CHAPTER 6

Experimental Climate Services

In addition to its basic climate research, CDC provides an extensive range of experimental climate services. Climate services require sustained and systematic communication of climate information to a broad spectrum of users, and interactions with users to determine their priorities and needs. A common objective of our experimental climate services is to address NOAA's goal of improving mechanisms for dissemination of climate and weather products. Enhancing access to climate information also facilitates basic climate research and expands the scientific basis for informed public planning and policy decisions.

Research at CDC and elsewhere indicates that there are currently substantial barriers to the effective use of climate information (e.g., requirements for better and more timely access to data, improved visualization, user-specific needs, and organizational obstacles to factoring climate information into decisions). CDC employs various approaches to overcome such barriers, in order to develop improved NOAA climate products that address both research scientist and non-traditional user needs. Experimental climate services activities in CDC fall into five categories: 1) enhanced weather and climate monitoring products and experimental climate forecasts; 2) WWW based value-added access, analysis, and visualization tools for climate data; 3) user studies and societal interactions; 4) Western Water Assessment activities; and 5) public health and climate research.

6.1 Experimental monitoring products and climate forecasts

CDC research has lead to the development of a number of experimental climate monitoring and forecasts products, which are systematically updated and evaluated along with operational products. Collectively these efforts provide the scientific research community and non-traditional users access to enhanced climate information, current climate conditions, and climate forecasts.

6.1.1 Value Added Diagnostics and Visualization Products for Weather and Climate Monitoring

The CDC WWW-based maproom (http://www.cdc.noaa.gov/map/) provides a focal point for monitoring and prediction products on climate variability, climate impacts and climate-weather connections. The CDC maproom encompasses a broad range of diagnostic products and enhanced visualization tools for weather and climate monitoring. A vast majority of these diagnostic and value-added visualization products were designed initially to support in-house research. These are now active research areas themselves, with goals being to develop enhanced climate and weather monitoring products and to evaluate operational and experimental climate and weather forecasts. The core of the maproom consists of analyzed and predicted fields of climate variables that are updated on a daily basis, and that provide the raw data for both conventional and experimental products. The maproom is also a host site to enable a similar scope of studies by non-CDC scientists.

The maproom supports CDC's research, diagnostic and assessment activities by serving as: a) a testbed for new products related to climate monitoring and prediction; b) a means to interact with users of climate and weather information; c) a way to familiarize climate researchers with ongoing climate anomalies; and d) a tool to interpret the current state of the climate with emphasis on coherent modes of variability such as ENSO, MJO, NAO, etc. Weekly maproom briefings provide a forum to discuss the maproom products and to monitor the performance of new products.

Several maproom improvements have been undertaken since 1997. Some of these have involved streamlining scripts, consolidating products, and ensuring timely access to data streams. Specific improvements and additions related to maproom content include:

1) Applying Java animation scripts to climate variables for time averages from daily to seasonal,

2) Use of the NCEP reanalyses as the basis for global atmospheric products rather than the NCEP operational data,

3) Monitoring coherent modes of tropical OLR variability, including the MJO,

4) Monitoring storm tracks based on a sea level pressure algorithm (storm track data from 1958–present also available),

5) Prediction of seasonal anomalies based on the historical response to SSTs in an ensemble of AMIP runs,

6) Monitoring atmospheric angular momentum budget for intraseasonal and longer term variations,

7) Monitoring the states and ensemble predictions of Northern Hemisphere teleconnection patterns,

8) Implementing 500 mb height anomalies and regional plots over North America from the NCEP ensemble predictions,

9) Implementing probabilistic Week 2 predictions from the NCEP MRF/AVN ensemble.

CDC's interest in attribution of climate anomalies, and comments from users of climate information (including EMC and CPC), helped drive the development of many of these products. Development of new methods in climate prediction within CDC, on both weekly and seasonal time scales, has resulted in an increase in experimental prediction products for the maproom.

Web usage statistics for the maproom show that the NCEP MRF ensemble predictions to 15 days are among the most popular products. CDC displays both conventional variables (e.g., 500 mb geopotential height) and experimental products (e.g., forecast probability of a 1 or 2 standard deviation anomalies in 850 mb temperature) in the maproom. There is substantial interest in these products from national energy companies which monitor long-range weekly forecasts. In the future, CDC will continue to develop new products that will help identify the variability and trends in the earth's climate. User interactions will help CDC identify existing products and how they may be improved.

6.1.2 Multivariate ENSO Index (MEI)

In addition to providing easy access to interannual indices and maps of climate variability, CDC provides a near-real time monthly updated Multivariate ENSO Index (MEI) based on six COADS atmosphere-ocean variables over the entire tropical Pacific basin: sea-level pressure (P), zonal (U) and meridional (V) components of the surface wind, sea surface temperature (S), surface air temperature (A), and total cloudiness fraction of the sky (C). One week after the end of each month, the MEI is extended based on near-real time NCEP marine ship and buoy observations summarized into COADS-compatible 2-degree monthly statistics. During the summer of 1997, the MEI was put on the WWW and quickly gained popularity as a monitoring product with monthly updates on the 1997–1998 El Niño (**Fig. 6.1**). In the past five years, the time series

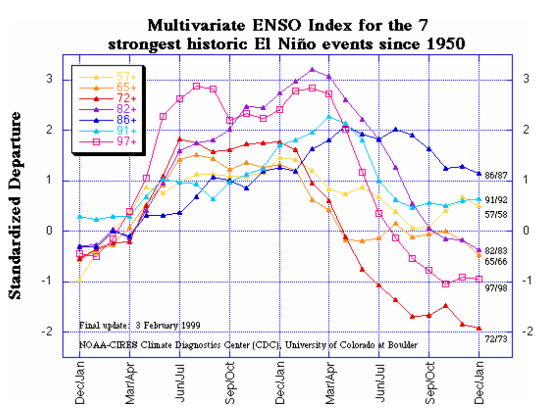

Fig. 6.1. The seasonally normalized MEI documents the evolution of individual El Niño (shown here) and La Niña events, allowing for direct intercomparison of the relative strength of ENSO events since 1950 (http://www.cdc.noaa.gov/~kew/MEI/).

of the MEI has been distributed to hundreds of scientists and many other interested parties, and included in many publications, both scientific and popular.

6.1.3 Linear Inverse Modeling Forecasts of Tropical Sea Surface Temperatures

The development of a linear inverse modeling (LIM) approach to generate low-frequency climate forecasts is a prime example of CDC basic climate research directly contributing to the NOAA goal of providing new and improved climate forecasts. As a service to the scientific community, since the mid 1990's CDC has produced LIM tropical SST forecasts and made the forecasts available on the WWW and in the *EFFLB* along with appropriate verification statistics. CDC provides monthly predictions of tropical Indo-Pacific sea surface temperature anomalies (SSTAs) with 3, 6, 9, and 12 month lead times using a linear inverse modeling procedure with tropical Indo-Pacific SSTAs as predictors (**Fig. 6.2**). Anomalies are calculated relative to the standard 1950–1979 COADS climatology. CDC also produces similar LIM monthly predictions of northern tropical Atlantic Ocean and Caribbean sea surface temperature anomalies (SSTAs) with 3, 6, 9, and 12 month lead times. In contrast with tropical Indo-Pacific forecasts, these predictions are generated using global tropical SSTAs as predictors and anomalies are calculated relative to the COADS 1950–1993 climatology.

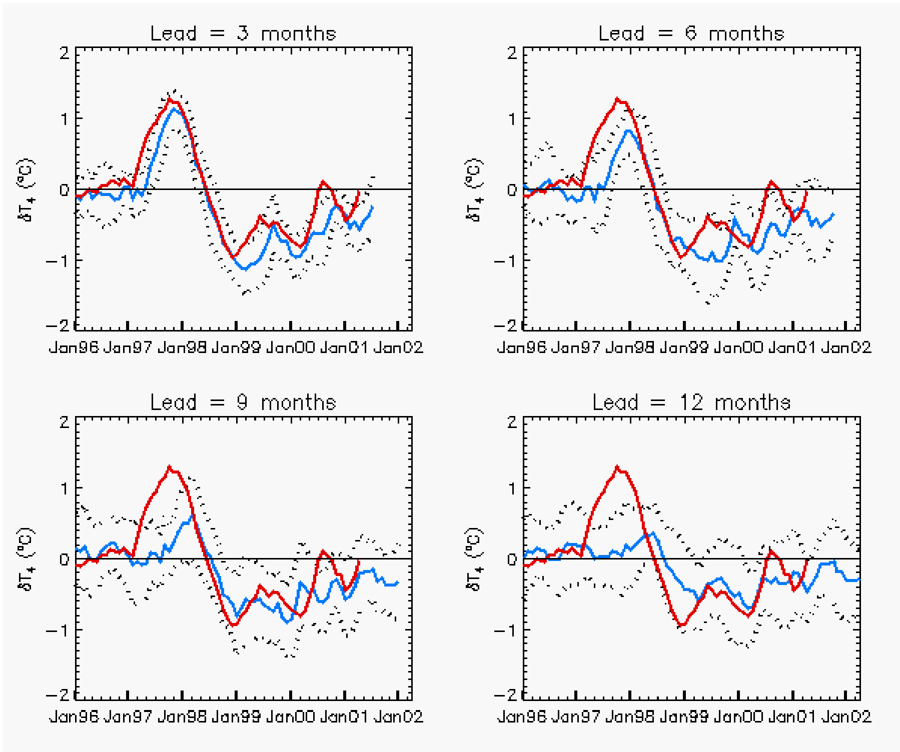

Fig. 6.2. Predictions of Niño 4 SSTA (solid blue line) and verification (solid red line). Dashed lines indicate one standard deviation confidence intervals appropriate for the LIM forecast (as opposed to those based on the history of standard deviation of previous forecast errors).

6.1.4. Subseasonal LIM forecasts of Tropical heating and extratropical circulations

For over a year, CDC scientists have used LIM to make medium and extended range (Weeks 2 to 6) forecasts of weekly average anomalous 250 and 750 mb streamfunction and tropical diabatic heating (**Fig. 6.3**). The procedure (described in Chapter 2) is similar to the method used to predict tropical Indo-Pacific and Atlantic/Caribbean sea surface temperature anomalies, except that streamfunction and diabatic heating are the model variables and the time-scale is weeks instead of months. NCEP MRF model forecasts at Week 2 and current verifications are provided for comparison when available (**Fig. 6.3**). The CDC wintertime and summertime forecasts are currently made out as far as six weeks ahead. A second forecast, the Combined forecast, is made by combining the LIM technique with the NCEP MRF ensemble mean Week 1 streamfunction forecast. Throughout the winter (Dec. 1–Feb. 28) and summer (Jun. 1–Aug. 31) these forecasts are updated daily. Much of the skill in these LIM forecasts, particularly at the extended range, is not only due to anomalous tropical convection related to ENSO but also to the extratropical response to the MJO. Advances in this experimental climate services forecast product will depend both on continued model development and evaluation and

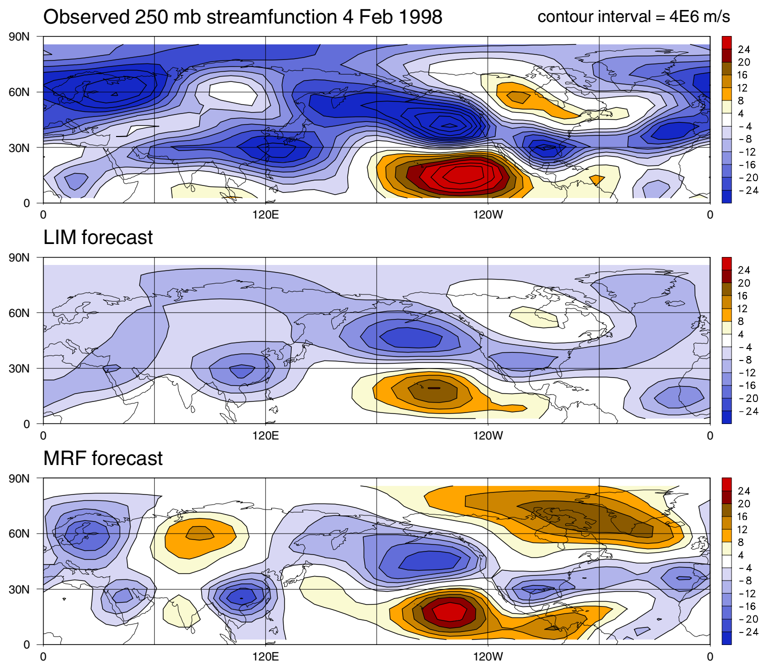

Fig. 6.3. Top: Observed 7-day running mean 250 mb streamfunction pattern for February 4, 1998. Middle: Week 2 linear inverse model forecast of 7-day running mean 250 mb streamfunction verifying against top panel. Bottom: Week 2 MRF forecast verifying against top panel.

on enhanced monitoring and prediction of MJO activity.

6.1.5 Other experimental forecast products

CDC provides monthly experimental CCA forecasts of tropical SSTs, precipitation, 500mb height, and surface temperature for the subsequent 4 overlapping 3-month season (**Fig. 6.4**, http://www.cdc.noaa.gov/~gtb/seasonal/). Predictions of tropical SSTs are derived from 4 different sources: (1) an inhouse CDC canonical correlation analysis (CCA) model, (2) the NCEP's Climate Modeling Branch (CMB) SST forecast, (3) the International Research Institute's (IRI) forecast of tropical SSTs, and (4) the CDC LIM Indo-Pacific SST forecast. Each tropical SST forecast, plus their linear average, are used as boundary conditions for predicting seasonal climate anomalies. A second CCA model relates the first 28 EOFs of tropical SSTs to a similar 28 EOF basis of an atmospheric predictand. The predictands are seasonal tropical precipitation anomalies, Pacific-North American seasonal temperature and precipitation anomalies, and Pacific-North American seasonal 500-mb height. The predictand data are derived from ensemble simulations from four atmospheric GCMs (NCEP MRF9, ECHAM3, CCM3, GFDL-R30) run for 1950–99 and forced with the monthly varying global SSTs. The atmospheric prediction is made by first projecting the predicted tropical SST anomalies onto the 28 EOF SST basis set for 1950–1999. The CCA model, based on zero-lag relations of this SST and the individual

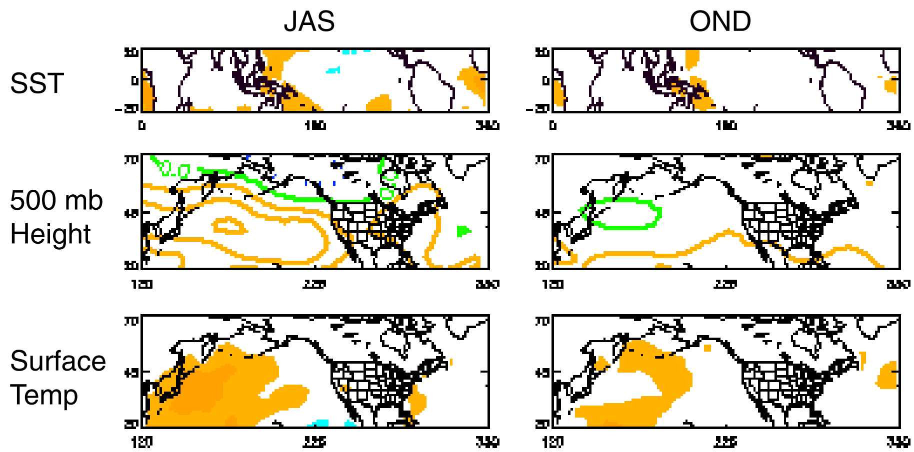

Fig. 6.4. CDC experimental June 2001 forecasts for July-August-September 2001 and October-November-December 2001.

atmospheric predictands derived from the GCMs, is then used to predict seasonal precipitation anomalies and atmospheric circulation.

6.1.6 Week 2 predictions and the atmospheric angular momentum budget

CDC is working with the Dodge City (KS) NWS Office to link weather and climate phenomena, and to anticipate errors in Week 2 predictions in various forecast models. This collaborative effort contributes directly to the "Special 2 week weather outlook" (http://www.crh.noaa.gov/ddc/wx/2week.txt) issued routinely by the Dodge City NWS Office. These Week 2 outlooks are produced using probability distributions of atmospheric circulation and other variables from Week 2 ensemble model forecasts to develop initial discussions of Week 2 conditions. The initial discussions are then diagnosed and modified to account for model biases using a suite of WWW-based products, including CDC maproom atmosphere angular momentum (AAM) and outgoing longwave radiation (OLR) products, that provide additional information on antecedent and existing conditions.

Synoptic experience indicates that low and high global AAM influences the variability of blocking and Rossby wave dispersion over the Pacific basin region.The Week 2 discussions use such synoptic insights to interpret the ensemble predictions and to determine the likelihood for systematic errors during particular regimes. Cases of good or bad Week 2 forecasts over the Pacific basin region are selected for more intensive study and diagnosis, always within the context of the phase of ENSO, the MJO, the seasonal cycle and Rossby wave dispersion. Additionally, in the last two winters Week 2 predictions of the Pacific basin circulation anomalies by the linear model discussed in Section 6.1.3 have provided unique insights into the role of tropical convection in forcing the extratropics. Aspects from an interesting case of this past northern winter are discussed below.

Figure 6.5 shows that during the last year ~50–70 day oscillations in global relative AAM have been prominent. These oscillations started in July 2000 and continue to the present (July 2001). They are superimposed on a persistent negative AAM anomaly (–1.5 sigma), reflecting weakened subtropical westerlies. The weakened westerlies coincide with cool (warm) sea surface temperatures in the tropical eastern Pacific (Indonesian region) and all have been present since ~August 1998. This easing of the subtropical westerly flow during the last 2 years opposes the observed trend in the NCEP/NCAR reanalysis during the last 30–40 years. The intraseasonal oscillations are closely related to the tropical convective forcing of the Madden-Julian oscillation, although not exclusively. Mid-latitude processes related to momentum transports, eddy feedbacks and mountains also force anomalies in global and zonal AAM and produce additional variability in the time series.

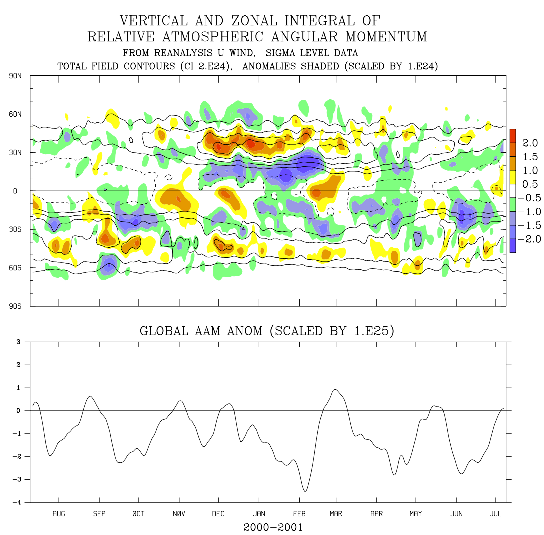

Fig. 6.5. (Top) Time series of the vertically and zonally integrated relative atmospheric angular momentum from July 2000–July 2001. (Bottom) Global atmospheric angular momentum anomalies since July 2000.

A prominent feature of the 2000–2001 northern winter, seen in the top panel of **Fig. 6.5**, is a large zonal mean anomaly pattern in the Northern Hemisphere. Starting in mid-November 2000, strong westerly flow develops in mid-latitudes (30°–50°N) with weaker than normal westerly flow in adjacent latitude bands. The easterly anomalies in the subtropics intensify and help drive global AAM to very low values during the winter period. Minimum values are reached in early February 2001, and are followed by a rapid rise to positive values during February 2001. Two physically significant events precede the rise.

In late January 2001, a strong MJO organized over the Indian Ocean and moved eastward reaching the dateline around 1 March 2001 (not shown). The evolution of the zonal AAM, seen in equatorial regions of **Fig. 6.5**, is consistent with the composite MJO. As positive convection anomalies move east across the ocean warm pool, zonal mean west wind anomalies develop on the equator and propagate poleward into the subtropics. MJO-related positive frictional and mountain torques contribute partially to the global AAM rise.

At about the same time (late January 2001) a subtle change occurs in the zonal mean flow at ~55°N as the easterly zonal wind anomalies transitioned to westerly anomalies. This subtle change initiates a chain of events that is represented synoptically by the composites in **Fig. 4.10**.

Stronger westerly flow over the mountains at 55°N produces topographic Rossby waves that move negative mass anomalies equatorward. Simultaneously upper level wavetrains amplify and disperse over the mountains and contribute to meridional momentum and heat transports. The resulting upper level momentum sinks in the subtropics tend to force easterly wind anomalies at the surface, i.e., a positive frictional torque, contributing another portion to the rise in global AAM. We suspect this is typical behavior for intraseasonal (20–90 days) AAM variations during northern winter, i.e., tropical MJO-induced forcing and extratropical transport-induced forcing both contributing to AAM changes.

6.2 Value added analyses and visualization tools

6.2.1 Climate Observations and Reanalysis

An important component of climate services is the development of visualization and analysis tools for the immediate synthesis and diagnosis of large operational climate datasets in near real time. CDC maintains a large and diverse collection of climate datasets in support of in-house research, which are also publicly available. Providing value-added access to high-quality, long-term records of observations is increasingly important to meaningfully evaluate climate system change, and to place such change in the context of natural variability. Outside users can download these data for further analysis; however, the amount of data available is often extremely large and not readily accessible without significant effort. CDC thus also provides a number of visualization and analysis tools that allow users to "test" out the data before going through the process of downloading. CDC's in-house scientific expertise provides insights into the types of questions climate researchers are investigating and the preferred WWW display and analysis tools to address these questions. A diverse number of visualization and analysis tools are available through the CDC Interactive Plotting and Analysis Pages (http://www.cdc.noaa.gov/PublicData/web_tools.html). A subset of these visualization and analysis tools plot data, or averages of data, over different times, allow users to specify the region, variable, type of plot (mean, anomaly, long-term mean, or time-by-latitude plots for example) and various other parameters. User-specified averaging over different intervals can be applied to study the average effects of phenomena such as ENSO (e.g., **Fig. 6.6**), or to examine possible decadal climate changes. On shorter time scales, users can systematically analyze synoptic variability or examine the current weather/climate in greater detail by

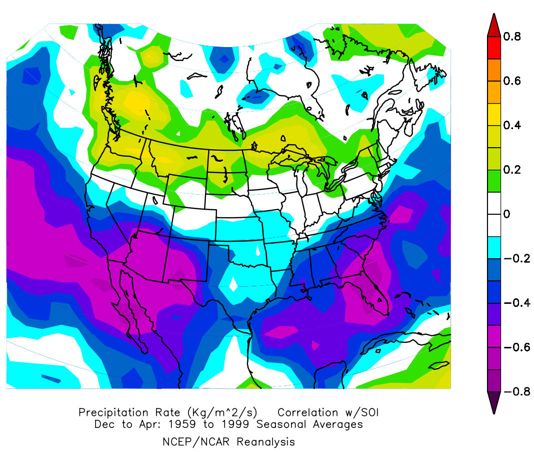

Fig. 6.6. WWW-based graphic generated using the correlation analysis tools to evaluate the relationship between NCEP Reanalysis precipitation and the SOI.

using a choice of the monthly mean compositing page, the daily compositing page, the US climate division dataset plotting page, the time section plotting page, the operational data plotting page, and the chi-corrected heating atlas. CDC also provides more sophisticated analysis tools such as a monthly correlation page, the US climate division correlation page, and a wavelet analysis page.

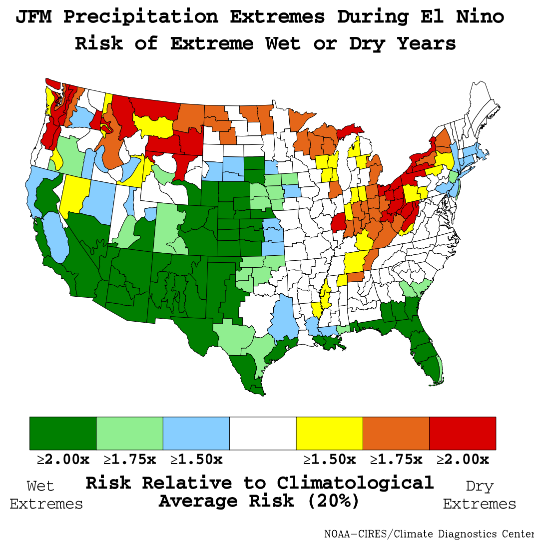

Fig. 6.7. Increased risks of precipitation extremes for Jan.-Mar La Niña conditions based on the SOI for 1896–1995. Relative risks at the 1.75x and 2.00x levels of either dry or wet extremes are significant at the 93.6% and 98.2% levels, respectively.

The correlation/regression analysis tools allow users to test (linear) relationships among the data and a suite of common indices of atmospheric or ocean variability (e.g., ENSO, PNA, or the AO), or a user-specified time series. The wavelet analysis tool allows users to examine the variability of some common atmospheric or user-provided time series. CDC also provides a WWW-based experimental climate services product that estimates the relative risks of extreme precipitation and temperature anomalies in relation to ENSO (e.g., the regional increased risk of extreme warm/cold or dry/wet, **Fig. 6.7**, http://www.cdc.noaa.gov/Climaterisks/).

All of these WWW tools are used extensively for research, for educational purposes by teachers, and to assess current or possible future weather and climate conditions by both public and private sector decision makers (e.g., energy companies, water managers). In addition, the plots and analyses generated by these pages have been presented at a wide variety of scientific meetings and have been incorporated in books and journal articles by both CDC and non-CDC scientists. The ideas generated by users able to quickly explore the data have made the CDC WWW-based visualization and analysis tools extremely useful and have saved much time and energy for researchers both outside and inside CDC.

6.2.2 Climate Model Output

CDC has begun assembling large ensembles of climate model simulations of the 20th Century, many of which have been performed at other institutions, and making these data accessible to the research community for evaluation and intercomparisons. As part of this effort, CDC has developed a parallel set of WWW-based visualization and analysis tools to intercompare GCM simulations of climate, explore causal mechanisms for change in long-term observed records, and to establish the fidelity of model simulated climate. These WWW-based tools allow considerable user interaction and manipulation of the data using CDC computing platforms. GFDL R30 resolution model climate simulations are currently available and may be intercompared with reanalysis climatologies (http://www.cdc.noaa.gov/gfdl). The GFDL data will be augmented to include AMIP-style simulations for 1950–1999, and runs using idealized SSTs. Also available on-line is the NCAR CCM3 AMIP climate model simulations spanning 1950–1999 with globally prescribed and tropically prescribed SSTs (http://www.cdc.noaa.gov/Composites/CCM). In addition to generating composites, the user can perform correlation analyses of the CCM3 response to various SST forcings (e.g., **Fig. 5.1**) at http://www.cdc.noaa.gov/Composites/CCM/Correlation/. Anticipated changes in computing infrastructure will permit an increasingly larger volume of climate model data to be made available on-line, and it is likely that CDC will increasingly host model data to support climate assessment research.

6.3 User Studies and Societal Interactions

CDC has conducted studies to evaluate the usefulness of climate information and products. This research is part of a broader effort to provide improved climate information to support more informed decision-making, and is designed to complement CDC climate diagnostics and modeling research. Initial studies have provided insights into how climate information and products are and could be used, while simultaneously identifying areas for research on experimental climate products (**Fig. 6.8**).

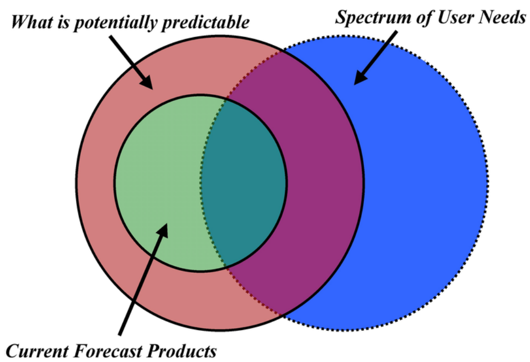

Fig. 6.8. Schematic showing the relationships among current products, potentially predictable climate information, and needed climate information. Directions for applied research are suggested by the purple overlap region.

6.3.1 Climate information and water management

CDC research has focused on the decision processes related to critical natural resource or society-relevant problems that are affected by climate. Goals are to learn what climate information is wanted and when, and how such information relates to specific decisions. In ongoing interactions with users, desired climate products are identified and the usefulness of prototype climate products is assessed.

One example of this strategy has been to focus on what is known about climate and integrate this information into our understanding of the annual cycle of reservoir management decisions (**Fig. 6.9**). In the Upper Colorado River Basin and Gunnison Basins, reservoirs that were originally built to provide reliable irrigation supply, hydropower, and recreation are now being operated to address additional concerns of maintaining appropriate flows for fish and water quality. Augmentation of spring peak flows and maintenance of late summer minimum in-stream flows in order to support the recovery of endangered fish are new issues in reservoir management. CDC has engaged reservoir managers seeking information to help address increasingly complex issues, and thus who are willing to consider new uses of climate information.

As illustrated in the decision calendar schematic (**Fig. 6.9**), NOAA long-lead precipitation and temperature forecasts can be incorporated into a fall forecast of winter snowpack accumulation with implications for subsequent April–June runoff. An improved understanding of ENSO influences on seasonal evolution of snowpack can lead to a more accurately planned "start of fill" target. By late spring, the NOAA long lead precipitation and temperature forecasts can be incorporated into summer season forecast irrigation demands. Throughout the spring one to two week precipitation and temperature forecasts can be used to provide improved estimates of volume and timing of spring releases needed to augment peak flows for habitat restoration and for flood mitigation. Throughout the summer, one to two week precipitation

Fig. 6.9. The Reservoir Management Decision Calendar indicates the timing of select planning processes (purple bars) and operational issues (blue bars) for the Upper Colorado River Basin reservoirs. Also shown are the potential use of various types and timings of climate and weather forecasts (yellow bars) that could be used to address these concerns. The width and position of the bars indicate the intervals of relevant time periods. The distinction in classifying an activity in ones of categories: "Planning process" can be thought of as making strategic decisions in anticipation of upcoming events, whereas "operational issues" can be thought of as making tactical decisions on implementing a course of action in response to a near term event.

and temperature forecasts can be used to improve hydropower and irrigation scheduling, as well as low flow mitigation.

The decision calendar has proven useful in linking water resources management planning processes and operational issues with potential uses of variable lead-time forecasts and climate information. Future CDC climate applications research are anticipated to employ a similar approach, using the decision calendar framework to assess the role of climate information in decision-making related to energy, forest fires, air quality, and human health issues.

6.4 Western Water Assessment: A Regional Integrated Assessment for the Intermountain Western United States

CDC has collaborated with researchers from CIRES and the University of Colorado to develop the Western Water Assessment (WWA), an interdisciplinary research project linking climate, water resources, and society. The project is designed to do integrated interdisciplinary research and to interact with users in an effort to ensure society relevant research. The WWA, funded through the NOAA/OGP Regional Integrated Sciences and Assessments (RISA) program, represents an effort to forge genuine partnerships among the scientific community, climate service providers, and users. The goal is to provide the relevant climate/hydrology information that will support informed decision-making and thus reduce vulnerability to the impacts of climate variability and change.

CDC's WWA research has focused on the role of climate information for the decision-making process for water managers in the Upper Colorado River Basin. Colorado and the Interior West are ideally suited for a regional focus since the climate conditions (e.g., snowpack, timing of peak runoff, and extreme events) are orographically controlled. Investigations have evaluated the use of existing suites of climate predictions and products by the region's decision makers for specific sectors, and have undertaken the task of developing new products, or adding value to existing ones. The effort involves frequent interactions with users through regular briefings, workshops, coordination meetings, or web-enabled tools. The applied climate research aims to provide an improved regional description of climate and its variations on spatial and temporal scales that are relevant to users. Applied hydrologic research examines the role and evolution of snowpack, and identifies those predictable weather and climate patterns that influence variability in regional hydrographs.

6.4.1 User interactions

Over the past two years, CDC scientists have worked with managers of reservoir operations in the Upper Colorado to determine how climate information might be used more effectively throughout the water year. These user studies involved: a) direct participation in planning by attending and or hosting reservoir management meetings, b) partnering with the Denver Water Board and Colorado River Water Conservation District to hold a workshop focused on the use of climate information and seasonal forecasts in water resource management focused on endangered fish habitat restoration, c) preparation of “Climate Forecast Discussions for the Upper Colorado Basin” for distribution to USBR and other interested water managers, d) providing briefings on climate forecasts and current status to the Colorado Drought Task Force and various water resource coordination meetings for the Upper Colorado Basin, and e) focused user studies described previously. These activities, while labor intensive, have established the needs and potential uses of forecasts and climate information in water resource management. The next step will be to incorporate climate forecasts and information into the NOAA Colorado Basin River forecasts used by reservoir managers. On-going activities are focused on implementing a technology transfer process to integrate seasonal climate information into river forecast procedures. A collaborative effort with the Colorado Basin River Forecast Center, in Salt Lake City is envisioned following an iterative process of identifying prototype climate products needed by the River Forecast Centers and then developing applied climate research products.

6.4.2 Regional climate variability

Identified user needs and interests in regionally based climate information have helped motivate research to enhance understanding of climate variability in the intermountain western US. CDC researchers have performed empirical analyses on western U.S. precipitation patterns (derived from historic climate station and automated SNOTEL data) at a number of spatial and temporal scales to document and provide insights into patterns of observed range of climate variability. These analyses have concentrated on the South Platte and Upper Colorado River basins, and have also assessed higher elevation climate records relative to more continuous low elevation sites (**Fig. 6.10**). Results for Colorado reveal relatively low temporal variability in the regionally important winter precipitation season at high elevations (red/orange colors), which contrasts with more variable winter precipitation at lower elevations (blue/green) colors.

CDC researchers also developed hydroclimatically based experimental “climate divisions” using multivariate analysis of the annual cycle of precipitation in order to improve monitoring of the seasonal evolution of precipitation across Colorado (**Fig. 6.10**). The resulting experimental “climate divisions” regions explain more than half of the average local precipitation variance. Since each regional average explains more precipitation variance than the operational divisional time series, these internally consistent experimental regions are proposed as alternative to existing climate divisions to monitor the seasonal evolution of precipitation.

6.4.3 Regional hydrologic variability

Identified user needs and interests in regionally based climate information also have helped motivate research focused

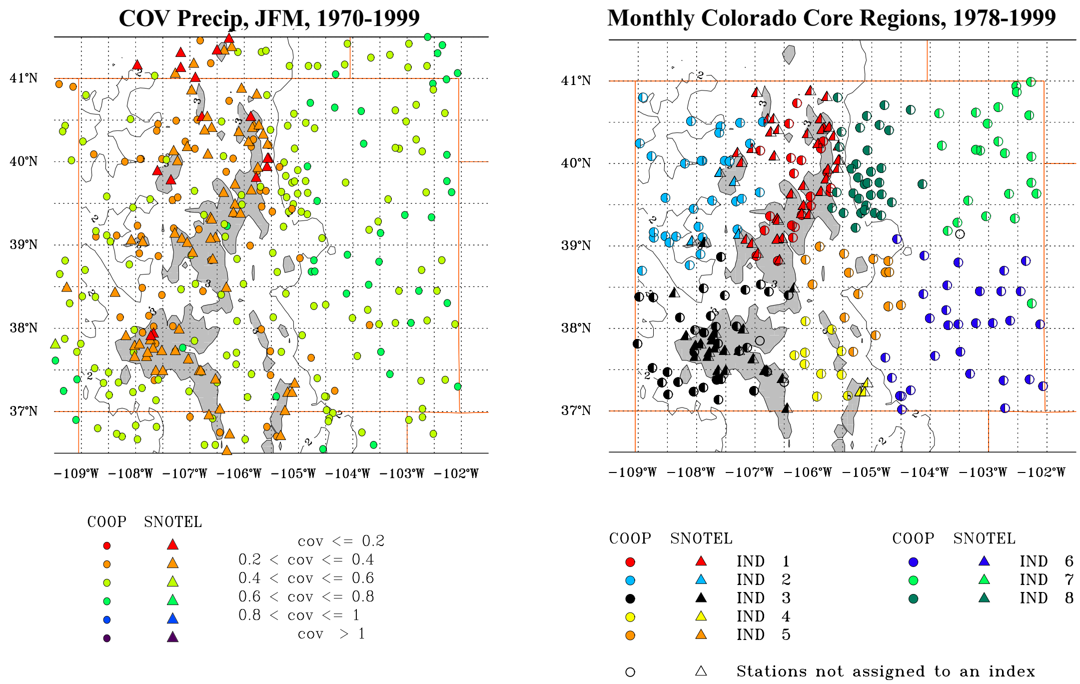

Fig. 6.10. Wintertime coefficient of variation for precipitation data at individual Colorado stations (left panel) and proposed experimental "climate divisions" based on multivariate analysis of the annual cycle of precipitation (right panel). The low wintertime coefficient of variation in the left panel indicates reduced interannual variability. The colors in the right panel correspond to individual experimental "climate divisions" and the amount of color for each symbol reflects the amount of variance explained at individual stations by the experimental "climate divisions" regional precipitation index.

on the potential for predicting the magnitude and timing of late spring/early summer peak runoff. The observed hydrologic regime in the upper Colorado River Basin is driven largely by the cold season snowpack dynamics, warm season melt, and characteristic space-time scales of relevant weather and climate precursors. Seasonal streamflow variations and peak floods in the West reflect an integration of seasonal-to-interannual climate influences (through snowpack development in the cold season) and weather patterns on month-to-seasonal time scales (responsible for snowmelt in the spring). The magnitude and timing of springtime peak streamflow represents the joint influences of the wintertime climate (as reflected in the snowpack), and the springtime weather patterns that aid in the melting of snowpack. Diagnostics and monitoring of intraseasonal-to-interannual hydroclimatic variations in the Yampa River drainage have shown consistent relationships between the April 1 snowpack and April–July streamflow. Analysis of historical records suggests that over 60% of the observed variations in streamflow can be explained by a linear snow-streamflow relationship (**Fig. 6.11**).

The large-scale climate controls on extreme (high and low) snowpack years in the Yampa River Basin can be interpreted in terms of composite SST anomaly patterns. Low snowpack occurs during winters with anomalously warm

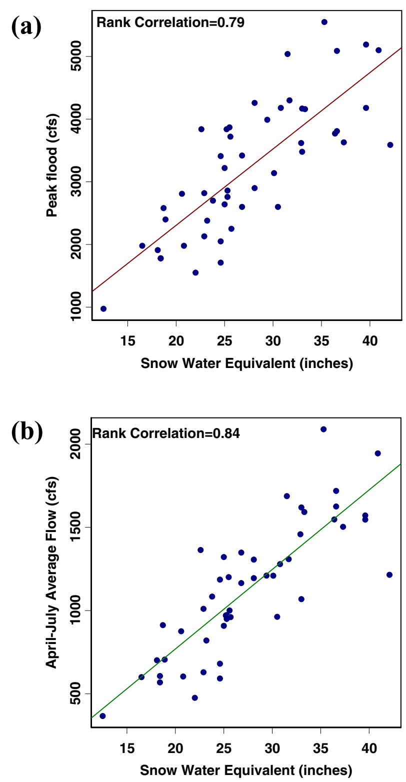

Fig. 6.11. Yampa River streamflow: relationship between April snowpack at Rabbit Ears snow monitoring station and Maybell, Colorado streamflow. (a) Relationship between April 1 snowpack and subsequent snowmelt peak flow. (b) Relationship between April 1 snowpack and April–July streamflow.

tropical Pacific and a cold North Pacific. High snowpack years are associated with warm North Pacific SST and a cold tropical Pacific SST anomalies. Ongoing research is investigating: (a) the associated winter and spring variations in intraseasonal precipitation and temperatures to assess the risk for extreme surface hydrologic variations, and (b) the underlying mechanism for the associated patterns of SST anomalies and their predictability, to aid snowpack predictions.

Streamflow during the April–July melt season is driven by regional temperature patterns that determine the shape of melt hydrograph and the timing of peak flow. The timing of peak flow (or annual maximum flood) is critically important for reservoir operations and assessing downstream flood potential. Preliminary analysis suggests a causal relationship between the regional temperatures and the timing of peak flow. In the Yampa region, a three-to-five day lag is observed between the temperature and snowmelt-driven streamflow. Further, the amplitude of Eastern Pacific and Pacific North American teleconnection patterns (April) show a statistical relationship with the date of peak streamflow. The results from these analyses point to the potential for modeling and forecast of snowmelt and the timing of peak flows, based on a detailed analysis of medium-range temperature variations and available forecast products. Near real-time monitoring of the relevant hydroclimatic variables and CPC temperature forecasts for the Yampa region are now available on the WWW (http://www.cdc.noaa.gov/~sjain/waterpulse/).

6.5 Public Health and Climate Research

During the last decade, there has been considerable interest in better understanding the possible impacts of climate variability on public health. This interest has evolved into a basic research component within the CDC experimental climate services portfolio. These interdisciplinary research activities not only provide a better understanding of the relationships between climate variability and human health, but also guide climate research to ensure the development of the climate information needed to better forecast or monitor potential public health crises.

6.5.1 Precipitation and encephalitis

CDC is currently collaborating with epidemiologists at the University of California at Davis and the Scripps Institution of Oceanography on possible associations between interannual precipitation changes and variations in the incidence of western equine encephalitis (WEE) in the Central Valley of California. WEE and SLE (St. Louis encephalitis) are mosquito-borne diseases endemic in California. Human vaccines and therapeutic drugs currently are not available for the viruses, and vector abatement remains the only method of controlling human infection. Vector abatement relies strongly upon accurate surveillance of environmental conditions to provide sufficient warning to implement intervention. Amplification of encephalitis viruses to levels that place the human population at eminent risk of infection depends on the rate of virus replication in the mosquito host. The replication rates are related to temperature and mosquito population size which in turn are related to surface water availability. Improved understanding of global (and tropical Pacific) atmospheric teleconnections, the use of numerical model guidance for long range forecasting of climatic conditions in California, and the availability of short-range forecasts in conjunction with hydrological models, can collectively provide accurate depictions of snowpack and run-off. Quantitative relationships between climate and enzootic virus amplification are being developed retrospectively to forecast the level of virus activity during the principal transmission seasons of spring and summer.

6.5.2 Climate variability and Kawaski disease

A second collaborative research project with the University of California at San Diego and Scripps is to improve current understanding of the possible link between weather and climate variability and Kawasaki Disease (KD), an acute illness of the circulatory system primarily affecting infants and young children. A winter and spring seasonal KD peak has been recognized for over two decades, but recent studies suggest an association at synoptic time scales as well. KD incidence data for San Diego County from 1994 to present shows a moderate correlation with precipitation. The distribution of cases is characterized by the presence of clusters in which multiple KD cases occurred within a time interval of just a few days. Fifteen clusters occurred during the cool season (November–April) between 1994 and 2000. Weather patterns were examined starting 6 days before and continuing through 6 days after the date of KD onset (first day of fever is designated day 0) for the first child in the cluster. The composite patterns were compared to a second control sample of randomly selected days for the same cool seasons (1994–2000), but during prolonged periods with no KD events. The 700mb height anomaly field was composited over the 15-event sample set. The atmospheric circulation pattern preceding the occurrence of KD data clusters exhibit strong negative anomalies over the North Pacific upstream from San Diego (**Fig. 6.12, left panel**), indicating an active storm track and typically wet conditions in San Diego County. This pattern appeared to be developing by Day –6, was very strong on Day –4, and then persisted, though weaker, for several days thereafter. In contrast, the composite from control sample days extracted from the non-KD periods shows no significant anomaly pattern in atmospheric circulation over the Pacific (**Fig. 6.12, right panel**). Inspection of the 15 individual KD clusters revealed precipitation of at least 0.1" associated with 10 of the clusters. These results warrant further investigation and exploration of other variables (humidity, cloud cover, minimum temperature, time elapsed since last significant rain storm) in relation to KD clustering.

CDC scientists are also part of an international regional network to foster interdisciplinary research to better understand the relationships between climate variability and human health in the Americas. As part of a five-year project funded by the InterAmerican Institute for Global Change Research, a major effort is underway to develop a database of climate and selected human diseases, primarily vector borne diseases, such as malaria and dengue fever, to allow diagnostic studies and monitoring activities to be carried out.

EPILOGUE

CDC is uniquely positioned within NOAA's emerging climate services. Through its diverse research in climate diagnostics and analyses, CDC is an extensive user of new and enhanced climate forecasts and products. Participa-

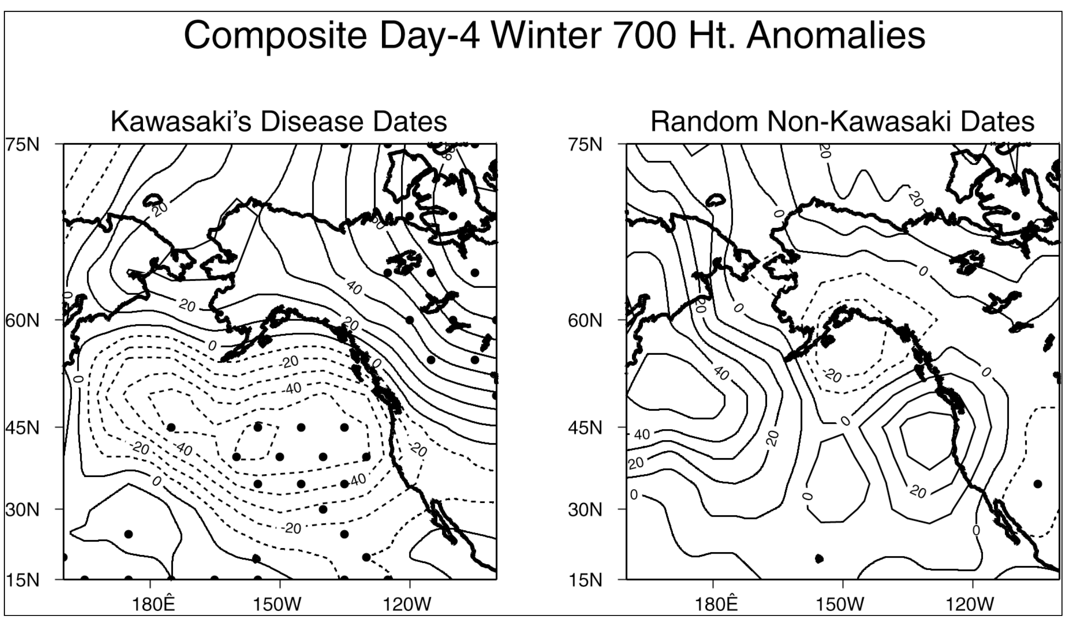

Fig. 6.12. Composite 700 mb height anomalies, 4 days prior to the onset of KD case clusters in San Diego County. Dots denote significance of being different from the null hypothesis (zero anomaly) with 90% (or greater) confidence by a t-test.

tion in the NOAA-CIRES western water regional integrated science assessment project engages CDC in research to identify gaps between climate information and societal needs, and to develop decision support services that make climate information and products more useful. Finally, as an experimental provider of climate services, CDC is developing the infrastructure and expertise to provide improved access to climate and weather products for use by the scientific research community and less traditional users.

CDC will continue to develop experimental research products that meet the needs of both the scientific research community and less tradition users of climate information and forecasts. To ensure improved regular and systematic communication of needed climate information, CDC will work to formalize partnerships within NOAA and outside of NOAA. Within NOAA, enhanced interactions with OAR (e.g., GFDL and ETL), NESDIS (WRCC and NCDC) and NWS (NCEP/CPC and RFCs) will ensure the development of experimental climate monitoring and forecast products that can be used by, and then transferred to, operational distribution centers. As climate science matures, there is a greater awareness in society of the importance of climate, and the emerging role for climate information in decision-making related to energy, forest fires, air quality and human health, and water resources management. Although these are national issues, there is a growing recognition that providing an improved scientific basis for public planning and policy decisions will require regionally specific climate information and products designed to meet local, state, and regional interests. In collaboration with WRCC, CDC will continue to expand the links between fundamental climate research and regional applications to society-relevant problems, including the timely and routine transfer of data, products, and information to current and future user communities. Enhanced partnerships between CDC and university-based regional climate assessment activities, as well as identified stakeholders in the West, will be essential to accelerate the increased flow of climate information to support decisions. In-house research at CDC will continue to work directly with active, or potential, users of climate information to improve the understanding and usefulness of climate information while identifying areas for research to develop new and improved experimental climate products. In addition, CDC research will be expanded to identify the possible impacts of climate variability on public health and to develop climate products that better forecast and monitor potential public health crises.

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