted real-time climate information, delivered electronically, and research to improve the accuracy. The summary of that workshop was completed by July 1981, and it became the Analysis and Information Branch's reference. A product to emerge from this conference was the Climate Dial-Up Service (CDUS), which pre-dated bulletin board systems, and was developed at 1200 baud, and later 9600 baud modems. CAC was ahead of its time as staff puzzled over sending graphic products in color, before high-speed communication, the Internet, and web "standards" made these concepts routine and fast.

The 1988 drought led to a closer working relationship between the Analysis and Information and the Prediction Branches. Staff learned the meaning of good, accurate, and concise writing as CAC issued the Drought Advisory series. As this was before the widespread use of email, National Weather Service Director Elbert W. (Joe) Friday even visited the World Weather Building once to personally pick up some Drought Advisories.

A small but momentous event was the acquisition of a color copier to meet the demand for drought maps. At that time color products were extremely rare. The demand for color maps from headquarters, however, meant that CAC had to send the maps out to a nearby copying center. The Department of Commerce (DOC) provided the funds (approximately $60,000). Dave Rodenhuis provided the stimulus for CAC to acquire the first color copier in the Department. The copier sat outside Laver's office and was password-protected so its use could be monitored.



U. S. DEPARTMENT OF COMMERCE
WEATHER BUREAU

U. S. DEPARTMENT OF AGRICULTURE
AGRICULTURAL MARKETING SERVICE

Weekly Weather and Crop Bulletin

Edited by J. L. Baldwin

Volume XLV, No. 18 — NATIONAL SUMMARY FOR WEEK ENDING MAY 5, 1958 — Washington, D. C.

Publication of this bulletin began in 1872 as the Weekly Weather Chronicle. It is now issued under general authority contained in Act of January 12, 1895 (44 USC 213), 53d Cong., III Sess. Quotation or reproduction of this material is encouraged. Please give credit to U. S. Weather Bureau and, in case of signed articles, to authors.

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WEATHER OF THE WEEK

Last week's weather was mild and wet in the East, unseasonably cold and wet in the Mississippi Valley, unusually cold for the season in the Great Plains with precipitation ranging from very light in northern portions to extremely heavy in the south, and near-normal temperatures with little or no precipitation prevailed in the Far West.

Showers occurred on 4 to 6 days from the lower Great Plains northeastward through New England, generally totaling from 1 to over 3 inches. Heaviest rains fell in the lower Mississippi Valley. The least weekly total reported in Arkansas was 1.74 inches and the highest 12.67 inches at Dumas. Accumulations in northern Louisiana for the past 10 days, where showers occurred daily, ranged from 10 to 12 inches. For the same period in Mississippi, 12 to 28 inches fell in the upper and lower Delta region, the lower half of the north-central portion of the State, and the upper half of the south-central portion of the State. Serious flooding occurred in Texas, Louisiana, Arkansas, and Mississippi, and local flooding in the Ohio Valley and southern Oklahoma.

In most of southern New England moderate to heavy rains fell on April 20, giving Providence, R. I., a total of 7.21 inches of precipitation for the month, the greatest April total in 54 years. At Boston, Mass., precipitation for the past 6 months, November 1957 through April 1958, totaled 40.04 inches, the most for any 6-month period of record there and more than an inch greater than the normal amount for an entire year; this wettest 6-month period follows Boston's driest 10-month period, January through October 1957.

Scattered hail damage and a few tornadoes occurred in the lower Great Plains and South. On Sunday May 4, a severe windstorm in southern Maryland destroyed a large number of tobacco barns, with losses estimated at many thousands of dollars.

April ended with a near-record, late-season cold snap in northern areas east of the Rockies. On the 29th, freezing occurred as far south as Kansas and Missouri, and lows of 6° and 5° were reported from North Dakota and Minnesota respectively. Several states reported slight crop damage. Up to an inch of snow fell in extreme western Kansas, 4 inches in Billings County, North Dakota, and as much as 5 inches in northern New England. L.H.S.

FLOODS

Flooding during the past week was confined mostly to the Southern States. Flooding was serious on the Trinity, Sulphur, and Sabine Rivers in Texas, Cypress in Louisiana, Ouachita in Arkansas, and Pearl River in Mississippi. The Cypress River crested at a near record crest at Morningside, La. Record stages were observed on Bayou Dorcheat near Minden, La., and on Bayou Bodcau at Sarepta, La. The Ouchita River is cresting at Camden, Ark., on May 5 at a stage of 44 feet, 18 feet above flood stage. Serious flooding is occurring on the Pearl River. On May 5, the stage at Jackson, Miss., was rising.

The heavy rains which fell over the weekend have resulted in sharp rises to flood stage on many streams and aggravated flood conditions already in progress along some other streams. The Trinity River is cresting at Trinidad, Texas, on May 5 at a stage 13 feet above flood stage. The Guadalupe River crested at Gonzales, Texas, on the morning of May 5, 12.4 feet above bankfull stage. Many roads in the area were closed by the high water and many acres of farmland were flooded. A crest of 29 feet, 8 feet above flood stage is expected at Victoria, Texas, on May 8. This high water will affect several hundred families and inundate several thousand acres of grazing land below Victoria.

Crests up to 7 feet over bankfull stage are expected on May 5 and 6 along the Sangamon, Kaskaskia, and Big Muddy Rivers in Illinois and along the Grand and Chariton Rivers in Missouri. (River Services Section, Hydrologic Services Division.)

EFFECTS OF WEATHER ON CROPS AND FARM ACTIVITIES

SMALL GRAINS.--Freezing temperatures on 1 or 2 nights in the northern half of the Interior retarded growth but, otherwise, caused only limited damage to small grains. Excessive rains in the lower Mississippi Valley were damaging as far west as eastern Oklahoma and northeastern Texas, but winter wheat continued to develop rapidly, and growth is rank throughout most of the central and southern Great Plains. Leaf rust infestation intensified in the northern low Rolling Plains of Texas and spread eastward where the grain is heading in waterlogged fields. In northwestern Texas and eastern New Mexico, the rank growth has depleted surface moisture and well-timed May rains will be needed to maintain prospects. The crop is jointing as far north as central Nebraska, and is in the boot stage in southern Kansas and Missouri, with a few early fields heading. Winter wheat prospects continue favorable in the Pacific Coastal States, except for some damage by earlier wet weather in California.

In the Southeast, warmer temperatures favored growth of small grains and prospects continue to improve, with the crops maturing in northern and western Florida.

Harvest of early wheat and barley fields started in the Yuma, Ariz., area and barley harvest is underway in the desert valleys of California.

Spring grain seeding is virtually completed, except the most northern areas of the Great Plains, the Pacific Northwest, and northern Atlantic Coastal States, and is nearing completion in most of these areas.

Rice seeding is well along in the upper coastal area of Texas and all the land is plowed in Louisiana, with one-fourth to one-half of the seeding finished. In Arkansas, seeding is one-half completed in many areas, but stands are poor and considerable replanting will be necessary. Field

Figure 3. The U.S. Weather Bureau and USDA issued their first joint *Weekly Weather and Crop Bulletin* on July 1, 1940. (This is a later issue.)

Joint Agricultural Weather Facility (JAWF)

The United States Department of Agriculture (USDA) and National Weather Service (NWS) established the Joint Agricultural Weather Facility (JAWF) in 1978. Since its formation, it has been located in USDA's headquarters in Washington DC. JAWF is a cooperative effort between CPC and USDA's World Agricultural Board and the National Agricultural Statistics Service.

The NWS staff of four meteorologists consisted of a section chief and meteorologists with expertise in crop weather, global synoptic weather analysis, and satellite image interpretation. They also excelled in oral presentations providing daily and weekly weather briefings, and they needed skill and patience in map-making, since a vast quantity of charts were prepared for briefings and the *Weekly Weather and Crop Bulletin* (WWCB). The NWS personnel at JAWF provided the information and data that the USDA agricultural meteorologists at JAWF required to evaluate potential crop responses to the weather.

Often the first two days of the week involved preparation of the WWCB. The U.S. Army's Signal Service first published this bulletin in 1872 as the *Weekly Weather Chronicle.* The title was later changed to its current name, and its scope expanded (Figure 3).

During the 1990s, the WWCB was posted on the Internet, and the number of subscribers to the printed copy steadily decreased. The printed format also underwent significant changes as the section chief, Douglas Le Comte (who worked at JAWF from 1988 to 1998), modernized the venerable publication.

JAWF meteorologists participated in the development of the *U.S.*

Drought Monitor (USDM). CPC's Doug Le Comte produced the first experimental seasonal drought outlook map in 1999 (Figure 4, page 35). CPC's JAWFer (David Miskus) and USDA JAWFer (Brad Rippey) took part in producing the USDM. JAWF also participated in the production of the more recent *U.S. Drought Monitor* that assesses current drought conditions.

Information Monitoring

The Famine Early Warning System Network and Climate Assessment Database are examples of CPC's information-monitoring efforts. In 1985, major famine in Ethiopia led the United States Agency for International Development (USAID) to establish the Famine Early Warning System (now officially known as the Famine Early Warning System Network, or FEWS NET). While the original focus was Africa, USAID broadened the scope after September 11, 2001, to encompass Afghanistan, Central America, and the Caribbean. The FEWS NET goal is to lower the incidence of drought- or flood-induced famine by providing to decision makers timely and accurate information regarding potential food scarcity. With early warning, countries and agencies can take appropriate mitigation measures.

CPC works closely with USAID, the National Aeronautics and Space Administration (NASA), the U.S. Geological Survey (USGS), and Chemonics International to provide the data, information, and analyses needed for FEWS-NET. The CPC issues a weekly weather-hazards assessment that gives an overview of conditions that may affect food security (such as drought, flooding, cyclones or extreme temperatures). This assessment is distributed to decision makers, field representatives, and other users via e-mail and the Internet. CPC will also develop products, reports and briefings when conditions warrant, such as in the event of an imminent tropical cyclone.

CPC's Climate Assessment Database (CADB) is one of the primary data sources for short-term climate monitoring. The database consists of daily global summary parameters (emphasizing precipitation and temperature) using observations for approximately 8000 stations and is used by CPC in forecast verification, climate-related product generation, publication and Internet dissemination. This database dates to 1982 when CAC staff convened to discuss enhancement of existing services. Led by senior programmer Vernon Patterson, development began on the current database known then as the 366-Day files, to include more stations, more parameters, and a new file format. George Fulwood joined Vern Patterson and David Miskus to work on the database.

Quality control of the database evolved from manual efforts by Bob Churchill to automate software checks. Vern Patterson and Arthur Thomas modified precipitation estimation procedures in 1983 (originally developed by the Air Force Global Weather Center in 1981) to improve CAC's precipitation summary quality.

One of the major highlights of the CADB activity was the Climate Dialup Service (CDUS) initiated by Fred Finger. The CDUS was a microcomputer request and reply system which allowed access to products via modem and personal computer. Originally a "free" service, a fee structure was developed by Joanna Dionne to recoup some of the costs of system maintenance. Under David Rodenhuis, the CDUS was phased out as more products were disseminated via the Internet.

Stratosphere

Approximately 40 years ago, Sid Teweles undertook a Special Project within the National Weather Service to analyze conditions in the stratosphere. This project grew out of the efforts of the International Geophysical Year (IGY, 1957–1958) and the International Quiet Sun Year (IQSY, 1964–1965) to expand ground-based observations of the atmosphere. This was the first attempt to examine synoptic features of the stratospheric circulation from 100 hPa up to 0.4 hPa on a routine basis.

Over the years, the responsibility for this effort was assigned to the UAB of NMC led by Fred Finger (later transferred to CAC). UAB contributed to many developmental programs including:

- Space shuttle reentry trajectory information for NASA,
- Radiosonde corrections/adjustments,
- International radiosonde comparisons conducted under the World Meteorological Organization (WMO),
- First global upper stratospheric analyses derived from ground-based and satellite data (1978),
- Stratospheric warming bulletins,
- Ozone and temperature trend information for international and national assessments of ozone depletion and climate change, and
- Radiosonde/rocketsonde/satellite lidar comparisons.

African Desk

The Center's African Desk was established in 1994 to support climate service capacity building in Africa. Under a 1994 agreement with the African Centre of Meteorological Applications for Development (ADMAD) and the Drought Monitoring Centres in Nairobi and Harare, the Desk produced its first wind, Sea Surface Temperatures (SST), Outgoing Long wave Radiation (OLR), precipitation, and temperature maps. These products were faxed monthly to users.

At the request of the World Bank, the African Desk issued its first subjective seasonal rainfall forecast for Zimbabwe on July 13, 1995. By June 1996, The African Desk issued its first objective forecast based on canonical correlation analysis (CCA) for the July to September 1996 Sahel rainfall.

Today, the African Desk prepares and distributes via Internet and the worldwide web probabilistic seasonal rainfall forecasts for sub-Saharan Africa and regional and global model data. It provides FEWS NET with an overview of African weather and climate conditions that may have an effect on food security (such as drought, flooding, cyclones or extreme temperatures).

Another service the African Desk provides is to host visiting meteorologists from African countries for the purpose of training, information exchange, and building climate service capability (Figure 5). Ten of the former African Desk visitors are now in leadership positions in their respective countries.

Figure 5. To date, CPC has hosted 43 meterologists from 28 countries in Africa.

Wassila Thiaw, who oversees the African Desk, and Vadlamani Kumar, who provides computer-programming support, have been the permanent staff since its establishment. In March 1995, a visiting scientists program provided additional support.

Regional Climate Centers

The 1978 authorization for the National Climate Program included the recommendation to establish two special programs: the Experimental Climate Forecast Centers, and the Regional Climate Centers (RCC). The RCC program was an effort to recapture a national program in climatology that would include the participation of all of the states. It was developed to meet local and regional needs for a broad range of climate products and their interpretation. The Centers would maintain expertise in climate, monitoring current climate conditions in their area, and providing convenient and timely access to accurate and reliable climate information. CPC had oversight of the RCC program between 1992 and 1997, serving as a natural bridge to regional climate issues. This association was viewed by many as a natural synergism: CPC would benefit because of its heightened awareness of local and regional climate issues, and the RCCs would gain an increased understanding of the national program in climate services.

The concept for the RCCs was based on some of the ideas originally articulated by Helmut E. Landsberg, who was Director of the Office of Climatology, U.S. Weather Bureau in the 1950s and 1960s. Landsberg was convinced of the value and utility of analyses obtained from the climatic record, and he worked slowly and systematically to build a network of State Climatology offices. However, by 1973, competing demands for resources led NOAA to transfer the responsibility for funding and managing the offices to the individual states. Many states did not have the resources to sustain the offices.

The passage of the National Climate Program Act in 1978 gave renewed hope for a comprehensive program in climate services at the regional level. Stan Changnon from the Illinois State Water Survey was one of the most effective and energetic leaders who understood, both as a geographer and climatologist, the value of commercial applications of historical climate data. NOAA's National Climate Program Office had the lead responsibility for this Federal program. Ed Epstein, the first National Climate Program Director, followed by Alan Hecht, tried to raise the consciousness for climate issues at the federal level.

The potential for federal support and national recognition that utilized a concept of "regions" was not met with unanimous support. However, Stan Changnon was able to articulate a vision to a new generation of climatologists. With support from a number of the State Climatologists, Alan Hecht and Norm Canfield at NOAA worked to create a viable national program, eventually establishing six Regional Climate Centers (Figure 6, page 35).

The RCCs were established one-by-one as federal funding became available. Then in 1992, with shifting national priorities in climate research and services, the responsibility for the RCC program was transferred from the National Climate Program Office to CAC. Bob Bermowitz became the Program Manager, and he worked diligently to build the national program.

The patience of Bob Bermowitz, the energetic leadership of Stan Changnon, and the steady successes of the six centers kept the program on track despite the challenges surrounding the mix of state/regional and federal/private rights and responsibilities, and the competing demands of climate and modernization. In 1997 NOAA transferred oversight of the RCCs to the National Climatic Data Center (NCDC).

The RCCs continue to be valuable and important partners of CPC. The difficulties of the past have been largely overcome in recent years as the rapidly expanding demand for climate services across the nation has challenged all providers to stay abreast of new developments.

Monitoring and Diagnostics:

Reflections of Eugene Rasmusson, Chester Ropelewski, Phillip Arkin, and Vernon Kousky

The overarching goal of the Diagnostics Branch was the development and implementation of an operational program for the real-time dissemination of comprehensive diagnostic information focused on seasonal to interannual climate variability. For this to happen, it was necessary to develop an extensive suite of climate diagnostic databases to support a broad program of climate monitoring and mission-oriented diagnostic research. A notable element of this effort was the wider application of geosynchronous and polar orbiter satellite data, as well as surface marine observations.

Activities during 1979–1989

Beginning with very limited diagnostic capabilities, the Diagnostics Branch staff developed and implemented, over a period of a few years, a comprehensive real-time diagnostics capability. In addition, they published a large number of refereed papers on various aspects of interannual climate variability, and made major contributions to several national and international climate programs.

The initial Diagnostics Branch staff consisted of individuals who transferred from The Environmental Data and Information Service (EDIS), National Environmental Satellite Service (NESS), the Environmental Research Laboratory (ERL), and other elements of NWS. They included Eugene Rasmusson (Chief), Phillip Arkin and Wilbur Chen (EDIS), Arthur Krueger and Carl Ericson (NESS), Thomas Carpenter (ERL), and Philip Clapp, John Kopman, and Roderick Quiroz (NWS). During the period 1979–1986 Clapp, Ericson, Krueger, and Quiroz retired, while Chen moved to the Prediction Branch. Five new members, John Janowiak, Richard Reynolds, Chester Ropelewski, Michael Halpert, and Vern Kousky, joined the staff between 1980 and 1984. Between 1986 and 1989, the branch added Kingtse Mo, Anne Seigel (Kinter), Diane Davidowicz, Diane Marsico (Stokes) and Ed O'Lenic (who transferred to Prediction Branch in 1987).

DEVELOPMENT OF CLIMATE MONITORING TOOLS

The development of diagnostic capability required a strong, mission-oriented research program. This included the development of a better description and understanding of the dominant modes of interannual climate variability, and the development of indices for characterizing the state of the climate system; and in particular, the state of the major modes of variability.

The diagnostic databases that were available when CAC was established were mostly oriented toward the tropics. This was also true of the ongoing research of several staff members. These factors contributed to an early focus on interannual variability in the tropics and in the equatorial Pacific in particular. This turned out to be fortuitous, for it resulted in the Diagnostics Branch being uniquely prepared to assume the lead in the global dissemination of real-time diagnostic information during the evolution of the unusually intense 1982–1983 ENSO warm episode.

Initially, Phillip Arkin continued work on two projects that he had initiated while at EDIS: (1) the analysis of the "tropical strip" winds and Outgoing Long wave Radiation (OLR) data sets that had been produced by Jay Winston's NESS group, and (2) an investigation of the relationship between the Atlantic Tropical Experiment (GAPP) radar rainfall data and GOES satellite statistics. These projects resulted in two publications and Arkin's doctoral dissertation. They partially inspired two follow-on projects that were of major importance to the development of an operational diagnostic capability.

In light of the implementation of global optimum interpolation at NMC, Arkin, working with John Janowiak, who arrived in 1981, undertook the expansion of the tropical strip analyses to a global "Climate Diagnostics Data Base (CDDB)." The CDDB included half-monthly statistics (means, variances, covariances) of the basic state variables (winds, temperature, geopotential height and moisture), computed from the NMC Global Data Assimilation System (GDAS) analyzed fields at all mandatory levels. Monthly history tapes covering the entire period since the Optimum Interpolation (OI) became operational (1979), were provided by Roy Jenne (NCAR), after which real-time updating began in 1981. The CDDB statistics allowed the computation of half-monthly values of mean and eddy transport terms, and provided CAC and the climate community with a real-time half-monthly "snapshot" of the state of the global atmosphere from the surface to 50 MB. It also allowed the NMC Development Division to see, for the first time, the operational analysis monthly statistics in near real time.

The CDDB became operational just prior to the 1982–1983 El Niño, and the monthly and seasonal mean maps, which it contained became the backbone of the atmospheric part of the *Climate Diagnostics Bulletin* that was initiated during this event. The CDDB remained the prime atmospheric database for diagnostic monitoring and diagnostic studies until the mid-1990s when the CDAS/Reanalysis data became available. In many ways, the CDDB concept was a model for CDAS/Reanalysis.

Concurrent with the development of the CDDB, Arkin, working with Janowiak, designed and implemented an archive and climatology of OLR from the NOAA polar orbiting satellites. The OLR data set spans one of the longest periods of record of any archive of remotely sensed data and continues to be widely used. It is indispensable for real-time monitoring of tropical convection and for characterizing anomalies in tropical precipitation.

Arkin's study of the relationship between GATE radar rainfall amounts and GOES satellite statistics resulted in the development of a simple but effective index of tropical convective precipitation that he initially called the GOES Precipitation Index (GPI). The success of this effort led to the establishment of a project to collect GOES infrared histograms. The procedure was operationally implemented in late 1982, and was a crucial element in the near real-time diagnosis of the evolution of tropical rainfall anomalies associated with the 1982–1983 warm episode. Subsequently, this project came to the attention of Pierre Morel and the Tropical Ocean-Global Atmosphere (TOGA) Scientific Steering Group (SSG). They held a workshop on satellite precipitation to determine ways of producing and distributing these estimates on a regular basis. Eventually, this effort grew into an important part of the WCRP Global Precipitation Climatology Project (GPCP), with Arkin as its first Project Manager.

After joining the Diagnostics Branch in 1981, Chester Ropelewski developed a polar ice cover database. Working with Janowiak, he then undertook the development of the important Climate Anomaly Monitoring System (CAMS).

CAMS is a station-oriented data set of monthly mean land surface temperature and precipitation. It is used to monitor anomalies in land surface temperature and precipitation worldwide. It was assembled from historical archives that were obtained from NCAR and is routinely updated on a monthly basis from GTS reports. Because precipitation amounts do not adhere to a Gaussian distribution, gamma distribution parameters are computed and stored as part of the CAMS database in order to characterize precipitation anomalies properly. CAC initiated CAMS in 1985, and it is still used operationally.

In addition to research activities directly related to the development of the diagnostic data bases previously discussed, Diagnostics Branch staff members made a number of significant contributions during this period to the description and understanding of interannual climate variability. In an influential study of the ENSO cycle, Rasmusson and Carpenter described the evolution of what became known as the "canonical warm episode." An unsung participant in this effort was Rob Quayle (NCDC), who provided, for the first time, a consolidated surface marine data set for the tropical Pacific that made the study possible. In a related study, Arkin described the typical patterns of 200 MB circulation anomalies associated with the warm and cold phases of the ENSO cycle.

From an Empirical Orthogonal Function (EOF) analysis, Krueger and Tom Heddinghaus (Analysis and Information Branch) identified a pronounced ENSO signal in the OLR data, thus demonstrating the importance of these data for monitoring ENSO cycle precipitation anomalies. Chen analyzed the usefulness of a number of commonly used two-station Southern-Oscillation Index (SOI) surface pressure indices. He demonstrated the superiority of the Tahiti minus Darwin Index, which became the standard SOI index for CAC (Figure 7, page 36).

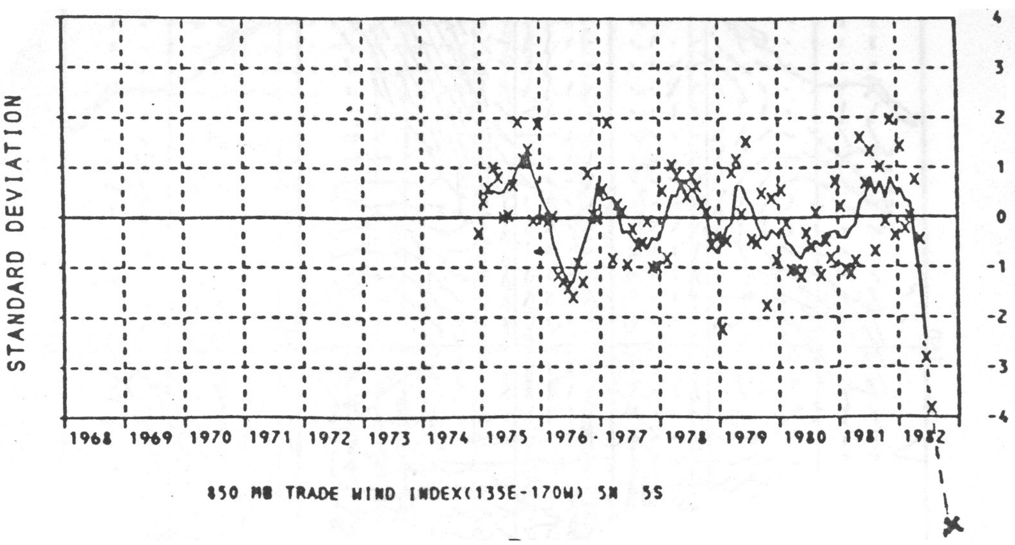
Quiroz arrived at CAC with a long and distinguished record of studies of the circulation of the troposphere and stratosphere. He continued this work during the early years of CAC with two papers on the contribution of the long waves to troposphere and stratosphere winter temperature anomalies.

THE 1982–1983 MAJOR ENSO WARM EPISODE

During the major 1982–1983 ENSO warm episode, national and international media viewed CAC as an authoritative source of information. This major climate event served as a catalyst for the development of a number of climate diagnostic products, which became CAC's standard output.

James Rasmussen, CAC Director, had for some time been interested in initiating a regular diagnostics publication suitable for widespread distribution. *The Climate Diagnostics Bulletin* (CDB) grew out of a number of special Diagnostics Branch publications during the early stages of the 1982–1983 warm episode. This included articles for the *Tropical Ocean-Atmosphere Newsletter* (TOAN), a publication associated with the NOAA Equatorial Pacific Ocean

Figure 8
One of the anomaly patterns indicating the 1982 El Niño was the trade wind index, which showed a dramatic departure from normal. From the first CDB (September 1982).



Climate Studies (EPOCS) program. Arkin also published a "quick-look atlas" of analysis products, based on the CDDB that provided a useful perspective on the evolution of the warm episode.

The oceanographic and meteorological communities were uncertain as to what was occurring in the equatorial Pacific during the summer of 1982. Consequently, this seemed to be an appropriate time for CAC to publish a statement describing the evolving anomaly patterns. The first "bulletin" of what evolved into the CDB, entitled *The Global Climate Fluctuation of June–August, 1982,* was published and distributed in early September 1982 (Figure 8). The discussion of conditions hedged as to whether this was the beginning of a major swing in the Southern Oscillation, or simply a strong, short-period fluctuation. However, by November 10, when the second bulletin, entitled *A Major Warm Episode in the Eastern Equatorial Pacific* was published, CAC had no doubt as to what was occurring. Additional bulletins, published in February, April, and July 1983, documented the entire evolution of the event.

The 1982–1983 warm episode led to the initiation of a comprehensive suite of diagnostic products for monitoring the ENSO cycle. This included a variety of anomaly maps and indices. Among the new indices were the NINO 1, 2, 3, and 4 indices of SST for various sections of the equatorial Pacific (Figure 9, opposite).

LESSONS LEARNED FROM THE 1982–1983 ENSO EVENT

Notable achievements during the post 1982–1983 warm episode period included the expansion of the scope of the CDB and the development and implementation of a "blended" sea surface temperature analysis scheme, which incorporated information from both surface marine observations and satellite retrievals.

Arkin, ably assisted by John Kopman, was largely responsible for the assembly of the monthly CDB prior to 1984. In many ways Kopman is the unsung participant in this and many other projects during the early years of the Diagnostics Branch. He was able to perform a great variety of important tasks skillfully and efficiently. In August 1984, Vernon Kousky arrived and soon assumed the task of editing of the CDB. Under his perceptive guidance the CDB evolved from its singular focus on the Tropical Pacific to include a global analysis of the state of the ocean-atmosphere climate system. In January 1986 CAC issued the first *ENSO Diagnostic Advisory* (Figure 10). Over the years the ENSO Advisories have evolved into a regular monthly ENSO Diagnostic Discussion in the CDB, which assesses the current state of the ENSO cycle and presents an outlook for upcoming months.

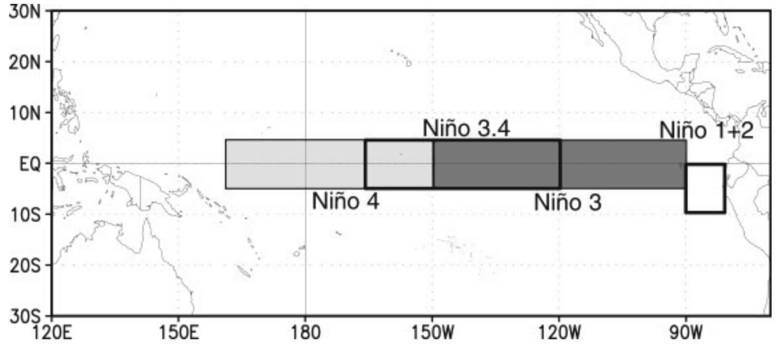
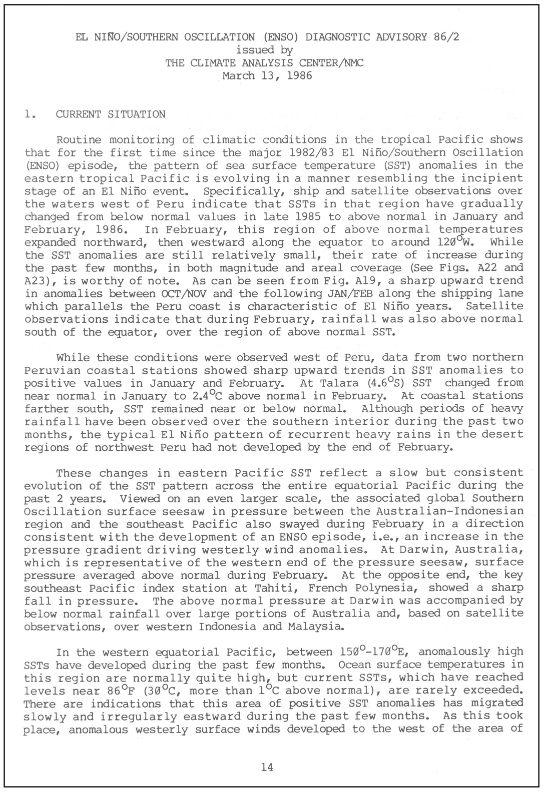


Figure 9
The Niño 3.4 index for the crucial central equatorial Pacific has become a universal index of ENSO SST variability.

Work on an improved SST analysis system began shortly after the arrival of Richard Reynolds in June 1980. The need for an improved SST analysis system became painfully evident during the early stages of the 1982–1983 warm episode. Serious problems arose in the NMC operational analysis, which was based on SST in situ observations. Unusually high SST values were being rejected because they were too far from the initial guess field. The NESS analysis, based on satellite retrievals, also had major problems. Because of contamination by aerosols from the El Chichon eruption, the tropical retrievals were biased toward colder than expected values of SST. These retrievals were interpreted as clouds and rejected. Over areas that contained missing data, climatological values were inserted for the analysis.

Aware of these problems, Reynolds constructed in situ (ship observations only) monthly mean SST analyses that showed strong warming along the equator. The



EL NIÑO/SOUTHERN OSCILLATION (ENSO) DIAGNOSTIC ADVISORY 86/2
issued by
THE CLIMATE ANALYSIS CENTER/NMC
March 13, 1986

1. CURRENT SITUATION

Routine monitoring of climatic conditions in the tropical Pacific shows that for the first time since the major 1982/83 El Niño/Southern Oscillation (ENSO) episode, the pattern of sea surface temperature (SST) anomalies in the eastern tropical Pacific is evolving in a manner resembling the incipient stage of an El Niño event. Specifically, ship and satellite observations over the waters west of Peru indicate that SSTs in that region have gradually changed from below normal values in late 1985 to above normal in January and February, 1986. In February, this region of above normal temperatures expanded northward, then westward along the equator to around 120°W. While the SST anomalies are still relatively small, their rate of increase during the past few months, in both magnitude and areal coverage (See Figs. A22 and A23), is worthy of note. As can be seen from Fig. A19, a sharp upward trend in anomalies between OCT/NOV and the following JAN/FEB along the shipping lane which parallels the Peru coast is characteristic of El Niño years. Satellite observations indicate that during February, rainfall was also above normal south of the equator, over the region of above normal SST.

While these conditions were observed west of Peru, data from two northern Peruvian coastal stations showed sharp upward trends in SST anomalies to positive values in January and February. At Talara (4.6°S) SST changed from near normal in January to 2.4°C above normal in February. At coastal stations farther south, SST remained near or below normal. Although periods of heavy rainfall have been observed over the southern interior during the past two months, the typical El Niño pattern of recurrent heavy rains in the desert regions of northwest Peru had not developed by the end of February.

These changes in eastern Pacific SST reflect a slow but consistent evolution of the SST pattern across the entire equatorial Pacific during the past 2 years. Viewed on an even larger scale, the associated global Southern Oscillation surface seesaw in pressure between the Australian-Indonesian region and the southeast Pacific also swayed during February in a direction consistent with the development of an ENSO episode, i.e., an increase in the pressure gradient driving westerly wind anomalies. At Darwin, Australia, which is representative of the western end of the pressure seesaw, surface pressure averaged above normal during February. At the opposite end, the key southeast Pacific index station at Tahiti, French Polynesia, showed a sharp fall in pressure. The above normal pressure at Darwin was accompanied by below normal rainfall over large portions of Australia and, based on satellite observations, over western Indonesia and Malaysia.

In the western equatorial Pacific, between 150°-170°E, anomalously high SSTs have developed during the past few months. Ocean surface temperatures in this region are normally quite high, but current SSTs, which have reached levels near 86°F (30°C, more than 1°C above normal), are rarely exceeded. There are indications that this area of positive SST anomalies has migrated slowly and irregularly eastward during the past few months. As this took place, anomalous westerly surface winds developed to the west of the area of

14

Figure 10
The first *ENSO Diagnostic Advisory* (1986) assessed the ENSO cycle and an emerging warm episode.

dissemination of these analyses began in November 1982. He also initiated monthly satellite-only analyses. A unique aspect of both analysis schemes was the use of a powerful non-linear filtering method developed by John Tukey, the famous statistician from Princeton University, to identify and reject isolated outlier observations.

In early 1983, Reynolds began his seminal work on combining the information from in situ and satellite analyses into a "blended" SST data set. The goal was to have the system operational in time for the beginning of TOGA in January 1985. Although he missed this objective by a few months, the blended analysis approach became the standard of comparison for new SST analysis products. The paper describing the method was completed in 1987 while Reynolds was at the UK Meteorological Office.

The 1984–1986 period marked a period during which Diagnostic Branch staff members conducted and published a large number of post-mortem studies of the 1982–1983 warm episode, and continued describing and diagnosing ENSO impacts in a global context. Quiroz turned his attention to ENSO-related atmospheric circulation features. During 1983–1986 he published several papers describing various aspects of the response of the global atmospheric circulation to the ENSO cycle.

During this period Ropelewski and Mike Halpert, who became a staff member in late 1984 after working part time as a student, began their study of teleconnections. Their studies described the typical worldwide land surface precipitation and temperature anomalies associated with the warm and cold phases of the ENSO cycle (Figure 11, page 36). This paper subsequently received the Mumm Award of the WMO and continues to be widely cited.

NATIONAL AND INTERNATIONAL PROGRAM PARTICIPATION

In the late 1970s, NOAA established the Equatorial Pacific Ocean Climate Studies (EPOCS) program. Krueger and Rasmusson were major NESS and EDIS participants, respectively, in planning of the program, and in the subsequent research activities, both before and after their move to CAC.

The first phase of the Global Atmospheric Research Program (GARP) ended in the early 1980s with the First GARP Global Experiment (FGGE). A second phase of GARP focusing on climate variability had been envisioned, which now became an initiative of the World Climate Research Program (WCRP). The first WCRP program element was the 10-year Tropical Ocean Global Atmosphere (TOGA) program, which began in 1985. The Rasmusson and Carpenter paper on the ENSO cycle played an important role in the decision of the WCRP Organizing Committee to focus the first WCRP initiative on ocean-atmosphere coupling in the deep tropics.

The term "ENSO" was invented by the organizing committee, not by Rasmusson and Carpenter, who referred to the phenomenon in their paper in the reverse order, i.e., Southern Oscillation—El Niño. Prior to the international decision to initiate TOGA, Rex Fleming, Director of U.S. FGGE, and Rasmusson obtained funding for a NOAA initiative ($800,000), which later became the first funds for the NOAA TOGA program. Rasmusson was also deeply involved in the international and national planning of TOGA. Upon the program's initiation in 1985, Diagnostics Branch staff members were broadly involved in TOGA research, as well as serving on TOGA panels and working groups.

Activities during 1990–1997

This was a period during which CAC matured and when Climate with the big "C" caught on as a hot topic to a broader community. There were a number of exciting developments in the climate community during those years, and the Diagnostics Branch was heavily involved. These included a major change in atmospheric monitoring by replacing the CDDB with analyses based on the NCEP/NCAR Reanalysis, the maturing of satellite precipitation estimates, a transition from centralized to distributed computing, a recognition of the ENSO's importance and the growing influence of CAC's Forecast Forum as the authoritative voice, the inclusion of ocean data products and model assimilation to the climate monitoring effort, and the growth in the number of research projects and contractors supported by outside funds.

During this eight-year period, the branch hired Alan Basist and Tom Smith (both later left CAC for the National Climatic Data Center), Don Garrett, Muthuvel Chelliah, Wayne Higgins, and Gerald Bell, while Diane Davidowicz, Anne Seigel, Dick Reynolds, and Diane Marsico moved on to other work.

INFRASTRUCTURE MODERNIZATION

It was primarily during this period that the transition was made away from a central processing "mainframe" environment in which scientists and programmers shared interactive terminals to a distributed processing mode using individual personal computers and UNIX-based workstations. While this transition was not unique to CAC's diagnostics group, the transition from mainframes to workstations resulted in dramatic changes in climate diagnostics and productivity. The availability of Reanalysis data combined with the computational power and graphical display capability of UNIX-based workstations allowed the production of analyses and computations that would have been unthinkable only a decade earlier.

The Reanalysis freed researchers from the artificial boundaries of monthly analyses, and the workstations provided the computer power. This was reflected in the quality and quantity of products in the *Climate Diagnostics Bulletin* and in the emerging web products. Regarding the latter, the web began to be used to provide products to users during this period. Many of CAC-generated graphics that appear in the black and white printed version of the *Climate Diagnostics Bulletin* began to be placed on web pages in colorized versions. The availability of the web and the utilization of it by Branch personnel revolutionized the way that CAC's products were disseminated to the global community.

REANALYSIS AND THE CLIMATE DATA ASSIMILATION SYSTEM (CDAS)

The development of the Climate Data Assimilation System (CDAS) and support of Reanalysis is perhaps the most significant advancement in climate monitoring capability at CAC during this period, and perhaps one of the most significant tools for climate science during the 20th century. Prior to the advent of CDAS/Reanalysis, the global atmospheric circulation was monitored using the CDDB, which contained monthly averages of quantities from the operational Global Data Assimilation System (GDAS). CDAS/Reanalysis was designed to support real-time weather prediction (Figure 12, page 37).

By the early 1990s, after a decade of GDAS-based data, it became clear that changes in the operational data assimilation system were confounding the ability to analyze climate variability. The CDAS/Reanalysis project at NMC (NCEP) was led by the Environmental Modeling Center (EMC) but with considerable participation from members of the Diagnostics Branch (Chelliah, Ebisuzaki, Higgins, Janowiak, Mo, and Ropelewski). The Diagnostics group established a constructive (albeit occasionally contentious) dialogue with EMC for quality control purposes and had a big influence on what output would be archived overall. The Diagnostics Group also designed the set of CDs with monthly mean Reanalysis data. These data replaced the old CDDB. A bonus from the Reanalysis Project was that CAC started to work more closely with EMC and was able to raise the profile of climate within NCEP.

IMPORTANCE OF ENSO AND CAC'S "FORECAST FORUM"

The pioneering ENSO work during the 1980s remained primarily in the research realm until late in the decade. By 1990, however, the Prediction Branch as well as the greater community realized the benefits from this research. Increasingly, the forecast community started to pay attention to ENSO and by the mid-1990s realized that most of its seasonal forecast skill was attributable to ENSO.

The relatively slow evolution of ENSO made it an ideal tool for seasonal climate prediction. However, the possibility of predicting ENSO itself, as had been demonstrated by Cane and Zebiak in1986, led some to speculate that perhaps such forecasts could be used to make seasonal climate forecasts farther out in time than just a single season. To that end, CAC invited scientists who were interested in exploring seasonal forecasting with multiple-season leads to submit their forecasts to CAC for inclusion in the monthly Climate Diagnostics Bulletin. This international coordination activity resulted in the "Forecast Forum" feature of the *Climate Diagnostics Bulletin* which began in June 1989 and continues today. The Forecast Forum has become the authoritative voice for NOAA's "official" ENSO forecast and is closely watched by the rest of the world.

SATELLITE PRECIPITATION MONITORING AND OCEAN DATA MODEL ASSIMILATION

While the station-data-based Climate Anomaly Monitoring System (CAMS) continued to form one of the backbones for real-time precipitation monitoring, satellite derived estimates began to assume a larger role. Until the late 1980s, OLR was the primary satellite-based proxy for rainfall. By the end of the period a number of additional estimation tools were developed by Pingping Xie (who began his career at CAC as a post doc then a contractor before becoming a federal employee) in collaboration with Phil Arkin and John Janowiak. Among these is CAC's Merged Analysis of Precipitation (CMAP) that was the first global precipitation data set in which rain gauge and satellite estimates of precipitation were merged and which offered global analyses available from 1979 at both pentad and monthly temporal resolution.

In addition, CAC asserted leadership as one of the primary developers of precipitation estimation products within the Global Precipitation Climatology Project (GPCP). Because both the CMAP and GPCP analyses require external inputs that are not typically available in real time, Xie and Janowiak developed the CAMS-OPI which has become the precipitation "analysis of choice" for real-time climate monitoring

The inclusion of ocean data products and model assimilations to climate monitoring began in the mid-1990s. The NCEP Ocean Data Assimilation System (ODAS) and the TOGA Tropical Atmosphere/Ocean (TAO) array provided a basis for the regular monitoring and diagnosis of the ocean substructure. As the TOGA array and the length of ODAS time series grew, the monitoring and analysis of the ocean sub-surface became standard diagnostics tools, and graphics of these analyses became regular CDB entries. These tools allowed interpretations of SST based on subsurface ocean behavior data. For example, new graphical products made it possible to track Kelvin wave activity and the associated impact on SST, thus providing information on whether changes in SST are short-lived [due to transient Madden–Julian Oscillation (MJO) activity] or whether the SST changes are likely to be maintained. The principle CAC scientists who worked on the subsurface ocean analysis were Tom Smith and Yan Xue.

MAJOR GROWTH IN EXTERNALLY FUNDED RESEARCH

The decade of the 1990s was a period of continued growth in the climate research community. This period also ushered in a culture change at CAC and NCEP with the hiring of an increasingly large and exceptionally talented scientific contract staff. This was necessitated by a succession of frozen federal budgets and the resulting inability to fill existing positions or create new federal ones, combined with the energy and continual formation of new ideas at CAC.

To fund this contract staff, numerous CAC scientists submitted proposals to non-NWS sources, primarily NOAA's Office of Global Programs and NASA, and were rewarded with the resources to hire and maintain this necessary and critical resource. An unanticipated but extremely welcome benefit of this change is the rich and powerful diversity (both gender and cultural) of scientific talent and expertise that has existed from its inception to the present day. The Diagnostics Branch participated in that growth through a number of OGP Programs. These include PACS (in its transition from EPOCS), GCIP, GPCP, CDEP and CDAS/Reanalysis. Participation in these projects resulted in further increases in the number of contractors working with CPC staff.

Activities during 1998–Present

The 21st century ushered in a transition from the "Diagnostics" to the "Development" Branch and with it a focus on improving climate monitoring products, forecast tools, improving knowledge of regional and global precipitation variations, and expanding CPC's support of an international hazards assessment. Continuing the trend begun in the 1990s, CPC's involvement in national research programs has continued to grow. The Development Branch participates in a number of OGP and NASA Programs, which include PACS, GCIP, GPCP, CLIVAR/VAMOS and Regional Reanalysis. These activities have led to an increase in the number of OGP and NASA proposals for which CPC scientists serve as the Principal Investigators. As a result, CPC contracted with approximately 20 scientists to work on various aspects of the funded research.

As of this writing, new federal employees included: Pingping Xie, Yan Xue, Song Yang, and Wanqui Wang. Departures included Tom Smith (moved to NCDC), John Kopman (retirement) and Arun Kumar (became Deputy Director of CPC). In addition, because of the reorganization, the entire Diagnostics Branch staff (except for Mike Halpert) was reassigned to the Development Branch as were: Jim Miller, Ron Nagatani, Mel Gelman, Craig Long, Rich Tinker (formerly with "Analysis and Information Branch"), Jae Schemm, Huug van den Dool, and Dave Unger (formerly with "Prediction Branch").

IMPROVED CLIMATE MONITORING PRODUCTS, NEW FORECASTS, AND FORECAST TOOLS

The reorganization of CPC coincided with an increased focus on prediction and the development of predictive tools. Several members of the Development Branch began participating in the forecast process to better understand the difficulties and problems involved in that process and to add a fresh perspective. As a result, several new objective tools were developed to assist the forecasts at all time periods (6–10 day, week 2, monthly and seasonal). One tool combines high-frequency ENSO-related impacts with low-frequency variability (trend) and is operationally available to CPC's forecasters in making seasonal outlooks. The consolidated Niño 3.4 forecasts are used to determine probabilities of El Niño, La Niña, or ENSO neutral conditions. The forecast tool is a blend of the trend and the ENSO composites, based on those probabilities.

Starting in August 1998, forecasts of anticipated tropical storm activity in the Atlantic and Caribbean basins were issued by CPC (Bell, Chelliah, and Mo) in coordination with the Hurricane Research Division and the Tropical Prediction Center of NOAA (Figure 13, page 40). These outlooks, issued in May and updated in August each year, predict overall activity as a function of tropical storm strength and duration. Similar forecasts for the eastern tropical Pacific began in an experimental mode during 2003 (Chelliah, Bell, and Mo) and became operational in May 2004.

A regional reanalysis was performed for the period 1979–2002, using the ETA model. This reanalysis effort (Mo, Chelliah, Higgins, Kousky, Schemm, Ebisuzaki—Operations Branch) is similar to the global reanalysis effort but is limited geographically to North America and the surrounding oceanic areas and has been done as a coordinated EMC/CPC activity. Eventually a regional data assimilation system (RDAS) will be run routinely by CPC in real time to update the data archive. It is anticipated that regional reanalysis (RR) will be used extensively in research studies dealing with the hydrological cycle and warm precipitation over the U.S. It will also be used in support of real-time monitoring activities during the summer North American Monsoon Experiment (NAME) field campaign.

Beginning in1996 Huug van den Dool and Jin Huang (and later Yun Fan) developed an extensive program in soil moisture monitoring and prediction. Currently CPC monitors calculated soil moisture over the United States as well as the global domain at various space and time resolutions. An historical data set in excess of 50 years is used to characterize the extremity of current anomalies. The physically based calculations also involve evaporation, runoff, radiation etc. This data is applied, mainly in summer, in the drought outlook and the official US monthly/seasonal outlooks.

IMPROVED KNOWLEDGE OF REGIONAL AND GLOBAL PRECIPITATION VARIATIONS

Improvements in global precipitation analyses featured a merged analysis of satellite estimates and station observations (CMAP), and the development of a new analysis technique (CMORPH) that provides high spatial (0.25 degree) and temporal (1/2 hourly) global analyses. CMORPH uses the rainfall estimates obtained from a variety of polar-orbiting satellite sensors (TRMM and passive microwave) and combines those estimates with infrared data from the geostationary satellites. CMORPH compares very well with observed precipitation (analyses based on station observations and radar estimates).

A substantial "data mining" effort has resulted in the development of daily objective analyses of precipitation (and temperature) in the U.S. using station data since 1948. These analyses were then combined with data from Mexico. In addition, real-time daily precipitation analyses were developed for South

America, also based on station data. Precipitation data obtained from first-order stations, COOP observations, hydro-networks, and agricultural networks serve as input to the analyses of consistent, high-quality daily precipitation data.

Wayne Higgins has coordinated the development of the relevant scientific and implementation plans of NAME. The main goal of NAME is to improve the prediction of warm-season precipitation over the U.S. Several years of scientific planning, assembling human resources, and securing funding have culminated in the conduct of the first phase of NAME in summer 2004. This intensive data-gathering phase will focus on the collection of rain-gauge data, radars, profilers, and radiosonde observations over several spatial domains or "tiers," with the most focused and intensive observations over areas of Mexico and the southwest U.S., regions strongly affected by the annual summer monsoon.

EXPANDING CPC'S SUPPORT OF AN INTERNATIONAL HAZARDS ASSESSMENT

The *ENSO Diagnostic Advisory* evolved into a regular monthly ENSO Diagnostic Discussion, which provides an update on the state of the ENSO cycle and a summary of the latest SST forecasts in the tropical Pacific. The Discussion is a stand-alone product that contains material similar to that appearing in the Forecast Forum section of the monthly *Climate Diagnostics Bulletin.* As a public service, CPC sends out an e-mail notification to more than 1300 individuals worldwide when the Discussion has been updated and posted on the web.

Over the years, CPC has been frequently called upon to provide relevant climate information for areas of the globe affected by disasters. Quite often the requests come from the U.S Department of State. Examples of recent Center responses to DOS requests include: flooding in Mozambique in early 2000, drought and reconstruction in Afghanistan, flooding in Central America due to Hurricane Mitch, drought in Ethiopia, and flooding along the Mekong River in Southeast Asia. Because CPC is looked upon as a critical resource for the assessment of U.S. interests worldwide, the Development Branch is leading an effort to implement a global hazards assessment capability that will be modeled after the highly successful U.S. Hazards Assessment issued by the Operations Branch (Figure 14, page 40).

Prediction

Reflections of Donald L. Gilman, Edward O'Lenic, Huug van den Dool, and Robert Livezey

The establishment of CAC was a significant event in the history of extended and long-range weather forecasting, which started in the 1940s. CAC's formation in 1979 is a mid-point on the evolutionary scale. Don Gilman, who was working on long-range forecasting prior to and after the formation of CAC, describes its first decade. Ed O'Lenic who has been involved with medium range prediction for many years describes the events in this field at CPC from 1979 to the present. Huug van den Dool details efforts in dynamic extended range forecasting (DERF) and the more recent numerous advances in seasonal climate prediction while Robert Livezey summarizes the 25-year evolution of the science and practice of U.S. seasonal prediction.

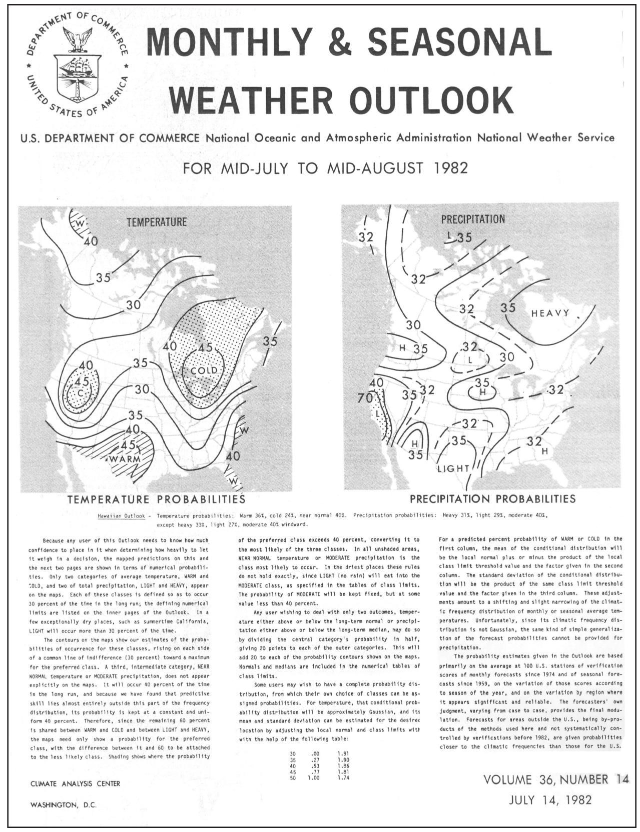


Figure 15.
In 1982, CPC issued the first monthly and seasonal weather outlook maps for temperature and precipitation showing probability contours.

The First Decade

During the first decade of CAC's existence, three significant changes occurred in its forecasting products. The most important change was the presentation of all temperature and precipitation outlook maps by means of probability contours for the defined classes, starting in 1982 (Figure 15). Seasonal (90-day) temperature outlooks had carried simple probability tags since first issuance in 1972, but users of the monthly outlooks had no information on their reliability except from tables in the 1961 *Weather Bureau Technical Paper 40* that CAC sent to paid outlook subscribers. The probability contours were drawn subjectively by forecasters, based on previous verification statistics stratified by season and location together with judgments of higher or lower confidence in the evidence for that particular forecast. These probabilities, one could assert, constituted the greatest increment of forecast usefulness in the program's history, late 1940s to now.

A second change was the continuing increase of the Branch's direct briefing responsibilities. During the 1970s, mainly stimulated by some spectacular winters and the oil supply crises, reporters, broadcasters, the Congress and federal agencies requested interviews and briefings from staff, beyond the published outlooks and local dissemination by Weather Bureau field offices. These demands increased during the 1980s, leading NOAA Public Affairs to establish a formal press conference for each winter forecast, and also requiring many TV visits, testimony at congressional hearings and special briefings for the Department of Energy and Agriculture, FEMA, and the Army Corps of Engineers. Bob Livezey, Jim Wagner, Tony Barnston. Huug vanden Dool, and Ed O'Lenic shared those jobs.

The third change in 1987 was the Branch assuming responsibility for the medium-range (6–10 day) forecasts, which O'Connor, Andrews and Hughes in the National Meteorological Center's Forecast Division had developed ten years earlier. CAC's Fran Hughes led this effort. This was a further example of CAC's acceptance of responsibilities beyond even the most elastic definition of "climate."

Medium-Range Prediction, 1977–2004

Medium-range forecasts are defined as forecasts of average conditions beyond the range for which individual daily forecasts have useful skill, ending about two weeks to, possibly, 30 days in the future. Today, this includes forecasts of 5-day means of 500 hPa height, surface temperature, and total precipitation at a lead of 5 days, i.e., an average of days 6–10 in the future. Similarly, forecasts of 7-day means of 500 hPa height, surface temperature, and total precipitation at a lead of 7 days, or, an average of days 8–14 in the future.

The term "lead" refers to the number of days between the release of an outlook and the first moment of its valid period. Both 6–10 day and 8–14 day outlooks are given in three categories, whose chance likelihood over 30 years is 33 1/3 % each (terciles) (Figures 16 and 17, page 41). The maps of temperature and precipitation outlooks show the total probability of the occurrence of the indicated category, while maps of the 500-hPa height forecasts are in the form of deterministic heights and anomalies. Routine monthly surveys of visitors to CAC's website indicate that these two outlooks are its most popular products.

From its inception in 1977 to 1987, the 6–10 day forecast operation was performed in the Forecast Division of NMC. It was the only operation in that division that made time-averaged forecasts. In 1987, William Bonner, Director of NMC, and David Rodenhuis, Director of CAC, agreed that the most appropriate office for the 6–10 day forecast would be CAC, because it prepared time average forecasts. Francis D. Hughes, a forecaster, and Vernon Jacobsen, a meteorological technician, were transferred to CAC as part of this agreement. As more models, including those of the ECMWF, and better computers became available during the late 1980s, it became clear that an average of the models, subjectively weighted by the forecaster in accordance with their expected (or recent) skill, was the most efficient method to incorporate their information.

Hughes and others did much to develop the use of this "Blend" technique in medium range forecasting. The 500 mb height forecast resulting from this ensemble of different forecasts served as the basis for the forecasts of surface parameters. Hughes was also responsible for tracking the skill of forecasts for days 3, 4, and 5, and 6–10 days. His statistics were very useful in demonstrating the progress, or lack of it, being made in these forecast operations.

The 1980s were a fertile time for research on low-frequency variability. Simmons et al. (1983) showed how barotropic waves extract energy from the mean flow to create the major teleconnection patterns and centers of action. Palmer (in 1988) and O'Lenic and Livezey (in 1989) made attempts, with varying amounts of success, to improve the predictability of major teleconnection patterns in the ECMWF and MRF models. The 1990s marked a period of rapid modernization and product development with many contributions by O'Lenic.

Workstations, promoted as an alternative to mainframe computers at NMC by David Rodenhuis, found a natural home at CAC and became intimately involved in the forecast process. Many previously manual processes, such as plotting and display of maps, were automated and rendered useable through web pages. A graphical user interface was used by the forecaster to create the weighted average of 500 hPa forecasts, the step with which every 6–10 day and 8–14 day forecast began. Verification became easier, and its results easier to display. More verification activities were undertaken.

Modelers' need for ever more powerful computers stayed ahead of actual computing capability. Improvements to forecasts can be traced to better models, better observational data and better methods of data assimilation. In fact, the increase in skill of operational forecasts appears to be directly related to computing power. Ensemble techniques made their appearance at NMC on December 7, 1992, when 14 individual 2-week forecasts were made from data at the same initial time. The technique first employed by forecasters was to look at every ensemble member individually. Eventually, however, skill scores and exhaustion made it clear that the ensemble mean was generally better than any single forecast tool, at least for predicting 500 mb height. Ensemble forecasts from other centers also became available, including those from ECMWF and the Canadian Meteorological Center.

As computing capability improved, probabilistic renderings of the ensemble information became available. This led directly to a change to a probabilistic format in October 2002 for forecasts for 6–10 days and forecasts for an average of days 8–14 (week 2).

Today's NCEP medium-range forecasts are prepared exclusively using output from Numerical Weather Prediction (NWP) models. The forecaster first creates a weighted average, or "blend," of the available model forecasts of 500-hPa height, subjectively assigning the weights. The resulting map becomes the official 500 hPa forecast and serves as the basis for forecasts of temperature and precipitation. The latter forecasts are enhanced by a number of techniques which relate conditions at 500 hPa to contemporaneous conditions at the surface.

These are called "downscaling methods." Among them are the venerable, but useful, Klein equations. Others include ensemble probabilistic maps of the observed temperature and precipitation maps that go with the ten best analogs to the blend map. Direct model output, corrected for recent biases and forecasts from calibrated predictions developed by Hamill et al. in 2004, is used for precipitation forecasts.

Some of the techniques from earlier operational procedures are still used today. For example, until 2002, 5-day means for days 6–10 were the primary medium range forecast product. The motion of the long waves is still considered. However, now the question is "which model is moving the long waves properly?" Perhaps our greatest challenge is to determine how to assimilate and apply the information from an increasingly large number of forecast tools. The local computing capability of workstations is quite helpful in this regard.

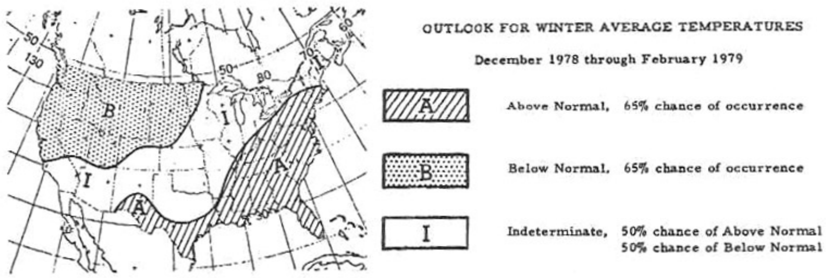
Teleconnections and ensembles of the ten best analogs to the 500 hPa forecast now serve as checks on the "sanity" of the model forecasts—if good analogs and strong teleconnections to the predicted pattern are found, it means the model forecast resembles patterns in the historical record of 5-day mean upper-air height. If not, it is more likely that the model pattern is transitory, or simply unlikely to occur and therefore, less likely to be reliable.

Improvements in the use of Numerical Weather Prediction (NWP), and therefore, medium-range forecasts, continue. One of the most exciting is calibration of model results, using decades-long sets of forecasts from an unchanging model, along with observations (Hamill et al. 2004). This method solves the long-existing problem of frequent changes to operational models which, though necessary, make their statistics non-uniform and difficult to use to improve the forecast output.

Dynamic Extended Range Forecasting

By 1970, NWP was the important tool for the short-range forecast. In the 1970s CAC and others made a few integrations to a month. In spite of large systematic errors, a few cases could be detected that gave hope for 'Dynamic Extended Range Forecasting (DERF). This optimism in the community propelled a comprehensive DERF program as a collaboration between CAC, Environmental Modeling Center (EMC), and various NOAA laboratories (GFDL, CMDL) and universities across the United States. DERF flourished from about 1985 to 1995. At CAC Steve Tracton was usually the lead scientist. Other staff working on DERF were Kingtse Mo, Wilbur Chen, Huug van den Dool, and Jae Schemm, ably supported by new employees, such as Wesley Ebizusaki, Jianfu Pan, J.C. Qin, Leonid Rukhovets and others, in collaboration with many Environmental Modeling Center staff (Kistler, Saha, Kalnay).

The EMC ran large numerical experiments in real time, whenever a window of opportunity arose (e.g., arrival of a new computer). Examples of such experiments were conducted in the winter 1986–1987, when CAC made 30-day runs (DERFII) each day. By 1990, CAC was conducting 90-day (DERF90) runs for 128 days. CAC made "free" multi-year runs (AMIP) in 1993, and ultimately ensemble forecasting. Recurring issues requiring attention were the systematic error, the loss of variability as the integration progressed, verification measures regarding the "limit of (practical) predictability," "return" of skill, forecast skill



The two categories Above and Below are to be compared to the long-term average or "normal" temperatures of the years 1941-70. Each category has a natural climatic frequency or probability of 50%. Each carries a 65% probability of occurring where forecast (shaded area), based on the verification scores of nineteen years of experimental seasonal predictions.

OUTLOOK FOR WINTER PRECIPITATION

Short odds of 11 to 9 favor a wetter than usual winter in many areas; among them the Great Basin, northern Great Plains and Rockies, and everywhere eastward from the Mississippi Valley to the Atlantic except Florida and the Southeast Coast. Only in the southern Great Plains and south Texas do similar odds favor a drier winter than usual. Precipitation for the West Coast, Southwest, and central Great Plains cannot be predicted this year.

The odds cited in this outlook are based on average performance scores for 19 previous winter predictions.

Figure 18. In 1978, CAC released its seasonal outlook for DJF 1978–1979 in late November in *The Average Monthly Weather Outlook*. The temperature outlook map indicated an emerging probability forecast. The odds cited were based on performance scores for 19 previous winters.

as a function of scale, and the detection of specific phenomena (e.g., blocks or MJO) in the outlook.

The largest impact on CAC's operations ultimately came from the new week 2 outlook, which was conceived entirely around daily ensembles of NWP integrations out to 17 days. For the longer lead seasonal outlook, the atmospheric "initial value" approach has remained elusive, and the emphasis for the seasonal forecast continues to be on "lower boundary forcing" to this day. Ultimately this made the funding of DERF problematic, since results appeared more likely for ENSO-forced impacts for the U.S. The need for research and development in the range between day 15 and day 60 (the monthly forecast) continues. Currently, funding of research proposals may be available for such phenomena as the Madden–Julian Oscillation (MJO).

Big Changes in Seasonal Prediction in the 1990s

During 1994, about the time Climate Analysis Center, National Meteorological Center became the Climate Prediction Center, National Centers for Environmental Prediction, CPC implemented large changes in the seasonal forecast, in terms of methods and protocol as well as in the volume of products released. This was the result of years of work on new methods and insights, and the arrival of new technology (workstations; Internet).

The change most visible to the user was replacing a single "zero-lead" seasonal forecast (such as releasing a December-January-February (DJF) outlook in late November (Figure 18) by a full suite of 13 seasonal forecasts at lead times ranging from 0.5 month to 12.5 months in 1995 (Figure 19, page 42) in 1995.

The notion "long-lead" (which has since stuck) refers to the change of zero to two week or longer lead times—i.e., even the first upcoming season is forecast 2 weeks ahead of time.

A second important change was the implementation of several new forecast tools: most notably, the Canonical Correlation Analysis (CCA; Barnston), the Optimal Climate Normals (OCN; Van den Dool and Huang) and the Coupled Model (CMP; Leetmaa, Ji and Kumar. CCA, a multi-variate linear regression at the pattern level, had been tested extensively by Barnston at CAC, starting from pioneering work by Barnett and Preisendorfer at the Experimental Climate Forecast Center at Scripps. The Coupled Model at NCEP followed the widely accepted "physical first principles" approach after first having created an operational ocean data assimilation system in the late 1980s. CAC introduced the OCN, persistence of the last 10 year's anomaly, to provide some lifesaver skill, especially at longer leads, for situations when the global SST was nondescript. Little did we know in 1994 how much OCN would contribute to skill in predicting seasonal temperatures. For more than ten years, Wagner had tested forerunners of the 2, 3, and 4 season lead experimental seasonal prediction in-house at CPC.

A third big change was an attempt to be nearly objective about the final outlook. The CPC implemented CCA, OCN and CMP following agreed upon protocol from developed skill (30 years or more), the normals period used, the units, the stations, etc. This allowed, at least in principle, consolidation of the three methods into the official outlook following a more-or-less rational objective "recipe." Before 1994 we had a few formal methods, such as the Livezey and Barnston analogue tool, but most other tools were subjective, and in the absence of a rational way of combining tools, a "pick and choose" outlook remains possible, rendering the whole process subjective. In their own right, CCA, OCN, and CMP were not revolutionary improvements, but the idea of having a "method in the madness" was the main improvement. Consolidation requires demonstrated skill over a long period.

While Jerome Namias and Don Gilman had the luxury of testing seasonal outlooks in-house in real time for 15 years before revealing their teleconnections to the public, by 1995 procedures for quick verification on what are essentially decades of hindcasts were developed. This included cross validation approaches, AMIP runs, and so-called "retroactive real time" studies, all leading to estimates of a-priori skill to be applied to the next forecast in real time. CPC's Livezey, Barnston, and Van den Dool did the main work.

The fourth change (mainly for the forecaster) was the use of modern technology. Before 1994 we had stacks of paper, acetate, pencils, and primitive graphics, but since that time we have been able to display each tool on a workstation, along with a-priori skill, making its use easy. Since we had to produce 26 maps, these technical aids became indispensable. Equally novel was the use of the Internet as an outlet for the final outlooks, along with all of the inputs. While the long-lead outlooks led to many new inquiries, users were able to find the answers on the Internet.

The official SST forecasts began in 1995. Both the CCA and CMP techniques extracted from global SST whatever seasonal predictive information existed over land. The global SST was to play a more important and explicit role than before, somewhat like the sudden appearance of mystical 500 mb height with the advance of barotropic models 45 years earlier. Specifically all eyes were focused on SST in the tropical Pacific where El Niño may develop. CCA (Barnston and Ropelewski), Constructed Analogue (CA; Van den Dool) and the CMP model were consolidated into one forecase by Unger in a box and whisker diagram (Figure 20, page 42). Around 1998 the Markov model by Yan Xue was added to this in-house ensemble.

The introduction of the notion, CL meaning climatological probabilities, presented a map representation challenge. This "informed we don't know" option applies when no reliable forecast signal emerges from the record. Prior to 1994 these portions of the maps were left blank.

Among the assorted smaller changes: CPC abandoned the familiar 30/40/30 tercile distribution and adopted the one-third each equi-probable tercile system. Probabilities were expressed as probability anomalies, and outlooks were no longer drafted by a technical drafts person. CPC discontinued narrative descriptions of the national outlook. It discontinued the printed version of *The Monthly and Seasonal Weather Outlook,* as it was called in 1994, with approximately 2,500 subscribers (much to the dismay of the Government Printing Office (GPO), which had profited from this publication for decades. CPC paid for printing, and GPO collected the subscription fees).

Many customers missed the printed document, and by mid January 1995, CPC made a limited set of print-outs of all outlooks entitled *The Long-lead Multi-Season Climate Outlook* and published the first issue in February for the period February 1995 to April 1996. Bob Churchill prepared the graphics. Long-range weather forecasting had officially changed to short-term climate prediction. After some years this paper publication was no longer needed due to the Internet.

Because of the large changes in a product that had remained the same for years, CPC had to convince its customers that we now had a superior product. Due to the attitudes and optimism of the day CPC found a great willingness by senior managers from Rodenhuis, McPherson, Friday, up to James Baker, the NOAA Administrator, to look upon this package as the payoff of the large investments of the past, especially the coupled model, ocean observing programs, and acquisition of various supercomputers. In some sense this was the success the administrators had wanted to declare.

With strong administrative support in place, CPC overcame natural resistance in the NWS in a process called CAFTI (Committee on Analysis and Forecast Technique Implementation). Part of the process included a crash-outreach program to inform users and NWS field office staff. Center personnel (O'Lenic, Barnston, Livezey, Van den Dool, Rodenhuis) held briefings around the country in the fall of 1994. The audience and active participants consisted of field and regional offices, the Regional Climate Centers, the press, universities, hydrologists, and other users.

Some of the changes made in 1994–1995, such as zero lead for the monthly outlook continue to be debated. The question of how to convey a probability forecast (e.g., 3 classes, 3 *equal* classes, 2 classes, absolute probabilities, probability anomalies) will not be answered to everybody's satisfaction. How objective or automated should one make the outlook? How strongly do we follow the formula procedures? Who establishes these procedures? The lively debate about CL (over time renamed I for indeterminate, CP for climatological probabilities, or EC for equal chances, but meaning the same) also continues. When to use the "near normal" class in probability outlooks remains problematic until skill levels improve significantly.

25-Year Evolution of the Science and Practice of U.S. Seasonal Prediction

U.S. seasonal temperature outlooks over the last decade are demonstrably superior to those issued in the 1960s through 1980s, even with the handicap of being issued with at least a half-month lead compared to their former short-lead counterparts. Modified Heidke scores have increased from 8 to 13 for all seasons and 13 to 20 for cold seasons. Overall this is not the case for the U.S. seasonal precipitation outlooks, but there are some spectacular exceptions, such as the 1997-98 El Niño year and the following two years of strong La Niña conditions.

These advances are directly traceable to the evolution from an almost entirely empirically-based, non-discriminating, linear approach to predictable signals to one that is still largely empirical, but accommodates different physical sources of the signals and properly addresses the substantial non-linearity of ENSO impacts over North America. Both innovations contribute to the separation of relevant signals from irrelevant cases and unpredictable factors, which otherwise compromise a linear approach trying to fit the entire record. Direct use of General Circulation Models for U.S. seasonal prediction still adds little value to the process, but this may change because of recent advances in the ability of NCEP's Seasonal Forecast Model system to replicate important modes of variability (such as ENSO and Madden–Julian Oscillation). This is encouraging, because we may be close to the limit of what can be accomplished empirically.

The transformation from the way of doing business in 1980 to developing an improved seasonal outlook took place in three distinct phases

(Continued on page 43)

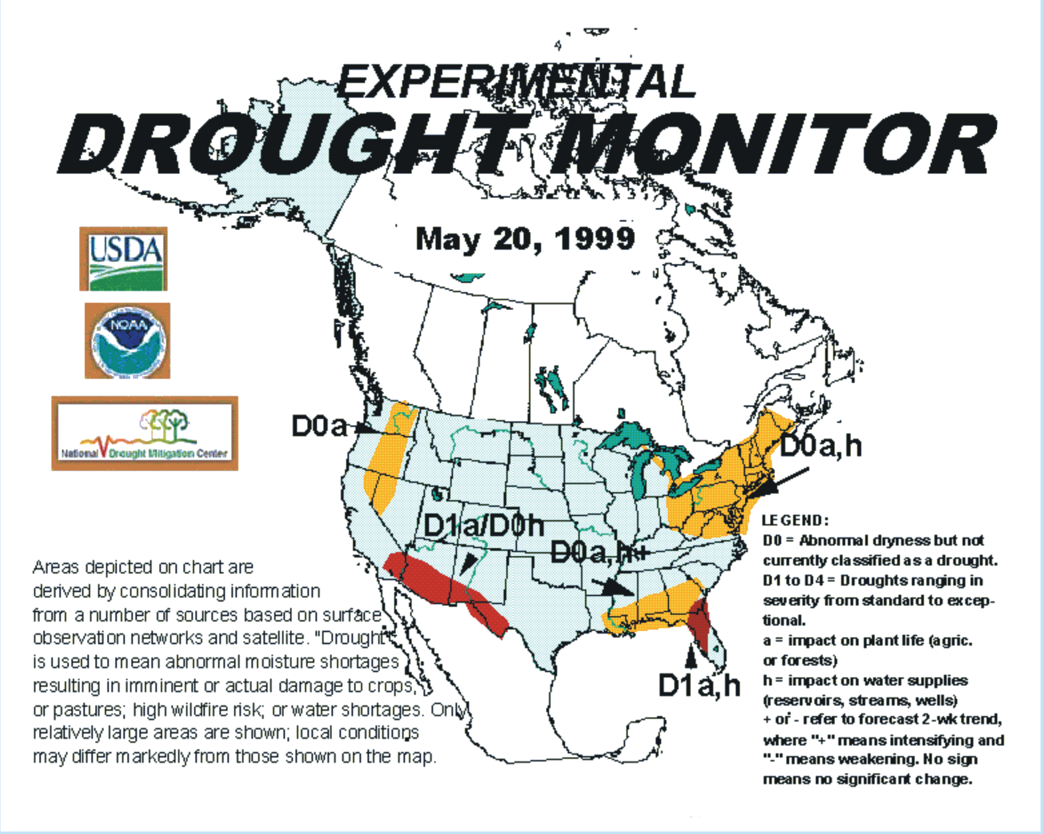


Figure 4. CPC produced the first experimental drought outlook map in May 1999.

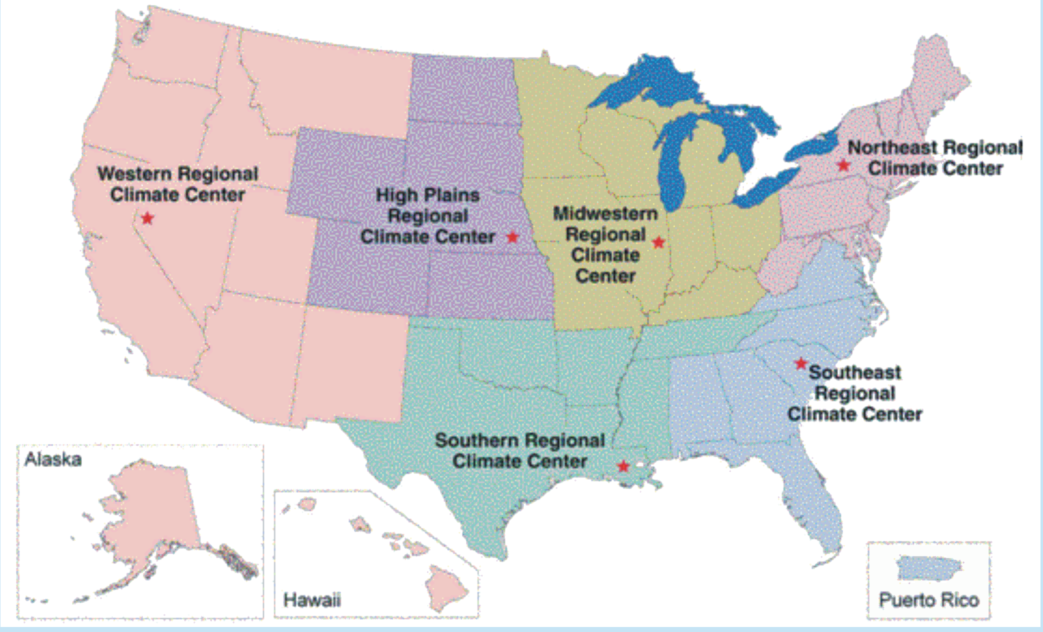


Figure 6. CAC assumed responsibility for the Regional Climate Centers in 1992 for several years.

Figure 7. CAC demonstrated the superiority of the Tahiti minus Darwin Index, which became the standard Southern Oscillation Index (SOI) as an indicator of El Niño (orange) or La Niña (blue).

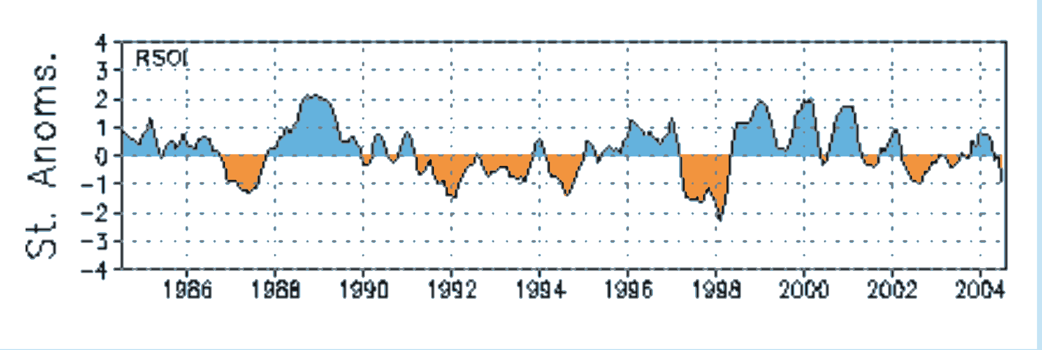
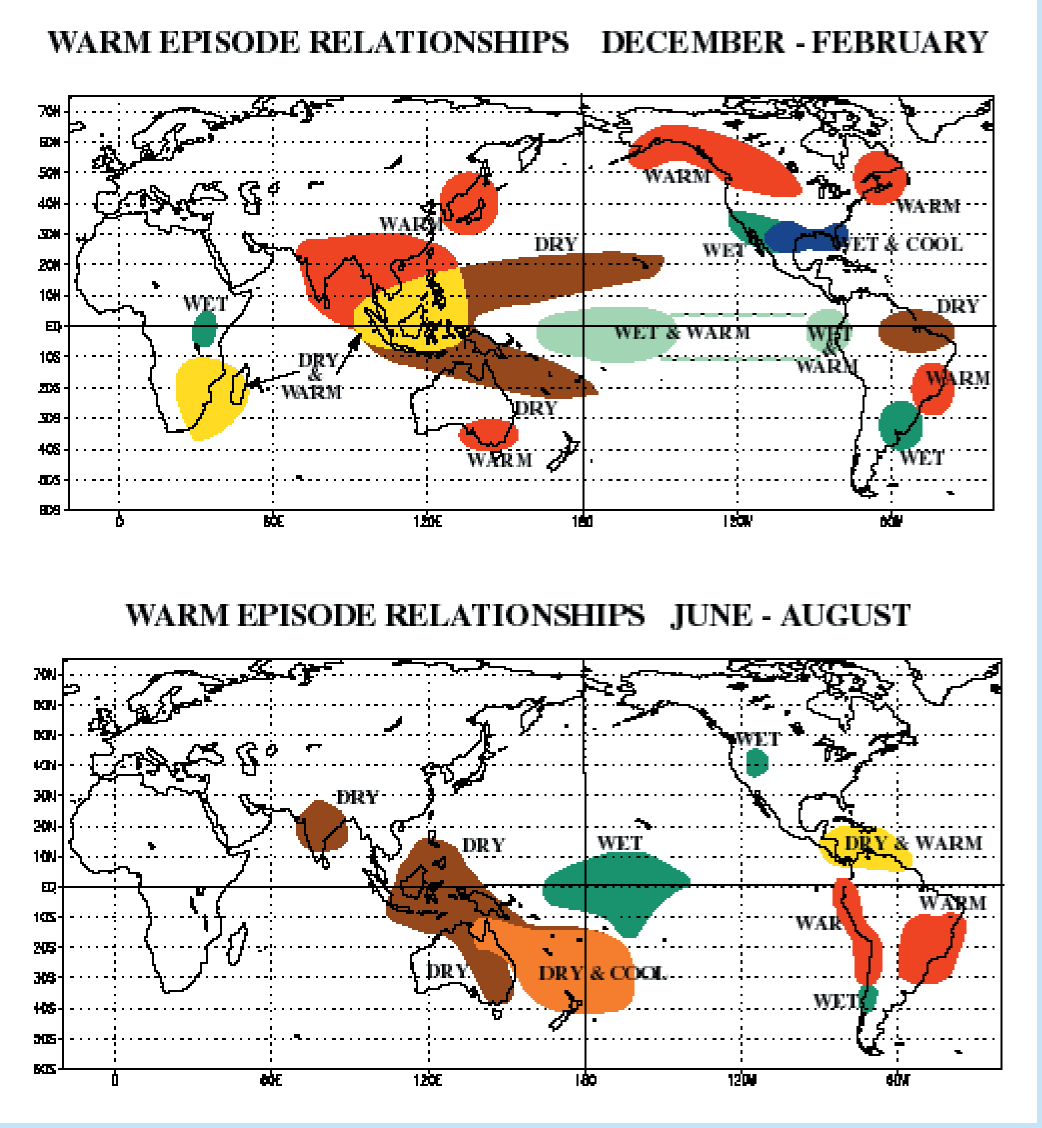


Figure 11. CAC conducted studies describing the typical worldwide land surface precipitation and temperature anomalies associated with the warm and cold phases of the ENSO cycle that are called teleconnections.



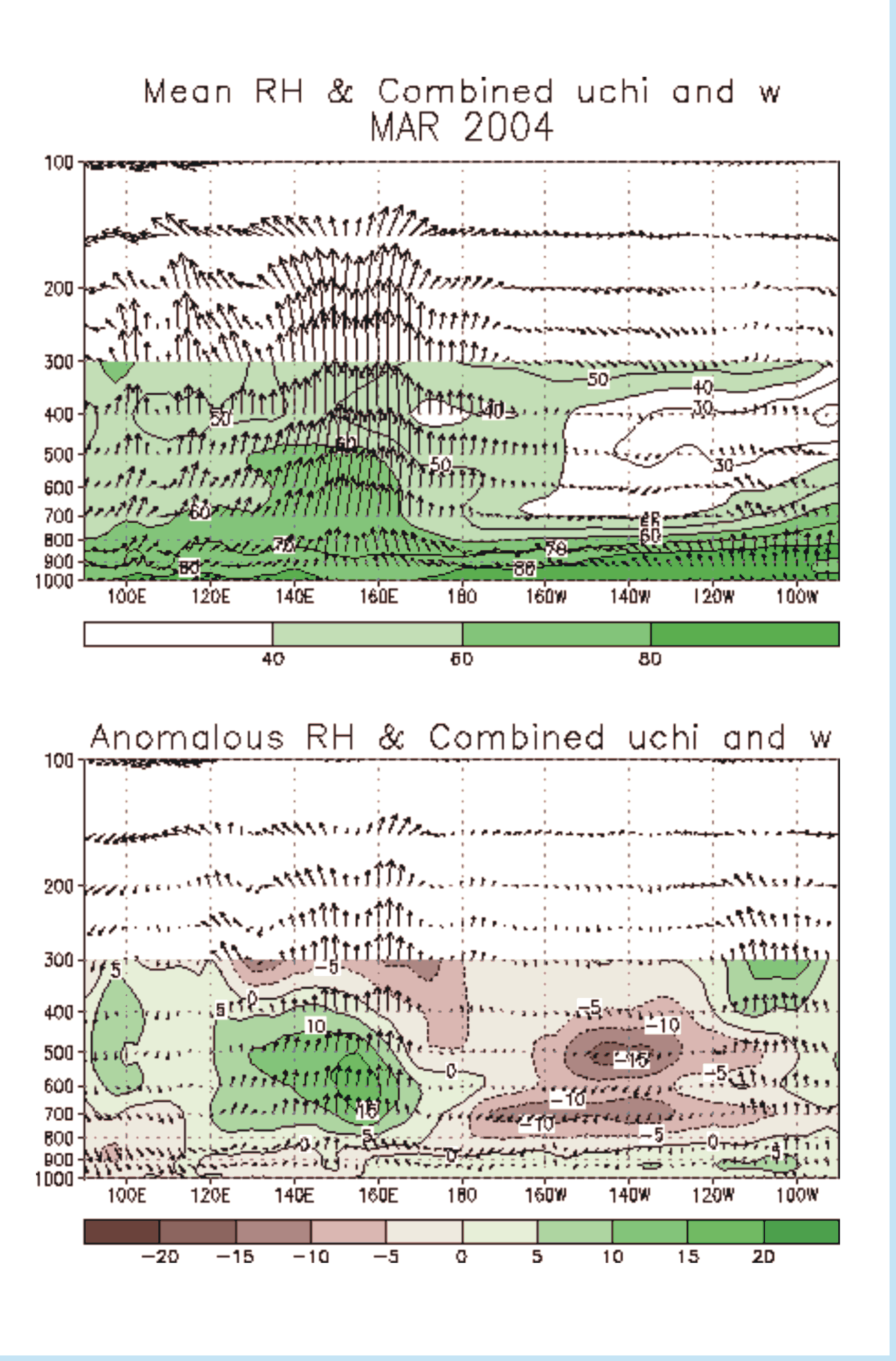
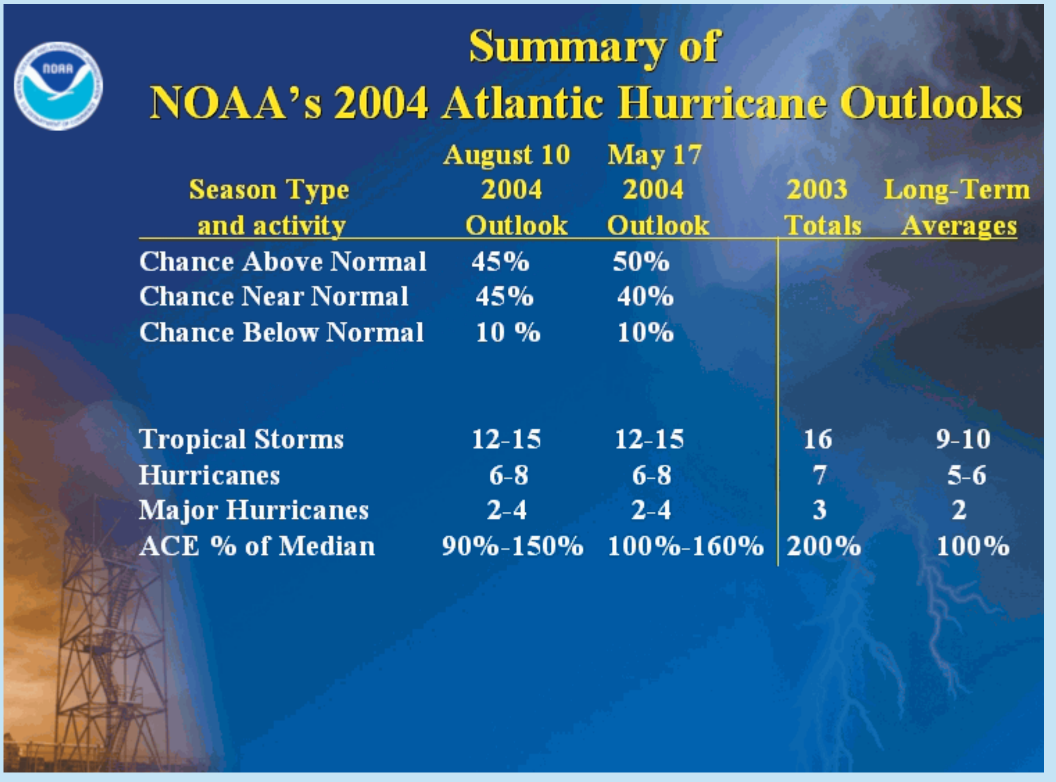


Figure 12. CAC's Climate Data Assimilation System (CDAS)/ Reanalysis shows the three-dimensional structure of the atmospheric wind and moisture distribution over the earth's surface and vertically in the atmoshpere. It is the primary tool used by CPC to monitor climate and to perform research.

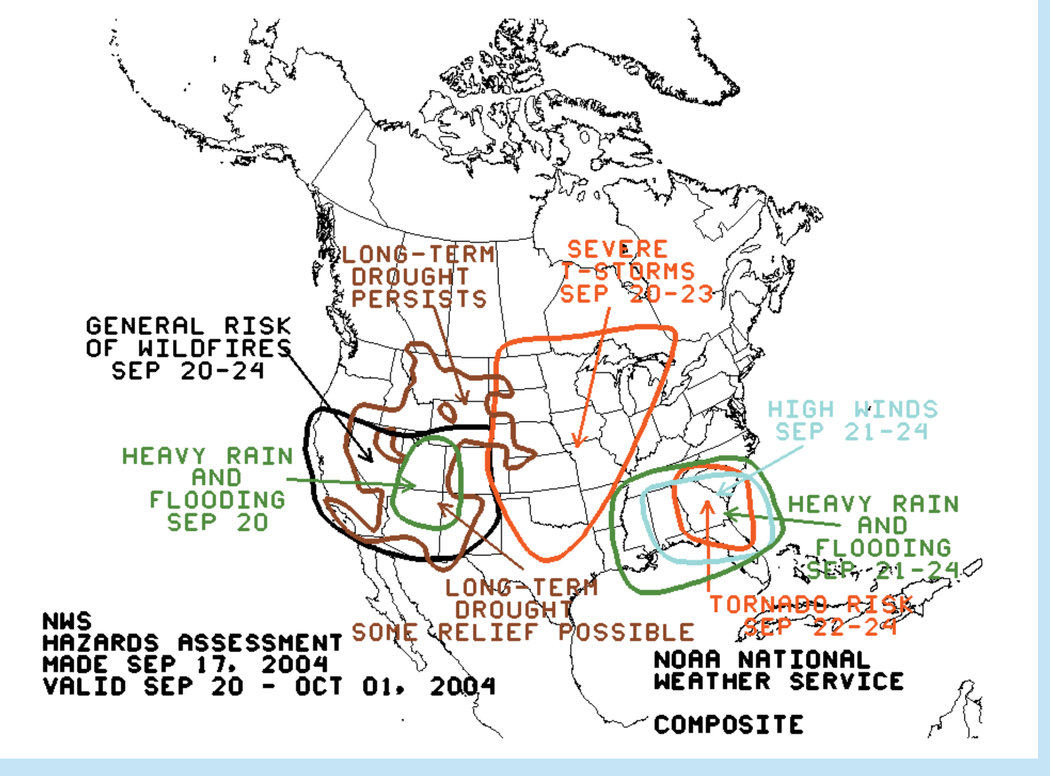
Figure 13. Several NOAA units together with CPC began Seasonal Outlooks for tropical storm weather in the Caribbean and Atlantic in 1998. Reports were published in May and August of each year. Hurricane outlooks for the eastern tropical Pacific began in 2003.

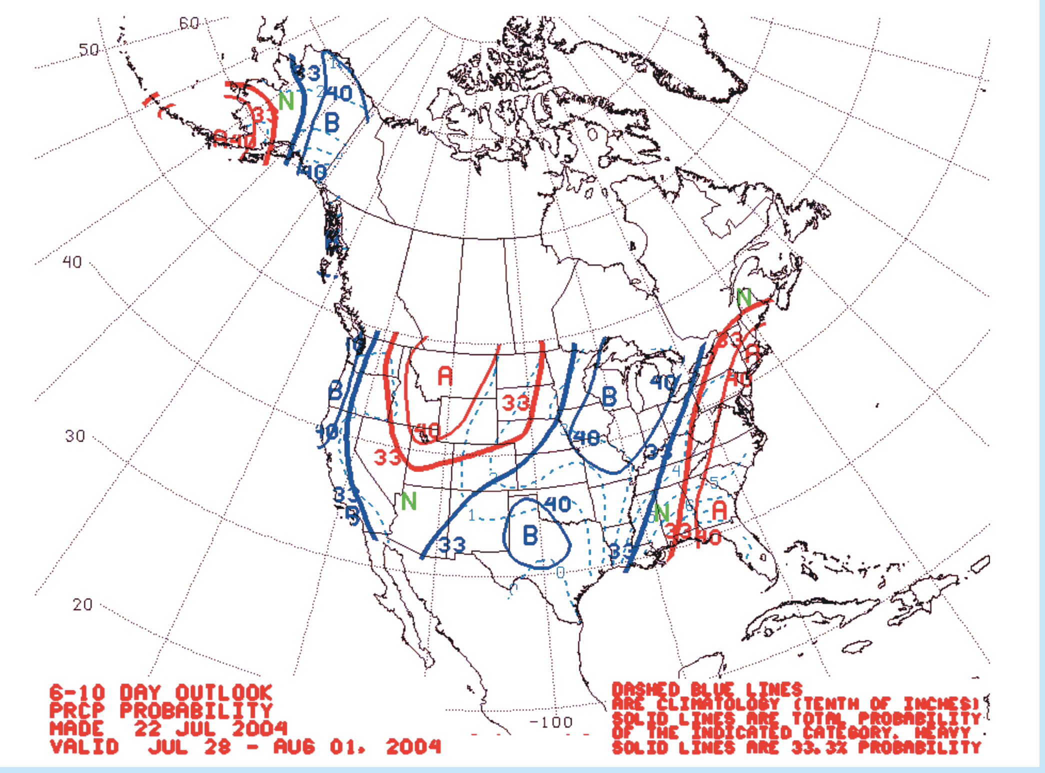


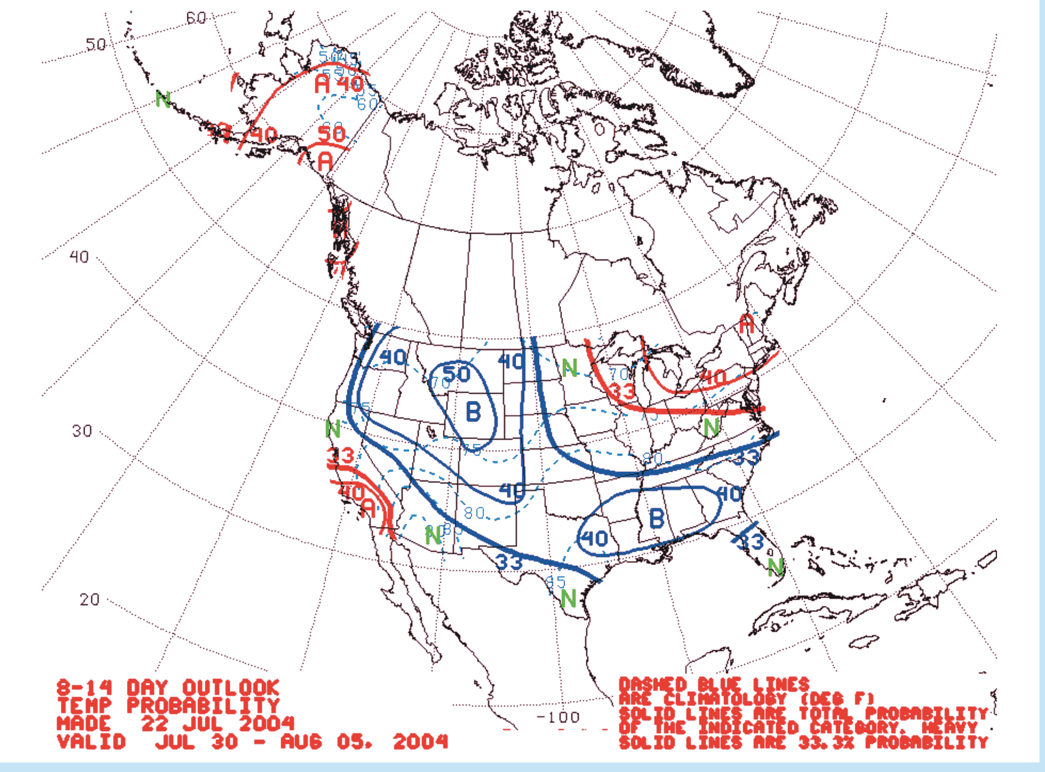
Summary of NOAA's 2004 Atlantic Hurricane Outlooks

Season Type and activity	August 10 2004 Outlook	May 17 2004 Outlook	2003 Totals	Long-Term Averages
Chance Above Normal	45%	50%		
Chance Near Normal	45%	40%		
Chance Below Normal	10 %	10%		
Tropical Storms	12-15	12-15	16	9-10
Hurricanes	6-8	6-8	7	5-6
Major Hurricanes	2-4	2-4	3	2
ACE % of Median	90%-150%	100%-160%	200%	100%

Figure 14. In response to requests for relevant climate data as it relates to natural disasters, CPC introduced the U.S. Hazards Assessment in 1999.







Figures 16 and 17. CPC's 6–10 and 8–14 day outllooks for temperature and precipitation are two of its most popular products.

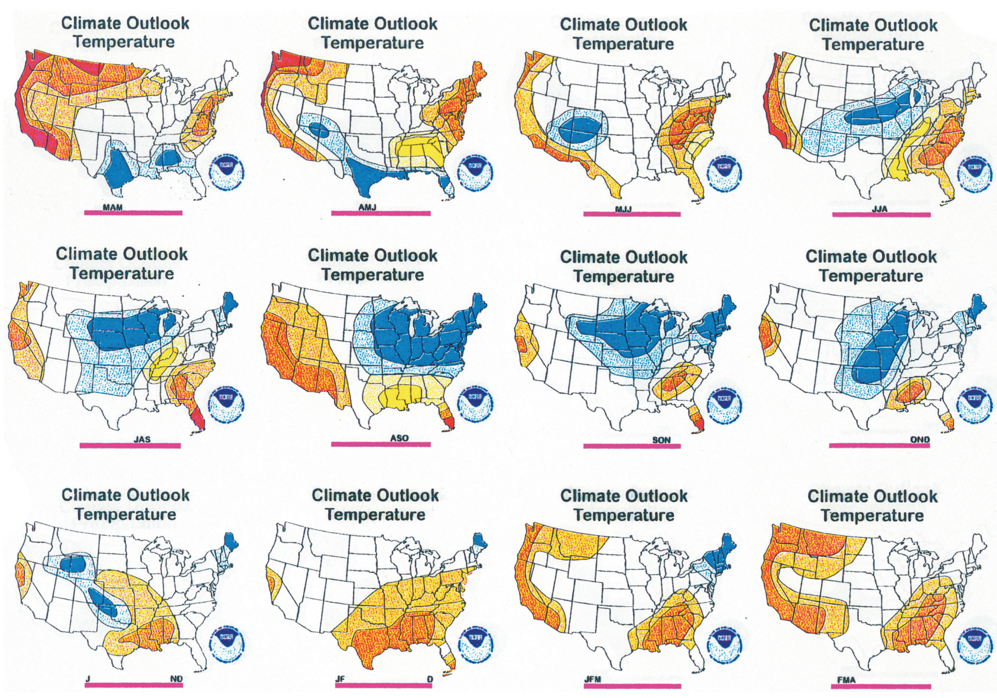


Figure 19. One of the earliest long-lead forecasts was published as *The Long-lead Multi-Season Climate Outlook* (vol. 1, no. 1, February 1995–April 1996). Red to orange indicates the probability anomalies for above normal, and blue for below normal. White areas indicate equal chances for above or below normal.

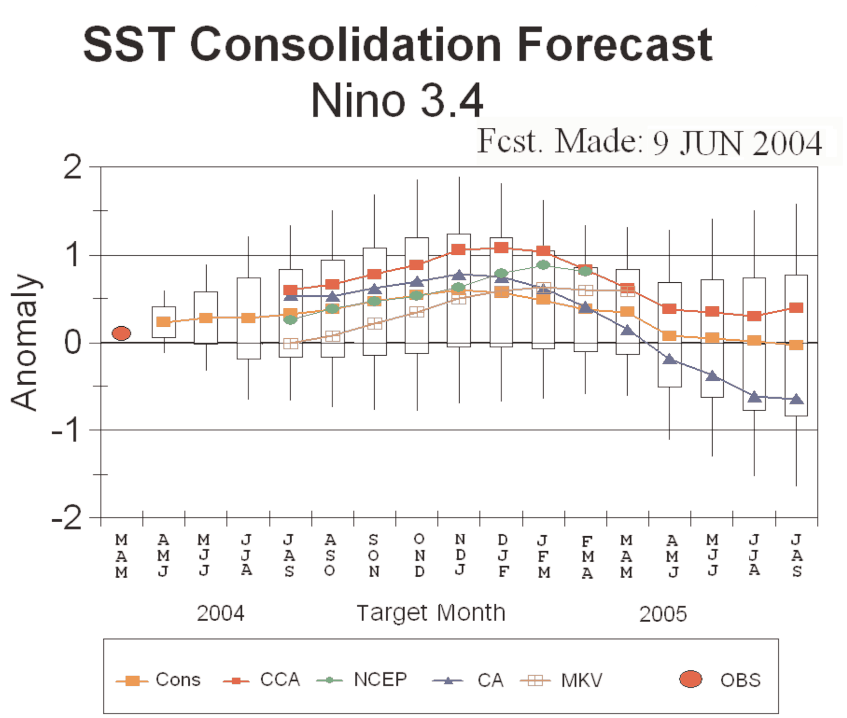


Figure 20. The first NIÑO3.4 SST forecast in early 1995 consisted of a graph by one tool. After 1995, a consolidated forecast with individual members shown and uncertainty expressed via box and whiskers, which is still in use today.

(continued from page 34)

and depended on a number of advances in the science and its supporting technology. These three steps will be described in broad terms and then some of the key events and seminal work that led to the innovations.

Seasonal forecasting was largely an empirical business in 1980, with very little physical underpinning. A collection of 700mb lag autoregressions were subjectively combined (with no quantitative basis for assessing sampling variability or statistical significance) and patched together with one-point teleconnections to form a forecast upper-air map of anomaly centers. Synoptic ideas and specific analog cases were then used to produce a surface forecast. This process produced forecasts that had a surprising amount of skill (almost as much as that demonstrated later by near optimum linear statistical techniques) because the lag correlations were implicitly (but not optimally) accounting for ENSO.

The first evolutionary step took place in the mid-1980s under the leadership of Don Gilman and consisted of providing the forecasters estimates of statistical significance for discriminating between the different lag correlations, i.e. a quantitative basis for separating the real signals from the false. This coincided with a general increase in the attention that empirical diagnosticians, modelers and forecasters paid to the effects of sampling variability and error and to the evaluation of laboratory results. During this period Livezey was actively encouraging a culture of objectivity in seasonal forecast research.

The next step forward took place in the early 1990s leading up to the implementation of the long-lead suite of outlooks in 1995. Tim Barnett and Rudy Preisendorfer at Scripps Institute for Oceanography and Pacific Marine and Environmental Laboratory (PMEL) respectively had discovered that canonical correlation analysis (CCA) could be successfully applied to interannual climate variability problems, including seasonal prediction, if predictors were first prefiltered with principal component analysis (PCA). Implementation of the technique at CPC by Tony Barnston automated much of the existing procedure, combining the lag correlation selection, teleconnection integration, and Klein specification into one optimum linear algorithm. When the 1995 long-lead format was installed, the CCA was paired with Huug van den Dool's Optimum Climate Normal (OCN, a simple technique that accounts for trend) as the baseline tools for U.S. seasonal prediction.

The third and last metamorphosis of the forecast process began in 1997 and continues at this time. That year represented the first opportunity to exploit over a decade of advancement in two related areas, ENSO prediction and United States ENSO temperature and precipitation teleconnections. Utilizing a coupled dynamical model developed by Ants Leetmaa, Ming Ji, Arun Kumar and others, two individual statistical models by Van den Dool and Barnston , and a technique to combine the three rationally by Dave Unger, CPC forecasters found themselves confidently forecasting a major El Niño for the 1997–1998 winter as early as the summer of 1997. To exploit the situation, Leetmaa, bolstered by the work of Livezey, Michiko Masutani, and Rich Tinker, encouraged the forecasters to abandon the linear statistical tools that would dilute the strong North America El Niño signal and use their direct knowledge of that signal. This new approach, with a focus on the effects of modes of variability relevant to a particular forecast situation rather than on a linear mix of everything available, has since been exploited on several occasions for highly successful outlooks. In fact, most of the improvements in seasonal temperature prediction and the few outstanding successes for precipitation can be credited to it. Recently Wayne Higgins and colleagues have developed a prototype forecast tool for objectively combining trend and the non-linear ENSO signal that shows promise for simultaneously optimizing the consistency of the outlooks and their skill.

Today's capability to predict ENSO fluctuations and its impacts, as well as our insights about other important modes of climate variability and their predictability (or lack thereof) that paint our seasonal canvasses, can be traced to seminal events and work in the 1980s. In 1981, Mike Wallace and Dave Gutzler of the University of Washington laid the foundation for our modern multimodal view of monthly and seasonal variability. In 1987, CAC's Tony Barnston and Bob Livezey made a major contribution to our understanding of variability on this timescale.

Studies of El Niño/La Niña impacts on the U.S. can be tracked to work at National Center for Atmospheric Research, Creighton University, and Scripps in 1981 with substantial reinvigoration by CAC's Chet Ropelewski and Mike Halpert in the wake of the great 1982–1983 El Niño. This event and Gene Rasmusson and Tom Carpenter's well-timed description of the life cycle of El Niño in 1982 inspired a whole new generation of dynamical and statistical modelers. These milestones were later underpinned by advancements in satellite and in situ ocean observing systems, the blended global SST analysis of Dick Reynolds in 1988, his subsequent progress with Tom Smith in historical SST analysis, and Ants Leetmaa and others in ocean data assimilation. Eventually confidence in descriptions of El Niño/La Niña and their global effects paved the way for clarifying the roles and importance of other modes of variability.

Seasonal prediction at CPC is on the verge of another transformation. Advancements in coupled ocean-atmosphere modeling by EMC and the exploitation of ensembles, multi-model ensembles, and sophisticated post-processors based on rich hindcast records ultimately will produce outlooks that will first match the performance of the empirical approaches and eventually supplant them.

The Workshops

By Robert W. Reeves

The annual workshops have been a vital and enduring aspect of CPC's intellectual life. They have been held every year since 1976, providing a unique and continuous opportunity for CPC and its partners in academia, the private sector, and other branches of local, state, and federal government to maintain contact and exchange diagnostic and research ideas in the context of an informal setting. By meeting in a different location each year, often at an academic institution, CPC has fostered the introduction of "new blood" to the science, fulfilling one of the founders' original goals. The Workshops were convened by the NOAA Climate Office from 1976–1978. The CPC has sponsored them since 1979.

Each year the workshop is held at the co-host's location and alternates between the eastern and western U.S. with one excursion into Canada (Figure 21). At least one technical session is devoted to the hosting institution's specialty subjects, and local graduate students are invited to present their ideas, often their first presentation before an audience of discriminating scientists.

The number of participants and presentations and range of topics have changed significantly since 1976. For example, the average number of participants during the three workshops between 1979 and 1981 was 90, with six topics and 46 papers. From 1998 to 2000, the average number of participants increased to 141, the number of topics to 13, and the number of papers to 128.

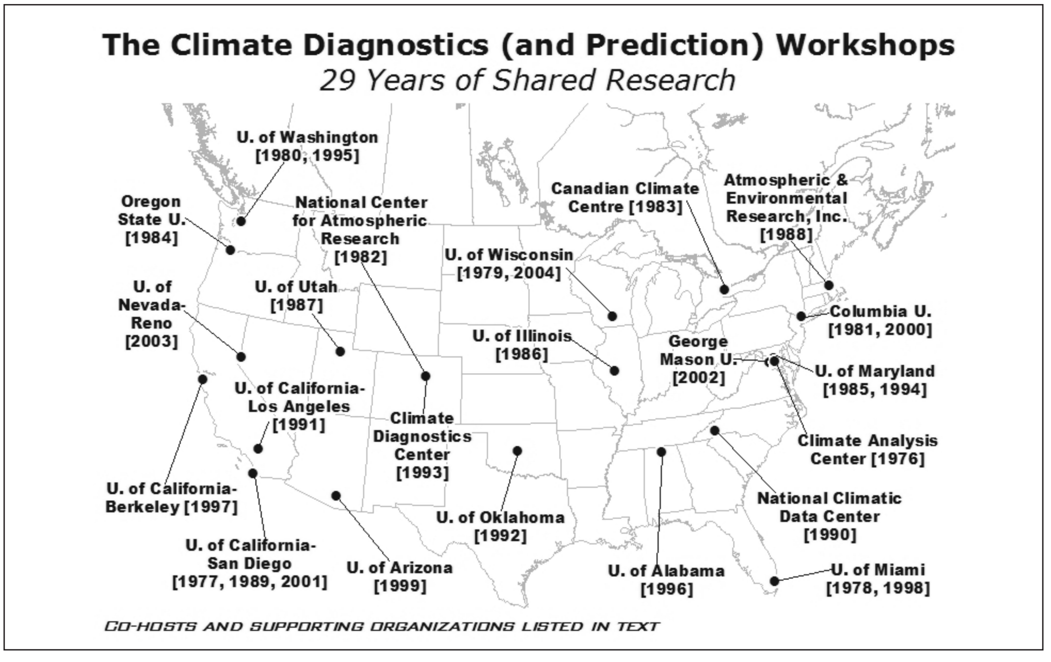


Figure 21. Locations of the Climate Diagnostics and Prediction Workshops from 1979 to 2004.

The workshop concept was part of the early discussions for a climate program. In summer 1974, Uwe Radok, Acting Chief Scientist for the Office for Climate Dynamics at the National Science Foundation, and Joe Fletcher, Deputy Director of the Environmental Research Laboratories of NOAA, were developing ideas for a meeting of interested climate diagnosticians. They referred to this gathering as a "Climate Clinic." In his November 1974 invitation to the clinic to be held in Boulder, Colorado, in December, Radok stated: "The feasibility of the clinic depends upon contributions of real-time information on a range of climatic indices for the construction of a continuing record of the current state of the global environment." He concluded with "It is hoped this meeting will produce a sample product for consideration by a larger group addressing the wider problems of the climate clinic and the diagnostic climate center."

Joe Fletcher convened the clinic on December 11, 1974. Material accompanying the letter of invitation included a "Terms of Reference" for the clinic and a hint that it would be the first in a series. Larry Gates of the RAND Corporation recommended that the clinic meet annually. The clinic served as a prototype for the current Climate Diagnostics and Prediction Workshops.

Two years later NOAA held the next "clinic," calling it the Climate Diagnostics Workshop. By this time, NOAA had established a Climate Office. Ed Epstein, Ron Lavoie, Norm Canfield, and William Sprigg were the key individuals within that office. Sprigg became the motivating force behind turning the clinic into an annual workshop (Canfield, personal communications). In 1976, Sprigg organized the first Climate Diagnostics Workshop held November 4–5 at the World Weather Building in Camp Springs, Maryland. He specified several criteria: (1) the date of the workshop (late October) should coincide with the National Weather Service Long-Range Prediction Group's preparation of the winter outlook, and therefore be most useful to that process; (2) presentations were to be based on unpublished material; (3) the information should be current, ongoing analyses and research in preliminary form, to submit to those assembled for suggestions and critique; and (4) the proceedings would be printed by Christmas of the same year.

The emphasis on unpublished current materials made these workshops unique because other meetings focused on finished work with little opportunity for discussion. At the Diagnostics Workshops spirited discussions were the norm.

According to Sprigg, Namias (who was at Scripps at that time) was highly supportive of the workshops because of these objectives. Sprigg organized the 1977 and 1978 meetings, and included an informative summary with each report.

The early workshops reflected an emphasis on annual climate review and diagnostics. Most of the presentations (22 of 24) at the **1976** meeting in Camp Springs, Maryland, hosted by the National Weather Service fell into that category.

In **1977** Scripps Institution of Oceanography of the University of California at San Diego was co-host. The 1976–1977 strong El Niño (at least in the Eastern Pacific) and unusual northern hemisphere winter drew attention of workshop attendees. The number of presentations increased to 36, but still focussed predominantly in monitoring and diagnostics. Rudy Preisendorfer's paper "Use of Empirical Orthogonal Functions in Diagnosing and Predicting Climate Fluctuations" was an important advance in methodology.

The interest in the 1976–1977 winter climate continued in the **1978** meeting in Miami. Several papers touched on the prediction problem. The co-hosts were the Cooperative Institute for Marine and Atmospheric Studies and the University of Miami.

The **1979** meeting in Madison, hosted by the Institute for Environmental Studies, University of Wisconsin, was the first time the presentations were organized into discrete sessions, one of which addressed modeling results (4 papers). Mike Wallace and Dave Gutzler of the University of Washington presented a paper that lent a "modern" respectability to the topic of northern hemisphere teleconnections. (According to Huug van den Dool, Namias was chagrined, for he believed he had done this a long time ago.)

The Joint Institute for the Study of the Atmosphere and Ocean (JISAO) at the University of Washington in Seattle hosted the **1980** gathering where the number of presentations had increased to 52, including 15 in the sessions Modeling and Prediction and Prediction Methods. The recognition of the connection of the Southern Oscillation and El Niño was evident in a number of papers. The monitoring of snow, ice, water vapor, and volcanic aerosols from Mount St. Helens was addressed in a separate session.

Lamont–Doherty Geological Observatory, Columbia University, hosted the **1981** workshop. The agenda included a review of recent climate fluctuations, tropical-mid-latitude connections, radiation budget, and prediction. The Climate Diagnostics Data Base (the precursor of CDAS/Reanalysis) was introduced, as well as pioneering work in statistical field significance.

By **1982** at the National Center for Atmospheric Research in Boulder, the number of presentations had increased to 65, and the workshop expanded to 5 days to accommodate this increased interest. The topic of teleconnections had drawn so much attention that it required two sessions to accommodate 19 papers! The effect of the eruption of El Chichon was the topic of 9 presentations. Don Gilman presented the "New Look of the Monthly and Seasonal Weather Outlook." Predictability began to get serious attention. At this October workshop, the attendees were not able to agree that the 1982–1983 winter would feature an El Niño. The volcanic dust had obscured the SST analysis.

The Canadian Climate Centre in Toronto hosted the **1983** meeting, including a session on ENSO—Historical Perspective. The 1982–1983 ENSO event began its "long run" as a major topic over the next several years.

The **1984** meeting in Corvallis, Oregon, hosted by the Department of Atmospheric Sciences, Oregon State University, included a session on West Coast climate variability (Africa, U.S., South America). Chet Ropelewski described CAC's new Climate Anomaly Monitoring System (CAMS), and CAC's Richard Reynolds described his well-known blended sea-surface temperature product.

The summer **1985** workshop, hosted by the Department of Meteorology, University of Maryland, College Park, was held in conjunction with the first World Meteorology Organization Workshops on "The Diagnosis and Prediction of Monthly and Seasonal Atmospheric Variations over the Globe."

The **1986** workshop in Champaign, Illinois co-hosted by the Illinois State Water Survey, and the Department of Atmospheric Sciences, University of Illinois returned to the traditional format. The workshop was extended to four days to accommodate 79 presentations. In the Proceedings, Bill Sprigg memorialized Rudy Preisendorfer of the University of Washington, who had died just prior to the workshop. A special session on precipitation, drought, and land surface processes featured the work of the University of Illinois and the Illinois State Water Survey. Jim O'Brien of Florida State University presented a summary of the 1986 El Niño forecasts.

The Department of Meteorology, University of Utah, held the **1987** workshop, which featured a review of the 1986–1987 warm event during a special session on intraseasonal oscillations. Steven Tracton's application of DERF to the monthly forecast problem and Anthony Barnston and Robert Livezey's operational multi-field analog forecasting of U.S. seasonal temperatures for the nonwinter seasons were two of 19 papers in a session on medium and extended range forecasting. An important session on climate data sets was included.

The drought of 1988 was a major topic at the **1988** workshop hosted in Massachusetts by Atmospheric and Environmental Research, Inc., in Cambridge. Special sessions on climate trends and coupled modeling recognized their growing importance. Medium and extended range forecasting continued to have a prominent place. Huug van den Dool mentioned that this workshop would be remembered for the tropical downpour that caught attendees unprepared as they walked from the conference center to dinner.

The workshop returned to the Scripps Institution of Oceanography in LaJolla in **1989**. The banquet presentation by MIT's Ed Lorenz gave reason for optimism among extended range forecasting interests. One of the sessions summarized long-range prediction at operational centers.

NOAA's National Climatic Data Center in Asheville, North Carolina, held the fifteenth annual workshop in **1990**. Quite naturally, a strong emphasis was on data sets. The Regional Climate Center program was the topic of a special poster session, the first use of posters in the workshop series.

The Department of Atmospheric Sciences, UCLA, hosted the **1991** workshop at its Lake Arrowhead Conference Center. The proceedings included CAC's

Huug van den Dool's dedication to Jerome Namias, a giant in long-range prediction who bridged the period back to C. G. Rossby and MIT in the late 1930s. In a departure from all previous workshops, the meeting did not begin with a review session of the past year's highlights.

In **1992** in Norman, Oklahoma, intraseasonal and interannual variability studies were highlighted by a session devoted to these topics. The workshop's multiple hosts were University of Oklahoma, the School of Meteorology, Oklahoma Climatological Survey, the Cooperative Institute of Mesoscale Meteorological Studies, and the NOAA National Severe Storms Laboratory. At this workshop the concept of a Constructed Analog was introduced.

The **1993** workshop was held in Boulder, with the NOAA/ERL Climate Diagnostics Center and the Cooperative Institute for Research in Environmental Studies of the University of Colorado as hosts. CAC's Bob Livezey wrote a dedication to the recently retired Ed Epstein, a long-time fixture of the U.S. climate scene. Poster sessions became a permanent part of the workshops, reflecting the growing interest in climate diagnostics and prediction.

The annual review of the past year's climate highlights, which traditionally began each of the workshops, returned to the agenda at the **1994** College Park meeting, hosted by the Cooperative Institute for Climatic Studies, Department of Meteorology, University of Maryland. Increased attention was placed on the detection of climate change. Sessions in reanalysis and ocean-atmosphere coupling reflected the growing emphasis in those areas, and predictability sessions claimed 13 presentations. CAC debuted its new long-lead forecasts.

In **1995** at the workshop in Seattle hosted by the Joint Institute for the Study of the Atmosphere and Ocean, University of Washington, Dave Rodenhuis' farewell remarks mentioned the "growth and excitement of a new understanding of global climate anomalies" during the 10 years he had been CAC Director. The name change to Climate Prediction Center, and a new method for presenting climate outlooks were noted. A session on tropical-extratropical interactions, one of which was chaired by Mike Wallace of the University of Washington, indicated the importance attached to this subject since the seminal paper on teleconnections at the 1979 workshop that he and Gutzler presented.

Earth System Science Laboratory at the University of Alabama in Huntsville hosted the **1996** meeting. Jim Laver, then Acting Director of CPC, stated that separate workshops on diagnostics and prediction or workshops with alternating themes had been considered, but that the final decision was to integrate the topics. The name changed to Climate Diagnostics and Prediction Workshop. The early sessions' focus was on prediction from Week 2 (7–14 days) to interdecadal as well as long-lead forecasts, experimental and operational. Sessions on use of satellite data reflected the focus of the work at the University of Alabama. There were more than 70 oral presentations and 32 posters.

The **1997** workshop hosted by the Program for Climate Model Diagnosis and Comparison, E. O. Lawrence Berkeley National Laboratory, Lawrence Livermore National Laboratory, University of California in Berkeley featured a special session on the life and work of Jerome Namias. Huug van den Dool and Don Gilman from CPC, Robert Haney from Naval Postgraduate School at Monterey, California, and Dan Cayan from Scripps Institution of Oceanography made the presentations. The major workshop topic was regional studies with sessions on the American and Asian monsoons and Global Energy and Water Cycle Experiment (GEWEX) Continental-scale International Program (GCIP). Discussions centered on the evolving El Niño and the upcoming winter forecast.

The 1997–1998 ENSO episode, its prediction, impacts, and its modeling received abundant attention at the **1998** workshop at the Rosenstiel School of Marine and Atmospheric Sciences, University of Miami.

The **1999** Tucson workshop, hosted by the Institute for the Study of Planet Earth and Institute for Atmospheric Physics, University of Arizona, experimented with 15-minute presentations (instead of 20 minutes) to accommodate the many oral presentations. Oral introductions to individual poster presentations were an innovation at this workshop. The U.S. Southwest weather and climate was a natural focus for three oral sessions and one poster session. Climate-related health problems are a concern in the Southwest, and the meeting included a session on that topic. The link between climate variability and extreme weather events was getting sufficient interest to warrant its own session.

In **2000**, the meeting returned to Palisades, New York, hosted by the International Research Institute for Climate Prediction, Columbia University. The "15-minute presentation" experiment was abandoned. The key sessions were on long-lead prediction on monthly, seasonal, and interannual time scales.

In **2001**, Scripps hosted the workshop for a third time. The opening sessions included an assessment of the 2000-2001 predictions (and beyond). Drought monitoring and prediction commanded its own session, and as did a special session on the North American Monsoon Experiment (NAME) chaired by CPC's Wayne Higgins.

George Mason University and Center for Ocean, Land, and the Atmosphere in Maryland hosted the **2002** meeting in northern Virginia. The recent U.S. drought drew several presentations. Decadal variability drew significant interest as did intraseasonal variability. The last day of the meeting was devoted to monsoons and North America Monsoon Experiment (NAME).

The Desert Research Institute in Reno, Nevada hosted the **2003** workshop. The focus of this workshop was on drought and monsoon systems, topics of importance to the western U.S. Interseasonal and interannual variability, both observed and in model predictions, were also a major focus of that workshop.

The **2004** Workshop in Madison marks a return to Wisconsin after 25 years.

CPC Partnerships

By Jim Laver and Daphne Gemmill

The task of understanding, monitoring, and predicting climate is enormous and requires national and international collaborative efforts. The CPC enlists the help of contractors, other NOAA components, federal agencies, international organizations, universities, and users of climate information to help achieve its mission. These partnerships will continue to play an important role in CPC's future. Some of the major partnerships are described below, although not in priority order.

Contract Support

CPC's current contractor is RS Information Systems, Inc. (RSIS). Prior to RSIS, other contractors included Research and Data Systems Corporation (RDC) and Scientific Management & Applied Research Technologies, Inc. (SMART). Contractor support greatly enhances CPC's efficiency and flexibility and helps keep the organization on the cutting edge of new science and technology.

RDC and RSIS (1989–2004)

CPC contracted with RDC for technical support in May 1989. Although CAC had had some small contracts with several companies, this marked the beginning of long-term buildup of contract support. In 2001, it awarded a contract to RSIS.

Initially, the contract tasks included research on inter-annual climate variations, and earth radiation budget and ocean data analysis, which led to the ocean data assimilation and coupled climate model. As CAC's research and products expanded, contractors provided support for surface rain gauge analyses, satellite rainfall estimates at various temporal scales and domain resolutions, global model development, model output diagnostics and applications, reanalysis, statistical forecasts, UV-B index forecasts, stratospheric dynamics and solar cycles, and surface/satellite ozone and temperature comparisons. With rapidly changing technology, contractors have more recently provided information technology support from system network maintenance and upgrade to configuration-planning assistance.

SMART (1990–1997)

In 1990, The Center contracted with SMART to work on Dynamical Extended Range Forecasting (DERF). SMART also provided materials and logistics for outreach meetings on the long lead predictions. By 1997, the budget "crisis" resulted in the termination of the SMART contract.

The Cooperative Institute for Climate Studies (1982–1997)

In 1982, Professor Ferdinand Baer, chairman of the Department of Meteorology at the University of Maryland, began negotiations with CAC and NESDIS to create a NOAA Cooperative Institute for Climate Studies (CICS) at the university. A year later, the parties signed a memorandum of understanding. Professor Baer became the Institute's first chairman. CICS and CPC collaborated on the Opsteegh-Van den Dool model (and its successors), which was used to study the impact of the tropics (OLR forcing) on remote locations through Rossby wave dispersion (Arkin, Chelliah). Other activities included the derivation of what became known as the Klein equations, and the beginnings of the use of soil moisture and constructed analogues (still in use at CPC today). The financial contribution of CPC to CICS became smaller over the years due to budget limitations and inflation, and the 1997 budget "crisis" terminated CPC's support. NESDIS continues to fund the Institute, and in recent years CPC has begun collaborative efforts with CICS and the Earth System Science Interdisciplinary Center (ESSIC) at the university.

NOAA Partnerships

The CPC joins with other NOAA offices to further climate research and forecasting capabilities.

National Weather Service (NWS) Headquarters, Regions, and Forecast Offices

The CPC works closely with NWS headquarters, and in particular with the Office of Climate, Water, and Weather Services' Climate Services Division (CSD). Over its brief history, CSD has worked with the NWS regions and CPC to improve NWS climate services. Examples include establishing climate focal points in each of the six NWS regions; developing formal training courses on climate topics; planning routine and special presentations on climate by CPC staff at regional meetings which include topics such as ENSO, drought, and seasonal outlooks; and organizing regional climate workshops to discuss plans for improving NWS climate services in the future. CPC works closely with the Pacific ENSO Applications Center (PEAC), located at and led by the NWS Pacific Region headquarters in Honolulu, to improve the understanding and quality of Pacific-related climate products for the Pacific Islands. PEAC reaches out to include collaboration with many other research and operational components in the Pacific.

National Environmental Satellite, Data, and Information Service (NESDIS)

For historical climate data and satellite data, CPC relies upon the NESDIS, National Climatic Data Center (NCDC), with which CPC has a memorandum of understanding. Real-time global satellite information from NESDIS is a critical component of nearly every monitoring and diagnostic product that CPC produces and delivers. The Regional Climate Centers, once funded through CPC and now through NCDC, play an important role in gathering and analyzing regional climate and weather information and the distribution of climate products to key users.

Office of Oceanic and Atmospheric Research (OAR)—Office of Global Programs (OGP), and the Research Laboratories

OAR supports applied research at CPC through proposals, resulting in contractor support of over $1 million per year. This research is for improved climate monitoring and forecasting on all time scales from next week to beyond one year. Some of the projects include atmospheric chemistry studies, the Network for Detection of Stratospheric Change, North American Warm Season Precipitation, GEWEX Americas Prediction Project (GAPP), Climate Change Data and Detection, and Climate Dynamics & Experimental Prediction. OAR research laboratory partnerships with CPC are discussed in other sections of this document. CPC partnership with the Climate Diagnostics Center (CDC) in Boulder, for example, has resulted in new research leading to better understanding of the impact of the world's oceans on drought and to improving the skill of Week-2 forecasts. CDC staff consults with CPC several times during the monthly process leading to the seasonal outlooks issued by CPC. Collaboration among CPC, Atlantic Oceanographic and Meteorological Laboratory (AOML), and NCEP Tropical Prediction Center and National Hurricane Center has resulted in six consecutive seasons of accurate hurricane season outlooks and a much better scientific understanding of the mechanisms that impact the hurricane season.

Interagency Partnerships

CPC collaborates with other federal agencies to develop and deliver products relevant to humanitarian relief, the status and outlook for worldwide agriculture, and improving remote sensing techniques and climate applications.

Agency for International Development African/Famine Early Warning System (AID/FEWS)

CPC delivers weather and climate monitoring, assessment, and prediction products to the AID/FEWS NETwork for the African continent, Afghanistan, and several Caribbean countries. AID/FEWS is becoming increasingly interested in a more global view.

National Aeronautics and Space Administration (NASA)

As a participant on joint science teams, CPC has worked with NASA in the following areas: improvements in operational and research satellite data; improvement in the NWS operational analyses; and improvement in understanding and predictability of subseasonal and seasonal climate variability. CPC is working with NASA toward a permanently funded, multi-agency supported, "reanalysis" or "Ongoing Analysis of the Climate System."

Federal Emergency Management Agency (FEMA)

CPC provides "heads-up" awareness of potential weather and climate hazards to assist in disaster preparedness through weekly briefings on Hazards Assessments.

U.S. Department of Agriculture/ NOAA Joint Agricultural Weather Facility (JAWF)

JAWF, composed of USDA and NOAA meteorologists and support staff, issue the *Weekly Weather and Crop Bulletin* and the weekly *U.S. Drought Monitor*. CPC staff brief USDA staff on global and regional weather and climate during regular daily, weekly, and monthly scheduled presentations, as well as in special circumstances, e.g., hurricane landfall and rainfall situations which potentially impact crop conditions.

U.S. Environmental Protection Agency (EPA)

Working with EPA, CPC develops, delivers, and improves UV Index and climate information for public health.

U.S. Department of Defense (DOD)

CPC provides the Department of Defense with information on international climate events.

Other National and International Partnerships

The CPC cooperates with other national and international organizations and countries on issues that range from operational products to applied research, including standards and bilateral agreements to improve climate product science and delivery. Some examples follow.

National Drought Mitigation Center (NDMC)

The, NDMC with CPC, NCDC, and USDA, has made an operational commitment to participate in the routine update and delivery of the weekly *U.S. Drought Monitor*. NDMC also provides valuable input to the *U.S. Seasonal Drought*

Outlooks issued each month, and works with national and regional drought interests to improve understanding and support for drought legislation, applied research, operational drought products, and national data critical to these items.

World Meteorological Organization (WMO)

CPC staff members have served on many WMO committees and working groups to address issues such as international data and product content, format and delivery, and prediction product and verification standards.

Bilateral Agreements

The U.S. has bilateral agreements with a number of countries where NOAA and CPC are involved. CPC is particularly active with China and Korea and has recently been developing new agreements with India and Viet Nam. CPC's focus in the China bilateral agreement is related to the climate and monsoons and includes visitor exchanges and applied research projects.

Universities and Other Institutions

The CPC has strong ties to the university community via interactions with cooperative institutes at several universities, and joint research opportunities for the North American Monsoon Experiment (NAME) and Applied Research Centers. CPC is grateful to the many universities and research institutions nationwide that have hosted CPC's Annual Climate Diagnostics and Prediction Workshops (see section on workshops, page 45).

International Research Institute for Climate Prediction (IRI)

The CPC relationship with the IRI is discussed in several other sections. It is built upon a common interest in national and international seasonal prediction, observing and predicting ENSO conditions, and international climate application development and delivery. In many ways the primary missions and objectives of CPC and IRI (e.g., operations and research) are complementary, and the collaboration continues in a process of periodic reviews. IRI and CPC staff communicate several times during the month in regards to the seasonal outlook issued by CPC.

Users and Decision Makers

Through workshops and meetings CPC works with users of climate information (e.g., energy, water resources, agriculture, insurance, disaster preparedness, weather risk management) to understand their product needs and ensure that climate forecasts and data are available, timely, and in a useful format. The NWS Climate Services Division has assumed leadership in this area, resulting in increased dialogue with users and decision makers and a greater determination and effort to focus on improving and developing products that are beneficial to them.

The CPC's Directors
In Their Own Words

Jay Winston (1979–1982)


Jay Winston

Early Climate Interest

My interest in long-range prediction was spurred in 1943 by Jerome Namias during my Air Force Cadet training at Grand Rapids, Michigan, where he was an instructor. Athelstan Spilhaus, Harry Wexler, and Lester Machta were also instructors. After World War II, I earned my master's degree at New York University, studying mean 5-day vertical motion. In June 1947 I went to work for Jerome Namias in the Extended Forecast Section. I was interested in the large-scale circulation, performed some analysis and research with hemispheric charts, and became a 5-day forecaster after about a year.

Participation in Early Planning

I think the idea for a diagnostic center originated with Joe Fletcher and Uwe Radok who were involved in the early planning for a "climate clinic" and a "diagnostic climate center." I was a participant at the important meeting in Boulder in December 1974 known as the climate clinic, a gathering of individuals interested in assessing real-time climate state and variations. As Director of the Satellite Laboratory, I could bring my experience with large-scale analyses of satellite data to the discussions. I was also active in the preliminary discussions in the mid- and late 1970s for establishment of a center, and was eager to be a part of it. However, as I was already Director of a laboratory, it did not make sense for me to give that up to be one of the "troops." Fortunately, I was offered the lead and accepted immediately.

Needs and Administrative Challenges

The major challenge when CAC was created was to organize it very rapidly, which we did—and to meld the various organizations into a working group. The pieces fell into place very quickly. There was a high level of esprit de corps as members were eager to be a part of the new organization. It meant renewed vigor for the extended prediction team, whose long-time leader and champion, Jerome Namias, had left in 1972. The issue of office space was one of the challenges, since CAC staff was housed on 3 different floors. Another impediment was related to staff travel, particularly to the annual climate diagnostic workshops, which were cosponsored by CAC. I considered it important that the primary organizer and sponsor have adequate representation at the meetings.

The Weather Service had an arbitrary rule that only a couple of individuals could travel to technical meetings, and I spent considerable time convincing Fred Shuman, NMC Director, to approve travel to these workshops for CAC staff, despite the fact that funds for travel were covered in the budget. Early implementation of a viable grants and contracts program was extremely important.

Major Impacts on the Technical Development

The establishment of a current climate data set was extremely important for CAC's startup activities. This was accomplished in a short period of time. Within two years the publication of a monthly *Climate Diagnostics Bulletin* had been accomplished under Gene Rasmusson's direction. In the prediction branch, Don Gilman was advancing toward replacing categorical forecasts with probabilities. In 1979, CAC assumed responsibility for conducting the climate diagnostic workshops, including the timely publication of the proceedings.

Since 1977 when it was held at the Scripps Institution of Oceanography, the workshops have been jointly sponsored by CAC and an external organization and hosted at the external cosponsor's site. A large emphasis was on the role of ENSO, and it was a topic of concerted effort at CAC. Art Krueger and I used satellite data to examine year-to-year variations in long-wave radiation and winds over the tropics. We made special note of the years when the cloud maxima were further east in the Pacific and comparing with the years when the maxima appeared in the West, relating that to Bjerknes' linking of the El Niño and Southern Oscillation in the late 1960s. I remember that Jacob Bjerknes visited NMC some years later, and we showed him differences from one year to the next; he was delighted to see what you could find in the clouds, something he had not observed before. We were studying some of those variations in the satellite data in the early 1970s.

Funding and Other Considerations

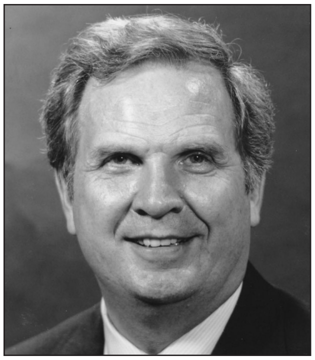
Financially, this was a secure period, with funding procured by the NOAA Climate Office under Ed Epstein. CAC had Weather Service support, although NMC Director George Cressman had no reason not to support it since he did not need to provide additional funds for its operation. On the other hand, the NWS had not fully accepted the climate concept. For that reason, the original concept of a diagnostic center was a NOAA unit under joint sponsorship of the

Weather Service, Data and Information Service, and the Satellite Service. While NWS management gave lukewarm treatment to ownership of CAC, Epstein finally decided that joint sponsorship was not workable, and assigned responsibility to the Weather Service. Seven years before the formation of CAC, the 5-day forecast responsibility had been moved to the Forecast Division of NMC. CAC absorbed the long-range prediction group with its responsibility for the monthly and seasonal forecasts.

Regrets and Unfinished Business

"One of the things we were trying to achieve was greater impact on public awareness of CAC's advisory capabilities. That has happened—it's almost overkill now. I think ENSO gets into the public medium, but may be played up too much now. The public certainly became aware of El Niño. The public now expects the outlook to be perfect."

James Rasmussen (1982–1984)



James Rasmussen

Early Career and the International Scene

I began my NOAA career in 1972 with the Global Atmospheric Research Program (GARP) Atlantic Tropical Experiment (GATE) Project Office led by Douglas Sargeant. GATE was a unique and massive undertaking sponsored by the World Meteorological Organization (WMO) and the International Congress of Scientific Unions (ICSU). My job title was Science Coordinator for the U.S. national program and involved cooperation and collaboration with the science and research teams from some 12 other nations who provided ships, aircraft, and personnel for the field experiment held during June to September 1974 and operated out of Dakar, Senegal.

I took over the task of directing the U.S. GATE Project Office soon after the field phase and led the office in undertaking the data management and research coordination tasks. In 1976 I joined the Joint Planning Staff for GARP at the WMO Secretariat in Geneva. The Staff was led by Professor Bo Döös and included a wonderful mix of people from all over the world (see article in the July 2004 *WMO Bulletin*). The major activity for GARP at that time was the extensive planning for the Global Weather Experiment [the First GARP Global Experiment (FGGE)] which was to follow GATE with the field phase taking place during calendar year 1979. FGGE was indeed a global endeavor and the GARP Joint Planning Staff became the international focus for the operations, organizing and monitoring activities and, if possible, suggesting corrections to the field experiment. My role was as Manager of the FGGE Operations Center—there were 10 or so people in Geneva monitoring operations, organizing and managing the logistics, and setting up radiosonde stations around the world. In 1980 Axel Wiin–Nielsen became Secretary General of WMO, and I took the post of Director of Program Planning and UN Affairs where I was involved in the early planning of the World Climate Program (WCP) which eventually would replace GARP in the WMO program structure. In January 1982 I returned to the U.S. in the capacity of Director of the Climate Analysis Center.

Taking the Reins at CAC

I succeeded Jay Winston who had organized and nurtured CAC and who made my first days on the job quite easy. Richard Hallgren was the head of NWS at the time and Bill Bonner was my immediate superior at NMC. I had some knowledge of the plans and the beginning phases of the World Climate Program and it was clear that CAC could play a crucial role, along with similar institutions in other countries, in developing the WCP.

CAC had three units: the Data and Information branch led by Fred Finger, the Diagnostics Branch under Eugene Rasmusson, and the Prediction

Branch under Don Gilman. The main thrust at the time was to begin to reach out and become more of a visible operational entity within the NMC framework. We sought the capability to provide access for users to real-time data and analyses, to build relationships to other institutions and programs, and to be a catalyst for furthering the understanding of monthly and seasonal climate diagnostics and prediction.

Arriving at CAC for the El Niño of 1982–1983

By the time I arrived at CAC, the 1982–1983 El Niño event had begun. That was the time of the famous paper by Eugene Rasmusson and Tom Carpenter (*Monthly Weather Review,* March 1983). What a heady time to step into a group that was new, had good ideas, and was having interesting discussions on just what they should be doing and how to do it! For example, the first attempts by Dick Reynolds to integrate satellite data with traditional in situ observations of sea surface temperature were becoming available—and demonstrated what now has become standard integrated analysis methodology. CAC had this prediction responsibility which was always a little bit of a mystery to me—I tried to understand that by going to Don Gilman's sessions where the four or five principal players including Gilman, Bob Livezey, Bob Dickson, Jim Wagner and others debated the evidence and eventually agreed on the prediction. The announcement of the winter forecast was beginning to be a relatively major media event and El Niño was beginning to be the hot topic.

External Partners and New Technical Directions

NWS wanted CAC to become more visible externally and connect with all the other groups around the country engaged in climate-related activities: the NOAA research laboratories, academia, and other agencies, such as NASA. CAC was nicely situated and structured to bring it all together, becoming the vehicle for exposing different ideas and analyzing climate variability in an integrated and collaborative way. It had the joint responsibility for both operations in its data and prediction services and in its diagnostic and research program.

The global perspective required for climate analysis and prediction nicely fit into the NMC which had as one of its responsibilities the operation of a World Meteorological Center for the World Weather Watch (WWW) Program of WMO. Through *The Climate Diagnostics Bulletin* and other cooperative efforts the opportunity to expose the emerging analyses from CAC was underway by the time I arrived.

On April 15, 1983, when it was obvious we had been in a huge El Niño episode, the staff gave me a copy of the special edition of the *Bulletin* signed by practically everyone in the organization. The *Bulletin* was, in an interesting way, the connection to all other parts of NOAA, other government agencies and the National Meteorological Services of other countries. One anecdote I recall was the reaction of the Australian Bureau of Meteorology when we had mentioned that the analysis showed a "drought" over large portions of Australia. This caused a bit of a flap since the term "drought" was a sensitive term used very cautiously in Australia because it triggered government action. We learned to stick to the numbers and let others use their own descriptive terminology.

That particular effort of attracting input from other groups in a non-threatening way served CAC and the science very well. Jim O'Brien of Florida State University would send his wind field analysis, Dick Reynolds was just cracking the nut of the SST analysis, the folks at Scripps were doing experimental forecasting, and we were doing the "official" forecasts. So the *Bulletin* allowed users of the information to compare and evaluate the diagnostics in a very open and straightforward way—something CAC accomplished to its credit, all the while keeping an open mind to others' input.

Toward the end of my tour at CAC we started to get the attention of NMC and GFDL with regard to integrating a numerical prediction model out for a longer period of time. In those days there was not a lot of computer capacity, everything was pretty tight, so it was a big commitment to undertake such an experiment. [ed. These efforts led to the Dynamical Extended Range Forecast program] I had meetings with John Brown and Norm Phillips of the Development Division who were not particularly confident that they would come up with anything, but they were willing to try.

The connection with GFDL was useful since the models, codes and computing systems were similar at both institutions and the GFDL scientists were eager. I suspect that bridge has been strengthened since Ants Leetmaa has led both institutions. It was our hope at the time to test a more objective approach to monthly and seasonal prediction to complement the subjective statistical one that was the only thing available at the time I was at CAC.

Role of CAC in the National Meteorological Center

We had good support from the Weather Service headquarters and we became a very visible part of NOAA, so we were not hidden in NMC. CAC was almost a separate entity in some ways, and Bill Bonner sought to integrate CAC as an effective component of NMC. Climate was a different animal, had a different set of clients and different external connections. Thus it was a little bit of fresh air for NMC too, because if one only does 5- to 10-day weather forecasts it is less interesting than if you expand to monthly and seasonal problems and the application of information to agricultural and economics sectors.

Expansion of Responsibilities and Capabilities

After 30 plus years of service in many different NOAA and international organizations, my memory of details of budget battles and organizational struggles has become a complete muddle! As I recall some new money and positions came in to CAC when I was there, associated with an agricultural initiative that was the outgrowth of a drought episode. Drought was a hot topic during those years as was the huge change in the ocean along the West Coast caused by El Niño (the warm water tongue extended far up the coast of the U.S. and affected the fishing industry). One of the interesting activities I became involved in was related to this. I had the opportunity to work with the political side of NOAA, the folks at the Department of Agriculture, and with the disaster preparedness people. The question was whether El Niño could be termed a natural disaster, because, if it was, all sorts of impacts could be realized, with attendant financial implications for making loans to the fishermen hurt by El Niño. We just explained the physical situation—there was no way for us to judge whether it should be considered a disaster or not—that was left to the politicians. Clearly the issues we were dealing with at CAC were becoming important issues for society, something that continues today.

In 1983 I was elected president of the WMO Technical Commission for Climatology (CCL), which afforded me the opportunity to represent the progress CAC was making nationally in the international arena. I remained President of CCL while I was the Director of the NWS Office of Meteorology until 1994 when I returned to WMO as Director of the WWW.

The Staff

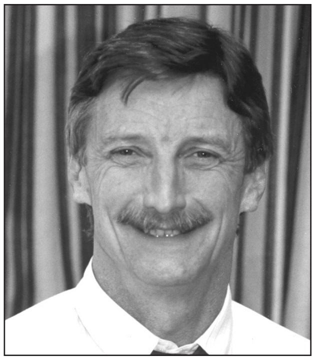
I apologize ahead of time for not being able to mention everyone who made CAC the wonderful place to work. However, a few names come to mind. I must mention Luke Mannello—every director of an organization needs a general manager: ordering a dedicated Xerox machine, ensuring the best price for printing, making sure everyone has adequate space and equipment , negotiating with the building management, tracking budgets and spending, etc. One might mention a problem or issue, and after a time, a proposal and solution would appear. Luke dedicated himself to CAC and I remember him with great fondness. Norma Jaxel was the administrative anchor point, a very pleasant and exceedingly competent person to work with, who led the small support staff.

On the science side we had an open office, and that made for a good exchange of ideas and critical analysis. Gene Rasmusson and Don Gilman had their own offices but everyone else was in the open space. I arranged for Ed Epstein to come on board in a special capacity as a senior scientist. He brought a wealth of experience and interests and contributed scientific guidance and ideas, taking the time to look at both the prediction problem and the diagnostics. CAC staff were congenial, cooperative, and most importantly, productive and in my opinion about the right size, from 30–40 people.

How did the prediction and diagnostics staff interact? Two "softies" such as Gene Rasmusson and Don Gilman would never rub against one another! There were good fundamental technical discussions and, I think, good science produced. Fred Finger's group (Jim Laver, Jim Miller, et al.) had offices on a different floor and this group in particular had interests in a lot of diverse things such as observing the ozone layer using satellite data and in the technical issues of radiosonde accuracy as well as the climate data bases and special products such as the Palmer Drought Index. The importance of these contributions became clearer to me after I left CAC.

I am sure that if I allow myself to sit and ponder my CAC years a bit longer I will recall any number of remembrances I could write about. It's best, however, to leave old retired warhorses alone to just graze and enjoy the fruits of the current generation's labors. I can vouch for the interest of the senior men's golf group at my golf club in the monthly outlooks as well as 1–5 day forecasts. They grudgingly agree the NWS products including CAC's products continue to get better.

David Rodenhuis (1985–1995)



David Rodenhuis

What a pleasure to be able to look back at the early years of development of CAC! Although I was not the first Director, I had the privilege of working with some very interesting people at the dawn, so to speak, of the revolution of awareness of climate variability and change. At that time I was thoroughly naïve regarding the bureaucracy of the NWS; worse, I didn't know it! Jim Rasmussen, the second "Chief of the Climate Analysis Center," recognized that I did not understand the political forces of the NWS and explained to me the modest role that climate should play in the broader context of the primary institutional preoccupation: modernization [sic], and public weather. Doug Sargeant took me aside and explained the necessity of engaging NOAA and turning their oceanographic aspirations into climate support.

From the viewpoint of Director Bill Bonner of NMC (NCEP), my employment was a sort of gamble on his part, I suppose. He had a preference for choosing "new blood" outside the government when a vacancy occurred. I had spent half a lifetime enjoying academic freedom at the University of Maryland, and he was not at all certain that I would succeed as a federal manager and public servant. His counsel was, "Don't screw it up!" This gives you some insight into Bill's confidence and into his belief that CAC was almost perfect as it was: Gene Rasmusson was a national figure on El Niño-Southern Oscillation, and Don Gilman as the only person in the scientific community who would regularly claim to forecast winter temperature and snowfall for the entire country. Moreover, he dared to conduct a national press conference on this subject—and got away with it! Jay Winston made substantial efforts to address climate issues with remote sensing data, and the monitoring of sea-surface temperature in the remote Pacific was a substantial accomplishment at that time. And, the gang from the Upper Air Branch led by Fred Finger gave breadth to a new CAC that extended from the ground (Jim Laver, climate applications) into the stratosphere (Jim Miller, ozone monitoring and stratosphere warming). There was even an CAC outpost at the Department of Agriculture—the Joint Agricultural Weather Facility (JAWF)—and one of the early dial-up climate information systems.

I was incredulous at the caution of Bill, and I could not absorb the wisdom of Jim. But it was clear to me, as well as to Joe Fletcher, who was the Director of ERL in Boulder, that a tidal wave of interest—scientific, public, and political—was already lifting "climate" out of the basement of statistical record keeping. I saw a tremendous opportunity for the NWS and NOAA to focus on issues, recruit scientists, and attract substantial funding. I thought this was obvious, and that the NWS and NOAA would be eager to support this new enterprise. Joe Fletcher was far more realistic. In retrospect, history has proved that everyone was right, only our perception of timing was different.

Within the NCEP family of divisions and centers, the Climate Analysis Center was described as "semi autonomous" compared to other centers that were closely tied to the mainline NWS mission of hurricanes, severe storms, and public weather. There were no regular staff meetings on corporate issues, but most division directors were quite cooperative in helping a center that was "collocated at NMC." We started out with our own research-funding program—about $800 thousand, I believe. And every year we had "our own meeting" (Climate Diagnostics Workshop) with the research community—from the universities, NSF/NCAR, NASA, the NOAA laboratories, and many international research laboratories—that continues to the present moment.

Mike Hall used the TOGA project office as a springboard for the Office of Global Programs and clearly saw the opportunity for climate studies. Further, he understood the cultural differences between NOAA and the narrow mission of the NWS. But our interests were also divided: his, on climate change, and mine in climate variability. There should have been a lot of overlap, especially on the ENSO studies and collaboration to engage NOAA on climate. I regret that we could not find a way to collaborate.

In this regard, several other players were Ken Hadeen, Director of the National Climatic Data Center, NESDIS/NOAA, and Ed Epstein and Alan Hecht, who were Directors of the National Climate Program with the fledgling Regional Climate Centers initiated by Stan Changnon. I hold Stan in high regard for his counsel and for his willingness to challenge the federal system and the private sector to improve their delivery of practical climate services, following in the steps of Helmut Landsberg, I believe. Two smaller groups also were part of the NOAA climate resources: the Assessment and Information Service Center (AISC/NESDIS/NOAA) in Washington, and the Climate Diagnostics Center (CDC/OAR/NOAA) in Boulder initiated by Joe Fletcher to ensure, also, that the NWS did not screw it up.

So, every line office, NOAA itself, and the nation had at least one center or office with a mission to address climate issues. And, I haven't even mentioned NASA, EPA, NSF/NCAR, and the university community. About this time the position of NOAA Chief Scientist was formed and was held for short periods of time by Bill Hooke and Ned Ostenso. With their help we came close to closing ranks a couple of times and worked together with a more unified purpose and collaboration on climate issues. Bill helped me organize the NOAA Review of CAC in which everyone I have mentioned participated along with all the NOAA Assistant Administrators. Subsequently, there were several meetings with Ned Ostenso in an attempt to take the next step and unify our work on climate (a scientific management council) that would attract resources, but in the end that was also unsuccessful.

CAC had the mission to monitor, diagnose, and predict the "climate," from the surface of the land and the ocean up to the high stratosphere, and from five days out to as far as credibility and resources would allow. And CAC had a nice mixture of experience and energy coming from the younger scientists to really develop the field.

Accomplishments

In an organization that is celebrating a record of existence of 25 years, it is hard to avoid the question of accomplishments. Those accomplishments inevitably depend on individuals, but each person plays such a different role, and the visible accomplishments depend on them as well. I think of Bob Churchill, Vern Patterson, John Kopman, and of course Jim Wagner. The more visible and corporate accomplishments always depend in an uneven way on the foundation of support as well as the inspiration of some thoughtful or energetic people. At this point I would especially like to recall the names of secretaries of that era: Gail Lucas, Kim Donaldson, Verna Michon, Peggy Davis.

Although there were some frustrations in the early years, they did not lead to failures, which would only become evident with the passage of time. In the middle of all the excitement there were a lot of technical accomplishments that can still be identified as notable. I am grateful for the opportunity to be close to these developments.

The remote sensing of sea surface temperature (SST) of the tropical Pacific in off-real time (monthly) was really eye opening at the time (Dick Reynolds, supported by TOGA Project). That led to moored buoys across the Pacific (McFadden; TOGA) and really increased our ability to monitor the most critical symptom of the Southern Oscillation. Remote sensing (NASA) also permitted extraordinary monitoring of Polar ozone depletion and graphically described the concept of an ozone "hole." Third, remote sensing was used to dramatically monitor drought (Tucker, NASA GFSC, FEWS Project) in regions where surface measurement (and water itself) were scarce; i.e., on the African continent. This was a factor leading to the creation of the African Desk at CAC.

Also during this time NMC began to experiment with desktop computing, while still depending on remote (dumb) terminals and 300 Baud modems to connect to the mainframe. I remember bringing the first microprocessor into CAC: a Sun, and then an Apollo processor. We hardly knew what to do with them! In reaction, one senior manager told me, "If you think there is going to be a microprocessor on everyone's desk at NMC, you're greatly mistaken." Subsequently the personal computer revolution, networking, and email did just that—all beyond everyone's imagination and anyone's hopes.

When I walked in the door, CAC could already claim to be a major player in the diagnostics of ENSO. Gene Rasmusson and his "young Turks" (Vern Kousky, Chet Ropelewski, Phil Arkin, and Dick Reynolds) were part of that breakthrough. Chet went on to lead the effort on empirical ENSO global impacts, Dick changed his initials to SST, Vern relentlessly churned out the

Climate Diagnostics Bulletin and documented every subsequent cycle, and Phil found a new frontier in the Office of Global Programs of NOAA.

The most provocative accomplishment that was truly owned by CAC was to make seasonal climate outlooks a year in advance. This has an interesting history, leading back to Jerry Namias who had passed the torch to Don Gilman along with the venerable Prediction Branch (Long Range Prediction Group). Their lab was filled with mysterious oversized books of historical analogues that were consulted each month behind closed doors by the high priests of the art. In a determined effort to develop improved forecasting techniques, Tony Barnston was a key figure, and we depended on Bob Livezey to search out the statistical significance in anyone's work. Even the thought of his challenge would often spur authors to do this dirty work of significance testing ahead of time. But the leadership for Long Range Forecasting was held by Huug van den Dool who developed the empirical basis for extended range forecasts of monthly and seasonal anomalies. He was not content with that and insisted that monthly outlooks should be true forecasts with the "lead-time" changed from zero to a week or more.

The path from subjective to empirical forecasting of monthly and seasonal climatic anomalies was stimulated by the thought that objective, physically based forecasts could be made for the same time scale. The DERF Project (Dynamic Extended-Range Forecasting) was organized through a joint effort of Climate Monitoring and Diagnostics Laboratory (CMDL), Climate Analysis Center, Geophysical Fluid Dynamics Laboratory (GFDL), and National Center for Atmospheric Research (NCAR) to attempt a numerical forecast of monthly mean state, and to sense the change of circulation regimes. Some additional support was obtained for this purpose, but the problem was too difficult. Eventually, controls of resources went over to the Office of Global Programs and were applied to other projects.

The empirical prediction work set a fast pace and a high standard, but the numerical prediction of climate anomalies was a great opportunity, but unattainable from where I was sitting. The difficulty was that the Environmental Modeling Center (the Development Division) held all the resources and their alumni were the Directors of NCEP. However, one day Ants Leetmaa walked in the door with a salary and position from AOML. He made the first attempts at CAC to numerically model the Pacific ENSO in the ocean that interacted with the atmosphere, and went on to make operational forecasts of ENSO impacts. This certainly must be recognized as first rank, albeit dangerous, work by Ants Leetmaa and his band. But for me the best moment was the day that Kanamitsu walked into my office and asked to join.

Eventually a different name was given to the Climate Analysis Center: Climate Prediction Center. The contributions of Don, Tony, Bob, and Huug with his forecasters of the Branch were the foundation, but Ants was also quite effective enrolling the capabilities of both the Diagnostics Branch and the Prediction Branch into numerical climate prediction.

The documentation of the Polar ozone hole through remote sensing was a joint effort of NASA and many others, but CAC was there. Jim Miller and Mel Gelman kept us informed. The "ozone hole" was just a piece of the big problem of global warming and the awakening of the green environmental consciousness. For that work I am exceptionally proud of the new concept of "near-real-time climate monitoring" that was used with the ENSO monitoring. That led to the monthly monitoring of global climate statistics, and then to climatic events, e.g., drought, on a monthly basis. But the really exceptional work was the *Annual Review* of global and regional climate anomalies, and drew on the input from a wonderful cross-section of national and international scientists. Chet Ropelewski, with his experience constructing the WMO Biennial Climate Review, and Mike Halpert were the first editors.

The Office

Certainly I was inexperienced in writing performance reviews or responding to budget pass backs. But that was not rocket science. Every year I would grab someone and write an "Initiative" for climate that would pass through the bowels of NMC, NWS, and NOAA. But not one of these ever was accepted. Most of the administrative work just took time, but required knowledge of CAC that could be produced quickly. In this regard, Luke Mannello and Gail Lucas were extremely helpful. Luke tracked the expenditures like a bloodhound and often corrected the NWS budget office when they got around to reporting at the end of the year. Gail knew the mechanics of CAC from working in the Diagnostics Branch, and kept peace and maintained a smooth operation, especially when I was off on an international trip to Geneva or Africa.

Of course, management of the budget was essential. I would urge spending down to the last dollar. Luke would humor me a little, but would always arrange to have a little reserve at the end of the year so that we never went into the red.

An interesting aspect of my new responsibility was spending the funds that we had on research that would invigorate and support climate monitoring. A solicitation and proposal-review process was organized that would support our decisions to fund extramural research.

In order to pursue the many technical questions in this new–old field of climate, we needed some supporting workers to off-load some of the work from more senior or energetic scientists in CAC. Of course, the staff positions were frozen and jealously guarded by NMC management. So, we started a support contract, but what a struggle that was to satisfy the paperwork demands of the Contracting Officer, "Rusty." Eventually, we had two contractors competing for our work.

Part of the support came from the "CICS Program"—a Cooperative Institute for Climate Studies—that was set up by Jim Rasmussen and Bill Bonner at the Department of Meteorology, University of Maryland. At first, this was simply a block grant (with NESDIS) for some joint investigations and a little extramural stimulation. I think it helped the faculty more than it helped CAC. But after the arrival of Huug van den Dool to the campus and then Lev Gandin (who actually worked for the Development Division), several graduate students began work at CAC, and the program became more substantial. As a former faculty member, I had an interest in the success of the program, and wrote an *Apologia* for CICS to stimulate the faculty to be more active (or appreciative).

One of the pleasures of leading CAC was the chance to create opportunities, collect a few positions, and hire good people. Not everyone you hire, of course, turns out to be what you expect. But the careers of several people (not mentioned earlier) have warmed me: Kingtse Mo, Rusty Martin, Lloyd Thomas, Gerry Bell, Muthu Chelliah, Jae Schemm, Dave Unger.

I directed most of my energy toward leadership challenges in climate and perceptions of opportunities—real or imagined. For example, the African Desk was initiated from "scratch" (with an idea; no funding). Subsequently, Wassila Thiaw took the lead and did a wonderful job to make it vital and sustain it against the forces of attrition.

There was also an opportunity to influence the international climate program at the World Meteorological Organization (WMO) during my time on the Commission on Climatology. The result was a new international climate applications program—CLIPS (Climate Information and Prediction System) Program. That effort was strongly supported by Marty Yerg in the International Activities Office of the NWS, and I made some extraordinary trips to Africa during that time.

I also tried to support the Working Group VIII (WG 8), of the U.S.-USSR Bilateral which was natural for me, after spending a winter in old St. Petersburg. The WG8 was a wonderful way to keep the technical exchange going during the cold war years. I enjoyed the company of many good people: M.I. Budyko, K. Kondratiev, V. Maleshko, and a host of others. I think the main consequence of that program was exhaustion of the KGB and the CIA keeping up with us, and a net transfer of data and scientists to the U.S.

Although CAC did not initiate the program, the Regional Climate Centers were "captured" from the National Climate Program just before Alan Hecht left for the EPA. There were a lot of challenges trying to redirect a very loose confederation of academics to become more responsive to national needs, as opposed to their obvious regional focus. The idea was Stan Changnon's but was an extension of the network of State Climatologists that Helmut Landsberg had started decades earlier. I spent many hours trying to figure out how to manage these mustangs without getting kicked by them, or by the NWS. Bob

Bermowitz was a steady and resourceful colleague, and Jim Laver also helped as the Deputy of CAC.

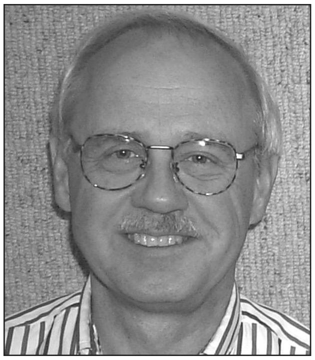
During the last years at CAC, Ron McPherson encouraged the applications of climate information and forecasts. This was remarkable, coming from the Director of NCEP, since this topic was more consistent with the historical roots of traditional climatology at NCDC or the thinking of Helmut Landsberg. I was frankly incredulous, since the NWS had been impervious to any previous proposal. However, I couldn't resist the opportunity to charge another windmill, and subsequently teamed up with Lev Gandin when I thought we might have sparked some interest.

At the very end, Susan Zevin from the NWS headquarters captured the attention of NOAA and discovered "climate" as her professional opportunity. Despite my 10 years of experience in the NWS, I saw opportunity where there was only political intrigue. Before leaving CPC, I was invited to report on our collective accomplishments at the Twelfth Congress of the WMO, and I left another manuscript with the NWS headquarters as a souvenir on my way out of town to Kansas City.

Conclusions

I am very grateful for 10 years of accomplishments, such as were possible, and an extraordinary time for scientific discovery: the ENSO, global climate anomalies, trace gasses and climate change, empirical climate prediction, global climate modeling and ocean-atmosphere coupled models reaching toward operational implementation. The challenges presented by the NWS and NOAA was sufficient for my struggle. Moreover, everything I learned was used again at the Aviation Weather Center, and in my present work at the Federal Aviation Administration (FAA).

I have to acknowledge, of course, that I was unable to substantially influence the NWS or NOAA on climate issues. Well, who can move heaven and earth? That which I am, I was. Subsequently, Bob Livezey is now doing his best in the NWS, and Ants Leetmaa has followed Mike Hall to do whatever is possible at NOAA. So, my personal objective is still achievable, but not by me. The numerical modeling of climate variability was also a lust of mine, and it is being accomplished now. Even so, it must meet the standards set by empirical prediction that have been set by CPC. This keeps reckless claims in check.


Ants Leetmaa

Ants Leetmaa (1997–2001)

Career Shift—Field Studies to Modeling

I received a doctorate in Oceanography from the Massachusetts Institute of Technology (MIT) and joined NOAA's Atlantic Oceanographic and Meteorological Laboratory as an observational oceanographer in 1977. It was a grand time, making new discoveries on every cruise, and getting to see the world. But in the early 1980s there was a gradual shift in emphasis in the world of oceanography from shipboard observations to moored buoys and from small independent programs to larger multi-institutional programs. Ocean modelers were also beginning to talk to observationalists and were having success in replicating not only the mean ocean circulation, but also its time varying aspects.

A simulation (which influenced my thinking and career plans) was that of George Philander and Anne Seigel for the 1982–1983 El Niño. Up to that time I was skeptical about models being able to replicate details of the ocean circulation. This simulation, however, appeared to capture many of the more subtle details in the eastern Pacific where I was doing field work. Also, I was ready for a career change. I had begun to wonder how one might approach doing a full ocean description in real-time considering the maturing of models and the basin scale observing program. I thought NMC might be an appropriate place considering that the classic work on the ENSO cycle of Rasmusson and Carpenter was done there, and they had a history of meteorological analyses, e.g., combining model and data fields. Gene Rasmusson, Norm Phillips (then at NMC), and George Philander helped convince Hugo Bezdek, Director at AOML, that at least a short-term move to NMC was a good idea. Rodenhuis was CAC Director and was a little nervous that this field oceanographer with no experience in numerical modeling could launch an ocean analysis program. I moved to CAC with the objective to develop a real-time ocean analysis capability.

Coupled Model Project Established

I began my ocean modeling and data assimilation work at CAC. In time this then became the foundation for a coupled modeling system for forecasting ENSO. After a couple of years the intense competition for resources and issues as to where modeling would be done in NMC led Ron McPherson, NMC Director, to create a special Coupled Model Project for seasonal forecasting attached to his office. McPherson helped assemble a staff by transferring five individuals from CAC and two from EMC into the project. Ming Ji, Arun Kumar, Dick Reynolds, and Diane Marsico came with me from CAC and John Derber and Ken Campana from EMC. Ming, Arun, and I put together a coupled model after two years of intensive work. Reynolds and Marsico performed the SST analysis.

It was a good coupled model competitive with anything in the external community. It was skillful in doing ENSO forecasts out to two to three seasons in advance and had a very good teleconnection pattern to the U.S. However, cultural and technical challenges remained as to how to get the model guidance into the official seasonal forecasts at CAC.

During this same period, CAC and the external seasonal forecasting activities funded by OGP diverged in their forecasting approaches. Dave hired Livezey and van den Dool, and the emphasis was on the development of statistical forecasting tools. That was a continuation of Gilman's approach. Even though we were on the same floor in the WWB, dynamics and statistics, like oil and water, did not mix well. McPherson liked this new modeling capability, and Rodenhuis had his people and their statistically based system. The rest of the world was moving on to dynamical techniques (at least for ENSO). After the Climate Model Project had developed and demonstrated the prototype forecasting capability, Ron decided to move it into EMC. I remained in Ron's office as de facto Chief Scientist for NCEP.

For the most part the Climate Model Project was funded by OGP at about $1 million per year. The NWS never contributed significant new resources since it was preoccupied with finishing modernization, and its commitment to climate was uncertain. During the four years I was CPC Director, I attempted to obtain the $1 million into our base budget from the Congress. I came close the first time when it was in the administration's budget, but a continuing resolution killed chances for new resources. Despite our successes with forecasting the 1997–1998 El Niño, NCEP never got additional resources from Congress while I was the Director; this only occurred after I left.

Cane–Zebiak Success and the IRI

Mark Cane and Steve Zebiak of Columbia University had a widely publicized successful forecast for the 1986–1987 El Niño event along with Tim Barnett at Scripps Institute for Oceanography and Jim O'Brien at Florida State University. This led to much discussion and enthusiasm for doing El Niño forecasting and the development of an improved capability for this. There was an interesting dynamic going on here, because I believe by this time OGP and the academic community had already begun to plan for an international research institute for climate prediction. Seasonal forecasting was a powerful new tool, and the academic side was thinking that rather than all the Weather Services of the world building their own forecast systems, there should be one place in the world where this is done—this eventually became the IRI. Plus they had little confidence that the operational NWS centers would step up to the task. Cane and Zebiak initially offered their model to us, but because we were building our own system, which could initialize the ocean forecast model and make global temperature and rainfall forecasts, we chose not to take this route.

My Directorship

Dave Rodenhuis left CPC in 1995, and the search for a new Director was on. I was not interested in the position, but I was frustrated with the lack of progress in the use of dynamical tools in the operational forecasts. I came around to thinking that if I were the Director that could be changed. As a Director, I had two main objectives: the first was to base the forecasts on physics, e.g., on an understanding of how the climate system worked. I did not particularly care how one arrived at the technique used to forecast the impacts, i.e., if there is an El Niño occurring, then determine the impacts based on El Niño rather than using statistical tools that combined a variety of sea surface temperature precursors. The second objective was to ultimately base the forecasts entirely on dynamical models. Nature presented an immediate challenge to CPC's traditional way of doing things as soon as I became Director.

By April–May 1997 we knew something major was happening with ENSO, e.g., a 100-year event was likely. We held a press conference with OGP. We recalled the major impacts of the 1982–1983 El Niño, and it was clear that the statistical tools were not up to the challenge of representing the projected impacts. CPC's standard procedures for that time produced rather a wimpy response, e.g., small shifts in probabilities in the Southeast and in the Pacific Northwest, but not in California and for the rest of the country. These were reasonable signals for weak events, but not for what we were forecasting. Extensive modeling studies suggested a robust response over the United States, especially in central and southern California. As the summer of 1997 approached, I knew that the appropriate forecast tools for the impacts of such an event were not available. I started working with Bob Livezey and Michiko Masutani on better estimates of the likely impacts. The subsequent forecast was highly successful.

The Flip Side of High Visibility

The high visibility that accompanied the 1997–1998 event, and the two following years, had its downside (especially since we did not receive any new resources). Whenever a major climate anomaly or event occurred, we would receive a call from a reporter who wanted to find out whether or not it was related to global warming. For CPC staff requests for information or an explanation of current events meant you had to temporarily halt your work (on the other hand it did make us think hard about how the climate system was working). So, in one sense, we were probably too successful. CPC became a primary source of information for climate variability; other centers such as NCDC were favored by the administration because of their interest in global warming. There was continual tension because of the national focus on global warming and the attempt by some to tie this to every major climate anomaly. In the end, the visibility and attention, which we actively sought to elevate CPC, wore me down.

Taking The Show on the Road

We began to see that our message was getting lost during this time when the large climate events were being linked to global warming. Whereas for the press conference announcing the 1997–1998 event only Mike Hall and I were available, now the list of "experts" could include the Vice President, the Secretary of Commerce, the head of NOAA, the head of the NWS, and perhaps someone from CPC. Climate was big news. We started to channel a lot of our energy in going out into the field and preparing material for local/regional press conferences. The time we spent in the Regions and with the local press paid off tremendously. The field offices were very interested in these activities and it was a great way to reach a broader community than that inside the Beltway. The NWS now has dedicated climate specialists in the Regional Offices and, I think, in the Weather Forecast Offices; Bob Livezey has played a major role in this. There is a real explosion in getting the message out, engaging the rest of NWS, and laying a cornerstone for a national Climate Service

Regrets and Unfinished Business

Despite the successes or perhaps because of them, things started to go awry. At the highest level in NOAA it was not obvious that the NWS was ready to take on climate in a serious way, e.g., climate was still one of its lowest priorities. At the lowest level, the feeling was that NCEP could use the same identical model for weather and climate forecasting. On the other hand I had come to the realization that the forecasting tools we needed had to combine both the impacts of climate variability and change. It was not obvious how that was going to happen at NCEP. All this put a lot of stress on the individuals involved in development of the dynamical climate forecast system. When Jim Baker, the NOAA Administrator, asked me to become Director at GFDL, the decision to leave CPC was not easy. Yet in the end, a need to have a seasonal forecast system, which can handle both climate variability and change, made the move to GFDL the only logical decision.

Jim Laver

Jim Laver (2002–Present)

Each of the four distinguished gentlemen who served as Director before me came to CAC/CPC as the new "Director." Since I have spent 32 years with NMC/NCEP and all 25 years with CAC/CPC as it evolved, I have had the unique opportunity to work for and with each of them. Working with the previous Directors was very interesting, educational, and very much broadened my approach to science and leadership. My perspective is also tied to many of the CAC/CPC activities in the history above, and I consider it a great privilege to have the opportunity to play a role in integrating our past and shaping our future. Below is some personal history before and during the CAC/CPC years, which leads up to the unique situation in which we find CPC today. A brief section follows on "CPC's Future."

Early Career Leading to the Climate Analysis Center (CAC)

My NOAA career began in autumn 1972 after nearly four years on active duty in the Air Force, forecasting for worldwide missions and exercises. As a student, and before being hired by NOAA, I had some exposure to U.S. Geological Survey (USGS) stream gauging and air pollution measuring. I was interested in just about any aspect of the environment from the tropics to the Arctic, but knew little of the oceans and their influence on the atmosphere. I was hired in late 1972 as a stratospheric researcher by Fred Finger, Chief of the Upper Air Branch in the Development Division (DD) (Director John Brown) of NMC.

During my first week, Mel Gelman showed me how we could analyze the northern hemisphere at 5hpa and 2hpa (we called them millibars in those days) with a handful of rocket observations. I did some work categorizing stratospheric warming events, revising the hemispheric Cressman analyses system for the stratosphere (100-10 mb), processing and analyzing rocketsonde data, and developing atmospheric profiles for several NASA experiment teams.

Successful people often have one or more mentors during their career, and while I have had several, Fred was my mentor in NOAA (see In Memoriam, page 103).

The CAC Years

In the late 1970s, when personnel assignments were under review for the proposed Climate Analysis Center (CAC), Fred Finger told me that several key individuals from the Upper Air Branch were being considered. Fred was concerned about losing some of his best talent. Fred said to me later that he spoke to Fred Shuman, NMC Director, to suggest that his entire branch be transferred to the new CAC. I assume Jay Winston agreed; eventually all the members of Fred's Upper Air Branch of the Development Division, NMC, became part of the CAC.

The AIB served as part of the CAC nucleus for operational global land surface data and monitoring, and was particularly customer-oriented. AIB also assimilated some data and delivery talent from other parts of NOAA, individuals who had experience collecting and quality controlling global surface data. The AIB also included a group who worked on-site at USDA providing crop-related information to the World Agriculture and Outlook Board. This group became known as the Joint Agricultural Weather Facility (JAWF) and grew from about 3–4 in 1979 to 6–7 in the 1980s.

Most of my work in the 1970s and early1980s involved practical applications. I attribute some success to thinking positively, anticipating a wide range of new opportunities in both the Upper Air Branch and later the CAC/CPC, listening for the "big picture" issues as well as for details and for finding ways to make problems or demands a win-win situation.

I benignly "infiltrated" each component of Fred's branch—stratosphere, global monitoring, JAWF—offering to resolve problems related to products, budget, staffing, communications, and hardware and software support. The "chemistry" was right and in those days promotions were possible through "accretion of duties," and I reached the GS-14 level in AIB before being selected by Dave Rodenhuis as the AIB branch chief. (One of the challenges for current CPC managers is the general inability to promote based on "accretion of duties." Currently nearly every advancement or "promotion" results from applying for "vacant" positions.)

Through the early 1980s, many AIB folks (including me) were not completely familiar with the Diagnostics Branch and Prediction Branch activities, and we had few cross-branch interactions. However, we had a great respect for Don Gilman, and for Gene Rasmusson, and the folks he hired.

Climate Services and Lack of "Guidelines"

In hindsight, the three CAC branches—Prediction, Diagnostics, Analysis and Information—were individually successful, but remind me of the current challenge of integrating the line office "stovepipes" in NOAA into the "climate matrix." Each branch had its idea of "climate services" and others inside and outside NOAA had their own definition as well. (Some "old timers" will remember a famous "memo," in which one prominent figure from the research side of NOAA claimed sole understanding of the real meaning of climate services.) Fred Finger was a very positive, service-oriented leader, who believed in giving customers what they wanted, so we did exactly what we thought was best for NOAA, and met with little resistance. There were few detailed guidelines for providing climate services in the NWS—neither station duty manuals nor detailed NWS "Directives."

CAC/CPC Deputy Director Years

In early 1994 Dave Rodenhuis asked me to serve as his deputy. I was a bit surprised, but not prone to turn down such a challenge—I was the second lucky fellow to hold that job. When Dave left for the Aviation Weather Center about a year and a half later, I stepped in as Acting Director. After about 18 months, significant budget cuts, and wrestling with a reduction-in-force aimed at about 10-percent of our federal work force, Ants Leetmaa was welcomed as the Director. When Ants left for GFDL in early 2001, I again became the Acting Director until my permanent selection in early 2002.

Size, Capability, and Success of the CPC Workforce

Our federal workforce is now restricted to about 50 full-time employees, of which approximately a third have doctorates. This is complemented by over two dozen full and part-time contractors supervised by one of the best scientist/managers in the business—Dr. Shi-Keng "SKY" Yang. We also are fortunate to have a senior UCAR scientist, Wassila Thiaw, leading our African desk effort, and part-time support from the ESSIC/UMD Deputy Director, Phil Arkin. I remember Dave Rodenhuis had an interesting technique for counting the staff we acquired, and eventually lost. He once proved on paper that we were entitled to 64 full-time employees. In spite of the decline, CPC remains one of NCEP's largest centers.

CPC's success and reputation is heavily dependent on our strong, talented, creative, and aggressive workforce—including our contractors. Of course, past Directors and past and present Branch Chiefs and our Contract Supervisor have helped bring out the best in that talent, as well as having provided good management and encouragement. The current senior leadership in CPC—Kumar, O'Lenic, Kousky, Higgins, Miller, van den Dool—are extremely productive and talented and are a pleasure to work with. That is also true for our workforce. Ants Leetmaa left CPC with a broadened product suite and a very much-enhanced reputation. I did not expect to "fill his shoes," but rather to build on what he had done. CPC staff has risen to the challenge of creating new products, new verification schemes, and new diagnostics and prediction tools, as well as making sure the much broadened CPC operational product suite is delivered on time—including weekends.

NOAA Leadership Support and Partnerships

A part of our science community believes NWS may not sufficiently support "climate," and NOAA may need a climate line office. I invite those folks to (re)read the preface to this document, read the material below, and visit NCEP and CPC. The support for climate, in NCEP, NWS and NOAA, has never been better—and it continues to grow. The NWS, under Jack Kelly, not only embraced the “seamless suite” of forecast products ranging from minutes to seasons, but also has incorporated “climate” in the NWS mission statement. The new NWS Director, David L. Johnson, is also a strong advocate for continuing the expanding role of climate in NWS. The NWS’ relatively new Climate Services Division (CSD), led by Bob Livezey at NWS headquarters, has made great strides in linking the work of CPC with the NWS regions, and thus the local Weather Forecast Offices throughout the U.S. CSD and CPC have developed and conducted training courses where dozens of NWS field staff have come to learn how we deal with climate—in partnership. Each NWS region is conducting climate workshops and has identified climate focal points at regional headquarters, and will soon have climate focal points in each WFO.

The NCEP Director and the NCEP Centers, led by Louis Uccellini, enthusiastically support climate. The NCEP and NWS Directors are fully engaged in every significant climate event from drought, to ENSO predictions, U.S. seasonal outlooks, and hurricane season outlooks. For example, this year Louis gave congressional testimony on drought in the western U.S. He has done more than just encourage EMC and CPC to develop a Climate Test Bed to accelerate progress in climate prediction on all time scales. He has challenged CPC to lead the effort, in close collaboration with EMC, and he has worked with OAR/OGP to develop initial funding and support that will lead to collaborations with NOAA laboratories and the external community. In August 2004, EMC and NCEP’s Central Operations (which includes supercomputer support) operationally implemented a new “Climate Forecast System” that provides an opportunity to take the next giant strides in improving sub-seasonal and seasonal prediction. CPC is planning new projects with each NCEP Center to link and integrate climate and weather.

I believe the NOAA “climate matrix” approach is working well under NOAA Climate Office Director Chet Koblinsky, who also serves as acting Director of OAR’s OGP. The cooperation between CPC/NCEP and OAR/OGP is now the best that I have experienced.

There has been terrific support for operational and development climate supercomputing from NCEP’s EMC and Central Operations, as well as from NOAA funding. The recent climate model implementation required approximately 3000 years of historical model runs, and the Climate Test Bed will need growing computer resources. These and other demands have led the predictions and projections component of NOAA’s climate program, under Ants Leetmaa’s leadership, to request additional supercomputer resources for FY07–FY11.

Partnerships are critical to the success of climate in NOAA, NWS, and NCEP, and are discussed in a separate section (page 51). This leads into CPC’s future discussed in the next section.

CPC's Future

Challenges and Limitations

How much improvement can we expect in the sub-seasonal, seasonal, and multi-seasonal forecasts for temperature, precipitation, and drought? Can we deliver probabilities of extreme events which are useful to decision makers? How much prediction potential is there in the summer and fall for next winter's favored jet stream patterns? Can we predict the impact of ENSO and MJO events on weather-climate means and extremes? Is the climate changing permanently in some areas of the globe, and what are the climate cycles, drivers, and interactions yet to be discovered? How far can coupled ocean-atmosphere climate models take us? Can we deliver products that are more valuable for decision makers? Can we develop better measures of performance and analyses of cost-benefit for climate products? Can we recruit, retain, and partner with the most talented scientists and support staff, and will our progress be measured only in small increments, similar to weather forecasting improvements, or can we expect some major breakthroughs in climate? Will a potential national budget deficit environment in coming years significantly hinder our progress in climate? These are some of the probing questions and challenges at the heart of CPC's future.

The Current Environment—Support and Partnerships

The recognition of the importance of climate across NOAA is now much stronger than ever before. The agency support of climate has also led to a much tighter coordination of climate in NOAA– from the leadership of NCEP and NWS, to NOAA headquarters and the NOAA Climate Office. We are witnessing a time when the willingness to work in partnerships is paying dividends. The NCEP Centers, the NWS regions, the OAR laboratories, the academic community, and the private sector will share in the progress. CPC will continue to do its part to sustain a very positive environment of support and partnership.

Reasons for Optimism

A discussion of CPC's partnerships appeared in an earlier section (page 53). However, a few examples of pushing-the-science-envelope through partnerships will help illustrate our reasons for optimism regarding the expectations for continuing and accelerating improvements in climate prediction and monitoring. The list of examples does not indicate any particular priority:

Climate Test Bed

The goal of this project is to accelerate the transition of research and development into improved NOAA climate forecasts, products, and applications. The collaboration among CPC, EMC, OAR/OGP, OAR laboratories, and the external community will accelerate our attack on the climate prediction problem on all time scales, with emphasis on dynamical coupled model applications and development.

North American Monsoon Experiment (NAME)

NAME is a relatively new and exciting international experiment aimed at improving the prediction of warm-season precipitation over North America. The field campaign concluded during the summer of 2004. NAME has established an effective collaboration of the research and operational communities, with the NWS/NCEP, NWS regions, OAR laboratories and OAR/OGP, several universities, and the Mexican Weather Service being among the participants. Years of productive research will result from the rich databases resulting from NAME.

New Climate Forecast System (CFS)

The CFS was implemented on August 24, 2004, by the NCEP Central Operations unit, following development by NCEP/EMC, and includes an ocean model developed by OAR/GFDL. With its realistic and non-biased long-term simulation of ENSO, and its stability without introducing "flux corrections," the model is a breakthrough providing a new potential for progress in seasonal to interannual prediction. This model will be a major focus of the Climate Test Bed.

Reanalysis

Many government and academic scientists and managers have recognized the need for an "Ongoing Analysis of the Climate System." Resources to embark on this program have been proposed in the FY06–FY10 NOAA budget plan for support of this program with NASA and DOE. The program's objective is to deliver a periodic updated analysis using many sources of data from the Global Earth Observation System of Systems (GEOSS).

Supercomputer Power for Climate

NOAA's annual support ($5 million) for the climate component of the NWS supercomputer and additional support for the backup supercomputer, guarantee much needed processing power for seasonal to interannual climate prediction. Additional NOAA-wide climate supercomputer funding is being considered in the NOAA FY07–FY11 budget.

International Humanitarian Support

Collaboration between CPC and the International Research Institute (IRI) for Climate Prediction at Columbia University has been important in optimizing humanitarian support to the U.S. Agency for International Development (AID) in south central Asia (Afghanistan). Routine support is also provided to U.S. AID for Africa, with special requests for detailed weather and climate forecasts for the Darfur, Sudan, and Chad crises-related areas, as well as for Haiti and parts of the Caribbean. In order to fully support the growing demand for international climate information and predictions, CPC and IRI have developed a memorandum of understanding.

OAR Climate Diagnostics Center (CDC) Partnership

During the past year, collaboration between CPC and CDC has resulted in: improved NOAA-wide support for permanent funding for a future, ongoing reanalyses, an internationally recognized joint publication on the influence of the oceans on drought, and a model bias correction approach to be implemented in late 2004 that promises a significant increase in skill for CPC's Week-2 forecasts. Talented researchers at CDC provide a constant stream of new approaches for improving predictions on all time scales.

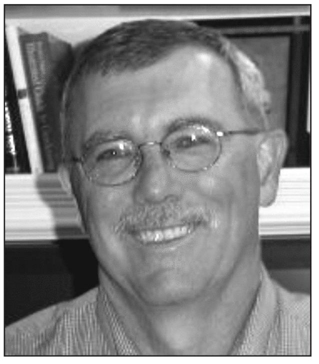
The Coming Decades

I believe we will create more opportunities for support, collaboration, and partnership, such as those cited above, in the coming years. If we order our priorities wisely, continue building solid relationships with our partners, improve our understanding of the needs of decision makers, keep up with technological advances, and recruit the best and brightest federal and contract staff, we increase the potential for climate predictions to be nearly as reliable and applicable as weather predictions in the coming decades. The environment has never been better for CPC's current staff and leadership to make progress in climate analysis, diagnosis, and prediction. We have an obligation to maximize that progress, and provide a solid "hand off" to the generation that follows.

CPC's Staff Reflections: In Their Own Words

History is defined as "the chronological record of events as of the life or development of an institution, often including an explanation of or commentary on those events." The people who were part of that institution give a human face to the record of the past. The current CPC staff, contractors, and consultants plus a few former staff share remembrances of their years working to improve climate analysis, diagnostics, and prediction. Staff from 1979 to 2004 and current contractors and consultants are listed on pages 101–102 (photographs from 1991 and 2004 on the inside back cover).

Phil Arkin

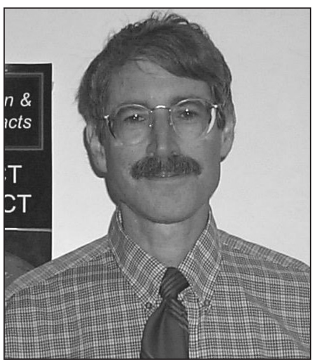

Phil Arkin

I arrived at CAC on May 7, 1979, bringing with me two projects: analysis of the GATE satellite data and comparison with the radar rainfall data, and analysis of the tropical strip winds and OLR that had been produced by Jay Winston's group in NESS. The results of the satellite analysis were successful and led to the establishment of a project to collect the data needed to calculate the GPI, which eventually grew into an important part of the Global Precipitation Climatology Project. I was made the initial Project Manager. The tropical strip analysis was limited. One day Gene Rasmusson brought me a piece of tablet paper with the Lorenz block diagram on it, the one that shows the energetics of the general circulation in terms of the mean and eddy components, and said that he wanted to be able to calculate the various terms. I wrote the code to create the Climate Diagnostics Data Base, which made that possible, and that eventually provided a lot of the atmospheric part of the *Climate Diagnostics Bulletin*. In June 1986, Gene retired, and I was named Branch Chief. Things went along smoothly, but without a lot of innovation that I can recall, until I decided at the end of 1989 to move to OGP to try program management. Chet then took over, and away they went.

Anthony Artusa

Anthony Artusa

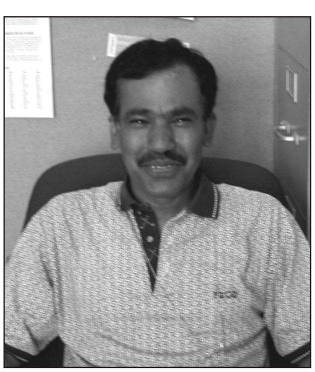
My 15 years with CPC have been a very good and very varied experience. From short-term climate and weather-related hazards forecasts to computer programming to an occasional presentation, I have learned a lot about the global climate system, and hope that my contributions have made a difference for CPC as well as for our users. Our work environment has constantly changed, both in terms of the technology and also in our responsibilities, which brought many challenges.



Tony Barnston

Tony Barnston

I would like to thank the following people for enabling my career at CAC to blossom: Bob Livezey, Don Gilman, Huug van den Dool, and Dave Rodenhuis. Those four people accomplished a bending of the rules to allow me to work 70 hours a week, but the 70 that I chose—mainly non-business hours. With the backdrop of a mainframe computer that jammed up daily, and daily office conditions that afforded so many opportunities for distraction, working off-hours was essential for significant achievement, particularly before 1993. If it were not for this administrative flexibility, my paper with Bob Livezey on 700mb monthly EOF patterns probably would have contained only one-third as many modes, my paper with Huug van den Dool on a degeneracy in cross-validated regression probably would not have existed, and my tailoring of the Barnett and Preisendorfer CCA method to the seasonal forecast operation would have gone through a much skimpier series of trials before establishing of the optimum predictor selection and design and optimum packaging for the forecasters. My sincere thanks goes to the four above-mentioned bosses. They found creative ways to solve stubborn problems by pushing the administrative envelope to the nth degree.



Muthuvel Chelliah

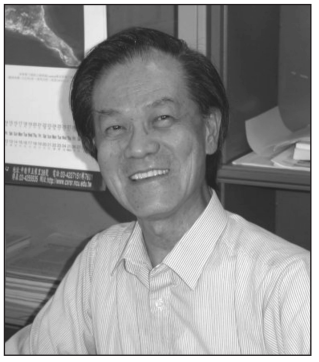
Muthuvel Chelliah

I joined CAC in 1988 as a contractor and in 1994 as a civil servant. I believe I was the first contractor hired. Soon after I joined, I felt privileged when I was asked to do the "monthly–seasonal climate briefing" for a season, a task usually assigned to civil service meteorologists' at that time. I remember vividly when I got a call from the Director, now my friend, who spent half an hour telling me how I could improve my work in so many thousand ways. When I was working on my doctorate (1985) at the University of Maryland, and then later when I was a Research

Associate at the CICS, I had several opportunities to visit CAC to meet with Huug van den Dool, Phil Arkin, John Janowiak, and others, and I used to think to myself, *enough with the modeling stuff (what I was doing then), CAC is the place to work where there is real data, real stuff, and real forecasts.* In the late 1970s, before my entry into the meteorology field, while going for my first interview at the Indian Institute of Tropical Meteorology, I was delayed several hours because a powerful tropical cyclone (so called in India) had just made landfall. There was so much loss of life and devastation. While sitting in the train for hours on the way to my interview, I wondered *why can't people predict these!* What an irony!

Wilbur Chen

The daily ordeal traveling from Rockville to World Weather Building and back was a drag till Dr. Cressman joined the carpool. It took the "Cressman's Analysis" to wipe out all the boringness of the snarling journey. It was certainly a great privilege to be so close to a giant such as Dr. George Cressman.

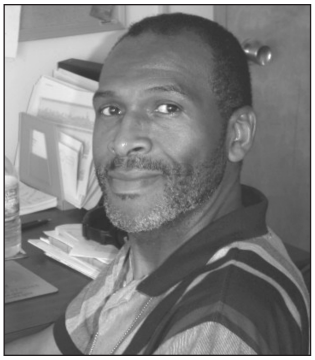


Wilbur Chen

Bob Churchill

My years in CPC started in 1979 or 1980. I was in the Space Flight Meteorology Group in Washington. In the late 1970s, NASA allowed each center to select its weather support structures. At that time, KSC opted to use the USAF for weather support. JSC opted to retain the National Weather Service for weather support services, and the Washington Branch was disbanded. I was then assigned to CAC. One of my first responsibilities was to maintain and update meteorological and climatological products and data sets, later known as the Climate Data Base. The CDB became more automated, and my job switched to quality control. We wrote programs comparing synoptic and airways messages, and I would make decisions on what was correct. I also did the weekly and monthly graphics in the *Weekly Weather and Crop Bulletin.* I would come in on a Sunday, do the analysis, and mail to JAWF. For the *Bulletin,* I was responsible for the United States Climate message which consisted of monthly climatological parameters. I also quality controlled international CLIMAT messages, updated the data into the CDB, and worked on computer graphics (El Niño, La Niña, Seasonal Outlooks, and Hurricane Outlooks).

George Fulwood


George Fulwood

I joined CAC in 1983 as a mathematician and computer programmer when our mainframe was an IBM 360/195. I worked with Vernon Patterson on our daily global precipitation and temperature processing system, which evolved into our Climate Assessment Data Base (CADB), a principal source for short-term climate monitoring. I also inherited the growing degree-day program from Billy Struble of the Automation Division. Along with Vern, Bob Churchill, Joanna Dionne, and David Miskus, we've seen our processing move from the IBM 360/195 to the NAS9000 (a nightmare due to storage differences), to the Cray where our processing was on fire (really) to an SGI and now back to an IBM-SP. Along the way we grasped terms like VSAM and rba's, bufr and grib, and began to express disk-space usage in megabytes, gigabytes, and terabytes instead of tracks and disk packs! A request and reply (bulletin board) system was designed and implemented (under Fred Finger) before posting products on the web became the rage (under Dave Rodenhuis). I've outlasted two Directors (Rodenhuis, Leetmaa). I've seen Dave become a section chief at JAWF, Joanna move to headquarters, and my tag-team partner and graphics champion Bob Churchill retire. I have become responsible for the CADB. I have also outlasted a good friend, excellent programmer, and mentor, Vernon Patterson, who passed away last year. Vern was a major contributor to our data processing and a major architect of the CADB.

Mel Gelman


Mel Gelman

I began my meteorological career in October 1965 with the Upper Atmosphere Branch of the Atmospheric Analysis Laboratory, the original stratospheric group that in early 1966 formed the Upper Air Branch of the Development Division of the National Meteorological Center. My original assignment was to develop techniques and perform subjective hand analysis of stratospheric temperature information from 5 up to 0.4 hPa (35–55 km) from meteorological rocketsondes and radiosondes. With the formation of CAC, the group's expertise was incorporated into the Analysis and Information Branch. Among my many interesting assignments, I contributed to the international assessments of ozone, climate variability and change, provided to NASA temperature and wind information along the trajectory of the returning space shuttles, and for DOD provided atmospheric information relating to effects of the atmospheric variability on re-entry vehicles. I spent a month in Dzambul Kazakstan as leader of the U.S. group in the International Radiosonde Intercomparison and have served on many committees in developing and using stratospheric information from rocketsondes, radiosondes, and satellite instruments.

Daphne Gemmill


Daphne Gemmill

Seven years ago I accepted a detail to CPC to help the Director with outreach efforts during the 1997–1998 El Niño. Working for CAC had its humorous side. Both Dave Rodenhuis and Ants Leetmaa managed to attract the attention of the Florida Tourist Board when they predicted abnormal temperatures for Florida for the winter season. Dave had a lengthy press interview, and the only quote was that given the above normal forecast for the winter, his mother would not have to worry about him wearing his long underwear. They soon learned that they had to be careful what they said to the press. Then there was the tornado warning, and we were to evacuate to the stairwells. Given the building is full of weather junkies, everyone ran to the 8th floor to watch for it. I found a party on the "safe" second floor where everyone was watching a large-screen monitor of the storm's development and eating popcorn and cookies.

Mike Halpert

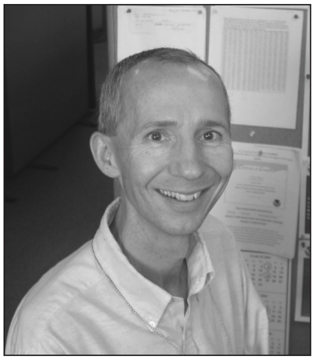

Mike Halpert

I began my career as a student for four summers during the early 1980s, working with (for) Chet Ropelewski on the 6th floor of the good old World Weather Building. More than 20 years later, I still find myself on the 6th floor, albeit on the other end. I can just about imagine the changes that have taken place through the years, but surprisingly it can't be done. I was involved in some very significant El Niño research during the early part of my career (thanks Chet), and spent a fair amount of time working on Climate Assessments. After 15 years, a move to the Operations Branch helped to rejuvenate my career, as a change was in order. Throughout my 20+ years, doing research, assessments, and now operations, I have been fortunate to have spent time working with quality (and some fun) individuals, making CPC an enjoyable place to work.

Tom Heddinghaus


Tom Heddinghaus

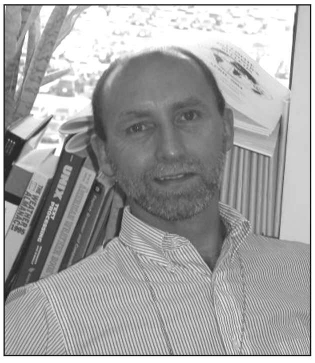
During my tenure at CPC, I implemented weekly *Palmer Drought and Crop Moisture Indices* for hydrological and agricultural monitoring. I also developed heating and cooling degree-day programs for energy monitoring and created weekly Palmer Drought, heating, and cooling degree-day forecasts along with four-month probability projections of the *Palmer Drought Index.* I produced daily near-real time U.S. climate division temperature and precipitation values for use in NCDC climate rankings and various indices and products.



Wayne Higgins

Wayne Higgins

During my 10 years at CPC, I have witnessed a revolution in the public's perception of climate's role. This is due, in part, to increased understanding of the influence of climate variability (e.g., ENSO) on the weather patterns that affect our daily lives. I believe that much of the credit for this goes to CPC, whose exemplary managers and top-notch scientists have molded the climate agenda, produced the products and services, and communicated with the public. I have no doubt that CPC's role in this process will continue to expand in ways that may take us down unfamiliar roads. But CPC is up to the challenge. On a personal note, I particularly want to thank Chet Ropelewski, for inviting me in, Ants Leetmaa, for teaching me the fundamentals of scientific leadership, Jim Laver, for showing me that it is possible for one person to do the work of 100, and Vern Kousky, for countless stimulating scientific discussions through the years.



John Janowiak

John Janowiak

I feel privileged to have worked for most of my career at CPC (since 1981), shoulder to shoulder with so many bright, energetic, and agreeable people. I am grateful to have had the opportunity to explore interesting avenues of research, always knowing that my interest would be cultivated within CAC and that I could rely on my peers for constructive and honest advice. And while this engendering spirit has been a constant at CPC, I marvel at the vast changes that have taken place in the diversity of its personnel, both federal and contract. These aspects will, in my opinion, keep CPC a viable and relevant institution for years to come.

Bhaskar Jha

Bhaskar Jha

At CPC I have worked on atmospheric general circulation modeling of the atmospheric response to global SSTs and selected ocean basins. I have also worked on seasonal atmospheric predictability assessment and the role of the oceans and of air-sea interactions, cause and effect of ENSO, climate variability, and climate diagnostics.

Hann-Ming Henry Juang

It was an enjoyable job of building massively parallel computing capability into seasonal forecast model (SFM) and implementing SFM into NCEP operational suite on 2001, while I was at CPC.

Masao Kanamitsu (Kana)

I may be the first (and the last?) modeler to work at CPC. Working and attending CPC's forecast briefing reminded me of early 1970s when I worked with weather forecasters. At that time, no forecasters believed model forecasts, and my comment was almost always silently neglected, but with some respect! In the last 30 years, model forecast skills improved to an extent that weather forecasters couldn't make forecast without it. I sincerely hope the similar model improvements occur in the "long-range forecasting."

Vern Kousky


Vern Kousky

My 20 years at CPC have been very rewarding—many friends, great colleagues, and enhanced vocabulary, including OLR, SST, ENSO, MJO, AO, AAO, PNA, NAO, OCN, CCA, MRF, GFS, CFS, GPCP, GDAS, CDAS, ODAS, RCDAS, CMAP, CMORPH, and Reanalysis I and II. A lot has happened at CPC in the last 20 years! There are fewer phone calls and letters but much more e-mail. Nowadays each employee has a personal computer or workstation within easy reach. Not like the good old days when we had to sign up on a list to get a half-hour slot on a dumb computer terminal.

Vadlamani Kumar


Vadlamani Kumar

I joined CAC's African Desk program in May 1994. Having trained in applied mathematics and spent some time in information systems, I found a wonderful place where I could put my knowledge and experience to work in the pleasant company of a world-class scientific community. I have really enjoyed my work at the African Desk.

Bob Livezey


Bob Livezey

I spent 17 of 31 post-doc years at NMC/NCEP, 13 at CAC. Don Gilman brought me into CAC close to its inception in early 1980, Dave Rodenhuis brought me back (from two years at NASA/GSFC) in 1987 as Principal Scientist, and I left in 1999 as Senior Scientist and Lead Seasonal Forecaster to spin up and head the Climate Services Division at headquarters. My research interests have included diagnosis of climate variability, ENSO teleconnections, seasonal prediction and verification. My favorite papers developed at CAC were Livezey and Chen (1983), Barnston and

Livezey (1987), Livezey, Masutani, et al. (1997), and Livezey and Smith (1999). While at CAC I became an AMS Fellow, served with Pete Lamb as the inaugural editorial team for *The Journal of Climate,* wrote a couple of book chapters, and shared a Department of Commerce Gold Medal for the 1997–1998 winter forecasts. However my best forecast ever was for the winter of 1989–1990 because it was considerably harder to make than for 1997–1998.

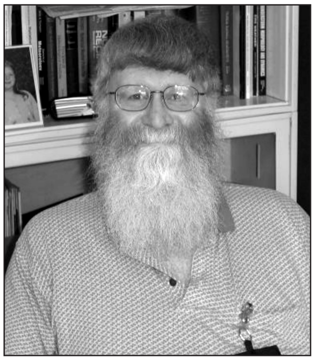
Norm Maisel

During my tenure at CAC I developed a probabilistic (frequency of like sign) teleconnection atlas with A.J. Wagner. I say probabilistic since this was not one of those linear correlation type analyses where all the non-linear goodies were filtered out. I believe this atlas is still is use for the 6–10 day forecast.
I also worked with John Roads in developing analysis of model verification.


Luke Mannello

Luke Mannello

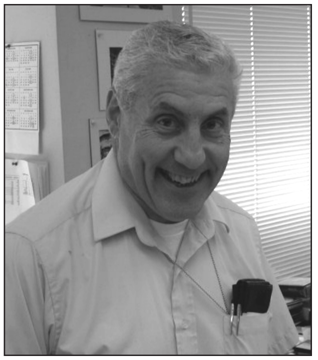
I have fond memories of my years at CAC during January 1980–September 1994. I enjoyed the many challenges, the self-motivated staff, and the good fortune of working directly for the first four Directors: Jay Winston, Jim Rasmussen, Bill Bonner (Acting) and Dave Rodenhuis. My performance was enhanced by the output and results produced by the talented and dedicated members of CAC. My experiences with the Climate Analysis, Diagnostic, and Prediction Branches were always interesting and informative. CAC has performed its mission well these past 25 years, and I am proud to have been a member. With pride in the past and with confidence in the present, I wish everyone the best future. Thanks for the memories.


Russ Martin

Russ Martin

I've worked at CPC for more than half its existence, which is frightening but I am not sure exactly in which way. It is fun being able to keep one's finger on the pulse of the climate, even though it is a slow pulse. I have enjoyed the variety of work that I do, although I never have time enough to pursue all my research ideas. The people here are fun to work with, and now the facilities are exactly what one would expect for a top scientific organization in the 21st century. I've enjoyed helping people by giving them forecasts and climate information. Now if they would all learn I can not tell them what the weather will be for their wedding on a Saturday at 3 pm six month hence.

Jim Miller



Jim Miller

I joined the unit in 1966 and, save for a one-year sabbatical, have been with CPC and its antecedents for 38 years. I now lead and promote development of NWS programs to monitor stratospheric ozone and temperature and to maintain climate awareness of weather over Africa. The former is accomplished in close cooperation with NOAA, NASA, and the international community and entails detailed monitoring of current climate conditions as well as trend analysis on historic data. We utilize data from ground-based (Dobson, balloonsondes, Umkehr, lidar, and microwave) and satellite (SBUV(/2), SAGE, UARS) observations. I also participate in national and international programs to detect and depict stratospheric ozone and temperature change, including WMO Ozone Assessments and SPARC programs. I developed and implemented the NWS Ultraviolet Index forecast system. I also work with USAID/Famine Early Warning System and the Africa Desk to monitor weather patterns over Africa for weather-related crop and human-resource impacts. This includes utilization of satellite and ground-based data to monitor rainfall estimation and the development of a weekly African Threats Assessment.

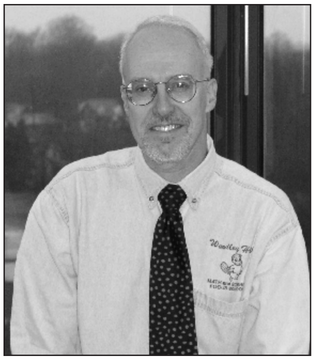
Dave Miskus

I was introduced to CAC in 1980 as a co-op student, one year shy of being a "CAC pioneer." During those early years, the co-ops were responsible for the manual quality control of U.S. weather data, especially precipitation, under Art Thomas' direction. That work led to "data quality control and anomaly adventures" via the IBM 360/195 and Fortran code that initially used computer punch cards as input (anyone remember those?). Eventually, I became part of CAC's Climate Assessment Data Base (CADB) team (Vern Patterson, George Fulwood, Joanna Dionne, Bob Churchill). For mental-health breaks, we enjoyed casual lunchtime softball games. Much of the CADB information and related products went into the *Weekly Weather and Crop Bulletin* (WWCB), and CAC special publications (e.g., *Weekly Climate Bulletin* and *Special Climate Summaries*), with which I was involved from the mid-1980s into the mid-1990s. During much of 1999, the fear of the "Y2K glitch" kept our CADB team busy. In 2000, I became the WWCB Managing Editor and Section Chief at JAWF, located at the USDA South Building in Washington.

Kingtse Mo

Kingtse Mo

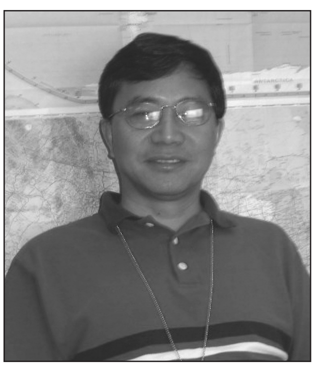
CPC is a fun place to be. Mother Nature is unpredictable so my life is never dull. We form teams and get the job done. My co-workers are also my best friends. How wonderful can it be?



Ed O'Lenic

Ed O'Lenic

I consider myself fortunate to have found my way here in 1985, partly through the encouragement of Phil Arkin. From 1985–1989, Bob Livezey, Tony Barnston, and Huug van den Dool were my mentors and research collaborators on papers on low-frequency variability and trends. Beginning in the late 1980s with Jon Hoopingarner doing the programming, I moved CAC's 6–10 day forecast operations from hand-drawn maps and computer printouts to human-computer interactive processes on workstations. In 1994 Huug van den Dool, Tony Barnston, and I developed a new, probabilistic long-lead seasonal and monthly forecast system. Late in 1997 the Director, Ants Leetmaa, wanted a product to address weather hazards in the context of climate. I asked him to give me free reign to develop the new product, the U.S. Threats (later, Hazards) Assessment. The product combines web-disseminated maps and text with telephone conference calls and much collaboration with experts outside of NCEP. The U.S. Threats Assessment became operational in 1999, after a 2-year experimental trial period. In 2000, CPC implemented forecasts for days 8–14, which quickly became the second most popular product on our web site, after the 6–10 day forecast.



Peitao Peng

Peitao Peng

The dominant mode of CPC's 25-year record is an upward trend. I hope the trend will be kept, and we will see a more prosperous Center at its 50th birthday.

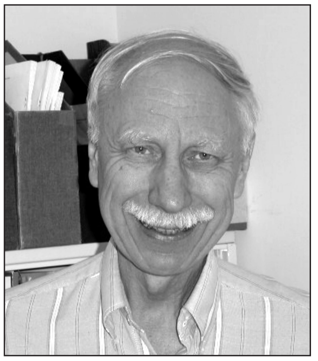
Rod Quiroz

A recollection of my association with the center, up to my retirement in 1985, should include an expression of deep gratitude for the opportunity to round out a life-long career in meteorology with a full series of years focusing on problems different from my earlier emphasis on problems of the very high atmosphere. These last years provided interesting challenges in new problem areas, now closer to the ground and even skimming the tropical waters in a search for understanding of the El Niño. Our investigations were more than ever driven by a never-ceasing curiosity shared by wonderful colleagues, in a desire to advance our knowledge pertinent to human problems.

Brad Rippey

Even though I left CPC in 1998 following an eight-year stint, I retain a close working relationship with the group through the Joint Agricultural Weather Facility. JAWF, comprised of CPC and U.S. Department of Agriculture employees, was created just a few months prior to the May 1979 establishment of CAC. Among the most prominent JAWF publications are the *Weekly Weather and Crop Bulletin,* which has not had a name change since 1924 and has a storied history dating to 1872. The policy governing the two-agency publication of the WWCB, unwritten when the Weather Bureau was transferred from the Department of Agriculture to the Commerce Department on July 1, 1940, was formalized in 1958 and solidified by the establishment of JAWF.

Chet Ropelewski


Chet Ropelewski

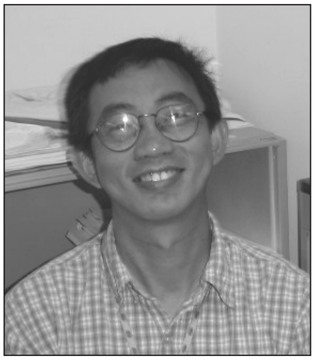
Jim Laver asked many of us to describe our "most significant achievements" of our time at CAC. In my case it was getting hired into Gene Rasmusson's Branch. The early 1980s were one of those rare periods in science when the ideas were in the air, the data were coming on line, the tools to analyze the data were being developed, and CAC was in the middle of it all. These were exciting and productive times made better by the day-to-day contact with a group of world-class climate researchers who were challenging and fun to work with. When people would ask me how I liked my work I'd always reply 'I've got the best job in NOAA' and, indeed, it was.

Paul Sabol

The most important situation I can recall occurred when CAC responded to a query from South Dakota with respect to the *Palmer Drought Severity Index.* Specifically, the most probable case of the three possibilities would be used as the week's index; however, in a few situations the index would tend to fluctuate wildly as the probabilities changed. One of the meteorologists called the fluctuation a quirk, but the Central Region referred the question to the Director of NCEP. We were in a meeting, discussing the problem, when I suggested that we use a weighted average of the three cases. This new index was dubbed the Modified Palmer Drought Index (PMDI). Strangely enough, it was not until I tackled Geography 639A, Land Cover/Land Use Change, after my federal retirement, that I gained a real working knowledge of the PMDI via an attempt to compare the PMDI to the Normalized Difference Vegetative Index (NDVI) as a project for the course. A paper resulted from the change in 1990–1991: Heddinghaus, Thomas and Paul Sabol (1991): *A Review of the Palmer Drought Severity Index and Where Do We Go from Here?*

Jae Schemm

I joined CAC in December 1993 and managed to survive the ice-covered WWB parking lot in January 1994. Since then, nothing seems to be such a daunting task any more. I am still striving to make contributions to the mission.


Wei Shi

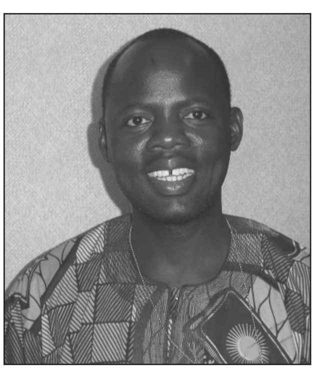
Wei Shi

CPC is one of the best places in the world to work on climate research. I have enjoyed working with my colleagues ever since I joined them about seven years ago. That is probably why I still keep driving 80 miles back and forth each day to come to work. I look forward to the day when CPC moves to the new building in College Park, Maryland.


Yucheng Song

Yucheng Song

Congratulations on CPC's 25-year anniversary. This is a good place to interact with dynamic people, to learn tricks to implement those mission-critical tasks. It is also a good place for first-hand climate forecast in case you are planning a trip to the Mediterranean three months later. Seasonal forecast is tough. My thanks to the support and constant encouragement from people that I worked with and talked to at CPC.


Wassila Thiaw

Wassila Thiaw

The 25th anniversary of CPC coincides with the 10th anniversary of the Africa Desk. I arrived on March 25, 1994, to help establish the Africa Desk, a unique project that builds capacity at meteorological and climate services in Africa, but even more importantly helps advance our understanding of the mechanisms associated with climate variability in Africa and its impacts on the U.S. An important contribution of the Africa Desk is to look more closely into the inherent links between the West African monsoon system and the Atlantic hurricane activity.

My journey began on an August afternoon in 1993, when, as a postdoctoral candidate at NESDIS, I ran into David Rodenhuis, Director of CAC, who introduced himself and asked if I would come to his office and discuss a project he had in mind. Soon after I joined CAC, Vadlamani Kumar was hired to join our team. I appreciate the collaboration with Anthony

Barnston, who taught me all I know about climate forecasting—and that of so many scientists at CAC. Phil Arkin had already left when I joined, but he is the one who showed me the way to the U.S. when I met him in Germany 16 years ago. More recently, the integration of some of the Africa Desk activities with FEWS/NET propelled the Africa Desk to a new dimension. I appreciate the collaboration with Alvin Miller and the rest of the team.

M. Steven Tracton

I served as operational forecaster (monthly) and project leader of the program in Dynamic Extended Range Forecasting (DERF) during my tenure at CAC which spanned the period 1985–1995. DERF encompassed a study of various issues in predictability, for example, scale interaction processes, blocking, and tropical–extratropical interactions. These efforts in turn led to pioneering efforts in the development and applications of ensemble prediction concepts and procedures, now acknowledged as fundamental tools in operational medium to extended range forecasting.

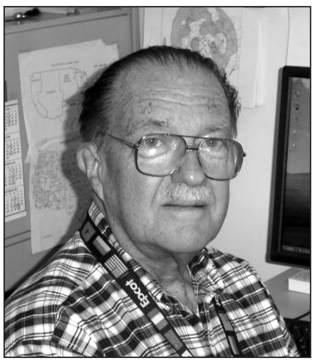
Huug van den Dool


Huug van den Dool

A summary of 25 years: "QED is up," "the blend," Versatec, cms, vms, jcl, vi, Niño3.4, the bowling alley, the fishbowl, CDDB, CAMS, CCA, CAC, baby El Niño (93), DERFII, DERF90, AO, NAO, QBO, MJO, any O, lagged average forecast, ensembles, D+8, zero lead, the Klein, PC, CAC, EOT, EOF, REOF, working group VIII, GCM, Van den Dool bias, field significance, skill mask, a-priori skill, grid, Grib, grads, Gibbsing, NMC Office Note, OI SST, anomaly, AMIP , AWIPS, N-Awips, Gempack, PNA, root zone, runoff, soil moisture, climate division, station data, urban effects, Palmer, percentile, composite, analog, antilog, constructed analog, bimodality, low-frequency, probability, conditional probability, Kalman, Bayes, Brier score, RUC, ROC, Eta, spectral method, Lagrangian, Eulerian, persistence, damped persistence, Internet, web URL, virus, software, A, B and N, I–>CP–>CL–>EC, the 'user', seamless suite, end-to-end, metrics, milestones, non-CL, OGP, pass back, out year, soft money, NRC fellowship, SMART, RDS, UCAR, GFDL, CDC, IRI, inverse model, thermocline, sanity check, calibration, bias, reliability, 30/40/30–>1/3rd each, ENSO, OLR, convection, consolidation, NOAA-12, EWP, dAVA, Cmorph, LDAS, NLDAS, GLDAS, ELDAS, 2-class system, chaos, predictability, prediction skill, anomaly correlation, Heidke, SS1, SS2, hit rate, Rossby, Namias, Gilman, ftpprd, http, e-mail, google, CV, Tellus, skill degeneracy, ASOS, normals, OCN, CO-2, climate-skeptics, CPU, normal modes, ELLFB, Cliper, precip analysis, Barnes, Gandin, Cressman, stove pipe thinking, 82/83, AMS, AGU, EGS, Niño3, SOI, Kelvin wave, outreach, equitable threat assessment, b9x, CMP12, SFM, CFS, MRF, GFS, performance measure, Gwpas, fully successful. . . . Happy 25th.

Jamie Vavra

I thoroughly enjoyed CPC (1995–1999) working under Jim Miller, with Alan Herman as a mentor. My work with him on the African precipitation estimates for the Famine Early Warning System was the most interesting project in my career to date. It certainly was a challenge to decipher his programs! Thanks to Joe Harrison, Bob Churchill, and George Fulwood for keeping me laughing. I have fond memories of my time there.


Jim Wagner

Jim Wagner

In 1965, Jerome Namias hired me out of MIT to come and work for the Extended Forecast Division (then called the Weather Bureau). I had wanted to work in an area where there was the greatest challenge and was aware that the area of extended range forecasting had the greatest need of improvement, which included (then) days 3 to 5 and monthly and seasonal forecasting. Such ideas as a 6–10 or 8–14 day forecast were not even dreamed of, and I had noticed that the 30-day forecast was usually simply an echo of the 72-hour daily forecast or the 3–5 day forecast made the previous day. At that time, there was research being done on seasonal forecasts, but they were not released publicly. After Jerome Namias retired from the Federal Government, the Long Range Prediction Group, under Don Gilman, was formed with most of the staff time devoted to operations rather than to research. I did a study on the feasibility of making daily extended range predictions out to 6 days ahead using the then latest and best available model, the new 6-level Primitive Equation (PE) Model. Most research was devoted to developing better models to improve the short- and medium-range forecasts. Then the 6–10 day forecast operation, started by James Andrews (one of Namias' original employees) and later under Francis Hughes, was brought to CAC. For several years, Fran and I did nearly all the 6–10 day forecasts, made only three times a week on MWF and only for the Lower 48 states.


Yan Xue

Yan Xue

I joined CPC as a civil servant in February 2001 and have contributed to operations by developing Markov models for forecasting tropical Pacific SST and sea level, MJO index for real-time monitor of Madden-Julian Oscillation, and by maintaining subsurface ocean analysis tools for the *Climate Diagnostic Bulletin* and ENSO diagnostic discussion. I have also evaluated and improved the reconstructed SST developed by NCDC and the global ocean data assimilation system developed by EMC.

Shi-Keng Yang (SKY) and Jeannette Wild


Shi-Keng Yang


Jeannette Wild

Congratulations to CPC on its 25th anniversary and for the 15th anniversary of contracting. For all the contractors who have worked at CPC, our hats are off for jobs well done. Your efforts have made the contract tasks integral parts of operations. CPC provides, for many of the aspiring young contract scientists and staff, a grand vision for serving the nation and humanity, while CPC is in turn rewarded with outstanding talent and energy. It is foreseeable, far beyond climatic uncertainties that the future mission will continue to be accomplished by the joint force of civil servants and contractors in hand-in-hand cooperation.

Song Yang


Song Yang

I joined CPC in 2001 as an expert on short-term climate variability and predictability. My area of expertise is in the dynamics of coupled atmosphere–ocean–land processes, and I have strived to contribute to a better understanding of the association between El Niño-Southern Oscillation and Asian-Australian monsoons. As a research meteorologist, I am currently applying climate modes and advanced statistical tools to improve the understanding of the variability and predictability of U.S. precipitation and the climate variations in Asia and the Pacific and Indian Oceans. I have enjoyed my time with CPC, where I actively deliver various climate services and conduct internationally collaborative activities.

Qin Zhang


Qin Zhang

I've been conducting forecast simulation and long-term integration of the coupled forecast system (CFS). I'm currently working on diagnostics coupled model results for improving the seasonal forecast. In particular, I make an analysis of the low-frequency modes of atmospheric and oceanic variability, such as ENSO. I also study the predictability of SST anomalies in both Pacific and Indian Ocean and investigate seasonal and intraseasonal air-sea interaction.


Shuntai Zhou

Shuntai Zhou

CPC's 25-year anniversary also marks my 10-year anniversary. I am proud to be a member of the stratospheric group, and to contribute to stratospheric monitoring and research, including ozone depletion, dynamical coupling to the troposphere, as well as external forcing such as solar variations. It is well known that the stratosphere plays a very important role in climate change and climate prediction. I wish that CPC becomes a leading organization in stratospheric research and application in the future.

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*The original 1979 staff.

In Memoriam

By Mel Gelman

CPC IS VERY FORTUNATE TO HAVE MANY OF THE KEY PLAYERS in its formative years still active in the climate field. We do want to remember the only Branch Manager who has passed away, and honor by name the staff whom we know to have passed away. Any omissions are due to lack of information.

Frederick G. Finger 1924–2000

Frederick G. Finger died in March 2000, at the age of 75. His friends and associates remember him warmly and with respect, for his many kindnesses to the people he came in contact with, and for his dedication to his profession. He is best known professionally for his work, begun in the 1950s with Sidney Teweles, on the analysis of stratospheric temperature, developing adjustments to radiosonde data to account for solar radiation errors, and for describing stratospheric warmings. He was a Fellow of the American Meteorological Society (AMS).

Fred began his studies at New York University in 1952 and in 1958 he joined Sid Teweles, and worked at the Stratospheric Analysis Project set up by Harry Wexler, in the Weather Bureau's Office of Scientific Services, to perform research on data acquired during the International Geophysical Year. Fred's research and determination of corrections for radiosonde errors allowed stratospheric charts to be analyzed. This work also contributed to the improvement of radiosondes worldwide. He was recognized for his talents in research, his journal publications, and for his diligent work. In 1965 Fred became Chief of the Upper Air Branch, in the Development Division of the National Meteorological Center.

Under Fred's leadership, the Branch expanded its work in stratospheric analysis of radiosonde data, and extended the work into the upper stratosphere, using rocketsonde data and satellite sounder data. With the establishment of CAC, the scope of Fred's Analysis and Information Branch's interest expanded to include global surface climate data and real-time global climate analysis. His extensive experience in working with data problems helped in developing quality control procedures for near real-time checking of surface meteorological data reports, for use in climate applications. Automated procedures were developed to summarize data and derive analyses and illustrations for the *Weekly Weather and Crop Bulletin,* in cooperation with the Department of Agriculture. Fred showed practical innovation and determination for quick delivery of products to users by developing the Climate Dial-Up Service (CDUS). As a part of the NWS Family of Services, CDUS delivered hundreds of thousands of products per week via request/reply modems and phone lines, long before such "bulletin boards" became popular.

Fred Finger was an effective researcher and manager because of his love for finding answers to difficult problems and his management and leadership skills.

In remembrance,

—Robert Bermowitz, Vilhelm Bjerknes II, Francis Hughes,
Keith Johnson, Vernon Patterson, and Arthur Thomas

Acknowledgments

In writing this twenty-five-year history of the climate prediction center, we were fortunate that the Directors and many key players could be interviewed and could also provide early documents from their files. We combed the NOAA libraries and the Library of Congress law library for additional documentation.

The concept of this history originated in 2002 with Tom Pagano (from the Oregon Department of Natural Resources). Pagano suggested that the first monthly outlook had been issued in 1953, making 2003 the 50th anniversary. According to the archives, the monthly outlooks were first printed in spring 1947. CAC, however, was approaching a 25th anniversary: in a July 1977 memorandum, Ed Epstein, then at NOAA headquarters, handed responsibility for a new climate center to the National Weather Service; the NWS formally established CAC with a June 4, 1978, memorandum, but it was not until the next spring that Jay Winston came aboard as first Director and units from other parts of NOAA were added. The Analysis and Information Branch was included by August 26, 1979. So, we are commemorating the events of 1979 with this publication and with a special session at the October 2004 Diagnostics and Prediction Workshop in Madison, Wisconsin.

We are grateful to the many people who made possible this publication and workshop. Jim Laver, Huug van den Dool, John Janowiak, Shi-keng Yang comprised the publication review committee. Contributors include Phil Arkin, Douglas LeComte, Melvyn Gelman, Don Gilman, John Janowiak, Vern Kousky, Ants Leetmaa, Jim Laver, Bob Livezey, Jim Miller, Ed O'Lenic, Rod Quiroz, Jim Rasmussen, Gene Rasmusson, Dave Rodenhuis, Chet Ropelewski, Huug van den Dool, Wassila Thiaw, and Jay Winston. Don Gilman has been associated with CAC since its formative years and has provided guidance throughout the project.

Invaluable discussions and interviews were held with Phil Arkin, Tim Barnett, Tony Barnston, Gene Bierly, Norm Canfield, Art Douglas, Ed Epstein, Joe Fletcher, Larry Gates, Dave Gutzler, Alan Hecht, Jim Laver, Ants Leetmaa, Bob Livezey, Jim O'Brien, John Perry, Dave Rodenhuis, Uwe Radok, Jim Rasmussen, Gene Rasmusson, Kelly Redmond, John Roads, Bill Sprigg, Huug van den Dool, Mike Wallace, Robert M. White, Jay Winston, and Steve Zebiak. Many thanks to the current Director, Jim Laver, and the chief of the Climate Services Division, Robert Livezey, for their guidance and support without which this report would still be on the drawing board.

—Robert W. Reeves
Climate Services Division

—Daphne deJ. Gemmill
Climate Prediction Center

Glossary of Acronyms

ACMAD—African Centre of Meteorological Applications and Development
AIB—Analysis and Information Branch
AMIP—Atmospheric Models Intercomparison Project
AOML—Atlantic Oceanographic and Meteorological Laboratory
CAC—Climate Analysis Center
CADB—Climate Assessment Database
CAMS—Climate Anomaly Monitoring System
CAMS-OPI—CAMS OLR Precipitation Index
CDAS—Climate Data Assimilation System
CDB—*Climate Diagnostics Bulletin*
CDC—Climate Diagnostics Center
CDDB—Climate Diagnostics Database
CDEP—Climate Dynamics and Experimental Prediction
CDUS—Climate Dial-Up Services
CFS—Climate Forecast System
CICS—Cooperative Institute for Climate Studies
CIRES—Cooperative Institute for Research in the Environmental Sciences
CL—Climatological Probabilities
CLIVAR—Climate Variability and Predictability
CMAP—CPC Merged Analysis of Precipitation
CPC—Climate Prediction Center
CSD-Climate Services Division
DERF—Dynamic Extended Range Forecasting
DOC—Department of Commerce
ECMWF—European Center for Medium Range Weather Forecasts
EDIS—Environmental Data and Information Service
ENSO—El Niño Southern Oscillation
EOF—Empirical Orthogonal Function
EPOCS—Equatorial Pacific Ocean Climate Studies
ERL—Environmental Research Laboratories
ETA—a Greek letter used to represent the vertical coordinate used in a numerical model.
FEWS NET—Famine Early Warning System Network
FGGE—First GARP Global Experiment
GARP—Global Atmospheric Research Project
GATE—GARP Atlantic Tropical Experiment
GCIP—GEWEX Continental-scale Intercomparison Program
GDAS—Global Data Assimilation System
GEWEX—Global Energy and Water Cycle Experiment
GFDL—Geophysical Fluid Dynamics Laboratory
GPCP—Global Precipitation Climatology Project
GPO—Government Printing Office
GTS—Global Telecommunications System
ICAS—Interdepartmental Committee for Atmospheric Sciences
ICSU—International Council of Scientific Unions
IGY—International Geophysical Year
IQSY—International Quiet Sun Year
JAWF—Joint Agricultural Weather Facility
MJO—Madden- Julian Oscillation
MRF—Medium Range Forecast
NAME—North American Monsoon Experiment
NASA—National Aeronautics and Space Administration
NCAR—National Center for Atmospheric Research
NCDC—National Climatic Data Center
NCEP—National Centers for Environmental Prediction
NESS—National Environmental Satellite Service
NMC—National Meteorological Center
NOAA—National Oceanic and Atmospheric Administration
NSF—National Science Foundation
NWP—Numerical Weather Prediction
NWS—National Weather Service
OCD—Office of Climate Dynamics
OCN—Optimum Climate Normals
ODAS—Ocean Data Assimilation System
OI—Optimum Interpolation
OLR—Outgoing Long wave Radiation
PACS—Pan American Climate Studies
PEAC—Pacific ENSO Applications Center
PMEL—Pacific Marine Environmental Laboratory
RCC—Regional Climate Center
RDAS—Regional Data Assimilation System
SMART—Scientific Management and Applied Research Technologies, Inc
SOI—Southern Oscillation Index
SSG—Scientific Steering Group
SST—Sea Surface Temperature
TAO—Tropical Atmosphere/Ocean
TOAN—Tropical Ocean-Atmosphere Newsletter
TOGA—Tropical Oceans Global Atmosphere
UAB—Upper Air Branch
USAF—United States Air Force
USAID—United States Agency for International Development
USDA—United States Department of Agriculture
USDM—United States Drought Monitor
VAMOs—Variability of the American Monsoon System
WCRP—World Climate Research Program
WMO—World Meteorological Organization
WWW—World Weather Watch
WWCB—*Weekly Weather and Crop Bulletin*

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Drought Advisory

Drought Outlook

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Climate Diagnostics and Prediction Workshop