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Countering the Loading-Dock Approach to Linking Science and Decision Making

Comparative Analysis of El Niño/Southern Oscillation (ENSO) Forecasting Systems

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This article provides a comparative institutional analysis between El Niño/Southern Oscillation (ENSO) forecasting systems in the Pacific and southern Africa with a focus on how scientific information is connected to the decision-making process. With billions of dollars in infrastructure and private property and human health and well-being at risk during ENSO events, forecasting systems have begun to be embraced by managers and firms at multiple levels. The study suggests that such systems need to consciously support the coproduction of knowledge. A critical component of such coproduction seems to be managing the boundaries between science and policy and across disciplines, scale, and knowledges to create information that is salient, credible, and legitimate to multiple audiences. This research suggests institutional

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mechanisms that appear to be useful in managing such boundaries, including mechanisms for structuring convening, translation, collaboration, and mediation functions.

Keywords: *science policy; boundary organization; coproduction; climate forecasting; institutions*

In the last twenty years, El Niño/Southern Oscillation (ENSO) events have risen from relative obscurity to phenomena that routinely command local to national attention. Their effects influence societies around the globe and spawn a range of natural disasters, changes in resource availability, and even political upheavals (Glantz 2003). As ENSO becomes better understood, scientists and policy makers have seen an enormous potential for using forecasts of ENSO events and their associated effects to assist emergency preparedness, agriculture, tourism, water management, fisheries, and energy sectors at international through local levels (National Research Council 1999). From regional planning bodies to national ministries to multinational firms to individual farmers, many actors already have used ENSO forecasts. Yet, such use is sporadic at best and there is growing demand for more effective use of scientific and technical information.

Such demand is part of a chorus of calls that science and technology (S&T) should play an increasingly central role not only in predicting climatic events but in the more general goal of meeting human-development needs while protecting the Earth's life-support systems (Cash et al. 2003; Kates et al. 2001; Lubchenco 1998; United Nations Educational, Scientific, and Cultural Organization 2000; United Nations 2002; World Bank 1999). These calls are balanced, however, by concerns that S&T-driven policy without connection to culture, ethics, and place can lead to more problems than it solves (Lansing 1991). Thus, one of the current central challenges is to better link S&T and decision making in ways that are more socially embedded and that attempt to better balance economic, cultural, and social needs. At the same time that there is this increasing demand that S&T should be better linked to decision making, there is little systematic understanding of what kinds of institutions can effectively achieve this (International Council for Science 2002). This article addresses these shortcomings by contributing to a nascent and growing body of research and practice that asks the following question: How can systems of research, observation, assessment, and decision support be better designed to address the complex and difficult challenges of sustainable development?

In this article, we hope to improve that understanding. Specifically, we seek to explore how institutional factors promote or constrain the production and use of ENSO forecasts both to improve ENSO forecasting itself and to illuminate the more general question of how to improve decision making through the better use of existing knowledge and technology related to the environment and Earth-society systems. To accomplish this, we trace the varied use of ENSO forecasts to the structure and functioning of the institutions and organizations that link scientific knowledge with individual, social, and political decision making. We study and compare two cases: ENSO forecasting in the Pacific Islands, mainly due to the efforts of the Pacific ENSO Applications Center (PEAC), and ENSO forecasting in southern Africa, centered on a number of institutions affiliated with the Southern African Development Community (SADC).

Situating our analysis in an emerging framework wrought from multiple disciplines, we outline and discuss this framework in the second section. The third section provides a brief description of the cases. The fourth and fifth sections present a comparative analysis of the two cases. The last section comprises a discussion of the implications of our findings both for theory and for practice.

Theoretical Framework: Coproduction across Boundaries between Science and Action

Earlier work on the determinants of effective scientific advice for policy has established several heretofore unconnected building blocks from which we draw a framework of analysis. Central to this framework are three interacting concepts. First, S&T systems are characterized by multiple boundaries—between science and policy, between disciplines, across organizational levels, between the public and private sectors, and between knowledges (Gieryn 1995; Jasanoff 1987). A fundamental challenge in S&T systems is to manage these boundaries, taking advantage of their benefits (e.g., protecting scientists from accusation of political bias) while minimizing their inefficiencies (e.g., producing knowledge that is irrelevant to decision making) (Cash 2001; Gieryn 1995; Guston 2001; Jasanoff 1987).

Second, countering the notion that technocratic solutions in which experts should be isolated from decision makers has been the concept of coproduction—the act of producing information or technology through the collaboration of scientists and engineers and nonscientists, who incorporate values and criteria from both communities (Guston 1999; Jasanoff and Wynne 1998).

This is seen, for example, in the collaboration of scientists and users in producing models, maps, forecast products, or other outputs that are valued by the researcher (e.g., they push their field forward, gain them status, satisfy curiosity, can be published, etc.) and the decision maker (e.g., they help solve a problem, chart potential options, protect the decision maker politically, etc.).

Third, research and practice suggest that S&T information is likely to be effective in influencing decision making to the extent that it is perceived by relevant stakeholders to be not only scientifically credible but also salient and legitimate (Andrews 2002; Clark et al. in review; Funtowicz and Ravetz 1993; Lindblom 1990; Wildavsky 1987). A critical challenge for S&T systems is to maintain threshold levels of salience, credibility, and legitimacy while managing tradeoffs between them. For example, attempts to increase one often decrease another, as in cases where public participation increases the salience of research to decision makers while decreasing the credibility of the information to peers in the sciences. Ideas about salience, credibility, and legitimacy are closely linked to concepts about producing socially robust knowledge that is not produced in a social vacuum but within the social and political milieu in which it is going to be used (Broad and Agrawala 2000; Gibbons 1999).

Critical to this framework, and what is innovative in our approach, is understanding the interaction of these three concepts and integrating them—how to manage boundaries to maintain salience, credibility, and legitimacy for audiences on different sides of boundaries so that socially useful knowledge can be produced and used (Cash et al. in review).

One of the effective approaches for resolving such tensions within S&T systems builds on the notion, identified by scholars of social studies of science, of boundary organizations: organizations that play an intermediary role between different arenas (Cash 2001; Clark et al. 2002; Guston 2001). Whether formalized in organizations specifically designed to act as intermediaries or present in organizations with broader roles and responsibilities, several institutional functions seem to stand out as characteristic of systems that effectively harness science and technology for sustainability by ensuring salience, credibility, and legitimacy across boundaries. These include (1) convening; (2) translation; (3) collaboration, especially to assure the coproduction and use of boundary objects; and (4) mediation. These four functions interact but should not be seen as hierarchical nor their implementation as linear. That is, systems do not start convening and then move to translation and so on. They appear in different mixes in different systems. One goal of this research is to test to what degree the existence of these features leads to effectiveness in linking science to decision making, what institutional mechanisms support these functions, and how these functions influence the salience, credibility, and legitimacy of information.

Four Critical Functions

Convening connotes the process of bringing parties together for face-to-face contact. This is hypothesized to be an important function, as it forms the background for relationships of trust and mutual respect. Convening also can provide the foundation for providing the three other functions outlined below. In studying this function, we sought information on how and in what contexts actors from different spheres were brought together.

Translation can be literal, as when information providers speak one language and users another. This is often the case in developing-country contexts in which the government operates in the language of the former colonial power and the users speak tribal languages or in which scientific outputs derived from United States or European sources are generally in English and users speak other languages. Translation also can be metaphorical, as when the actors on different sides of a boundary rely on such different core sets of assumptions that they cannot understand what the other is saying even when speaking the same literal language (Dryzek 1997). Boundaries often separate worlds defined by different jargon, causal maps, experiences, and presumptions about what constitutes salience, credibility, and legitimacy. For example, academic researchers often are accused of relying on jargon in their communication with actors outside academia. Moreover, each discipline within academia is steeped in its own jargon. From the outside, jargon is isolating and alienating, yet within a discipline, jargon makes for efficient language use and allows a crispness of definition that assures that everyone inside understands what is being discussed. To understand this variable, we investigated the mechanisms for translating information across boundaries and the relative effectiveness of different mechanisms.

Collaboration is a function that brings actors together in an effort—by different experts or experts and decision makers—to coproduce applied knowledge (e.g., models, forecasts, and assessment reports). Such efforts are manifest in analyses, research and development (R&D), or assessments that are interdisciplinary, cut across multiple levels, or involve multiple different perspectives along the continuum of expert to decision maker. One class of collaboration produces what have been termed boundary objects in the social studies of science literature and are closely linked with the idea of coproduction. Boundary objects are outputs that "are both adaptable to different viewpoints and robust enough to maintain identity across them" (Star and Griesemer 1989, 387). Different actors collaborating in the coproduction of outputs receive different benefits from the collaboration: information useful for a decision maker or research that is publishable for a scientist. Institutions that can support collaboration increase the likelihood that useful, robust, and credible information will be produced (Gibbons 1999). In investigating collaboration, we looked for evidence of mechanisms used by organizations to support, encourage, and facilitate collaboration across multiple boundaries.

Mediation is a process by which different interests are represented and evaluated so that mutual gains can be crafted and value created in a way that leads to perceptions of fairness and procedural justice by multiple parties (Andrews 2002; Susskind 2000). Often, it is not disagreement over fact but over goals that drives conflict, and resolution can only be achieved through mediation and negotiation rather than more information or better understanding (Ozawa and Susskind 1985). Mobilizing science and technology for sustainability often requires active mediation of those conflicts (Andrews 2002; Jasanoff 1987; Ozawa and Susskind 1985). If it is agreed that the construction of knowledge takes place in a social and political context and that such a context is characterized by multiple boundaries, mediation might have a central place in the dynamic of producing policy-relevant information. This reasoning was used in the structure and activities of the World Commission on Dams, an assessment effort that explicitly designed its process around professional mediation and facilitation exactly because it was addressing issues that were characterized by conflict and polarized perspectives (Khagram 2003). In studying mediation, we investigated institutional mechanisms that supported conscious acknowledgement and addressing of differences, conflict resolution activities, and third-party involvement in settling or avoiding disputes within the S&T system.

Understanding these four functions and their relationship to managing boundaries and producing salient, credible, and legitimate information provides a framework from which we can begin exploring ideas about how systems of research, observation, assessment, and decision support can be better designed to address the complex and difficult challenges of sustainable development. Toward this end, we undertook a comparative analysis of two systems of ENSO forecasting, one in the central Pacific Ocean and one in southern Africa. That research is described in the remainder of this article.

Case Studies

Methods

Data for the study were collected from extended, semistructured telephone interviews with fifteen climate experts and forecast users in the Pacific and southern Africa. The interviewees were chosen for the range of perspectives they could provide on the development and implementation of climate forecasts. The sample included key actors in regional ENSO forecasting centers, such as the Pacific ENSO Applications Center (PEAC) in the Pacific and the Drought Monitoring Centre in Zimbabwe, as well as users of those forecasts, such as emergency managers in the Pacific Islands and farmers in southern Africa.

The interviews were divided into several sections, each containing a number of lead questions on a topic followed by probes designed to help clarify, deepen, and/or broaden the discussion. The interviewees were asked to describe their organization and their position in it; the critical challenges facing their organization; the structure of the climate-information network as they see it; the salience, credibility, and legitimacy of the forecast information provided by or used by their organization; and what they believed contributed to salience, credibility, and legitimacy. Although all topics were covered in some depth in each interview, the interviews were not rigidly conducted; the interviewees were encouraged to discuss whatever issues they found most important. The interviews were conducted between December 2001 and August 2002, and the average length of an interview was one hour.[1]

In addition to the semistructured interviews and informal personal communications, we obtained data on each system through examination both of peer-reviewed published materials and of gray literature (e.g., agency reports, workshop proceedings, etc.) as well as material from Web sites.[2]

As noted below, the two case studies are not perfectly comparable because of vast differences in the regions, but we are able to glean qualitative lessons from examining differences between them.

The Cases

As documented widely in the last twenty years, ENSO events produce a wide range of social, economic, and environmental effects (Betsill, Glantz, and Crandall 1997; Glantz 2000; Glantz 2001; National Research Council

1999). Societies around the globe feel the effects across numerous sectors: agriculture and food security, fisheries, diseases, human settlement disruption, and aberrations from typical storm activity.

While many societies have had long traditions of using a variety of different indicators to predict the weather associated with ENSO events (Orlove, Chiang, and Cane 2000), it is only since the mid-1970s that scientists have devoted significant resources to understanding and predicting ENSO. As ENSO appeared both on scientific and policy agendas, multiple regional efforts began to link the emerging forecasting capabilities to on-the-ground decision making. Numerous organizations, such as the United States National Oceanic and Atmospheric Administration (NOAA), the International Research Institute for Climate Prediction at Columbia University's Lamont Doherty Earth Observatory (IRI), the United States National Center for Atmospheric Research (NCAR), the United Kingdom's Hadley Centre for Climate Prediction and Research, Australia's Commonwealth Scientific and Industrial Research Organization (CSIRO), and the World Meteorological Organization (WMO), have dedicated research funding to understanding ENSO. They have invested in understanding the complex ocean-atmosphere dynamics that underlie ENSO events and their social and environmental effects, building tools that can predict the onset and severity of ENSO events, integrating traditional methods of climate forecasting, and discovering and implementing ways of making predictions useful to decision makers at multiple levels and for multiple sectors.

A growing body of literature has examined the effects of forecasting on responses to ENSO events. For example, Betsill, Glantz, and Crandall (1997) examined the 1991–92 ENSO event in southern Africa, analyzing the potential cost savings from receiving earlier forecasts. The work also highlighted several of the cross-scale problems with the 1991–92 forecasts, such as only informing high-level bureaucrats of the impending event with few mechanisms for disseminating information to lower levels (i.e., to farmers through the agricultural-extension system).

Several researchers have examined the particular difficulties of applying uncertain and imperfect information about complex causal phenomena. Barrett (1998), for example, identified the critical importance and the difficulties of linking the forecast of the climate event with forecasts of effects that matter to decision makers on the ground. In Australia, Hammer and his colleagues (2001) outlined the importance of interdisciplinary approaches that stress learning and the usefulness of simulations.

Orlove and Tosteson (1999) analyzed ENSO forecasting and application in five countries, including Zimbabwe. They concluded that measures to link national and regional forecasting systems to international systems "indicate a rapid (if late, relative to other cases) coevolution of information and institutions that have made the climate more favorable for application of ENSO forecasts in Zimbabwe. However, greater efforts must be made to assure closer articulation with end-users" (43). A team of researchers from Norway's Center for International Climate and Environmental Research came to similar conclusions about the connection to potential forecast users in Zimbabwe, finding both a lack of broad dissemination of forecasts and a need to improve the capacity of farmers to use the forecasts to adapt to predicted climate variability (O'Brien et al. 2000). Further investigating the challenge of linking forecasts to users, Patt and Gwata (2002) examined credibility, legitimacy, and institutional constraints that limit forecast use, suggesting the importance of participatory forecast development and iterated trust-building communication between forecasters and users (see also Patt 2001). Exploring constraints as well through in-depth survey techniques, Phillips and her colleagues (2001) cite not only gaps in credibility between indigenous forms of knowledge and new forms produced by the emerging climate-science community but also constraints on credit, seed availability, and other factors that make even credible forecasts less salient (Hammer et al. 2001).

Several recent studies have examined the distributional effects of forecasting. Broad, Pfaff, and Glantz (2002), for example, found that different interest groups (e.g., industrial fisheries and artisanal fisheries) had differential access to recent ENSO forecasts resulting in heterogeneous distribution of benefits and costs (see also Broad 2000; Broad and Agrawala 2000). Finally, NOAA, a central funder of climate-forecasting activities, has undertaken a variety of self-evaluations (International Research Institute for Climate Prediction 2000) that describe the building and maintaining of a growing network of climate forecasters, scientists, and stakeholders, while at the same time acknowledging the need to more systematically understand the institutional dimensions of linking forecasts to decision making:

> 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. (Buizer, Foster, and Lund 2000, 2137)

The research examining the use of seasonal climate forecasts has come to resemble the findings in two other related areas as well: communicating information about health and safety risks and technology transfer. The field of risk communication developed out of the experience of governments trying to persuade people to engage in lower-risk types of behavior, such as wearing seatbelts while driving, or to accept new technologies that were perceived as particularly dangerous, such as nuclear power (Wynne 1996). Formal risk analysis often produced robust estimates of the differential safety of different technologies and behavior patterns, and policy makers initially believed that people would react to that information, changing their behavior accordingly as soon as they learned the numbers (Leiss 1996). To the dismay of economists, who propounded solutions to risk problems that relied on people's own preferences and values, the simple provision of risk information proved inadequate (Zeckhauser and Viscusi 1996). The maturation of the risk-communication field saw first the use of carefully tailored messages to try to convince people of the accuracy of the risk estimates and eventually the recognition of the need to treat the information users as partners in the process of developing appropriate responses within an appropriate institutional framework (Fischhoff 1995). The information users need to understand is not only the basic risk numbers but also the process through which they were generated, to the point where they can evaluate the numbers critically and selectively apply them to their lives.

The study of technology transfer has undergone a similar evolution. As Agrawala and Broad (2002) discuss, the literature reveals a series of four conceptual models describing how technology moves from its development to its use. The appropriability model assumes that technology that is useful and appropriate will sell itself with little need for producer push to transfer it to a new context. The dissemination model provides a caveat that the technology developers will need to spread information but that once users learn of the new technology, they will take it up. The knowledge-utilization model requires not merely the dissemination of the information but the demonstration of its effectiveness. Finally, the contextual-adaptation model recognizes that new technologies are not adopted as if they were ready-to-wear fashion but rather sewn, in bits and pieces, into the fabric of the users' social setting and existing practices. According to this last model, effective technology transfer requires users to understand the new technology not simply to the point of being able to take it out of the box and turn it on but rather to the point of being able to take it apart, put it back together slightly differently, and fix it when it breaks. Achieving that level of understanding requires a sustained relationship between producers and users.

The many studies of forecast communication and use have begun to show that the information they convey both resembles risk information for which participatory communication (coproduction) is necessary and constitutes a new technology to be transferred, which again requires a sustained dialogue.

Our research builds on these studies, illuminating some of the institutional mechanisms that address some of the constraints and challenges that other researchers have identified. We further try to understand the robust finding across these different research efforts that even in cases where the science is right, decision makers do not listen or change behavior. Our work contributes to this growing body by outlining the conceptual connections between boundaries, salience, credibility, and legitimacy and the importance of mechanisms that foster coproduction. To do so, we turn our attention to our case studies.

We examined two regional systems that are particularly amenable to comparison: the ENSO research and applications system in the central Pacific Ocean, encompassing Hawaii and the United States–affiliated island states, and the ENSO forecasting system in southern Africa. Both systems began maturing at approximately the same time, after the 1992–93 ENSO event. Both receive funding and technical support from NOAA and other international organizations, and both attempt to link science originating in developed countries with decision making in developing countries. While similar in these dimensions, both systems also vary in a number of important institutional dimensions, thus allowing us to compare how institutional factors might contribute to effectiveness at linking science and decision making. Naturally, in systems as complex as these, there are also differences in the two systems that we cannot control and that are unrelated to the institutional dimensions we investigate. Political dynamics, inherently different levels of signal-to-noise ratio in the two settings (stronger ENSO signals and teleconnections in the Pacific versus southern Africa), and general level of development differ in our two cases. At the end of the article, we discuss how these differences influence our conclusions.

Pacific ENSO Applications Center

In the early 1990s, the Office of Global Programs (OGP) at NOAA began to explore the utility of new forecasts for coastal-zone managers on

Hawaii and the United States–affiliated Pacific Islands (USAPI).[3] With OGP funding, a partnership between OGP, the Social Science Research Institute at the University of Hawaii, and the Pacific Basin Development Council (PBDC—a regional association of the USAPI governments) held a scoping meeting early in 1992. Organized and driven by actors representing the continuum from climate research, social-science research, and potential users of climate forecasts, the meeting brought together a range of perspectives to describe the current state of the science, but more importantly, to ask the following question: How should forecasts be produced so that they might be useful to managers in the region? This scoping work led to the birth, in 1994, of the Pacific ENSO Applications Center (PEAC).[4] In addition to the original partners, PEAC included the participation of the NOAA National Weather Service/Pacific Region (NWS/PR), the University of Hawaii/School of Ocean and Earth Science and Technology (UH/SOEST), and the University of Guam/Water and Energy Research Institute (UOG/WERI).[5] PEAC's mission is to conduct research and forecasting for the benefit of the USAPI and the islands' various economic, environmental, and human-services sectors.

The Southern African Drought Monitoring Centre

In 1991–92, southern Africa experienced a severe drought with wide-ranging effects on food production and availability and direct effects on the livelihoods of over 100 million people in the region. At the time, regional ENSO forecasting was in its infancy, and while several forecasts were produced through the National Weather Service/Climate Prediction Center (NWS/CPC) and Australia's Bureau of Meteorology, they had little effect on food security, agriculture, and drought-preparedness activities (Betsill, Glantz, and Crandall 1997). With both the experience of the 1991–92 event and the improving skill of regional ENSO forecasting, NOAA, WMO, regional decision makers, and scientists began structuring an ENSO forecasting system that could better take advantage of the emerging science. The Southern African Development Community (SADC), an already existing regional economic-development association of southern African states, took the lead in organizing such a system in partnership with NOAA, WMO, USAID, the World Bank, and the National Meteorological Services (NMSs) of member countries.[6] One of the principal new organizations that originated from this partnership was the SADC Drought Monitoring Centre (DMC),[7] supported by the United Nations Development Program (UNDP) and WMO and housed in Harare, Zimbabwe. Like PEAC, the DMC has helped shape the

ENSO forecasting system in the region, has collaborated with existing institutions and built new institutions, and has structured relationships between a diverse set of actors and organizations. These include those noted above and the IRI, United Kingdom Meteorological Office (UKMO), SADC's Regional Early Warning Unit (REWU), Regional Remote Sensing Unit (RRSU), and the Famine Early Warning Systems Network (FEWS-NET).

A Comparison of Boundary Functions

Although in a number of dimensions the Pacific and southern African systems are similar, their institutional structures and activities differ enough to allow systematic comparisons of characteristics that contribute to their effectiveness. In this section, we outline how the four different functions—convening, translation, collaboration, and mediation—are manifested differently in the two cases.

Convening

In the PEAC case, scientists, forecasters, and decision makers (for example, representatives of all the governors of the USAPI, water managers, fisheries managers, emergency management, and representatives from many state, federal, and island agencies) met regularly at the beginning of the process. Such broad collaborative participation galvanized an iterative process that fostered periodic evaluation of the needs of the users of forecasts and the capabilities of the climate scientists and forecasters. Using NOAA funds, PEAC played the central role as convener, institutionalizing participation of multiple players in such a way as to take advantage of critical expertise at critical times. At PEAC scoping meetings, crossing boundaries between scientists, forecasters, and decision makers was achieved by bringing key actors representing those groups together as joint collaborators in designing the scope of an ENSO research and applications system in the Pacific. PEAC thus presents an innovative vision of how to convene stakeholders: rather than have the stakeholders outside of PEAC and invite them to the table when issues arise, include them within the PEAC planning process from the very beginning. Other stakeholders, as they became interested in PEAC, also were invited to join. In traditional stakeholder practices, the boundary organization reaches out to obtain the input from people on both sides of the relevant boundaries. In PEAC, by contrast, those people were part of the boundary organization itself, with a role in making decisions about how it would function. PEAC was the funded institutional setting in which climate scientists, meteorologists, hydrologists, epidemiologists, and economists collaborated on research and forecasting outputs that captured the important uncertainties and dynamics of ENSO events.

This feature of PEAC—that it convened through inclusion in the organization rather than simply inviting others to the table—also highlights how its accountability was divided among several communities. PEAC was accountable, for example, to its funder, NOAA, through contractual arrangements and the granting process. Funds could have been withdrawn or additional funding denied if PEAC did not perform in accordance with its obligations. On the other side of the boundary are the decision makers—agency bureaucrats, technicians, and elected officials—all actors who could have withdrawn from their relationship with PEAC. Such dual accountability arrangements forced PEAC to address the interests, concerns, and perspectives of actors on both sides of the boundary, thus increasing salience, credibility, and legitimacy.

In southern Africa, the SADC's DMC is itself a small organization, working in the building compound of the Zimbabwe Department of Meteorological Services. Like PEAC, the DMC organizes events in which the convening function takes place. The most important of these events is the biannual Southern African Regional Climate Outlook Forum (SARCOF). Coordinated by the DMC in collaboration with NOAA, IRI, WMO, and the RRSU, SARCOF brings together experts and stakeholders from across the entire region to produce a forecast in September before the planting season and reconvenes in December to make corrections.

The majority of SARCOF participants are meteorologists from the SADC region's National Meteorological Services (NMS), as well as from the IRI. Before the September SARCOF, the DMC sponsors a multiday capacity-building workshop for young meteorologists from the NMSs. In this workshop, the scientists use a common statistical methodology to develop tercile rainfall forecasts for their home country. For each country, the scientists use principal-component analysis to define two to three subnational regions in which the influence of climate drivers is similar. For each subnational region, the scientists then select the most significant drivers (such as tropical Pacific or North Atlantic sea-surface temperatures) to construct a statistical model for rainfall in the early (October, November, and December) and late (January, February, and March) seasons. Within each region and seasonal period, the scientists are able to assign probabilities in terciles (for above-normal, near-normal, and below-normal rainfall).

The scientists bring these national forecasts to the SARCOF meeting, where members of the early-warning organizations and other stakeholders join them. The latter include people from NGO and development organizations (such as the World Food Programme), specific economic sectors with the countries (such as hydropower planners), and academic researchers. Two main items of business dominate SARCOF. First, the nonmeteorologists make presentations about their concerns and information needs. Second, and more time-consuming, the forecasters meet among themselves to iron out differences between their national forecasts based on the principle that climate does not respect political lines on the map. After a day or two of negotiation, the scientists present their consensus forecast to the others at the meeting, leaving time for discussion of the forecast's implications. SARCOF concludes with a press conference.

Translating

As in many systems for linking S&T to decision making, arenas on different sides of boundaries within the PEAC system were defined by different languages. One of the critical roles that PEAC has played is translating across these boundaries to facilitate mutual comprehension in the face of such differences. Such translation is seen in the collaborative efforts to produce forecasts in which final outputs used a language that could best be understood by target audiences. In this case, the language of historical analogy was more understandable than the language of probabilities. PEAC used scientists who were facile in both languages and could translate between them and provided the many meetings to identify what language worked best.

In southern Africa, the DMC has done little translating, relying on national organizations for that. Certainly, translation is necessary in the literal sense, as within the SADC region, there are three European (English, Portuguese, and French) and dozens of African (e.g., Afrikaans, Shona, !Xhosa, and Zulu) languages spoken. In the figurative sense, however, there may be a need for greater work by the DMC. It currently expresses the information in its forecasts using models and jargon that the meteorology community easily can understand but that other users have a difficult time deciphering, such as the tercile format of the forecasts (O'Brien et al. 2000). Reflecting comments made by all interviewees and existing literature, one official, a project director of the SADC regional early-warning system, stated:

> In terms of . . . communication with the users with these forecasts, we need to work on the language, the information content that we put out to the users to be able to, because, at the moment, sometimes the language, an ordinary farmer might not understand probabilities and so on. So we really need to work on those.

One of the more difficult challenges in this regard is integrating mathematical and model-derived scientific prediction with local knowledge. As a Zimbabwe NMS official noted:

> We realize that they also have got traditional forecast systems that they rely on, especially when you are looking at some of the small-holder farmers that prevail in southern Africa. So, we're saying we need to understand their systems a little bit better before we can actually come in with this [forecast] information to try and influence the way they do things.

Collaborating

Through participation mechanisms that fostered joint production and packaging of outputs during the forecasting process, the PEAC system was able to create products that were salient to a range of decision makers. Historical and statistical analyses allowed managers to better compare potential future events to past events in which management actions were not taken and negative outcomes ensued.

Multiple actors contributed to the construction of the forecasts, including NWS/CPC scientists, natural and social scientists at the University of Hawaii and the University of Guam, managers from multiple sectors, and representatives of the governors' offices. Each actor clearly benefited in a different way from the collaboration: receiving information on predicted rainfall for an agricultural-extension officer; hearing warnings of impending storms for an emergency manager; learning predictions of where fish might be for the fishing industry; and producing a publication in a peer-reviewed journal for a scientist. Though the forecasts had different value and meaning for each of these actors (an important part of being a boundary object), PEAC was able to coordinate and mediate activities such that there was enough overlapping meaning that a robust forecast could be produced.

The collaboration fostered by the DMC occurs primarily among forecasters from different agencies and countries rather than including potential end-users in generating useful information. One report from the October 2002 SARCOF meeting is consistent with this and confirms individual observations by interviewees:

> First, there was a sharp divide between forecasters and forecast users. There were no users invited to the consensus forecast group, and no climate expert was involved in any of the four users' working groups (health, food and agriculture, water and energy, and disaster management). Even though the users' group presentations had a lot of demands in common, no climate person made

> any effort to share perspectives about the feasibility of satisfying users' needs. For example, beginning and duration of rainy season was clearly something desired, but users left with no knowledge of whether climate scientists can (or want to) provide that information to them. (Patt, personal communication)

Efforts have been made by DMC and the national meteorological offices to communicate these kinds of probability forecasts through workshops, meetings, and other media, with inconsistent results and persistent confusion. As one Zimbabwe NMS official states (reflecting survey results from Phillips, Makaudze, and Unganai [2001] and other comments by interviewees):

> But when it comes to the local level, maybe the actual farmer who we want to benefit at the end of the day, we have actually realized that the way we communicate the forecast at times is very difficult for them to make an operational decision or a strategic decision as to what to do.

Such efforts, however, focus on communicating existing science to potential users of the information and are not true collaborations in which scientist and decision maker coproduce information.

For some constituencies, linking with actors outside the SADC system has been productive in attaining salient climate information. Primarily white large-land holders in Zimbabwe have turned to both their Commercial Farmers Union (CFU), which has an internal technical and research division, and to private consultants for sources of salient information. This was also seen in parts of the paprika-producing sector, which was constituted both by large- and small-land holders. Consultants and the CFU relied on some information originating in places like DMC and SARCOF but then were able to fine-tune it according to the specific needs of clients and constituencies. Such participation of consultants and technical expertise within the CFU provided intermediary functions that, currently, the SARCOF process does not provide.

Mediating

Part of PEAC's role is to mediate between the different interests, perspectives, and missions of the organizations and individuals that make up the network of the Pacific ENSO forecasting system. What kind of institutional mechanisms support mediation and what form does it take?

First, the actors involved in the founding of PEAC were individuals with already existing credibility and legitimacy in multiple spheres who represented long-standing institutions in the region. Mr. Dick Hagemeyer was the director of the NWS/PR and personally established weather-observation stations on several of the USAPIs in the1950s. Chip Guard had been the director of the Joint Typhoon Warning Center for four years when it was located on Guam and was a research associate at the University of Guam. Mike Hamnett was the director of the Social Science Research Institute at the University of Hawaii and had a long history of working on disaster management in the region (including being in the Peace Corps in Papua New Guinea and Kapingamwarangi in Pohnpei state). Eileen Shea had been an NOAA program officer in the region, and Jerry Norris was the executive director of PBDC coordinating activities for multiple countries.

Second, these leaders realized early in the process that conscious mediation would be a critical activity for any effective research and applications system. This is evidenced, for example, in a description of one of the first scoping meetings in 1992 when managers and scientists were brought together for the first time:

> She [a cofacilitator] and I facilitated a dialogue between the scientists and decision makers about . . . the beliefs of scientists about information and about certainty and uncertainty and probability and then the beliefs and needs of bureaucrats about the same thing. And we had the scientists characterize the bureaucrats and the bureaucrats the scientists, and then we brought them all back in the room together and said, this is what they said about you, and this is what they said [laughter], and it was interesting that, you know, everybody thought the other one needed certainty. (University of Hawaii social-science researcher)

PEAC organizers, climate scientists engaged in the process, and decision makers shared similar observations.

If two of the functions of mediation are to get actors in different arenas to understand the different perspectives and to find common ground, the exercise described above accomplished both. Scientists began to understand that managers were comfortable making decisions under uncertainty, and managers began to understand the concerns scientists had about making scientific claims in the face of uncertainty. This illustration is representative of myriad ways that PEAC relied on active and conscious mediation to bridge boundaries and facilitate the coproduction of useful and valued information.

Though PEAC undertook the mediator role, it also realized the importance of relying on existing intermediaries that also could play that role. Thus, one mechanism for linking forecasters and users of forecasts was to engage local people who already played trusted intermediary roles. This institutionalized a connection between PEAC and local decision makers while avoiding the problem of outsiders trying to break in to existing communities:

> And that's why paratrooper scientists are no good. I mean, they don't know what to do in the local setting. You need people who have worked with a variety of people on the ground who can get plugged in fairly quickly to the middle people. So it's not the farmers you worry about. It's the people that direct the agricultural extension who work with farmers that we've worked with. It's not the individual water consumers. It's the Water Utility and the Civil Defense Agency. (University of Hawaii social-science researcher)

Paralleling the relative lack of institutional mechanisms for translation in southern Africa, there were also relatively few mechanisms for actively engaging in mediation. Conflicts of interest characterize several significant parts of the system: between small- and large-land holders, exacerbated by the political climate in Zimbabwe in 2000–2002 in which the government was engaging in aggressive agricultural-land redistribution; between farmers and credit institutions, in which banks restricted credit in response to ENSO forecasts, making adaptation by farmers more difficult; and between national governments and NMSs and the DMC, in which political leaders were hesitant to allow the dissemination of forecasts that predicted negative outcomes. Each of these and the more benign conflicts across discipline and scale boundaries often require conscious and skilled mediation to facilitate the legitimacy of the process. One kind of mechanism that seems to be lacking in this regard is using actors who, as individuals, cross boundaries easily. There seem to be few people with credibility and legitimacy in climate forecasting who also have credibility and legitimacy in agronomics or agricultural decision making. This lack of mediation might be one reason why farmers in the CFU turned to private consultants or in-house technicians. Another reason may be race. Government employees tend to be black Africans, whereas white decision makers dominate many of the stakeholder organizations, such as the commercial farming sector. In many countries, there is still incomplete trust between whites and blacks.

A Comparison of Salience, Credibility, and Legitimacy

The functions of convening, translating, and collaborating have long been known, in scholarly literature if not in practice, to be critical features of functioning systems that link research and decision making. (The multiple and pervasive presence of systems that focus only on convening, or one-way translation, speak to the difficulty of institutionalizing these kinds of functions.) The importance of mediating in S&T systems only recently has been the focus of scholarly attention (Ozawa and Susskind 1985) and even less has been the focus of concerted efforts by practitioners.

What makes these functions critically important? In contentious public decision making characterized by uncertain science and emerging technologies, the charge of lack of credibility ("we don't believe this"), legitimacy ("the process has been corrupt"), and/or salience ("science answered the wrong question") can be devastating for finding solutions to complex problems. Each of the four functions outlined above plays a role in trying to create and maintain adequate levels of salience, credibility, and legitimacy. In the remainder of this section, we compare the two cases, analyzing how institutionalized convening, translating, collaborating, and mediation contribute to salience, credibility, and legitimacy.

The Pacific

Through the use of the four functions outlined above, PEAC's ENSO forecasts were timely and included information useful to a wide range of audiences. It increased credibility by bringing multiple types of expertise to the table. Thus, climate modelers, hydrologists, and oceanographers could produce an output that was credible from global to local levels and enhanced legitimacy by providing multiple stakeholders with greater and more transparent access to the information-production process. Thus, stakeholders from multiple arenas at multiple levels engaged in the process and found the process fair and legitimate.

This kind of structure was in contrast to an existing culture of linking science to decision making, summed up by a PEAC member's comment about the NWS, an agency that was not heavily involved in climate forecasting when PEAC was being formed:[8]

> National Weather Services, in general, have . . . the loading-dock approach to forecasting. You take it out there, and you leave it on the loading dock and you say, there it is. And then you walk away and go back inside. (University of Hawaii social-science researcher)

Although deciding how to present a forecast is critical, when to release forecasts is a critical part of salience as well. Information that is too early or too late for a decision maker's timeframe lacks salience. As a civil-preparedness officer on one of the USAPI recounted:

> The last El Niño happened in '97–'98. And it was really bad; it was the worst we've ever had. But we received the information in October. And so we started our public education right after that. [The PEAC scientist] came down to Palau, and then he gave us the information. So, right after that, we started our public education. And then, by the next year, the following year, around February, then it hit us. So there was a very good lead time there . . . it worked out pretty well, so that when the event came, it happened, and the people were so prepared, and then the people were not tired of hearing the word El Niño. (An emergency management officer in the Republic of Palau)

In this case, the salience of the forecast was influenced by whether or not it was released within a critical window of time in which there is enough lead time to make changes but not so much that people lose interest. If it is too late, the manager cannot take appropriate actions. If it is too early, however, there is a risk of fatigue by the public that might counter gains made by early warnings. For PEAC, there was a valuable lesson in the commentary by this civil-preparedness officer, a lesson that ultimately was learned through the institutionalized participatory meetings between the scientists, forecasters, and managers. Others in the system further commented that through the regional meetings, there was the opportunity to discuss concerns about timing and other requirements:

> We said, well, what would you have us do differently? They said, well, I think maybe tell us a month early or something. And we said, how about if we told you in June? They said, no, no, no, too early. They said, your scale is probably as good in June but maybe not. And if we start crying about the wolf in June, people are going to forget about it by November. (University of Hawaii social-science researcher)

In both of these cases, participation of the end users of forecasts and of forecasters themselves in regular meetings before the preparation of the forecast was critical to producing a forecast that was understandable to decision makers and timely.

The region covered by PEAC is millions of square kilometers, large enough that variations in large-scale patterns influence different islands differently. Furthermore, each island has its own topography, soil structure, ecology, and hydrology, which influence microclimatic dynamics and local weather. For example, variance in precipitation between leeward and windward sides of an island may dwarf the variance in precipitation resulting from an ENSO event. A PEAC scientist captured the importance of place-based understanding in the following way:

> Tailoring is imperative. You must talk about Yap things on Yap, Chuuk concerns on Chuuk, and Pohnpei problems in Pohnpei. It must be personalized. Many times, we get meteorological training programs that pertain to weather in the continental United States, not tropical weather. We feel it's not very useful to us. And, that's just the way the islanders look at things that aren't specifically tailored to them. A discussion of a water shortage on a Guam river won't get much attention on Pohnpei. But talk about a Pohnpei river, and it gets attention. (University of Guam climate scientist)

Clearly aware of these kind of pitfalls, PEAC addressed this challenge through its collaborative relationships that resulted in participation of national and international climate scientists from organizations from multiple levels: for example, IRI and the NWS/CPC; the UOG/WERI; and local islands' water-, weather-, or emergency-management agencies. Such collaborations resulted in increasingly place-based forecasts that integrated large-scale models of climate systems with the data collected through local monitoring and observation systems. These kinds of collaborative participation to link global phenomena and local realities appear in this description of a briefing to the Pohnpei legislature:

> After I talked to them about the event itself, the meteorology in layperson's terms and what to expect, the University of Guam PEAC hydrologists got up and started showing them what the effects would be on raising and lowering the water table and the river flow. We had to treat atolls much differently than we treated mountain islands. Some countries or states have only atolls, some have only mountain islands, and some have both. (University of Guam climate scientist)

Such institutionalized collaboration of multiple disciplines at multiple levels resulted in a package of information that had credibility for academic scientists and at the local level. The key in producing these outcomes was the structured participation of many actors, bringing many different bases of expertise to the table with a clear goal of producing a locally credible forecast partly derived from globally credible models.

Southern Africa

One of the primary motivations behind the formation of the DMC and the SARCOF process was to produce a forecast that would be legitimate and credible for users, especially for food-security planners (Orlove and Tosteson 1999). By including representatives from all of the NMSs in the process of creating a consensus forecast, SARCOF could generate a product that all of the SADC countries would be willing to use. That, in turn, would facilitate greater cooperation in emergency planning. As an NOAA/OGP program manager states:

> [A]ll the fourteen countries in Southern African Development Community have a stake in the administration of Drought Monitoring Centre . . . So they all have their interest in there, you know, and, so whatever DMC puts out is . . . recognized by all the member states in those countries.

SARCOF also is supposed to increase the credibility of the forecast, both by expressing it probabilistically and by including all of the climate scientists in the region in a transparent process. Finally, it was hoped that the SARCOF process would improve the salience of the forecasts:

> [In SARCOF] we develop some forecasts from a meteorological point of view, but then invite various users . . . where we actually say this is how we're going through the process of developing this forecast. And the users then get to participate in the process, at least listening through how we go about, you know, blending different techniques, and then come up with what we describe as a consensus forecast. (Drought Monitoring Centre official)

Where the DMC and the SARCOF process is not as successful as hoped, however, is in translating the information into layperson's terms that still reflect the probabilistic character of the information and in generating collaborative outputs. This, in turn, has a real effect on both the legitimacy and salience of the information.

First, many users simply do not understand how to interpret the tercile forecast information. Many of the SADC member countries have poorly developed systems for communicating forecasts to users and so simply pass on the forecasts that the DMC provides them. This then places the burden of creating understandable information on the DMC, something that it so far has refused to accept.

Second, the one-way flow of information that the DMC fosters—from forecasters to users—interferes with both the salience and the legitimacy of the forecasts. At the SARCOF meetings, stakeholders have the opportunity to suggest how the forecasts could be more salient for their needs. This has included the need for forecasts of the beginning and ending dates of the rainy season and greater local specificity. So far, the DMC has incorporated few if any of these suggestions, decreasing salience. Moreover, the DMC has not even stated why it is not including them, and this decreases legitimacy. If users came to understand that a forecast of the dates of the rainy season was simply not possible, they would at least know that their concerns had been heard. By failing to draw stakeholders into the process of the forecast generation and instead seeing the stakeholders as simply the end users of the information, the DMC has decreased its own legitimacy.

Discussion

Both the Pacific and southern African ENSO forecasting systems evolved with similar general institutional structures intended to provide salient, credible, and legitimate information about climate variability. Both are designed to connect scientists and decision makers at global to local scales, and both systems are structured around regular and iterated meetings that can bring multiple participants together to the same table. Despite these similarities, this research suggests that each system has used different kinds of institutional mechanisms, resulting in different outcomes. We understand that there are other differences between the systems that can explain different outcomes of decisions relating to climate-affected sectors (such as greater technical constraints and greater political corruption in southern Africa), but we attempted, through our interviews and data collection, to try to at least qualitatively trace causal connections. We believe that, especially given the greater constraints in places like southern Africa, the tentative findings about institutions are all the more relevant.

Perhaps the most striking difference between the two systems has been PEAC's relative success in producing decisions compared to the southern African system. In institutionalizing a close ongoing dialogue between scientists and the users of forecasts, information was tailored to decision makers' needs and the specific context in which they operate. Even before the official formation of PEAC, it was critical to the organizers of the incipient effort that a true dialogue be created and that scientists and users be brought together with equal standing for setting agendas, designing products, and evaluating success. By structuring participatory roles at critical times in the process, PEAC facilitated a legitimate process that engaged multiple stakeholders, produced salient outputs that met users' needs, and created credible forecasts that integrated global climate knowledge with local-scale knowledge. As such, PEAC's institutional structure and focus on the functions of convening, translation, collaboration, and mediation resulted in a system antithetical to the loading-dock approach of connecting science to decision making. The result has been decisions made by a wide range of managers from sectors including utilities, emergency preparedness, water management, and so on. At least from their perspective, the information-production process better prepared them for the 1997–98 El Niño event as compared to the 1982–83 event.

In the southern African system, SADC and DMC have not used institutional mechanisms that bridge the boundary between forecasters and users as well. While SARCOF generated a high degree of legitimacy among some participants, the unidirectional nature of much of the forecasting process has made it more difficult to establish legitimacy in certain sectors and at subnational levels and to produce salient outputs for many intended users and credible linkages between global and local knowledge. The result has been, in many sectors, unused information—information produced but not used.

The difference in degree of dialogue seen in the two cases seems to arise from the different mechanisms of communication that the two systems used. Both systems focused on convening functions to bring multiple actors to a common forum to engage questions about forecasting. However, convening mechanisms, while perhaps necessary, seem to be insufficient for effective communication. PEAC, for example, devoted additional resources to institutional mechanisms for translation and mediation functions. In southern Africa, these functions were less institutionalized and less used. Part of this results from the focus that the science agencies in southern Africa have had on producing scientifically credible outputs, sometimes at the expense of engaging users, and thus decreasing the potential salience and legitimacy of the process. With some sectors ignoring some forecasts, or in fact, never even seeing them, relatively fewer decisions to prepare for effects of ENSO events occurred. Thus, there seems to be an association between these lacking institutional mechanisms and lack of use of existing forecasts. For true dialogue to take place across boundaries that separate different languages, worldviews, and interests, these cases suggest that it is critical to focus on translation and mediation that can result in the constructive sharing of information and the agreement on mutual goals and methodologies. Such strategies as engaging intermediaries who already have legitimacy and credibility across boundaries and specifically focusing activities at meetings on mediation were mechanisms that were used successfully in the Pacific and less so in southern Africa.

For PEAC, the forecast itself was an item about which collaboration occurred between disciplines, between scientists and decision makers, and across levels. The participants coproduced the forecasts collaboratively, deciding what variables went into the forecasts, how they were presented, and how to integrate knowledge from multiple sources. Such use of a boundary object allowed for two-way education to occur, for trust to accrue over time between different groups, and ultimately, for the production of credible and salient outputs. To some degree, the DMC used a similar model in the building of consensus forecasts during the SARCOF meetings. These tended, however, to be weighted toward forecast producers, including forecasters from international and national organizations and scientific and management agencies with technical expertise. As such, SARCOF forecasts served the function as a boundary object for a narrower set of participants than did the PEAC efforts. The critical boundary that was not bridged in these exercises was that between the forecasters and users of forecasts, such as farmers, the health sector, and emergency managers. Thus, SARCOF missed opportunities to educate users about forecast products (e.g., how to understand probabilities), tailor forecasts to the local needs of decision makers, and integrate knowledge of global and regional climate with local knowledge of climate and weather to make them more credible. Not surprisingly, these potential target audiences did not make decisions with input from the forecasts, with negative results for the agriculture and food-security sectors.

Despite these differences in institutional mechanisms and the resulting levels of salience, credibility, and legitimacy that are attributed to these different systems, the southern African system and PEAC share many of the same fundamental building blocks. Such building blocks could be better developed in southern Africa relatively easily. For example, the SARCOF meetings could be restructured to provide better links between forecasters and users, focusing more on applications than forecasts and consciously mediating between different groups. Given the rapidity of transformation of the system in the ten years from 1990 to 2000 (especially in the face of political instability, fewer resources, and an ENSO signal that is not as clear as the signal in the Pacific) and the common links that the Pacific and the southern African systems share (e.g., NOAA, IRI, NWS), learning and adaptive change should be feasible.

Notes

1. The interview protocol, which had been vetted and pretested, and the transcripts of the interviews are available from the authors by request.

2. Drought Monitoring Centre, http://www.dmc.co.zw/; Southern African Development Community (SADC), http://www.sadc.int/; SADC Regional Early Warning Unit, http://www.sadc-fanr.org.zw/rewu/rewu.htm; Famine Early Warning Systems Network (FEWS-NET),

http://www.fews.net/; National Oceanic and Atmospheric Administration (NOAA), http://www.noaa.gov/; NOAA Office of Global Programs, http://www.ogp.noaa.gov/; Commercial Farmers Union, http://www.cfu.co.zw; East-West Center, http://www.eastwestcenter.org/; Social Science Research Institute (Hawaii), http://www.ssri.hawaii.edu/; Pacific ENSO Applications Center (PEAC), http://lumahai.soest.hawaii.edu/Enso/; Office of Hawaiian Affairs, http://www.oha.org/; Southern African Regional Climate Outlook Forum, http://www.dmc.co.zw/sarcof/sarcof.htm; International Research Institute for Climate Prediction, http://iri.columbia.edu/; and World Meteorological Organization http://www.wmo.ch/.

3. The United States–affiliated Pacific Islands are American Samoa, Guam, the Commonwealth of the Northern Mariana Islands, the Federated States of Micronesia, the Marshall Islands, and Palau.

4. See http://lumahai.soest.hawaii.edu/Enso/ for more information.

5. The name of the Water and Energy Research Institute was changed to the Water and Environmental Research Institute sometime in the late 1990s.

6. Member countries include Angola, Botswana, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe.

7. See http://www.dmc.co.zw/ for more information.

8. The United States National Weather Service/Pacific Region (NWS/PR) was not heavily involved in climate forecasting when PEAC was actively providing information and forecasts for the 1997–98 El Niño. The NWS/PR has now adapted many of the techniques of PEAC in its forecasting and outreach, and in fact, now funds PEAC.

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