



SMR/930 - 37

***"Workshop on El Niño, Southern Oscillation and Monsoon"***  
***15 - 26 July 1996***

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**"End-to-End Short Term Climate Prediction"**

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***Please note: These are preliminary notes intended for internal distribution only.***

# **END-TO-END SHORT TERM CLIMATE PREDICTION**

## **1. Introduction**

- a. Definitions**
- b. Useable Skill and the Problem of Applications**
- c. Confine Ourselves to Tropics–ENSO**

## **2. How We Got Here**

- a. ENSO**
- b. TOGA**
  - Research Objectives**
  - Research vs. Operations**
- c. The TOGA Observing System**
- d. Predicting ENSO**
- e. The Current Skill of Predicting SST in the Tropical Pacific**

## **3. End-to-End Prediction**

- a. The Concept**
- b. The Elements of an End-to-End Prediction System**

## **4. Incipient End-to-End Prediction**

**The Example of Peru and Brazil**

## **5. The Future**

**Improvements in Models and in Skill**

**Expansions of the Observing System: GOALS**

**The IRI**

# 1. Introduction

## a. Short Definitions

**\*Short term climate prediction: months to years—beyond the scale of deterministic predictability.**

[We are predicting for natural variability which cannot be altered by anything--NOT akin to predicting greenhouse warming].

**\*Short Definition:**

**“The use of fundamental science to develop sound predictive schemes which yield products that are explicitly useful to human activities like agriculture and fishing” (R.S. Lindzen)**

## b: Applications and Useable Skill

**In order for predictions to be useful:**

**\* There must be some skill in prediction in a relevant quantity**

**\* The forecast must be received in a precise and useable form**

**\* Some action must be possible as a result of the forecast**

**\* It must be verified that this action is (on the average) beneficial.**

**c. Confine ourselves to ENSO related variability:**

- 1. Skill been demonstrated for SST**
- 2. SST is tightly coupled to rainfall**
- 3. ENSO variability has impacts**
- 4. Countries have begun to learn to use the forecasts (Peru, Brazil, Ecuador, Chile, Australia, Indonesia)**

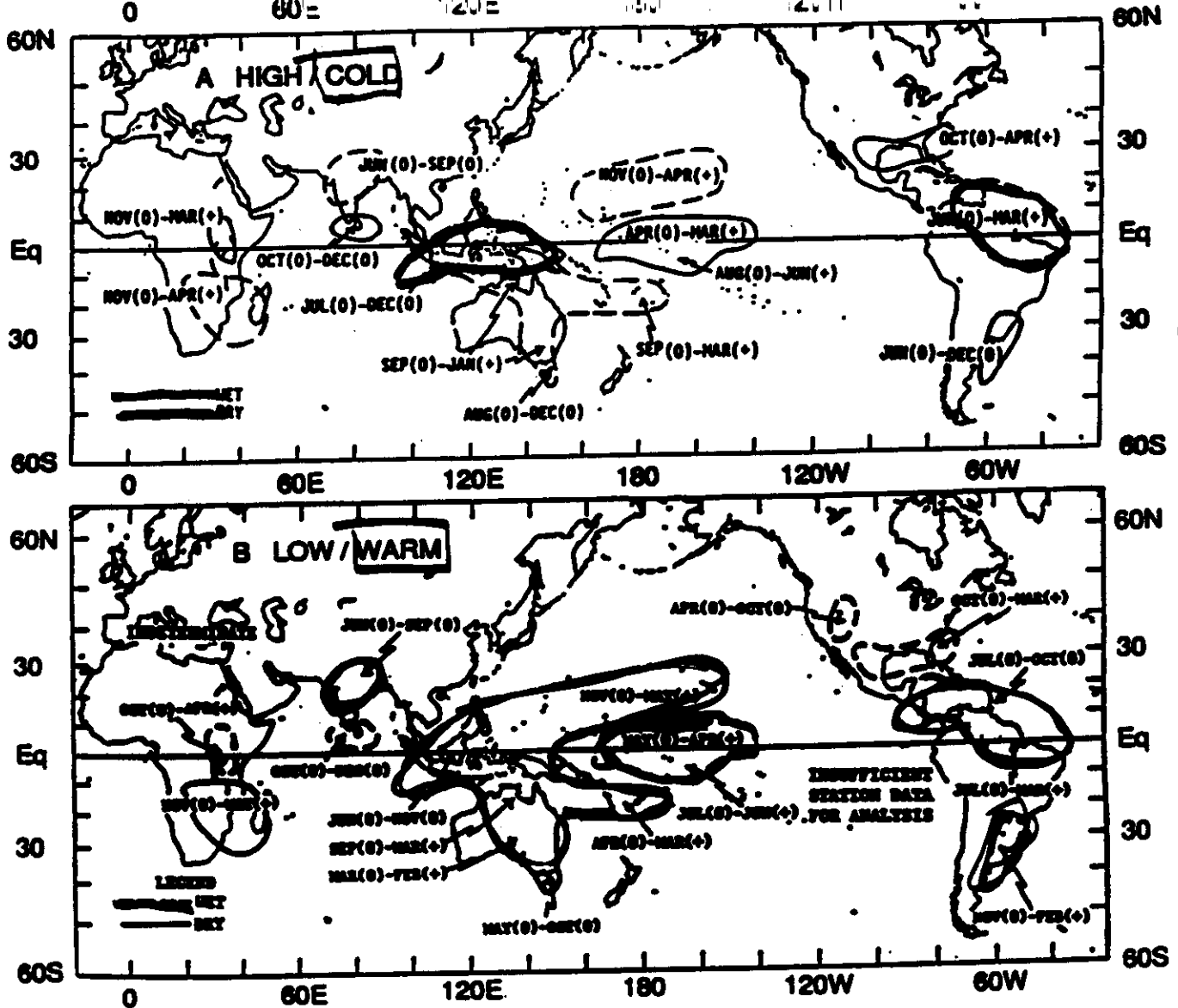


Fig. 8.1:6. Schematic representation of the principal areas of rainfall anomalies during the high (part a) and low (part b) phases of the Southern Oscillation. Source: Ropelewski and Halpert, 1987 (*Monthly Weather Review*, American Meteorological Society, and Ropelewski and Halpert, 1989 *Journal of Climate*, American Meteorological Society).

RAINFALL SIGNAL

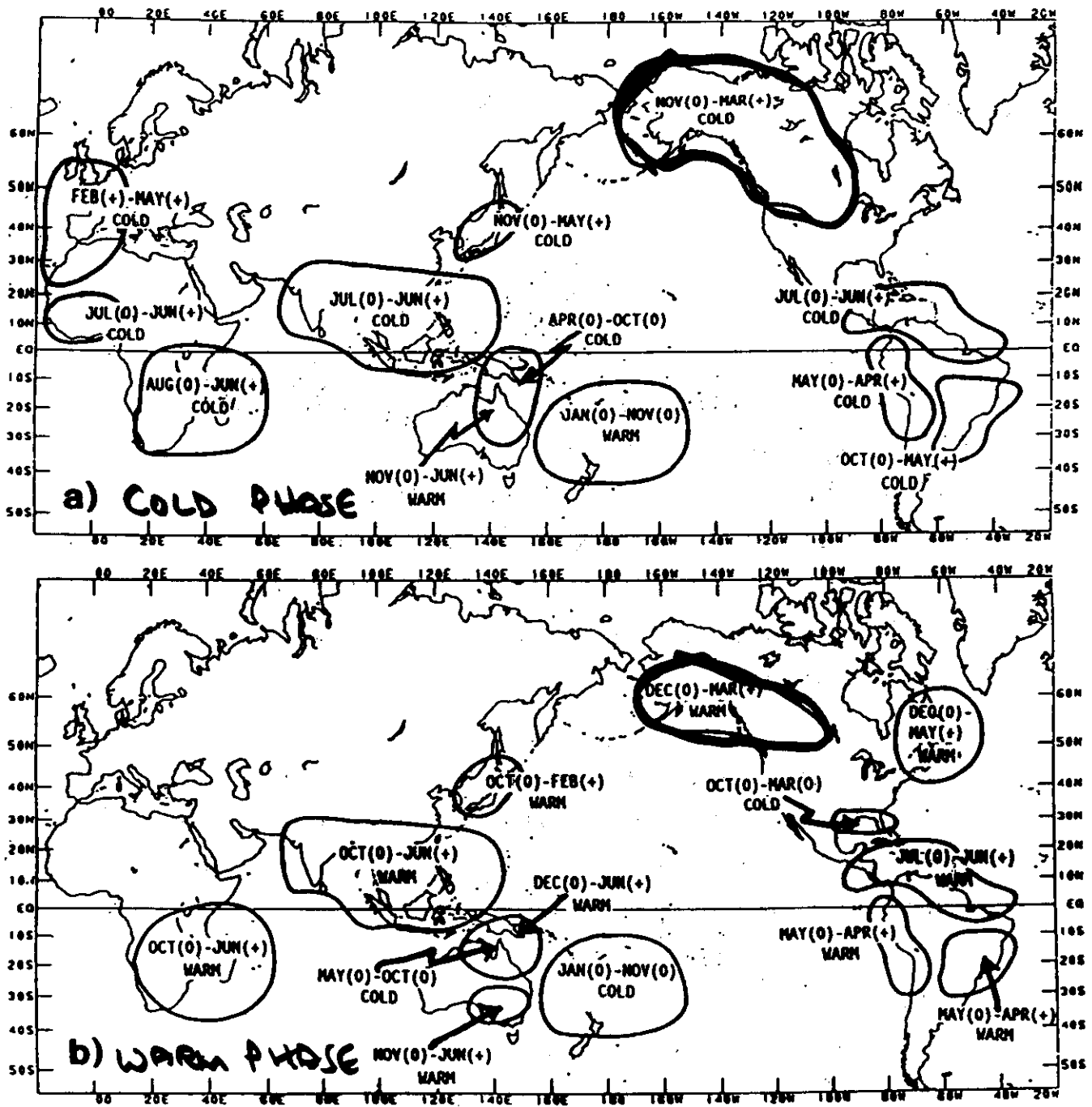


Fig.1 Schematic representation of the principal (a) high and (b) low SO-related temperature (from Halpert and Ropelewski, 1992).

T SIGNAL

## **2. How We Got Here**

### **a. ENSO**

### **b. TOGA**

#### **Scientific objectives:**

- 1. To gain a description of the tropical oceans and the global atmosphere as a time dependent system, in order to determine the extent to which this system is predictable on time scales of months to years, and to understand the mechanisms and processes underlying that predictability.**
- 2. To study the feasibility of modeling the coupled ocean-atmosphere system for the purpose of predicting its variations on time scales of months to years.**
- 3. To provide scientific background for designing an observing and data transmission system for operational prediction if this capability is demonstrated by the coupled ocean-atmosphere system.**

January 1985

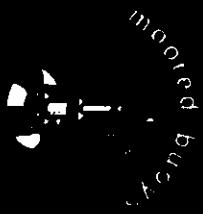
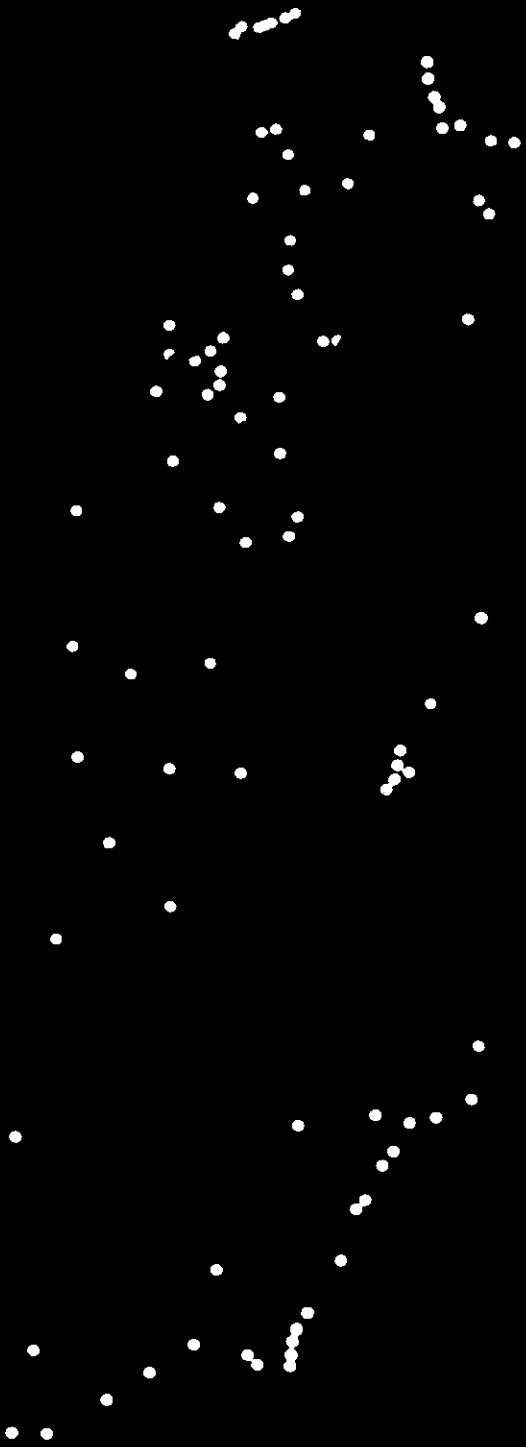
July 1990

December 1994

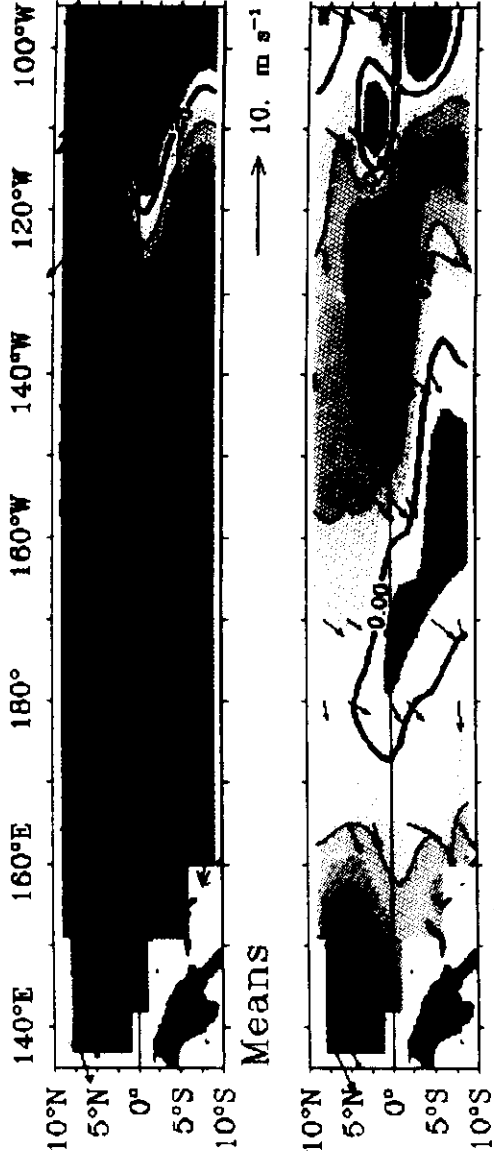


# Tropical Pacific Ocean Observing System

December 1994



TAO SST ( $^{\circ}\text{C}$ ) and Winds ( $\text{m s}^{-1}$ )

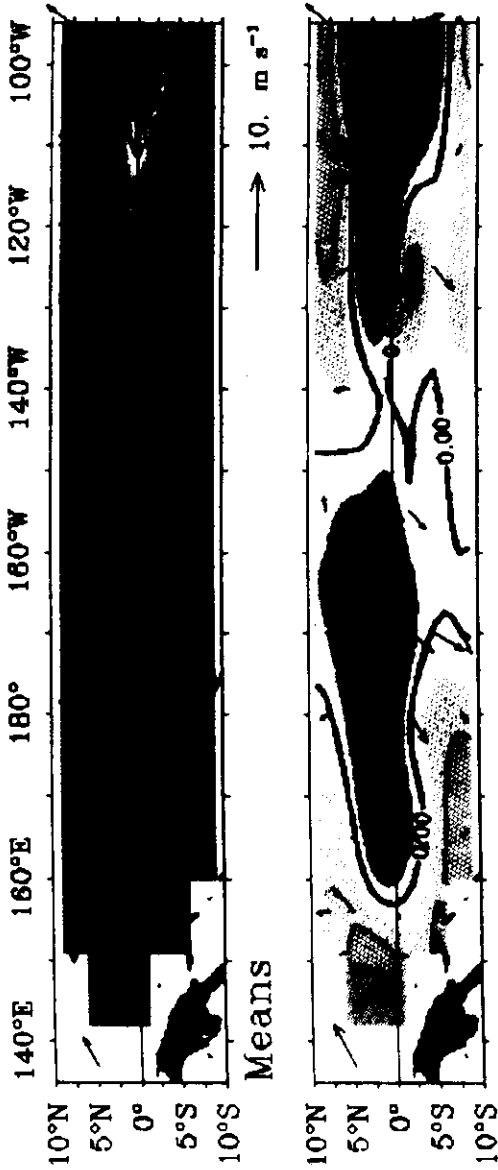


Five-Day Mean Ending on July 10 1996

TAO Project Office/PMEL/NOAA

[www.pmel.noaa.gov](http://www.pmel.noaa.gov) | Toga-tao  
| realtime.html

# TAO SST ( $^{\circ}\text{C}$ ) and Winds ( $\text{m s}^{-1}$ )



Five-Day Mean Ending on May 7 1996

TAO Project Office/PMEL/NOAA

<http://www.pmel.noaa.gov/toga-tao/realtime.html>

### **c. The TOGA Observing System**

**We can now observe the entire equatorial Pacific, surface and subsurface, and get the data in real time. It is available to all:**

**[http://www.pmel.noaa.gov  
/toga-tao/realtime.html](http://www.pmel.noaa.gov/toga-tao/realtime.html)**

### **d. Predicting aspects of ENSO**

**1. Why is it predictable beyond the limit of deterministic predictability?**

**Statistics depends on boundary conditions, esp. SST**

**Therefore: to be able to predict climate, need to be able to predict those boundary conditions.**

**2. How do we predict SST?:**

**Coupled A/O Model**

**Initialization--TOGA TAO**

**Making the forecast (SST every month—not “predicting ENSO”)**

**Verification: Correlation skill and rms error of NINO 3**

**3. How good are the forecasts?**

## **3. End-to-End Prediction**

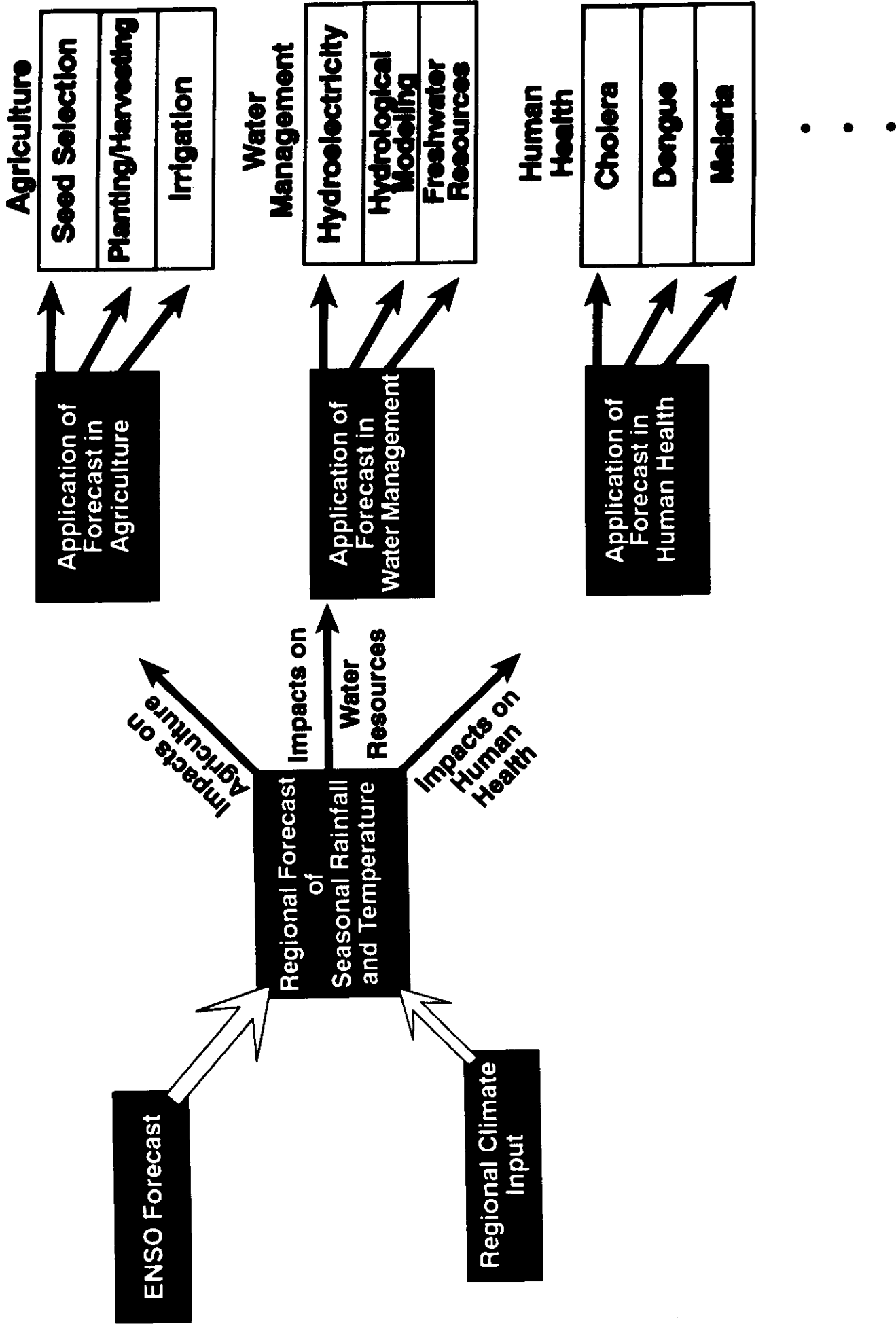
### **THE ELEMENTS:**

**Large Scale Forecasts**

**Regional Assessments**

**Impacts-Vulnerability**

**Applications**



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•  
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## **LARGE SCALE FORECAST:**

**\* Model: A coupled atmosphere-ocean model to make the predictions.**

**\* Appropriate Data: Quality controlled, ingested and assimilated into a form the model can accept.**

**\* Initialization: The data and the model must be combined to provide an optimal estimate of the state of the coupled system.**

**\* Large Scale Prediction: One, perhaps an ensemble of predictions must be run .  
[Regularly and Systematically]**

**\* Evaluation: The data must be used to see how good the forecast was and to provide an objective measure of skill and uncertainties.**

## **REGIONALIZATION:**

**\* Regionalization: Regional data and models combined to provide regional data products for input to regional forecasts.**

**\* Regional Forecasts: The regional data products combined with the large scale forecast to provide an appropriate regional forecast product. [decide on the appropriate regional site and scale].**

**\* Impacts: The impacts of the regional forecasts on various sectors are assessed. Depends especially on the Vulnerability of the sector.**

**[Vulnerability in general increases with time scale and with degree of underdevelopment]**

## **APPLICATIONS:**

**\* Applications: The regional forecasts are applied to different sectors of useability in the form of appropriate data products leading to actions.**

Generally have to understand the normal workings of the system being interfered with

**\* Effectiveness of Applications: Understanding and implementing appropriate ways of distributing and communicating information (including uncertainties) about seasonal-to-interannual variability, prediction, and applications to a broad user community.**

**Effectiveness may depend on**

**The completeness of scientific understanding: (possibility of unintended consequences)**

**Purpose of applications:  
management vs. exploitation  
short term vs. long term**

**Technological sophistication that can be brought to bear: Infrastructure**

**Liability issues**

**Centralized vs. Decentralized decision making**

**→ Public vs Private**

**Trust and understanding of hedging**

**Lack of local implementation.**

**Lack of understanding of normal workings of system.**

**\* Evaluation of Applications: The impact of the applications and the effectiveness of whatever actions are taken are evaluated.**

**Have to be able to distinguish the effects of the predictions vs. effects of whatever infrastructure is built to effect the predictions.**

## **CAVEATS AND DANGERS:**

**Overreliance on forecasts**

**Information can be used to corner a market**

**National security issues: may cause information to be withheld**

**Corruption: the economic value of a false forecast can be large**

**Information tends to benefit the prepared: unintended consequences of benefitting those not needing it**

**Liability issues for blown forecasts**

## **4. Incipient Applications**

### **a. NE Brazil**

#### **\* Populations:**

**Brazil: 150M**

**Nordeste 45M (65% Urban, 35% Rural)**

**Fortaleza 1.9 M**

**[Concentrate on State of CEARÁ and its institution FUNCEME (Fundação Cearense de Meteorologia e Recursos Hidricos)]**

**\* Rainy Season: Feb-May (ITCZ Furthest South)**

**[Anomalies Correlated with Atlantic and Pacific SST]**

**\* Prediction Method: Two Tier**

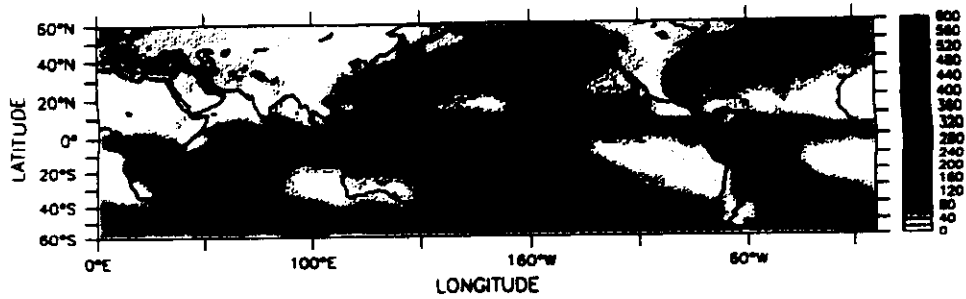
**Nowcast or Predict SST**

**Use High Res. AGCM for Regionalization**

**\* Applications: Mixed Bag**

T (days since 0000-) : 15

DATA SET: legates.msu.nc

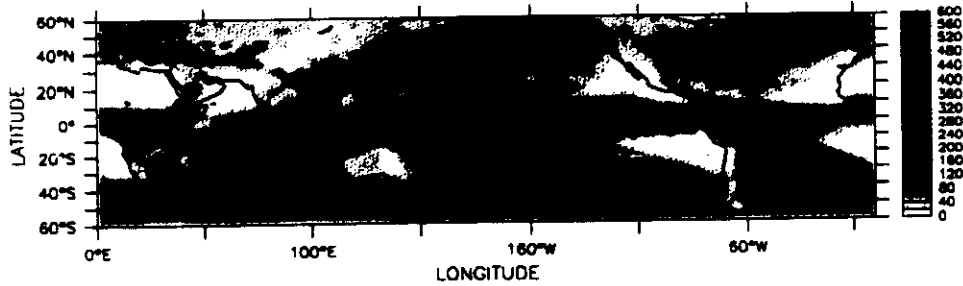


Legates-MSU combined precipitation clima (mm/month)

FIGURE 5.12  
NOAA/PWEL TRAP  
Sep 18 1988 11:02:00

T (days since 0000-) : 104.75

DATA SET: legates.msu.nc

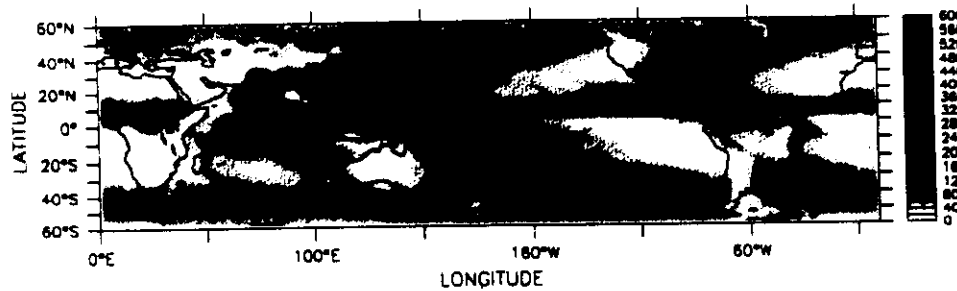


Legates-MSU combined precipitation clima (mm/month)

FIGURE 5.12  
NOAA/PWEL TRAP  
Sep 18 1988 11:01:07

T (days since 0000-) : 196.25

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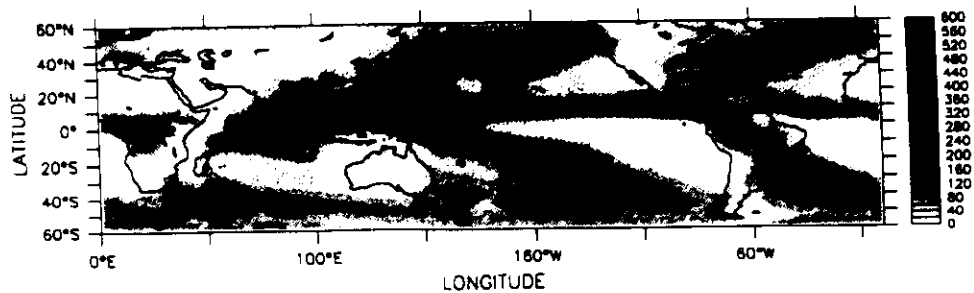


Legates-MSU combined precipitation clima (mm/month)

FIGURE 5.12  
NOAA/PWEL TRAP  
Sep 18 1988 11:02:04

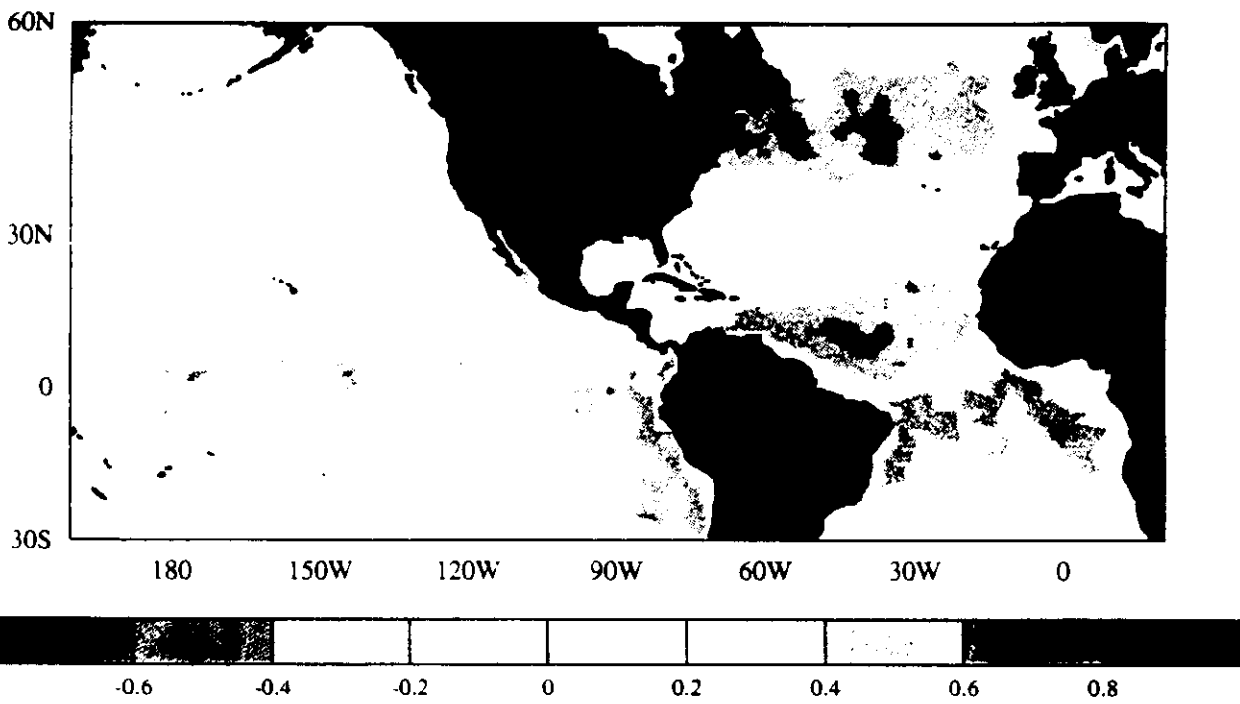
T (days since 0000-) : 288.25

DATA SET: legates.msu.nc



Legates-MSU combined precipitation clima (mm/month)

# Correlation of FMAM NE Brazil Precipitation and SST, 1946-1985



(a) OBSERVED RAINFALL ANOMALIES  
APRIL 1993 (mm)

(b) FORECAST RAINFALL ANOMALIES  
APRIL 1993 (mm)

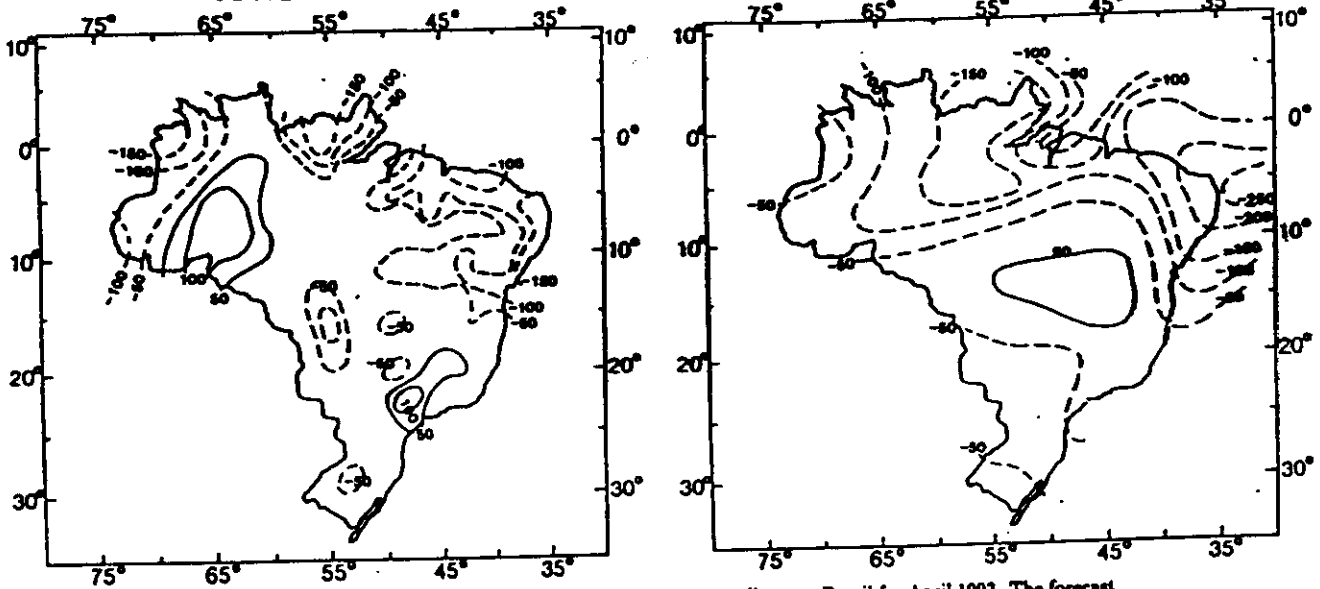


Figure 1 - Observed (a) and forecast (b) precipitation anomalies over Brazil for April 1993. The forecast anomalies depicted are the average of three realizations from simulations forced with March 1993 SST anomalies.

TABLE 1 (see text for discussion)

| FORECASTS FROM | CORRELATIONS |              |              |                       |                     |                     |
|----------------|--------------|--------------|--------------|-----------------------|---------------------|---------------------|
|                | $\sigma^2$   | $\sigma_n^2$ | $\sigma_s^2$ | $\bar{F}_j$ vs. AMIP+ | $\bar{F}_j$ vs. OBS | $F_{i,j}$ vs. $F_j$ |
| December       | 0.95         | 0.34         | 0.69         | 0.80                  | 0.70                | 0.82                |
| January        | 0.65         | 0.23         | 0.41         | 0.82                  | 0.68                | 0.75                |

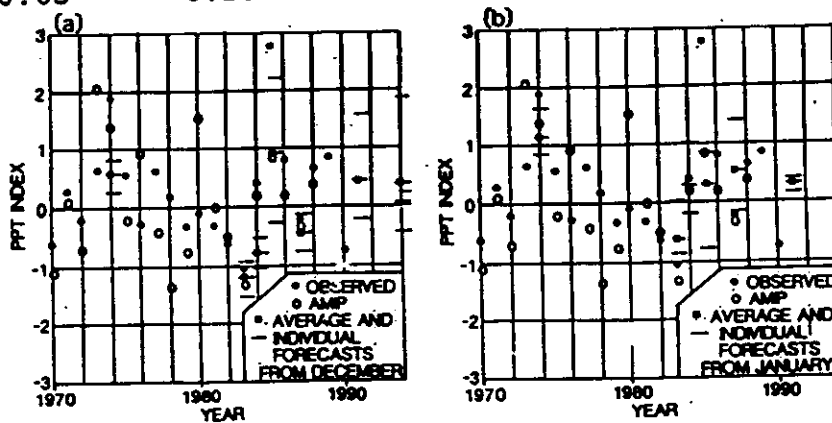
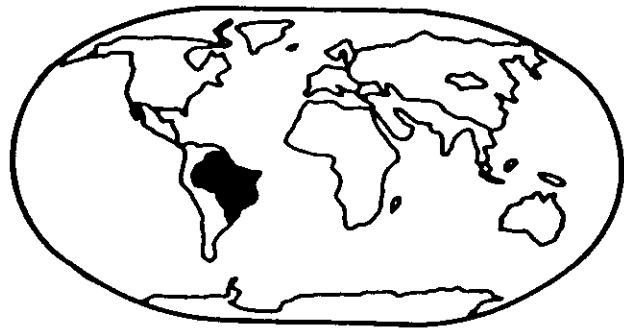
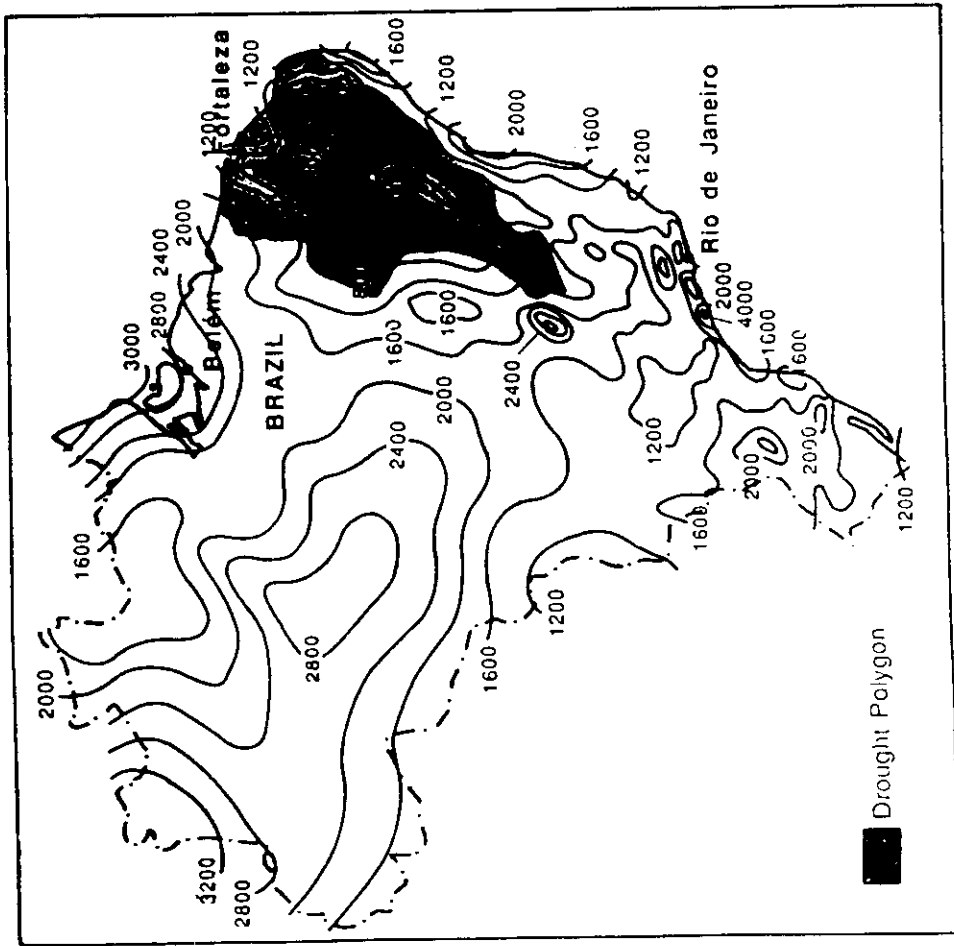
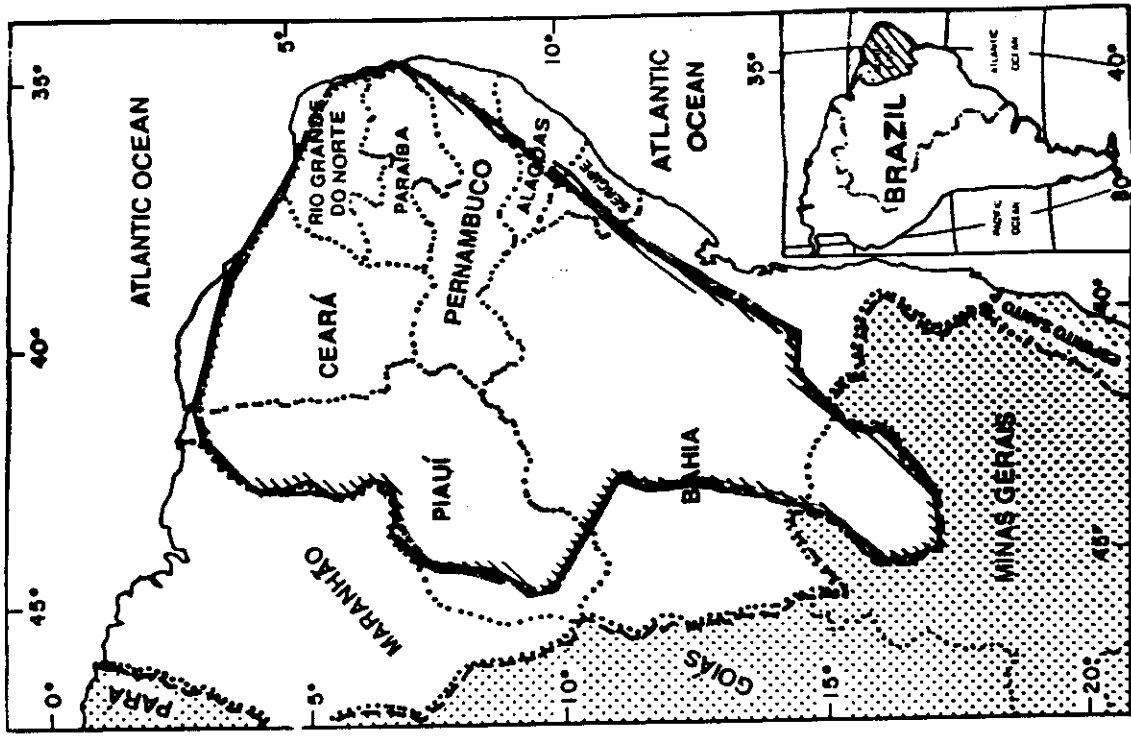


Figure 2 - a) Observed (solid circles), AMIP+ (open circles), and forecast indices of Ferrelite FMA rainfall (open squares show average forecasts, asterisks show individual forecasts) for forecasts using December SSTs. Also shown (Fig. 2a only) are an example of 5 experiments made using November 1989 SSTs. b) - As in Fig. 2a, but for forecasts using January SSTs.





# NE BRAZIL APPLICATIONS

| <u>Year</u> | <u>Precip.</u>          | <u>Grain Prod.</u> |
|-------------|-------------------------|--------------------|
| 1987        | 70%                     | 200,000mt          |
| 1992        | 73%                     | 530,000mt          |
| 1993        | <del>55%</del><br>45%   | 200,000mt          |
| 1994        | 120%                    | 1,100,000mt        |
| 1995        | <del>100%</del><br>102% | 900,000mt          |

[Average Grain Production:  
650,000mt]

# **5. The Future**

## **a. Improving Prediction Systems**

**\* Models**

**\* Coupled Data Assimilation**

## **b. Expanding Prediction Skill (GOALS)**

**\* In Pacific**

**\* Around Tropics**

**ENSO-Monsoon Connection**

**\* Tropics to Mid-Latitudes**

**\* Mid-Latitudes**

**Atmosphere-Ocean Interaction**

**Land-Atmosphere Interaction**

**Sea and Land Ice Interactions**

## **c. The IRI**

**A Centralized institution to:**

**\* Develop the tools of climate prediction and regionalization:**

**\* Interact with applications centers in the affected regions**

**[IRI will NOT do the Applications]**

**Current Status:**

**\* Pilot Projects Ongoing**

**Training: Lamont-Doherty**

**Models: Scripps**

**\* Ministerial Meeting Called by US**

**[November 1995]**

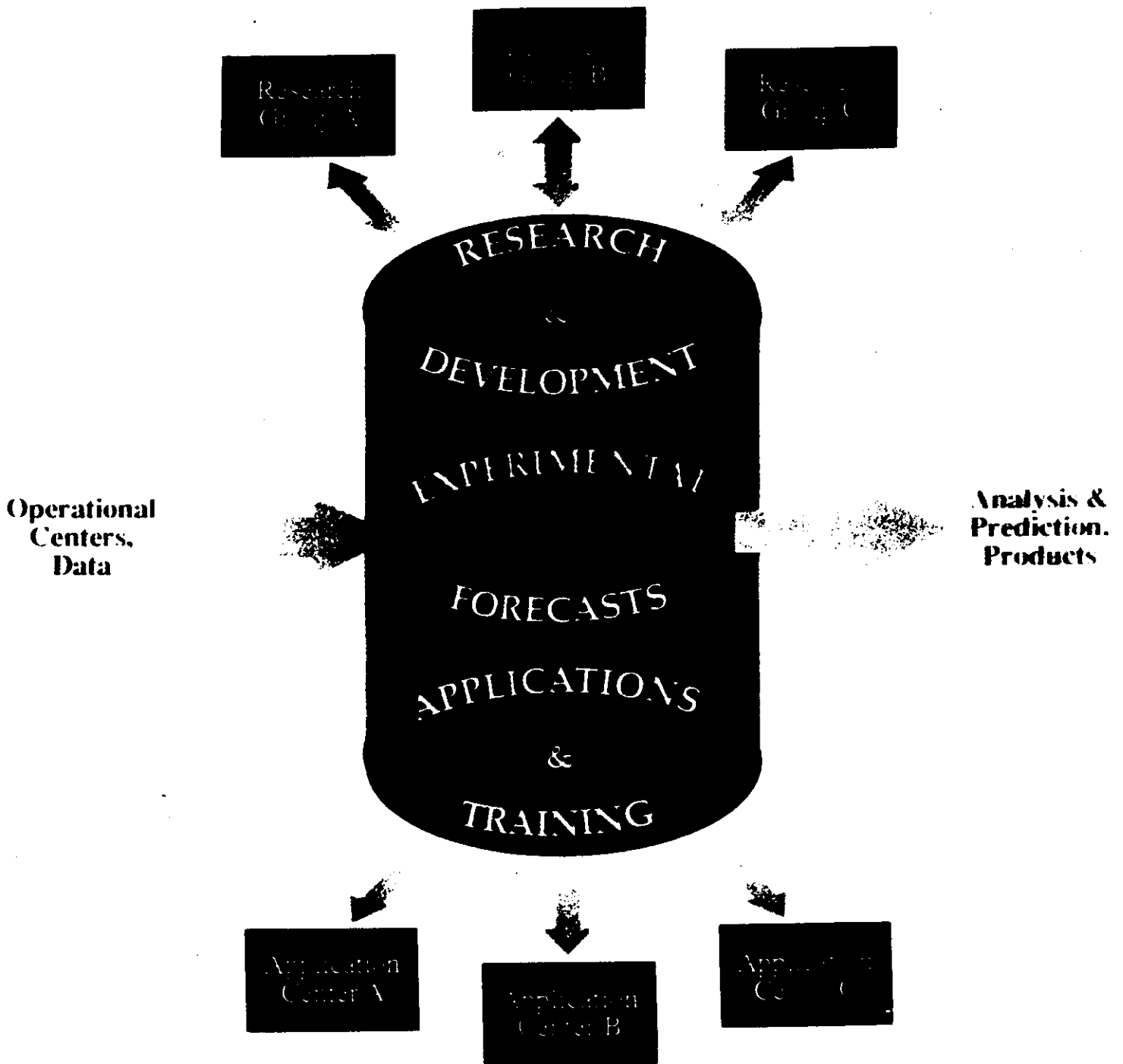
**Future Status:**

**?**



International  
Research  
Institute for  
Climate  
Prediction

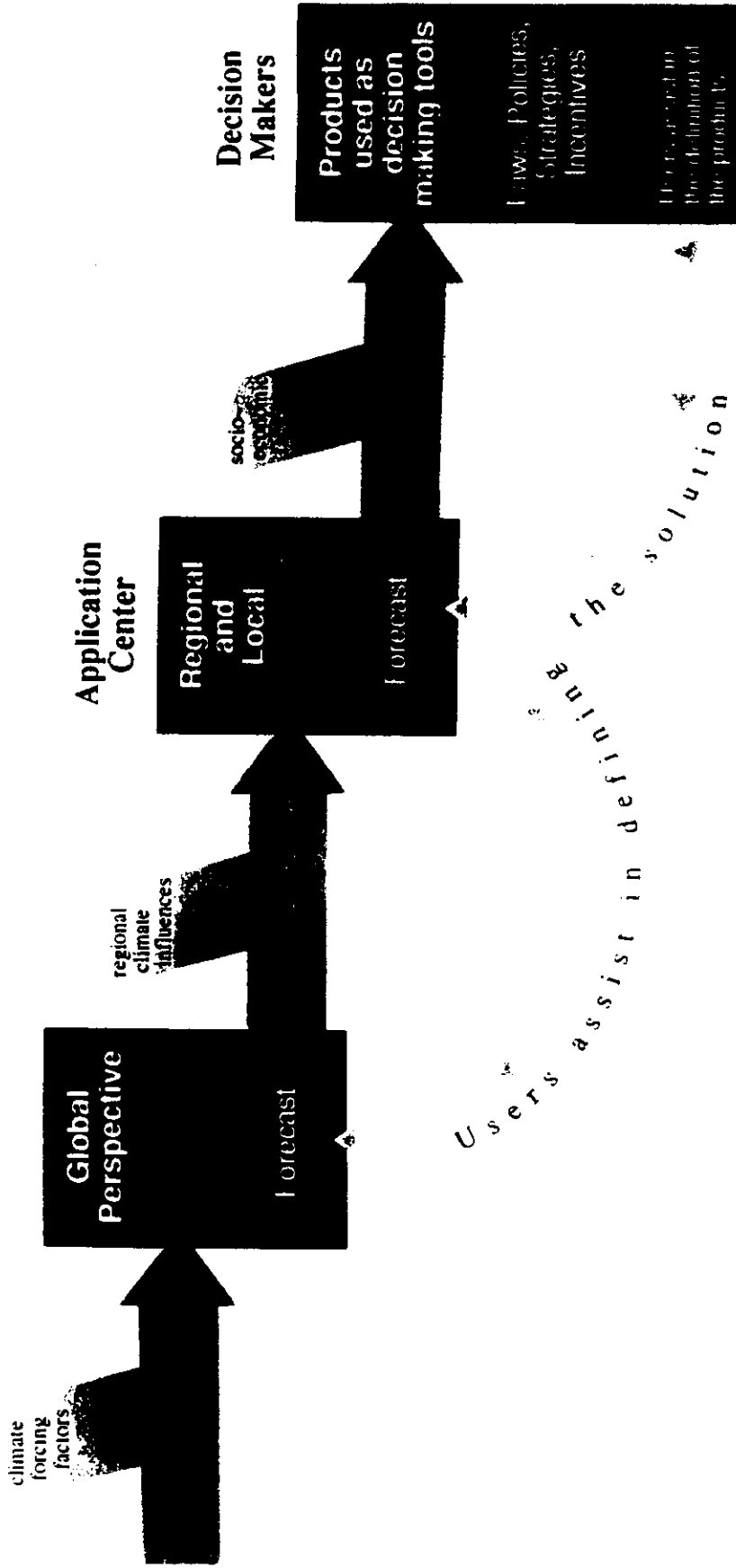




**Figure 5.1** The Institute's concept, including three main functions: Research and Development, Experimental Forecasts, Applications and Training. The concept also envisages a functional linkage with the international academic community (Research Groups) and a direct working linkage through a network of Application Centers.

# Forecast of Seasonal Climate Variability

## Core Facility



**Figure 5.3** Flow of information from the Core Facility, through the Application Centers to Decision Makers. The Core Facility forecasts the "global perspective". Application Centers add knowledge about regional climate influences, and forecast climate conditions within the region. Sociological and economic information is added to the forecast to provide Decision-Makers with material for planning purposes.

## **Conclusions:**

- 1. We need to learn to do applications in a long term and systematic way. Requires regular and systematic predictions without one event killing you.**
- 2. The prediction activity in the US is under the auspices of a program (T-POP) which got it off the ground but is basically subcritical. Needs a centralized activity.**
- 3. The observing system was built by a research program but needs to have a user to be maintained. The only activity which would seem to fit this bill is a prediction activity for benefit.**
- 4. We need to learn applications--doing it where the skill is demonstrated requires these applications to be around the Pacific basin. In a global economy, this also affects us.**
- 5. The IRI will focus research as it provides benefits. It was declared to be the ultimate deliverable of the TOGA Program.**