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Global Impacts and Regional Actions: Preparing for the 1997–98 El Niño

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ABSTRACT

It has been estimated that severe El Niño–related flooding and droughts in Africa, Latin America, North America, and Southeast Asia resulted in more than 22 000 lives lost and in excess of $36 billion in damages during 1997–98. As one of the most severe events this century, the 1997–98 El Niño was unique not only in terms of physical magnitude, but also in terms of human response. This response was made possible by recent advances in climate-observing and forecasting systems, creation and dissemination of forecast information by institutions such as the International Research Institute for Climate Prediction and NOAA's Climate Prediction Center, and individuals in climate-sensitive sectors willing to act on forecast information by incorporating it into their decision-making. The supporting link between the forecasts and their practical application was a product of efforts by several national and international organizations, and a primary focus of the United States National Oceanic and Atmospheric Administration Office of Global Programs (NOAA/OGP).

NOAA/OGP over the last decade has supported pilot projects in Latin America, the Caribbean, the South Pacific, Southeast Asia, and Africa to improve transfer of forecast information to climate sensitive sectors, study linkages between climate and human health, and distribute climate information products in certain areas. Working with domestic and international partners, NOAA/OGP helped organize a total of 11 "Climate Outlook Fora" around the world during the 1997–98 El Niño. At each Outlook Forum, climatologists and meteorologists created regional, consensus-based, seasonal precipitation forecasts and representatives from climate-sensitive sectors discussed options for applying forecast information. Additional ongoing activities during 1997–98 included research programs focused on the social and economic impacts of climate change and the regional manifestations of global-scale climate variations and their effect on decision-making in climate-sensitive sectors in the United States.

The overall intent of NOAA/OGP's activities was to make experimental forecast information broadly available to potential users, and to foster a learning process on how seasonal-to-interannual forecasts could be applied in sectors susceptible to climate variability. This process allowed users to explore the capabilities and limitations of climate forecasts currently available, and forecast producers to receive feedback on the utility of their products. Through activities in which NOAA/OGP and its partners were involved, it became clear that further application of forecast information will be aided by improved forecast accuracy and detail, creation of common validation techniques, continued training in forecast generation and application, alternate methods for presenting forecast information, and a systematic strategy for creation and dissemination of forecast products.

1. Introduction[1]

The purpose of this article is to summarize activities and responses implemented by the National Oceanic and Atmospheric Administration's Office of Global Programs (NOAA/OGP) and its partners during the 1997–98 El Niño, as a way of illustrating a number of possible research- and policy-related strategies undertaken in anticipation of this event.[2] It is hoped that les-

[1]A detailed description is provided in (NOAA/OGP 1999).

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[2]This article is intended as a companion to articles by Barnston et al. (1999) and Mason et al. (1999), which further elaborate on prediction accuracy, scope, and timing, as well as forecast generation during the 1997–98 ENSO event.

sons learned can be applied to future scenarios involving climate variability and the use of climate-forecast information.

NOAA/OGP has participated in numerous long-term efforts to catalyze directed interaction among internationally distributed groups of physical, natural, and social scientists interested in research on climate variability and prediction, in cooperation with regional experts in climate-forecasting applications and with potential sectoral users of climate information.[3] NOAA/OGP's mission over the last decade has been, in part, to stimulate the first steps in learning how these groups' expertise can be integrated to construct common language and methodologies for better understanding the application of seasonal-to-interannual climate forecasts, and to support research activities toward this end. These scientific and user groups have coalesced so that by the time of the 1997–98 El Niño they had already perceived a need for accurate, timely, and ultimately useable forecasts of climate variability related to ENSO. Cutting across disciplines, borders, and sectors they shared a motivation to learn from each other how to direct research and application activities in the service of an actual response.

During the event, these groups worked together using limited research budgets to provide experimental information in the absence of an established global infrastructure for coordinated climate forecasting and associated services. Although, impacts of the 1997–98 El Niño were often unanticipated, the opportunity and ability to protect lives and property in advance of impacts through the use of forecast information was indeed recognized. NOAA/OGP viewed research activities undertaken overseas as critical to improving understanding of climate-forecast applications in the United States. Implementing response strategies was also useful in that they offered a glimpse of what it will take to provide the world with comprehensive climate-forecast services.

From the summer of 1997 through the spring of 1998 many regions around the world were affected by climate patterns that departed dramatically from "normal." El Niño–related climate variability affected decisions about agricultural productivity, water supplies, fisheries output, the integrity of transportation, telecommunications and civil infrastructure, and the spread of life-threatening disease such as malaria, dengue, and cholera. Scientists consider the 1997–98 El Niño to be one of the most severe ENSO warm events of the twentieth century, tentatively estimated to have caused the loss of approximately 22 000 lives, with at least $36 billion in total costs from flooding, droughts, and associated impacts.[4]

While the variability of climate is inevitable, the loss of human life and economic disruption associated with climatic fluctuations, such as result from El Niño or La Niña, can be mitigated by advanced warning and preparation of contingency plans. Unlike the 1982–83 El Niño, the onset and related impacts of the 1997–98 event were predicted well before they occurred, using the Tropical Ocean and Global Atmosphere (TOGA) array of sea surface temperature–monitoring buoys in the equatorial Pacific, and predictive computer models [e.g., general circulation models (GCMs), statistical, coupled ocean–atmosphere, etc.]. Advances in the capability to forecast seasonal-to-interannual climate variability provided an unprecedented opportunity to prepare for El Niño–related climate impacts, and to mitigate socioeconomic damages, or in some cases, to reap benefits. Building on regional pilot activities for climate forecast applications, NOAA/OGP worked to link international scientific and sectoral user groups

[3]For the purposes of this article, "predictions" refer to the projected state or condition of physical phenomenon in a particular location at some point in the future expressed in basic scientific form, for example, advance estimates of sea surface temperature or precipitation/temperature anomalies, usually inferred from in situ or satellite observations, or the outputs of statistical or dynamical models: "forecasts" refer to predictions of lagged climate impacts that have undergone some form of interpretation, adding value so that they provide potentially useful and intelligible information to decision-makers, for example, Climate Outlook maps; "applications" refer to the use of climate predictions or forecasts in a decision-making context; "users" are any institutional or sectoral decision-makers in a position to use climate forecasts to optimize their climate sensitive choices. Computer generated predictions and forecast information products discussed in this article were created at NOAA's Climate Prediction Center (NOAA/CPC) and Climate Diagnostics Center (NOAA/CDC), International Research Institute for Climate Prediction (IRI), and the Center for Ocean, Land, Atmosphere Studies (COLA). While each institution produced its own unique set of products and made them available to the global community, usually via the Internet, CPC distributed these forecast data products primarily to reach decision-makers in the United States, while IRI and OGP worked largely to analyze, interpret, and communicate information to those participating in Climate Outlook Fora and other research activities overseas, or to provide information to U.S. government agencies operating internationally. In cases where OGP provided information domestically, it was typically provided as part of research-oriented projects.

[4]See Sponberg (1999).

around the world through planning, conducting, or encouraging 11 "Climate Outlook Fora" and other related activities to stimulate the development and application of forecast information.

The first section briefly covers NOAA/OGP's ongoing Pilot Program for the Application of Climate Forecasts, establishing a context for the Climate Outlook Fora, and outlining nearly a decade of research and organizational activities on climate forecast applications that preceded response to the 1997–98 El Niño.

The second section covers the methodology, regional conduct, preliminary evaluation, and recommendations of the Climate Outlook Fora, many of which were planned before the event occurred and served as a rapid means by which forecast information could be produced and distributed to users once the event was predicted. This section includes description of a method developed by the Southern Africa Regional Climate Outlook Forum (SARCOF) to quantitatively evaluate the consensus forecasts and user feedback from SARCOF, and figures related to the Northeastern South America Regional Climate Outlook Forum.[5]

Background

Activities during 1997–98 were made possible, in part, by nearly 15 years of collaborative research programs in climate science and forecast applications between partner institutions around the world. NOAA/OGP has helped make seasonal-to-interannual climate forecasting a reality through participating in

- conduct of the TOGA program,
- establishment of the TOGA Atmosphere–Ocean (TAO) array of sea surface temperature monitoring buoys in the equatorial Pacific,
- enhancement of the ability to predict ENSO and related climate variability using coupled ocean–atmosphere models,
- improvement of the capability to predict midlatitude climate variability based on increased understanding of ENSO forcing,
- launching of the IRI,
- development of regional forecast applications and the concept of an end-to-end system, and
- stimulating demand for probabilistic climate forecasts.

2. Pilot program for the application of climate forecasts

NOAA/OGP's Pilot Program for the Application of Climate Forecasts has evolved in conjunction with advances in the accuracy and utility of climate predictions, and with progress in applications and training made during workshops that the scientific community has supported since 1991.[6] The primary purpose of these initial activities was to develop a forecaster/user dialogue and provide a venue for information exchange among researchers and decision-makers in climate-sensitive sectors around the world. As the prediction capability and the interest in climate forecasts on the part of decision-makers increased, the need emerged for more formalized programs that would address applications in a systematic and comprehensive manner. NOAA/OGP's Pilot Applications Program was formulated to perform trials on the concept of an "end-to-end" system that would produce and distribute forecasts to users during extreme climatic events, and to support the development of the IRI.[7]

The Pilot Applications Program encompasses a suite of activities, which collectively provide the mechanisms for transforming research results into information designed to assist potential users, and distributes that information to key decision-makers in the public and private sectors. The purpose of the Pilot

[5]The appendix summarizes a selection of research and response activities managed in concert with the event not directly related to conduct of the Climate Outlook Fora, but relevant to NOAA/OGP's overall response to the event.

[6]Early efforts involved a course on ocean–atmosphere interactions in the Tropics (August 1991), a workshop on tropical climate variability and applications (August 1992), both at the International Center for Theoretical Physics (ICTP) in Trieste, Italy, and a Workshop on ENSO and Seasonal-to-Interannual Climate Variability: Socio-Economic Impacts, Forecasting, and Applications to the Decision-Making Process, September 1992 in Fortaleza and Florianopolis, Brazil.

[7]For the purposes of this report, an end-to-end system is one that draws on scientific research to regularly produce, apply, and distribute seasonal-to-interannual climate forecasts to decision-makers, who in turn feed back information to help enhance the research, and improve the production and distribution of the forecasts.

Applications Program is to advance the following objectives in collaboration with interested individuals, institutions, and countries around the world:

- analysis of the anticipated impacts of projected climate-related changes in the physical environment on natural and human systems;
- studies on vulnerability to short-term fluctuations in climate, and the influence of changing socioeconomic conditions;
- development, evaluation, and use of improved assessment techniques and methodologies, which provide for the integration of physical climate forecasts into existing decision-making structures;
- analyses of how the adoption of climate forecasts will alter management decisions in climate sensitive sectors, and how these new patterns of adjustment will, in turn, affect other sectors, the environment, and society as a whole;
- dissemination of targeted forecast analysis products designed to address specific resource problems or economic sectors; and
- education and training of a multinational cadre of scientists and decision-makers skilled in the use and interpretation of new forecast capabilities and analysis techniques.

The Pilot Applications Program had several initial regional foci (Latin America, Southeast Asia, the South Pacific, and Southern Africa), and one sectoral focus in climate and health across these regions (climate and human health under the ENSO experiment). Regions were selected based on evidence of ENSO-related physical and socioeconomic impacts in these areas. The objective of the ENSO experiment was to examine the relationship between climate variability and human health—specifically during the 1997–98 ENSO—to explore the potential for using climate forecast information to provide early warning of conditions posing a public health threat, and to enhance the dialogue among the climate, ecology, and health research communities and end-users of forecasts.

In order to address forecast applications in a systematic manner and provide as much consistency as possible, the activities in each region were based on common methodology, beginning with an analysis of the climatic and socioeconomic impacts of ENSO, and culminating in the incorporation of climate forecast information into existing decision-making processes. Each region's unique physical, social, and cultural characteristics influence its adaptive capacity and ability to successfully use a climate forecast, and consequently the way in which it experiences the impacts of climate variability. The methodology, therefore, drew from several approaches tailored to fit the needs and interests of a particular region, while cross-fertilization between regional experiences was expected and encouraged.

The objectives of the Pilot Applications Program progress through an integrated set of activities, conducted by a range of stakeholders. The primary methodological elements of the program are the following:

- Element 1: Preparatory studies
  Develop 6–12-month projects designed to indicate the potential for acting upon climate forecast information to mitigate climate-related impacts in affected sectors (agriculture, human health, water resource management, disaster preparedness, etc.).
- Element 2: Capacity building for applying climate forecasts
  Share preparatory study results, and develop longer-term (12–18 month) pilot application projects that will begin the systematic production and distribution of experimental climate-forecast products to decision-makers in selected sectors.
- Element 3: Institutionalizing climate forecasting applications networks
  Demonstrate regional forecasting capacity, ensure long-term use of climate-forecast information and promote the establishment of a regional climate-forecasting network to interpret and apply new forecasting tools to decision-making.
- Element 4: Review and evaluation
  Review and evaluate both the process and progress at each step of the program, providing feedback for activities conducted under each primary element and supporting continued improvement in the application of climate forecasts.

In many cases, NOAA/OGP's Pilot Program for the Application of Climate Forecasts catalyzed regional activities and set the scene for further projects related to the creation and application of climate information. The spectrum of regional projects, the ties built with individuals and institutions in the regions over the years, and the lessons learned about applications of climate forecasts through researcher–user dialogue fed necessary ideas, methodologies, and experiences into a process that helped spawn the Climate Outlook Fora.

3. Regional climate outlook fora

Prior to the 1997–98 El Niño event, few individuals and organizations around the world had used seasonal climate forecasts in practical decision-making, relying instead on persistence, climatology/seasonality, or folklore. Weather forecasts were frequently applied to planning on a daily and weekly basis, but longer-term climate predictions had largely been confined to the research realm. With recent technological advances in forecasting climate on seasonal-to-interannual timescales and predictions of the event and related impacts, NOAA/OGP recognized an opportunity to increase awareness of the existence and potential usefulness of climate forecasts. The Climate Outlook Fora, aimed at creating consensus seasonal forecasts and to better understanding user needs for climate information, coupled with the timing of the El Niño event, provided a real-world laboratory in which to test the practical application of seasonal forecast information.

Working with the United States and international partners, in particular the IRI, the U.S. Agency for International Development (USAID), and the World Meteorological Organization (WMO), NOAA/OGP organized and implemented Outlook Fora in Africa, Latin America, the Caribbean, and Southeast Asia (see Table 1). The fora involved scientists and representatives of universityand government forecasting organizations, National Meteorological and Hydrological Services (NMHS), and international forecast centers. At each Outlook Forum, climate scientists produced probabilistic, consensus-based, seasonal forecasts, or Climate Outlooks, for given regions. The consensus Climate Outlooks presented an opportunity for users (e.g., decision makers in different sectors) on a regional scale to systematically employ, albeit experimentally, probabilistic forecasts of rainfall distributions. It was intended that users would apply forecasts in a bid to incrementally improve the accuracy and outcome of management decisions made in anticipation of expected impacts.

Many of the Outlook Fora were held in conjunction with pilot applications design workshops, which allowed exploration of the uses of climate forecasts with users of the information from agriculture, fisheries, water resources, food security, and disaster preparedness communities. In some instances, adjunct press briefings and conferences were convened to inform the general public of the issued Climate Outlook and its potential applications.

Some activities at initial Outlook Fora included

- tutorials on climate mechanics, and the creation and interpretation of climate predictions;
- training sessions, including forecast verification, probabilities, techniques of forecast application, and user needs;
- presentation of user/intermediary requirements, based in part on outcomes from earlier pilot applications project meetings;
- presentations of regional climate information products;
- discussion of products, models, and methodologies, including quality selection criteria, regionalization of forecasts, and forecast parameters, investigation of methodologies for consensus Outlook development; and
- discussions on Outlook distribution and dissemination.

Several of the Outlook Fora benefited from design prior to predictions of the 1997–98 El Niño event. This lead time allowed for thorough advance planning and resource allocation, permitting the funding and preparation of various meetings over the course of the event unique to each region and allowing in some cases adjustments of the forecasts as the season progressed.

In this section, the general methodology for the planning and implementation of the Outlook Fora is outlined, and the basic structure of the Outlook Fora is described. General recommendations regarding forecast creation, dissemination, and application from all of the Outlook Fora are summarized at the conclusion of this section. The institutions listed in Table 1 represent those institutions that played major sponsoring and organizational roles at each forum. The large number of organizations involved attests to the fact that the Outlook Fora were cooperative efforts that required the dedicated support of individuals and institutions around the world.

a. Methodology[8]

Organizational elements of the Climate Outlook Fora included identifying participants and local orga-

[8]See Mason et al. (1999) for further details on these topics.

TABLE 1. A chronological listing of Regional Climate Outlook Fora conducted during 1997–98, including date held, location, target region, local host, and cosponsoring organizations.

Date	Place	Target region	Local host	Cosponsors
		Africa		
Sep 1997	Kadoma, Zimbabwe	Southern Africa	Zimbabwe Met. Service	NOAA/OGP, WMO, ENRICH, SATCC, IRI, UKMO
Dec 1997	Windhoek, Namibia	Southern Africa	Namibia Met. Service	NOAA/OGP, WMO, ENRICH, SATCC, IRI, UKMO
Feb 1998	Nairobi, Kenya	Greater Horn of Africa	DMC Nairobi	USAID-FDA, USAID-EWS, IAD, KMD, NOAA/OGP, UNEP, UNDP, WMO
May 1998	Abidjan, Ivory Coast	Western Africa	Met. Service Côte dí Ivoire	NOAA/OGP, World Bank, USAID-FDA, MEDIAS, START, ACMAD, ICRISAT, ECA, WMO
May 1998	Pilanesberg, South Africa	Southern Africa	S. African Weather Bureau	NOAA/OGP, ENRICH, WMO, SATCC, IRI, USAID-FDA, UKMO
		Latin America and Caribbean		
Oct 1997	Lima, Peru	Pacific S. America	INPESCA, IGP, Sealand Advisory Services, Inc.	NOAA/OGP IAI, WMO, IGP INPESCA, IRI, Sealand Advisory Services, Inc.
Dec 1997	Montevideo, Uruguay	Southeast S. America	Uruguay Rural Association	NOAA/OGP, IAI, WMO, IRI, Uruguay Rural Association
Jan 1998	Fortaleza, Brazil	Northeastern S. America	FUNCEME, INPE	NOAA/OGP, IAI, WMO, IRI, FUNCEME, INPE

TABLE 1. *Continued.*

May 1998	Panama City, Panama	Mesoamerica	CATHALAC	NOAA/OGP, USAID-FDA, WMO, IRI, CATHALAC, INRENARE, IAI
May 1998	Kingston, Jamaica	Caribbean	UWI, ODPEM	USAID-FDA, NOAA/OGP, WMO, IAI, UWI, IRI, ODPEM
		Southeast Asia		
Feb 1998	Bangkok, Thailand	Southeastern Asia	ADPC	USAID-FDA, NOAA/OGP

Organizations:

ACMAD	African Centre of Meteorological Applications for Development
ADPC	Asian Disaster Preparedness Center
CATHALAC	Centro del Agua del Trópico Húmedo para América Latina y el Caribe (Panama)
DMC	Drought Monitoring Centre (Nairobi)
ECA	Economic Commission for Africa
ENRICH	European Network for Research in Global Change
FUNCEME	Fundação Cearense de Meterologia e Recursos Hídricos (Brazil)
IAD	Intergovernmental Authority on Development
IAI	Inter-American Institute for Global Change Research
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IGP	Instituto Geofísico de Peru
INPE	Instituto Nacional de Pesquisas Espacias (Brazil)
INPESCA	Instituto Peruano de Investigaciones Pesqueras
INRENARE	Instituto Nacional para Recursos Naturales Renovables (Panama)
IRI	International Research Institute for Climate Prediction
KMD	Kenya Meteorological Department
MEDIAS	Réseau de recherche régionale sur les changements de l'environnetment global dans le Bassin Méditerranéen et l'Afrique Subtropicale (France)
NOAA/OGP	National Oceanic and Atmospheric Administration Office of Global Programs (USA)
ODPEM	Office of Disaster Preparedness and Emergency Management (Jamaica)
SATCC	Southern African Transport and Communications Commission
START	Global Change System for Analysis, Research, and Training
UKMO	United Kingdom Meteorological Office
USAID-FEWS	United States Agency for International Development Famine Early Warning System
USAID-OFDA	United States Agency for International Development Office of Foreign Disaster Assistance
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UWI	University of the West Indies (Jamaica)
WMO	World Meteorological Organization

nizers, developing a process for Outlook creation and presentation, and recognizing and taking advantage of regional distinctions. Each element was key to meeting the primary objectives of the Outlook Fora, which included

- developing and communicating a consensus seasonal Climate Outlook;
- facilitating research cooperation and data exchange within and between regions;
- improving coordination within the climate forecasting community; and

- creating and enhancing a regular dialogue between producers and users of the climate information.

It was also anticipated that conduct of the Outlook Fora would encourage regional development of self-sufficient, and ultimately permanent, forecast-production and distribution activities.

1) Planning and organization

(i) Identifying participants

In order to achieve the primary objectives, it was essential that key participants in each region be identified. Much of the current forecasting capability has evolved from university or government research centers, so the expertise in global or regional climate modeling generally comes from these institutions. To refine and downscale the relatively large-scale climate forecasts distributed by government and university researchers, it was recognized that meteorological expertise from NMHS would be an essential ingredient to a successful Climate Outlook Forum. Representatives of NMHS have access to the historical climate records often used for empirically based forecasts, the knowledge of local climate (e.g., the effect of mountainous regions on rainfall-distribution patterns), and an extensive network of people and mechanisms in the field capable of disseminating climate forecasts.

(ii) User–producer interaction

Potential users of the forecast information attended the Climate Outlook Fora to help shape the final product and identify uses of the information. By convening meetings that included both forecast users and producers, dialogue between the two groups developed, allowing for mutual exchange of perspectives, with the intention of maximizing forecast utility within the limits of predictive capabilities. For example, at the Outlook Forum for the Caribbean, members of the natural disaster preparedness community exchanged ideas with the forecasters on how climate information could be applied to help mitigate natural disasters such as El Niño–related droughts and floods, and on what type of information would be most useful (e.g., precipitation, temperature). In return, the forecast producers outlined the limitations of available climate forecasts (e.g., broad spatial resolution, scientific uncertainty) and empirically and dynamically based methods used to develop them.[9]

User participation stimulated opportunities for feedback regarding forecast content, format, lead time, delivery, and distribution, including

- making assessments of forecast performance and dissemination, including a preliminary evaluation of the value of the predictions and the potential benefits of the Outlooks;
- identifying the relationships between elements of climate prediction and user activities, gaps in production and dissemination, and impediments to optimal use of forecasts; and
- adjusting the consensus methodology to better address user needs.

(iii) Local hosts

Although NOAA/OGP consulted on the organization and implementation of all of the fora, much of the logistical and preparatory work for each meeting was conducted by local institutions. For example, in Panama, the Center for Water in the Humid Tropics of Latin America and the Caribbean (CATHALAC) was the primary organizer of the Mesoamerica Outlook Forum. In each of the three regions in Africa, Outlook Fora activities were organized around a regional meteorological institution: the Drought Monitoring Centre (DMC) Harare for Southern Africa, the DMC Nairobi for the Great Horn of Africa, and the African Centre of Meteorological Applications for Development (ACMAD) for West Africa and the Sahel. These WMO-supported regional institutions formed the nucleus of partnerships between NMHS, university researchers, and international forecasting and research organizations. Local hosts have a unique knowledge of the region, and their leadership was a critical factor in the success of the Climate Outlook Fora. For climate forecasts to be created and used on a regular basis in these regions, a sense of ownership of the climate forecasting and application process, such as that fostered through local organization of the Outlook Fora, is essential.

(iv) Sponsorship

Cosponsorship from multiple organizations was a key element of every Outlook Forum convened during 1997–98. The major partners in the Climate Outlook Fora included organizations from both the forecasting and applications communities at national, regional, and international levels. Full representation in each region allowed for the creation of what were truly consensus forecasts. By simply assembling mem-

[9] See also Table 2 on user feedback from SARCOF.

bers of the climate forecasting community together in one place, the Climate Outlook Fora also encouraged research cooperation and data exchange within and between regions.

2) Climate Outlook creation and distribution

(i) Tercile probabilistic forecasts

There are two main options for producing a consensus climate forecast. The first is a deterministic prediction based on a weighted average of all contributing forecasts. For example, a forecast for "above-normal rainfall for January to March 1998," accompanied by a statement outlining confidence in the prediction and details for alternate possibilities, would be deterministic. This option, while generally easy to understand, does not necessarily account for the range of possibilities within the naturally variable climate system.

Another option is a probabilistic forecast, stated as a probability distribution where confidence information is incorporated into the prediction itself. If a probabilistic forecast of "60% probability of below-normal precipitation," for example, was reduced to a simpler deterministic forecast (i.e., below normal, or dry), it would ignore the fact that in any given year and location, wet conditions may still prevail. For this reason, climate projections generated at the Outlook Fora were presented in terms of likelihood of above-, near-, or below-normal precipitation. By separating the possible outcome into three categories, and assigning a probability value to each, the forecasts were presented as tercile probabilistic forecasts. Although the probabilistic approach is new and unfamiliar to some forecast users, it accounts better for the chaotic nature of the climate system than do deterministic forecasts. Over an extended period of time, probabilistic projections based upon statistical and dynamical modeling can provide an edge in decision-making.

(ii) Empirical and dynamical models

Throughout the series of Outlook Fora, national-level forecasts tended to be empirical in nature, that is, based on historically observed climate patterns in a given area. In all cases, the Outlooks were rainfall projections. Precipitation was generally the variable of greatest interest to the users present, since it is the primary factor influencing flooding and drought, the most severe impacts associated with El Niño. The historical precipitation record for a given region was generally divided into thirds (or terciles) of above-, near-, and below-normal rainfall. For a 30-yr record, each tercile would cover 10 yr. In a typical year, there is equal probability that rainfall will fall into the above-, near-, and below-normal categories (33.3% chance for each category). This equal probability distribution is referred to as "climatology." During El Niño years, there is a shift in the probability that rainfall could fall equally into the three categories. For example, in a given area, 70% of El Niño years may fall into the wettest third, 20% into the near-normal third, and 10% into the driest third of the historical record. With the knowledge that an El Niño is under way, or is predicted to occur (based on observations and models of sea surface temperatures in the equatorial Pacific), the likelihood that precipitation will be in the wettest third of the historical record is 70%, while there is only a 10% likelihood it will fall into the driest third.

The forecasts were also based in part on two-tiered dynamical or statistical model simulations of the climate system. Observations of the climate system at a given time are programmed into these models, such as unusually warm sea surface temperatures in the equatorial Pacific during El Niño years. The models are then run to determine how the climate system will evolve over a given period of time. In some cases models are run multiple times, using slightly different initial conditions. These types of "ensemble" model runs provide a range of possible climate conditions within the model, from which probabilistic forecasts can be made.

(iii) Forecast assembly

To create a consensus forecast, it was first necessary to ensure that the Outlook participants shared a common understanding of the forecast methodology used. Preparation and training varied depending on the Outlook Forum. For example, in southern Africa, the better part of two days were dedicated to on site training sessions which reviewed statistical and dynamical prediction methods, the proposed consensus methodology, and user community needs, providing participants with groundwork to produce a seasonal climate forecast. In other regions, such as Mesoamerica, descriptions of the forecast methodology and presentation were distributed to participants prior to the Outlook Forum.

The next step was to reach a consensus regarding the likely evolution of sea surface temperatures (SSTs) and other important factors which would provide boundary conditions for the climate system over the course of the upcoming season. Although Pacific SSTs (and hence the strength and duration of the El Niño) were generally the primary climatic forcing factor considered at the Outlook Fora, individual regions

Table 2. Successes and areas for improvement according from the South Africa Regional Climate Outlook Fora (SARCOF) Post-Season Assessment Meeting, Pilanesberg, South Africa, May 1998.*

	Successes	Needs—Areas for improvement
General awareness	• Forecast consensus throughout region • Increased awareness of climate factors and forecasts amongst users • Use of media and increased publicity • Internet access to IRI, NOAA, UKMO, etc.	• El Niño often equated with drought conditions • Confusion between below-normal conditions and drought • Superstitions conflicted with forecast usage • Many users do not understand that seasonal forecasts are experimental • Outlook did not get to small farmers • Formal forecast dissemination structures needed • NMHS not the first source of forecasts • Outlook results evaluated too hastily by users • Media overemphasized Outlook certainty • Bolder NMHS efforts needed to control misleading information from news media • Packaging of forecast information not user friendly • Need for uniform definitions for drought and other climate terms
Science	• Consensus process resulted in fewer conflicting forecasts • Users informed forecasters of requirements • Users educated about terciles and exposed to forecast limitations • Better public understanding of climate teleconnections • Forecast lead time generally adequate • Predictors and climate factors identified • Diagnosed peculiarities of El Niño signal at midseason • Started process of understanding interactions of large-scale atmospheric flow patterns with smaller-scale climate anomalies • Outlook consensus building still formative • Understanding of physical climate processes weak • Too much emphasis on El Niño for forecast creation at the expense of other factors (e.g., South Atlantic SSTs) • Increase monitoring and studies of Indian Ocean and its effect on southern Africa climate • Users lack full understanding of probabilities, terciles • Terciles inadequate—extreme events need coverage • Need for forecast in Geographic Information System format • No sectoral interpretation (e.g., food security) for forecast by SARCOF • Historical forecast information needed • Improve regional rainfall observation network	• Inadequate spatial and temporal forecast resolution • Some forecasters overconfident in their predictions • Forecast periods do not adequately address differences in seasonal timing across the region • Forecast lead time not adequate for some users • No objective method to blend the forecasts • Difficult to maintain forecast standards • Individual forecast inputs to Outlook not equally weighted

TABLE 2. *Continued.*

Preparedness	• USAID complementary of SADC's role, led to increased preparedness • Facilitated long-term planning • Increased awareness of risks and feeling something can be done • Helped establishment of disaster management committees • Focused government response	• Difficult to manage user perceptions into useful mitigation strategies • Plans for response must be further developed • Governments generally did not have drought plans
Results	• Very accurate forecast for Namibia and Tanzania • User appreciation, particularly in Namibia, Zimbabwe, Tanzania, and Mozambique • Users able to provide value-added service for other end users • Forecast impact on markets • Namibia agriculture ministry adapted agronomic trials • Aided Namibia farmers' decision-making • Reinforced crop diversification in Malawi and Zambia • Stock farmers stored feed in South Africa and bought animals during favorable grazing conditions	• Poor forecast in some countries • Increased market volatility • Users did not always have capacity to adjust decisions according to forecast • Users interpretation of information did not always lead to good management solutions • Small farmers who made poor decisions based on forecasts became skeptical • Some farmers regretted not using information • Suspension of water rights and loss of water distribution in some parts of Zambia
Institutional issues and user–science interactions	• Enhanced communication with users • Highlighted critical value of NMHS • Collaborative efforts of international climate information community • Emphasized capacity building • Greater awareness and interaction between users, NMHS, and governments • Users involved in SARCOF process	• Capacity building not addressed fully for users and NMHS • Lack of regional SARCOF contacts • Users still thinking in deterministic terms • No training program to enable NMHS to do forecasts • Users need further help to understand probabilistic forecasts • Inadequate definition of users • Incomplete understanding of when decisions based on forecast are made • Wider net of user sectors necessary—forestry, wildlife, fisheries, etc. • Clearly define user needs and profiles • Recommendations for mitigation strategies should be tied to existing methods for coping with climate variability • Continued monitoring of users' reaction • SARCOF process needs support from NMHS directors • Institutionalize SARCOF within existing SADC institutions for sustainability • Strengthen NMHS–stakeholder interface

*This is a condensed version of the successes and needs list created during SARCOF. For a complete list please contact NOAA/OGP.

considered other factors as appropriate, such as SSTs in the Indian and Atlantic Oceans.

After reaching a consensus on background climate conditions, individual country rainfall forecasts based on empirical and dynamical methods were presented. In many cases, forecasts for a given area or for adjoining countries were very similar; in others there were discrepancies. In the latter case, participants would discuss the opposing forecasts and would eventually reach a common understanding. At each Outlook Forum, the process of creating a consensus forecast was supported by a representative from IRI. This person served as the chair of the Outlook Forum, facilitated discussions among forecasters, and provided a third-party perspective to ensure the forecasts were based on historical patterns, computer simulations, or climatic mechanisms typical of El Niño events.

Once the regional map was drawn and agreed upon, forecast probabilities for each climatic subregion were calculated and drawn onto the map. Ideally, the individual forecasts that serve as inputs to the Outlook Fora would have had a consistent format, covering identical regions and time periods, as well as exhibiting standard expressions of forecast skill. Given the relative youth of forecasting science, however, no single method has been agreed upon. Hence, all of the fora relied upon subjective interpretation of inputs to generate a consensus.

(iv) Outlook dissemination

The mere existence of a forecast by no means ensures that it will be used. Practical application requires that the forecast be disseminated responsibly to a broad group of potential users. Several methods were employed both during and after the Outlook Fora to distribute the forecasts. Press conferences were given at many of the fora to inform representatives of government, industry, media, and the general public about El Niño–related climate conditions, possible impacts, and methods to utilize climate information. This venue allowed participants to ask questions about climate-forecast products and potential applications in climate-sensitivesectors. Pilot-applications design workshops provided opportunities for sector-specific development of projects to utilize Climate Outlook information. Many representatives of NMHS also held press conferences and workshops after returning to their countries.

Outlook maps and accompanying descriptions were posted on the internet by the IRI and NOAA/OGP immediately following each Outlook Forum.[10] Through posting on the World Wide Web, the Outlooks were available to anyone with basic Internet access. In the Outlook descriptions, care was taken to emphasize the experimental nature of the forecasts and to refer specific questions to representatives of NMHS and other national organizations, many of whom attended the Climate Outlook Fora and were familiar with the capabilities and limitations of the consensus forecasts.

3) Comparisons of Climate Outlooks and observations

An evaluation of the Climate Outlook maps is necessary to determine the accuracy of the forecast given in each region. Ideally, a measure of forecast skill would involve a quantitative comparison of the forecast and observed conditions over several seasons. Since the forecasts at the Outlook Fora were probabilistic in nature, as opposed to deterministic, it is not possible to determine if they were "correct" or "incorrect." An area forecast to have a 60% chance of above-normal precipitation may have received above-normal rainfall, and yet the forecast would not technically be "correct." The forecast was that 6 out of 10 times the precipitation would, on average, fall in the upper-third of historically observed amounts. Since there is only one sample (in this case a season), as opposed to 10, it is difficult to rigorously test forecast skill.

One way to evaluate a probabilistic forecast is to assume it was essentially deterministic. For instance, if the Outlook indicated a 60% chance of above-normal rainfall, it was assumed that the forecast was for above-normal rainfall. Although this method ignores the probabilities assigned to terciles, it is a necessary assumption when evaluating a probabilistic forecast for a single season. This approach was taken by SARCOF participants, who then determined quantitatively how well the Outlooks for southern Africa matched observations for this region.

[10]Outlook maps and descriptions created at the Outlook Fora were digitized by the IRI and are available online at http://iri.ldeo.columbia.edu/climate/forecasts/sup/, or http://www.meto.gov.uk/sec5/NWP_seasonal/NWP-pef_ensarcof/index.html, or http://www.ogp.noaa.gov/enso/#Global_Climate. For related information see NOAA/OGP's Climate Information Project online at http://www.cip.ogp.noaa.gov/.

Using input from SARCOF participants, representatives from the Cooperative Institute for Mesoscale Meteorological Studies (CIMMS) at the University of Oklahoma, and the Drought Monitoring Centre (DMC), Harare, Zimbabwe, developed a method to evaluate quantitatively the SARCOF consensus forecasts (see Fig. 1).[11] Total rainfall for the season in question was determined and ranked according to the historical precipitation record from 1961 to 1994 at any given rainfall measurement station. For example, October–November–December (OND) 1997 was the 10th driest OND from 1961 to 1994 for one observation station, 15th driest for another, and so on. The rankings were then gridded spatially (on a two-degree latitude by two-degree longitude scale) and it was determined whether each grid box fell into the above-, near-, or below-normal tercile based on the period 1961 to 1994. By gridding the observational data at a small scale relative to the Climate Outlook, it was possible to account for spatial variability within forecast regions.

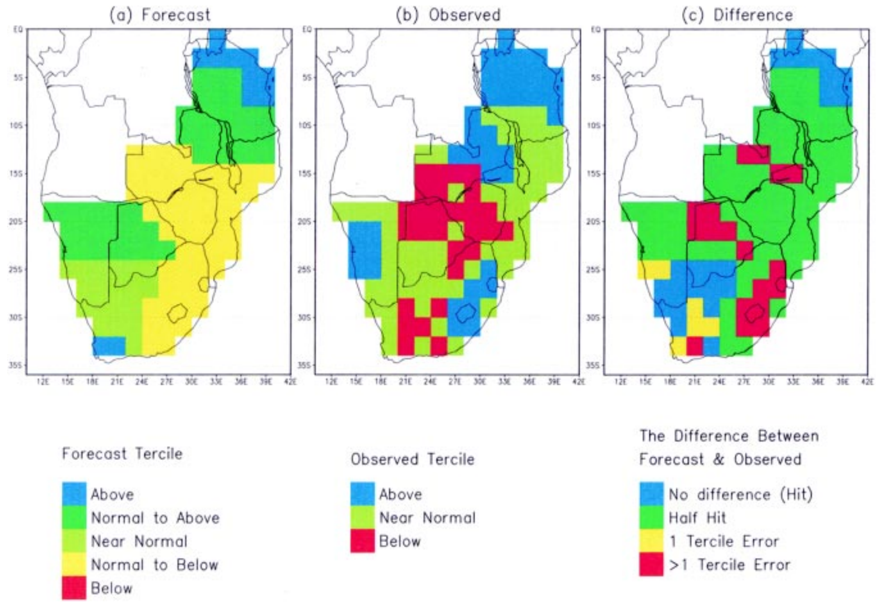

FIG. 1. Southern Africa Climate Outlook precipitation forecast and verification for Oct–Nov–Dec (OND) 1997: (a) climate forecast map based on tercile prediction of above-, near-, or below-normal rainfall completed at the first SARCOF meeting, Sep 1997 in Kadoma, Zimbabwe; (b) actual observed tercile rainfall for OND 1997; (c) difference between forecasted and observed conditions, produced at the SARCOF Post-Season Assessment, May 1998 in Pilanesberg, South Africa. An exact match is defined as a "hit." If observations match one of the two terciles with greatest probability, it is considered a "half hit." A one or greater tercile error was equal to "no hit." The overall hit rate for southern Africa over the Outlook period was approximately 50%, well above a chance level of 33% (M. Ward, University of Oklahoma Cooperative Institute for Mesoscale Meteorological Studies, 1999, personal communication).

The forecast map was then overlaid on the gridded rainfall data and scored based on the number of times it matched observations. An exact match was defined as a "hit," and if observations matched one of the two terciles with greatest probability (e.g., a forecast for near- to above-normal rainfall), it was considered a "half hit." A hit was worth one point, and a half hit was worth 0.5 points. Since there were a total of 124 grid boxes over the southern Africa region, a perfect forecast would receive a score of 124, or hit rate of 100%. A random forecast would, on average, produce a hit rate of 33%. (Similarly, a forecast for above-normal conditions everywhere in the region would have an average hit rate of 33%.) Additional forecast verification techniques (e.g., the Heidke skill score, LEPS, and relative operating characteristic) were also used to evaluate SARCOF forecast guidance, but they are not summarized here.

The evaluation for the October to December 1997 Outlook in Fig. 1 indicates the grid boxes in northern Tanzania were all hits. Southern Tanzania, northern Namibia, eastern Botswana, northeast South Africa, and most of Zambia, Malawi, and Mozambique had half hits. Southern Namibia and Botswana, and western portions of South Africa experienced hits and half hits, while other regions, such as northern Botswana and eastern South Africa had neither hits nor half hits. The overall hit rate for southern Africa over the Outlook period was approximately 50%, well above the chance level (33%), but far from perfect.

NOAA/OGP qualitatively compared expected conditions and actual observations in Mesoamerica, portions of South America, and the Greater Horn of Africa and West Africa to determine an approximate measure of forecast reliability. Observation maps were pro-

[11]The information presented here is only a partial summary of the SARCOF validation method and results. Please consult the U.K. Met. Office (UKMO) Web site to obtain a comprehensive description of the validation techniques, available online at http://www.meto.gov.uk/.sec5/NWP_seasonal/NWP_pef_ensarcof/report2/projassess2.html.

vided to NOAA/OGP by NOAA/CPC and the IRI. The data for the maps is a combination of land-based and satellite-derived precipitation values for the period 1979–95. Ideally, the observational period would be 30 years or longer, but collection of the satellite data did not begin until the mid-1970s. An example is provided allowing comparison between the forecast from the Northeastern South America Regional Climate Outlook Forum (Fig. 2) and observed conditions (Fig. 3).

For the purposes of the qualitative evaluations, we define a forecast with a 45%-or-greater probability of above-normal precipitation as equal to a deterministic forecast for above-normal rainfall. Similarly, a forecast with a 45%-or-greater probability of below-normal precipitation is defined as equal to a forecast for below-normal rainfall. Although the 45% value is somewhat arbitrary, it is significantly greater than climatology

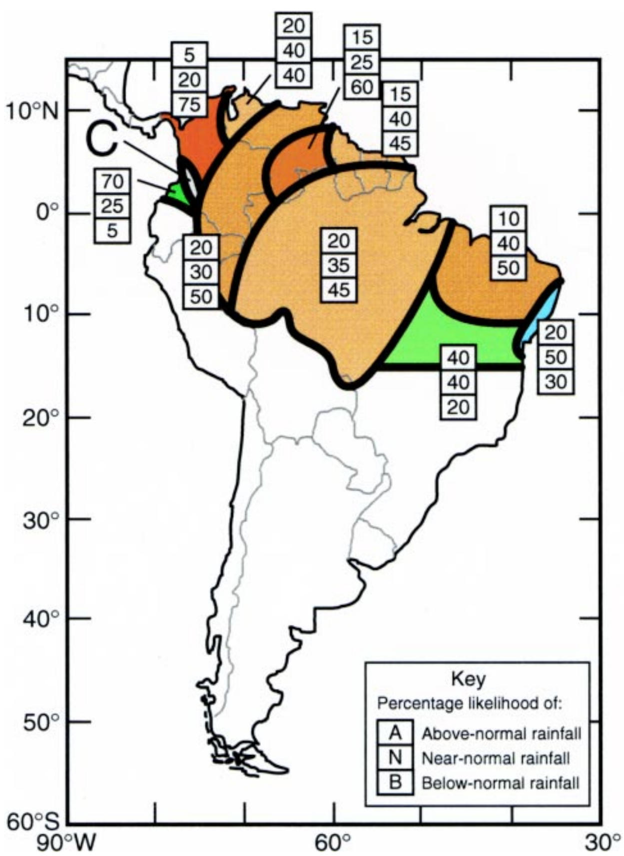

FIG. 2. Climate Outlook precipitation forecast of Feb–Apr 1998 for northern and northeastern South America produced Jan 1998 in Fortaleza, Brazil. This map provides probability distributions of the likelihood for below-, near-, or above-normal rainfall for each subregion. The "C" value stands for climatology meaning equal probability for above-, near-, or below-normal rainfall (IRI 1998).

(33.3%), indicating the climate system had at least a moderate tendency for producing rainfall amounts in a particular tercile. It is recognized that these forecasts are probabilistic in nature, however, and that by definition there will be instances when observed conditions fall into terciles with low predicted probabilities. In terms of the observational data, normal precipitation is defined as the 16-yr mean over the period from 1979–95. We define above- or wetter-than-normal precipitation as greater than 125% of normal (or mean) rainfall while below- or drier-than-normal is defined as less than 75% of normal.

The Northeast South America Outlook indicated there would likely be drier-than-normal conditions in northern Brazil from February to May 1998, particularly in the northeast. Observed precipitation amounts in this area were consistent with the Climate Outlook, although rainfall in northwestern Brazil was generally greater than 75% of average. The area of increased likelihood of near-normal rainfall in extreme eastern Brazil was not reflected in the below-normal precipitation observed for this region (although below-normal was forecast at 30% probability). The band of expected drier than normal rainfall running through eastern Peru, southeastern Columbia, and most of Venezuela was inconsistent with observations which indicated rainfall amounts near to above normal. Similarly, most of northern Colombia had near- to above-normal rainfall, even though below-normal amounts were projected (a 75% likelihood). Although rainfall amounts of 300% of average observed in northern Ecuador appear to be in agreement with the Outlook, the observational data lack the detail necessary to resolve the forecast in this region.[12]

b. Climate outlook fora recommendations

The Outlook Fora were largely successful in achieving the objectives of 1) developing and communicating consensus seasonal Climate Outlooks, 2) facilitating research cooperation and data exchange within and between regions, 3) improving coordination within the climate forecasting community, and 4) developing a regular dialogue between producers and users of the climate information. In fact, several

[12]The estimated percent normal precipitation maps used for the Outlook evaluation have a spatial resolution of approximately 2.5° longitude by 2.5° latitude. Since the forecast area in northern Ecuador is smaller than 2.5° × 2.5°, a higher resolution map of rainfall observations is necessary to evaluate the Outlook.

of the regions where the Outlook Fora occurred have already conducted or plan to conduct consensus climate forecast activities in 1998–2000. These activities will further advance collaboration between climate forecasting entities and decision-makers in climate-sensitive sectors.

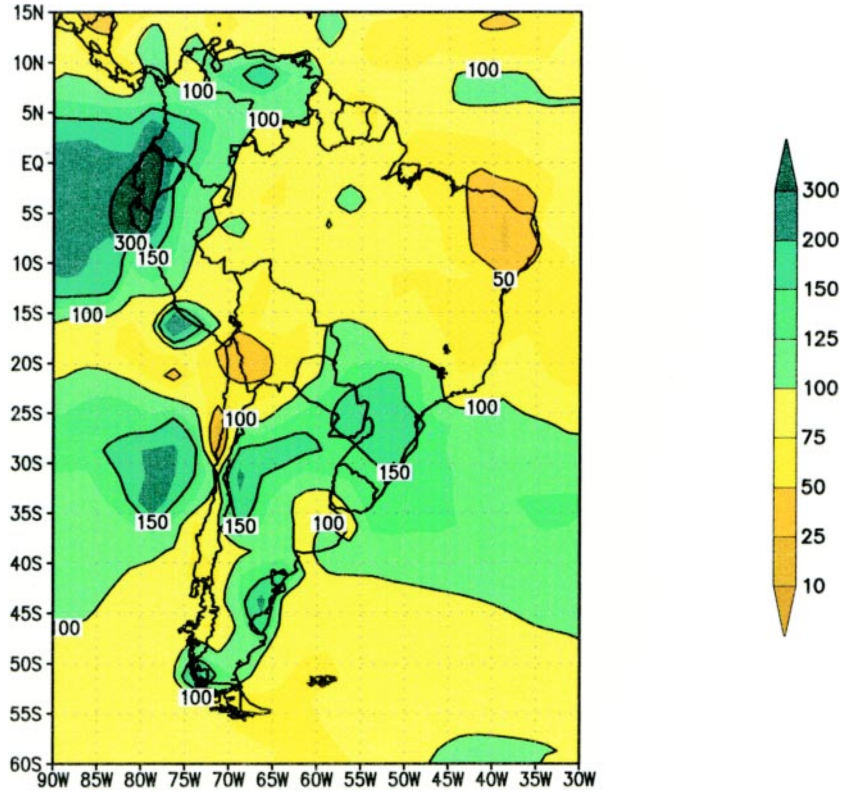

FIG. 3. Estimated percent of normal precipitation for the Feb–May 1998 period for South America. This observational data is a combination of land-based and satellite-derived precipitation values. Figures 2 and 3 can be visually compared to provide a qualitative sense of forecast performance, but does not account for the probabilistic nature of the Outlook (NOAA/CPC 1998).

1) Forecast accuracy and detail

While many of the forecasts for El Niño–related precipitation deficits or excesses were quite reliable and promising in their utility, they were by no means perfect. Further application of seasonal-to-interannual forecasts will be aided by improvements in their accuracy and detail. This will be achieved through continued research into the dynamics of ENSO and other ocean–atmosphere interactions outside of the equatorial Pacific that have a significant influence on regional to global-scale climate patterns. Forecast detail will improve as computer models capture more accurately the key climate system mechanisms and as computing power increases. In certain regions, forecasts based on historical data can be improved through compiling more complete and longer datasets of precipitation and temperature. Tailoring of forecast products to specific needs will also increase utility. For example, a forecast product describing the likelihood of extreme rainfall events may be more useful to a disaster manager than general seasonal precipitation trends.

2) Outlook fora methodology

(i) Training

In some cases, lack of familiarity with seasonal climate forecasting or lack of capacity limited the contributions of participants to the Outlook Forum process. To support the development of climate forecasting and applications in the region, additional training and educational opportunities will be necessary. As a result of previous training workshops, for example, those held at ACMAD in Niamey, Niger, national meteorological service participants at the West Africa Outlook Forum were better prepared to actively engage in the creation of the Climate Outlook. Also, the measured skill of their individual forecasts permitted a more objective blending of forecasts into a consensus. Training courses such as those that occurred at ACMAD are an essential component in building regional capacity to utilize climate forecast information. Training and educational opportunities are also necessary for the user community to enhance understanding of the capabilities and limitations of forecast information.

(ii) Forecast criteria

The potential usefulness of climate forecasts depends upon their accuracy. It is therefore essential that common criteria be established for the creation and evaluation of forecasts. For the Outlook Fora, forecasters in various regions used a number of verification methods for their individual forecasts which were often difficult to compare. Ideally, all forecasts should be verified in terms of a standard set of criteria to provide a common measurement base that can be used to inform future development of techniques.

The following set of draft criteria are under consideration by SARCOF. Participants at SARCOF generally agreed that a set of objective criteria are necessary to govern the inclusion of individual forecasts that serve as inputs to consensus Outlooks. Criteria are necessary because it takes many years to prove whether, and at what level, a forecast system demonstrates skill. If adopted, all forecast contributors would be required to submit a summary of their forecasting systems, including methods and estimates of skill levels expected in real time.

For empirical methods,

- assessing the skill in real time is controversial, but some estimate of skill independent of model training is needed;
- satellite records alone are generally considered too short to be used in empirical models;
- a dataset of 30–40 yr is considered necessary to derive reliable skill estimates; and
- a number of methods for testing skill levels are available, including cross-validation and retroactive real-time validation.

For dynamical models,

- in many cases validation cannot be performed due to an insufficient number of model experiments, but the general ability of a model to simulate atmospheric responses to sea surface temperatures contributes to confidence in the model's forecasts;
- some estimate of skill is required; and
- 10 yr of past forecasts are preferred.

Establishment of a skill-verification system will help prospective users of climate information determine which forecast products best suit their requirements. The need to provide common verification methodologies across differing forecast systems has been recognized by the World Meteorological Organization Commission for Atmospheric Sciences Working Group (WMO-CAS), and an internationally accepted standardized verification system (SVS) is currently being devised by the WMO. A training workshop linked to the Outlook Fora would be an ideal venue for exploring the practicality of using a common verification and validation methodology based on a common dataset.

In addition to the issue of validating individual forecasts, the skill of the consensus forecasts created at the Climate Outlook Fora also need to be evaluated. One example of quantitative Outlook evaluation is the method employed by SARCOF participants. Although this method does not fully address the probabilities associated with terciles, it is the type of quantitative and objective procedure necessary to avoid potential biases in qualitative evaluations. A major challenge to climate forecasters and users is to develop a validation technique for consensus forecasts that 1) accounts more fully for their probabilistic nature, and 2) provides a measure of skill that users of the forecast information understand.

3) Outlook communication and dissemination

(i) Terciles

The use of terciles and the term "normal" could be altered to provide the user with more detailed and clearer information. Although "normal" in the tercile scheme is defined as the middle third of the historical record, to a potential forecast user, "normal" is a subjective term that could result in expectations for climate conditions different than those originally forecast. One way to address this issue would be to provide forecasts in terms of probability that rainfall will exceed a given amount (e.g., there is a 70% chance that rainfall will exceed 20 cm over the next 3 months) or in terms of likelihood of extreme rainfall events. Using rainfall amounts would provide more information to the user while simultaneously avoiding subjectivity associated with the terms below, near, and above normal. Alternatively, regional maps of threshold rainfall values for each tercile would also encourage users to think in terms of rainfall amounts as opposed to what is "normal."

(ii) Communication links

Communications and connectivity, particularly with regard to email and the internet, were recurring themes at the Outlook Fora that will have to be addressed in order to realize climate forecasting and application goals. Communications capabilities differ greatly within regionsamong both the producers and users of climate forecast information. Vital communication links are supported by a range of technologies, from state-of-the-art Internet connections to unreliable telephones and radios. Collaboration between local, regional, and international entities will be vital to the development of improved communications links that will enhance the flow of information between forecast users and producers at a number of levels and across a myriad of sectors.

(iii) Systematic forecast creation and distribution

The Climate Outlook Fora and associated meetings prior to and during the 1997–98 El Niño event demonstrate clearly the need and potential for a long-term strategy for the regular generation, dissemination, and application of forecast information. To meet this challenge, NOAA/OGP is working in Africa, Latin America, the Caribbean, and Southeast Asia, with domestic and international partners, to develop regional forecast production and application capabilities. Creating systematic mechanisms and activities for climate forecast creation and dissemination will build on existing regional institutions and capacity, therefore enhancing the potential for the system to be maintained and further sustained with regional resources. The intended result will likely be a regular, ongoing series of climate updates, distributed to sectoral specialists and the public through NHMS and by other media, that would improve decision-making in the context of climate variability. Sector-specific activities would be undertaken to mitigate the impacts of predicted extreme climate conditions on vulnerable populations, as well as to enhance sectoral performance under benign or beneficial conditions.

(iv) Forecast value

The identification and monitoring of user activities in response to forecast information products and an estimation of the benefits obtained by selected users is an essential component of forecastapplications. Through successful application of climate projections, users will be more inclined to incorporate forecasts into their decision-making processes. Many of the participants of the Outlook Fora were surveyed to determine the value of the climate forecasts. "Value," like the term "normal," is a subjective one, and therefore difficult to measure. Evidence is often anecdotal, and determining what would have happened in certain instances had a forecast not been utilized is problematic. Nonetheless, survey results from climate forecast users in southern Africa, Latin America, and the Caribbean indicate that the Outlooks, although not perfect, were useful to many individuals in planning for and responding to climate variability associated with the 1997–98 El Niño.

5. Conclusions

The effects of climate variability associated with the 1997–98 El Niño were widespread and, in many cases, socially and economically disruptive. Natural disasters attributed to the El Niño event included food shortages, population displacements, disease outbreaks, and large-scale environmental damage caused by floods, droughts, and fires. Unlike the 1982–83 El Niño, however, knowledge of El Niño–Southern Oscillation, and predictions of its regional climatic effects, were used to anticipate and, in some cases, mitigate negative impacts through prevention and preparedness measures.

The NOAA/OGP response to the latest El Niño was in part made possible through groundwork laid by various United States and international research activities and pilot applications efforts. Ongoing activities in Latin America, the Caribbean, Southeast Asia, the South Pacific, and Africa provided the background experience and contacts necessary to coordinate effective means for creating and communicating climate forecast information prior to El Niño–related floods and droughts. At the core of this response were the Climate Outlook Fora. These meetings were an important first step toward enhancing regional capacity to incorporate newly available climate information into decision-making processes and in shaping the development of forecasting science according to user demands. In essence, the 1997–98 El Niño and anticipatory activities provided a chance for a "dry run" to learn how to apply this new climate forecasting skill and know-how in real-world settings.

The full potential of evolving climate forecast capabilities will be realized only when climate forecasts are routinely and systematically applied to practical problems in multiple sectors, both public and private, and at different levels, from local to international. The mere existence of forecasts does not necessarily translate into effective adjustment actions until decision-makers have determined how early warning information can best be incorporated into the context of their requirements. Equally, developers of forecast systems need to be informed by users of these requirements, including optimal methods from the user perspective for providing and presenting information.

Acknowledgments. Contributors from NOAA/OGP: Candyce Clark, Mark Eakin, Lisa Farrow, Sondra Lancaster, Katie Mastriani, Claudia Nierenberg, Caitlin Simpson, Macol Stewart, and Juli Trtanj.

Appendix: Related activities

In addition to the Pilot Program for the Application of Climate Forecasts and the Climate Outlook

Fora, NOAA/OGP was involved in several longer-term activities related to better understanding the capacity of society to utilize climate forecast information. The aim of these related activities and programs is to build linkages between research and user communities, to consolidate knowledge about the applications of climate forecasts, or to serve as a quick and effective means of distributing information to decision-makers in the U.S. government and worldwide.

- The Regional Assessments of Climate Variability, Social Vulnerability, and Public Policy Program seeks to improve our understanding of how global-scale climate variations across a range of time-scales manifest themselves in selected areas of the United States, such as, the Pacific Northwest and more recently in the southwest and southeast. Multidisciplinary teams examine how the dynamics of stakeholder decision-making in climate sensitive sectors, such as, agriculture, hydroelectric dam management, salmon fisheries, and forestry could be affected by the introduction of new analytical and predictive information.
- The Economics and Human Dimensions of Climate Fluctuations Program introduced a social science research element for understanding how humans and the climate system interact, including both human drivers of change and human responses to climate variability and change, fostering new connections between social, physical, and natural science, and identifying the needs of decision-makers in climate-sensitive sectors. The program is currently focusing on analyzing how society could make use of new forecasting technology for short-term adjustment and how socioeconomic factors impede or encourage adoption.
- The Applied Research Centers (ARCs) are a group of university- and government-based research centers and cooperative programs designed to further understanding of the climate system and its predictability from seasonal to decadal and from regional to global scales. Toward these ends the ARCS use general climate system research and modeling, analyses of historical climate records and the current atmospheric state, development of climate diagnostic techniques, and development of carbon system models. During the 1997–98 El Niño, the ARCs were involved in providing observational and forecast information to user groups through a variety of techniques. Participating ARCs included NOAA/CDC, the Scripps Institution of Oceanography Experimental Climate Prediction Center (SIO/ECPC), COLA, and the Florida State University Center for Ocean–Atmosphere Prediction Studies (FSU/COAPS).[13]
- The ENSO Rapid Response Project (RPP) sought to provide the best available climate information for regions around the world during 1997–98. In cooperation with IRI, the RRP—now the Climate Information Project (CIP)—served as an interface between the producers and users of climate information by providing monthly and periodic updates of ENSO products to officials in the United States and abroad and by eliciting their feedback on the usefulness of these climate products. Distribution included: Pacific Ocean SST observationmaps and forecasts, and precipitation and temperature observations for regions worldwide and on multiple timescales (NOAA/CPC); global seasonal precipitation and temperature forecasts (COLA); Net-assessment seasonal precipitation and temperature forecasts for regions worldwide and a comparison of the 1997–98 El Niño SSTs to other El Niño events (IRI); and a multivariate ENSO Index comparison of recent El Niño events (NOAA/CDC).
- The California Pilot Project on the Use of Climate Information (CAP) began December 1997 in collaboration with the University of California, Santa Barbara (and other state and federal contributors). In late Spring 1997, Californians had been warned to prepare for strong El Niño–driven storms that could cause severe flooding, landslides, hill slides, and mud flows. Approximately 25 people participated in the CAP research project including decision-makers from climate-sensitive sectors and climate scientists from government and university institutions. The goal of the CAP was to learn through dialogue if and how decision-makers could incorporate information on climate variability into their emergency and regular operations in preparing for and responding to El Niño impacts.
- The NOAA/OGP ENSO Web site was developed to provide the latest information on the 1997–98 ENSO event to a wide range of users on an ongo-

[13]This summary is intended to give a flavor of the activities that occurred; further information can be obtained by consulting the NOAA/OGP Web site http://www.ogp.noaa.gov/mpe/CDEP/cdep.html, or by directly contacting the ARC Web sites: NOAA/CDC—http://www.cdc.noaa.gov/ENSO, SIO/ECPC—http://meteora.ucsd.edu, COLA—http://grads.iges.org/cola.html, FSU/COAPS—http://www.coaps.fsu.edu.

ing basis.[14] It was designed to provide easy access to the latest observations and forecasts and present them in a way that was understandable to the public, media, decision-makers, and scientific users alike. The data were produced and updated by government and academic sources around the world. Beyond providing the latest updates, the site served as a place to educate the user on what El Niño, La Niña, and the Southern Oscillation are, how they are related, and what this means to them. The information provided through the Web site contained much of what was produced through the ENSO Rapid Response Project.

- Pacific ENSO Applications Center (PEAC) is a pilot-project that was established to conduct climate research and applications, produce forecast information products from a central source, and perform outreach and education activities in response to ENSO-related climate variability in the U.S.-affiliated Pacific Islands (USAPI). These include American Flag jurisdictions and Freely Associated States (FAS, former U.S. Trust Territory) of the tropical Pacific.[15] Activities were designed to address the needs of climate-sensitive sectors such as water resource and coastal zone management, fisheries, agriculture, civil defense, energy, health, and other sectors of economic and environmental importance. Other institutions forming the core of the PEAC include the National Weather Service-Pacific Region (NWS-PR); the University of Hawaii-Joint Institute for Marine and Atmospheric Research (JIMAR); the University of Guam-Water and Energy Research Institute (UOG-WERI); and the Pacific Basin Development Council (PBDC), a regional organization directed by the Governors of the American Flag jurisdictions with ties to the FAS. During 1997–98, the PEAC continued to publish the *Pacific ENSO Update*, a quarterly bulletin supplying climate forecast information.[16] The update along with staff visits afforded decision-makers an opportunity to take early steps (e.g., developing local government task forces) to reduce the impact of anticipated drought conditions.

[14]The address for the NOAA/OGP El Niño–Southern Oscillation Web site is http://www.ogp.noaa.gov/enso.

[15]Members of the USAPI include Hawaii, the Territory of Guam, the Territory of American Samoa, the Commonwealth of Northern Mariana Islands (CMNI), the Federated States of Micronesia (FSM), the Republic of the Marshall Islands, and the Republic of Palau.

[16]PEAC Web site and *Pacific ENSO Update:* http://naulu.soest.hawaii.edu/enso/index.html.

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