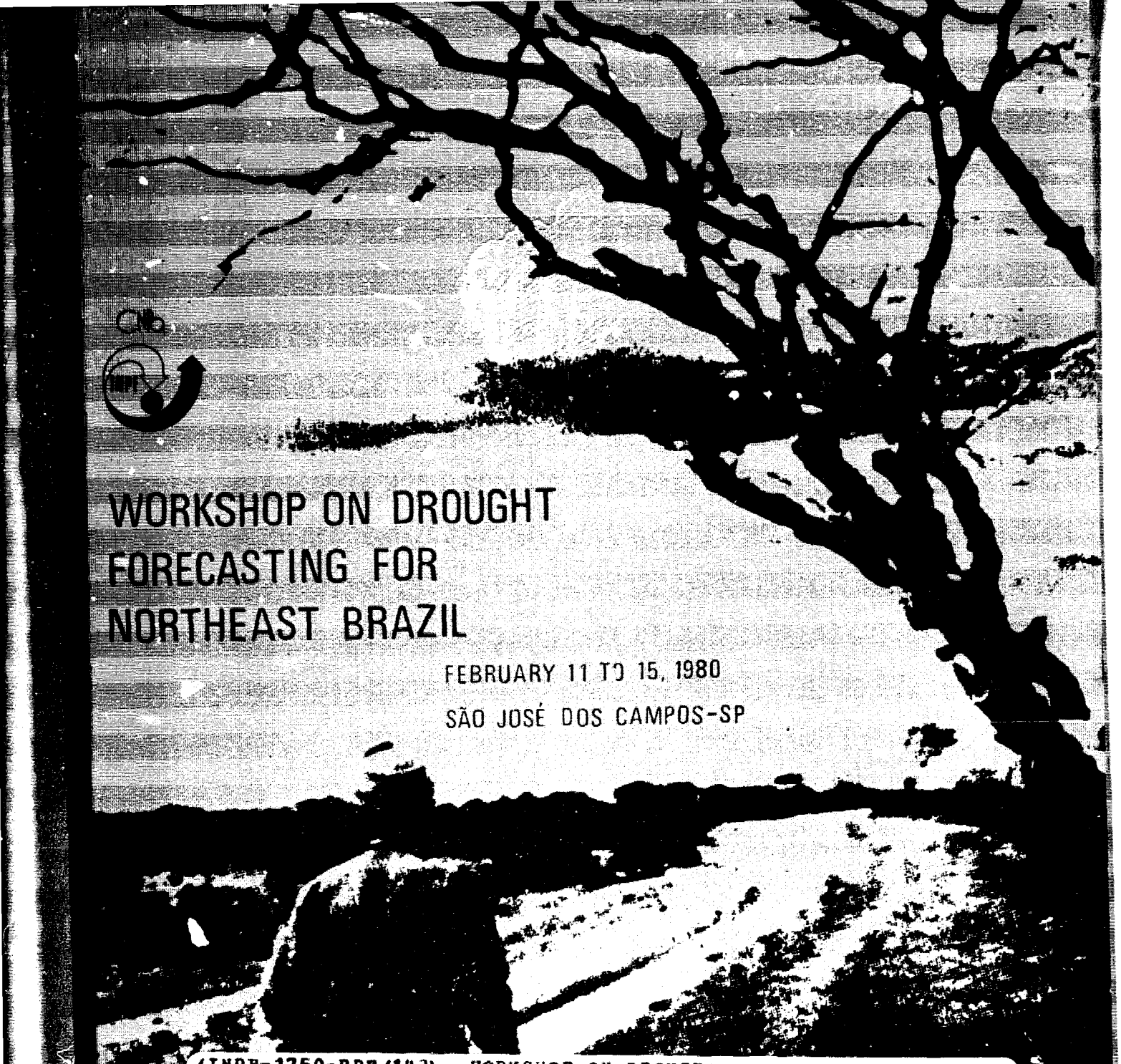

WORKSHOP ON DROUGHT FORECASTING FOR NORTHEAST BRAZIL

FEBRUARY 11 TO 15, 1980

SÃO JOSÉ DOS CAMPOS-SP

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16.Summary/Notes

This report was produced by a panel composed of the authors above, based on the presentations and discussions during a Workshop on Drought Forecasting for Northeast Brazil, sponsored by the National Research Council - CNPq, and held at its Institute for Space Research - INPE, at São José dos Campos, São Paulo, from February 11 to 15, 1980.

17.Remarks *The Workshop on Drought Forecasting for Northeast Brazil, which originated this Report, was partialy financed by the "Programa de Tropico Semi-Árido".*

O SERTANEJO E A SECA

(Montagem de textos de EUCLIDES DA CUNHA,
por Lucimar Luciano de Oliveira).

O Sertanejo é, antes de tudo, um forte.
Acompanhando morosamente, a passo, pelas chapadas,
o passo tardo das boiadas, o vaqueiro preguiçoso
quase tranforma o *campeão* que cavalga na rede ...
Mas se uma rês *alevantada* envereda, esquiva, adiante,
pela caatinga *garranchenta*,
ou se uma ponta de gado, ao longe, se tresmalha,
ei-lo em momentos transformado ...
Não há contê-lo, então, no ímpeto.

A seca não o apavora ...
Enfrenta-a, estóico.
Dois ou três meses antes do solstício de verão,
especa e fortalece os muros dos açudes,
ou limpa as cacimbas.
Os sintomas do flagelo despontam-lhe, então,
encadeados em série, sucedendo-se inflexíveis...
Passam as "chuvas do caju" em outubro, rápidas,
em chuvisqueiros prestes delidos nos ares ardentes ...
... e abaixa-se vagarosamente o nível das cacimbas ...
Os dias, estuando logo ao alvorecer, transcorrem abrasantes,
à medida que as noites se vão tornando cada vez mais frias.

... nos ares,
em bandos,
as primeiras aves emigrantes,
transvoando a outros climas ...

É o prelúdio da sua desgraça.
Vê-o acentuar-se, num crescendo, até dezembro.
... E espera, resignado, o dia 13 daquele mês.
É a experiência tradicional de Santa Luzia ...
Aguarda, paciente, o equinócio da primavera,
para definitiva consulta aos elementos.
Atravessa três longos meses de expectativa ansiosa
e no dia de São José, 19 de março, procura novo augúrio,
o último.
Se durante ele chove, será chuvoso o inverno;
se ao contrário, o sol atravessa abrasadoramente
o firmamento claro,
estão por terra todas as suas esperanças.
A seca é inevitável.

REPORT BY

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to the

CONSELHO NACIONAL DE DESENVOLVIMENTO CIENTÍFICO E TECNOLÓGICO - CNPq

based on a

WORKSHOP ON DROUGHT FORECASTING FOR NORTHEAST BRAZIL

held at

INSTITUTO DE PESQUISAS ESPACIAIS - INPE

São José dos Campos - São Paulo - Brasil

February 11 to 15, 1980

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I - INTRODUCTION

A. THE PROBLEM

The Northeast (NE) portion of the Brazilian territory, covering an area of over 1 000 000 square kilometers, has been afflicted by droughts at least as far back into the past as the colonial times. From the point of view of economic and social impact, the Northeast Brazil droughts, together with frost and floods in the Southern portion of the country, are the most significant examples of the influence of climate upon human activities in Brazil. However, the drought problem is by far the most serious one, due to the large population affected and to the fragility of the economic structure of the region. In instances of severe drought, in Northeast Brazil, the social and economic cost to the country is enormous.

Even though the so-called "drought problem" has many aspects, ranging from the meteorological one to the hydrological, sociological and economical aspects, this workshop concentrated only on the aspect of predicting precipitation in time scales of one month to a season, and in space scales of about 50 000 square kilometers and less. The fact that this might not necessarily correspond to the need of users, makes it necessary to raise at this early stage the point that it will be necessary in the future to develop appropriate interfaces with users in the areas of agriculture, water management and others.

A predictive effort must include the specification of how far into the future these predictions are needed. Even though it cannot be affirmed categorically that this is possible, a definition of a target of a few months is necessary in order to separate it from the different problems of predictions over a few days as well as from the problem of predictions a year or more in advance , for which there are no indications that it might be feasible at this time.

It is also important to define what is meant by forecasting.

In the context of this workshop, the view is taken that it means obtaining *a priori* knowledge of climate variations around the normal values. Thus the value of a forecast is related to information gained beyond long-term average conditions. The variable to be predicted is precipitation. A verification method must be established based on a network of stations.

It is realized that drought in Northeast Brazil is a local manifestation of larger scale characteristics of the atmosphere and even the oceans, a fact which permeates the recommendation of the workshop.

The objectives presented to the workshop were:

"1. to assess the state of the knowledge on climate variability | and predictability |, with a focus on the possibility of forecasting extreme events in Northeast Brazil.

2. to contribute to the establishment of a National research program, coordinated by the National Research Council, through its Institute for Space Research, devoted to the study of climate and its variations in Northeast Brazil, as well as to the development of forecasting techniques".

B. WORKSHOP PROCEDURES

The workshop was structured in three parts:

1. information was provided to the workshop by the Instituto de Pesquisas Espaciais - INPE. Appended are information papers relevant to the recommendations in this report regarding the availability of data (Appendix A), research personnel (Appendix B), and a summary of previous work done in Brazil on the subject (Appendix C).

2. A series of seminars on various aspects of the problem was presented by participants. Brief summaries of certain relevant presentations are appended.

Speaker	Title
• J. Rasmussen	The World Climate Program (Summary in Appendix D)
• S. Hastenrath	Towards the Monitoring and Prediction of Northeast Brazil Droughts (Summary in Appendix E)
• H. Riehl	Upper Air Patterns - Dry and Wet - Rainy Seasons (Summary with suggestions in Appendix F)
• W. Gray	Likely Physical Processes Relevant to to the Northeast Brazil Drought Problem (Summary with suggestions in Appendix G)
• J. Shukla	Predictability of Time Averages (Summary in Appendix H)
• J. Roads	Possible Dynamical Theories for Climate Prediction
• J. Smagorinsky	Simulation Capability of General Circulation Models
	Monthly Numerical Prediction

3. The workshop divided into four working groups to develop the specific recommendations of the workshop and draft the report that follows.

A list of participants in the workshop is attached (Appendix I) with institutional addresses. Brazilian participants contributed significantly in all aspects of the discussions and were particularly helpful in providing factual material.

The recommendations of the foreign participants in the Workshop are contained in the following report.

C. PROPOSED NATIONAL STRATEGY

The Workshop deals with the overall problem in several major streams such as data and data aquisition, diagnostic and empirical research and numerical model development. These streams are to some extent overlapping,

and they are interdependent, and will require resources, facilities and trained personnel. It will be necessary for Brazil to develop a strategy to determine priorities within each of these, bearing in mind their interdependence.

The workshop suggested that consideration should be given to ensure that activities which will potentially yield results at an early date (e.g. data acquisition, certain diagnostic and empirical forecasting, Ph. D. training) should be undertaken immediately with other activities carefully phased so as to provide a long term potential in other activities such as numerical model development.

The workshop suggested some mechanisms which might facilitate specific activities including a coordenated Brazilian effort as well as regional, bilateral and international cooperation.

II - DATA DEFINITION, ACQUISITION AND ARCHIVING

The National Research Council of Brazil has recently established an Advisory Committee to the Semi-Arid Tropics Program, charged with: promoting the processing and validation of climatological data; establishing priorities for the processing; establishing uniform validation criteria, and promoting easy access to data for research purposes. We recommend the full and rapid implementation of the goals of the advisory committee. The present section is intended to be in support of this effort.

The primary objective of the Northeast Brazil Drought Forecasting Program is to provide operational seasonal-monthly forecasts of precipitation. In order to do this, the relevant data must be gathered, archived, and analyzed. In the present section, we shall describe the Brazil data sets needed to define the drought, and the global data sets required to diagnose the mechanisms of drought. These data will be required for a variety of observational studies discussed in section III. Empirical methods to forecast drought and utilization of these data sources are considered in section IV. The data sets will also be used to initialize, calibrate, and validate the numerical models to be described in section V.

Consistent with the central objective of the Northeast Brazil Drought Forecasting Program of providing operational seasonal precipitation forecasts, the following data for all of Brazil seem to be of primary but not exclusive importance:

1. monthly means of precipitation for a large number of stations with continuous and long records;
2. monthly means of the pressure for a relatively small number of stations with continuous and long records;
3. monthly means of upper air data.

Important data sets exist at a variety of Brazilian institutions and elsewhere. A brief orientation is provided in the

following sections (a) through (c). For details of data requirements see Appendix J.

A. BRAZILIAN HISTORICAL DATA

Historical daily precipitation data for Northeast Brazil are available from Superintendência do Desenvolvimento do Nordeste (SUDENE) in the form of magnetic tape. The Departamento Nacional de Obras Contra a Seca (DNOCS) may be an additional source of daily rainfall data for the Northeast. Historical daily precipitation data for all of Brazil are available from Instituto Nacional de Meteorologia (INEMET) and Departamento Nacional de Águas e Energia Elétrica (DNAEE), with much of the data already on magnetic tape.

Historical daily surface data are available from SUDENE and INEMET, with some of the INEMET data already on magnetic tape.

Historical daily radiosonde and pilot balloon data are currently being processed and placed on magnetic tape. These data are available, but only in their original form. The Instituto de Atividades Espaciais (IAE) is processing the stations run by the Brazilian Air Force (FAB), while the Federal University of Paraíba is about to begin processing the stations in Northeast Brazil run by SUDENE in collaboration with INEMET.

B. BRAZIL "REAL-TIME" DATA

Monthly mean precipitation and surface temperature data are published by INEMET within a period of 15-30 days after the end of each month. In addition, INEMET calculates monthly means for the upper air stations in all of Brazil and sends this information to the WMO.

C. DATA FROM OUTSIDE BRAZIL

A variety of data sets from outside Brazil will be needed, such as upper-air wind, satellite cloud and wind data, long-term ship

observations and others. It is expected that these shall be acquired in due course through exchange at the international level. Therefore, recommendations shall focus on specific Brazilian sources.

RECOMMENDATIONS

While the original *in extenso* data sources described in (A) and (B) above shall be needed in a variety of special studies, it is felt that bulk-processed monthly summaries will form the basis for a great part of the studies discussed in sections III and IV. Accordingly, a high priority shall be given to the archiving of selected ensembles of monthly data in a readily accessible form (magnetic tape) at some suitable government facility. The approximate data priorities are as follows:

1. seasonal prediction on an operational basis will require very specific data sets. These are explicitly discussed in section IV (recommendations, (1)). Construction of these data sets is a task of very high priority;
2. upper air data - radiosonde and pilotballoon - at all existing stations;
3. surface pressure, temperature and humidity (for stations beginning on or before 1950 and in continuous operation until the present);
4. precipitation (for stations beginning on or before 1921 and in continuous operation until the present);
5. hydrological data (for stations beginning on or before 1950 and in continuous operation until the present);
6. wind data from commercial aircraft since 1960's;
7. high atmosphere rocket observations since 1960's.

III - OBSERVATIONAL STUDIES

Investigations of the many factors that govern climate and weather in the Northeast shed light on the impact of the atmosphere on life and economy of the region. They further lead to a rational approach to applications of human activity and set the stage for seasonal drought prediction.

We consider three main topics:

A. The variability of drought occurrence;
B. The relation of principal climatic controls to this variability;
C. The occurrence and structure of rain-bearing weather systems.

Only some examples of problems to be solved under each of these major topics are presented.

A. VARIABILITY OF DROUGHT OCCURRENCE

1. Composition of precipitation events, especially efficiency of precipitation for water supply.
2. Minimum effective water supply for human applications.
3. Definition of drought, its occurrence in space and time in one season. Heat and water budgets for selected areas.
4. Extended droughts: persistence over two or more years in different parts of the area.
5. Relationship between Northeast Brazil drought and the quasi-biennial, Southern, and other oscillations.

B. RELATION OF PRINCIPAL CLIMATIC CONTROLS TO DROUGHT VARIABILITY

1. Space and time scales of anomalies. Some controls are the subtropical anticyclones; vertical structure of basic currents; atmospheric stability, especially temperature inversions; ocean surface

temperatures; soil moisture; precipitable moisture; single and double ITCZ structures; cloud top temperatures.

2. Combinations of anomalies and their patterns on seasonal and shorter term bases in relation to droughts in one season.

3. Persistence and possible persistence prediction of ensembles of factors for 2 and more years.

C. OCCURRENCE AND STRUCTURE OF RAIN-BEARING WEATHER SYSTEMS

1. Composite model or models of structure of rain-bearing weather systems throughout the troposphere in relation to interlatitudinal influences.

2. Time evolution of a single rain system from birth to termination. Propagation of system is included. Variations of structure with time.

3. The effectiveness of rain production from weather systems; relation of effectiveness to drought and rainy periods.

4. Support for or supression of weather systems under the influence of climate anomaly ensembles given above.

5. Correlation between weather systems and the effectiveness with observed precipitation.

6. Possible rain inhibition from condensation nuclei in the air. Soil moisture content related to precipitation effectiveness by inhibiting or placing no obstacle against large transport of condensation nuclei into the atmosphere.

7. Convective intensity vs. thermal influences.

IV - EMPIRICAL PROGNOSIS

Some diagnostic studies indicate that droughts in Northeast Brazil are related at least in part to the behavior, and latitudinal position of the low pressure trough, confluence axis, and convergence band in the Atlantic sector. Circulation anomalies seem to evolve well in advance of the northern Northeast Brazil season. Departures in the large-scale circulation may manifest themselves in a variety of parameters, such as surface pressure, wind, and sea surface temperature, cloudiness and precipitation fields in the Atlantic, upper air winds over both ocean and continent, rainfall and pressure over Northern South America, etc.

The essence of the seasonal forecast of precipitation, particularly for the northern portion of the Northeast, appears to rest with:

1. the degree of correlation of the time lag of the Northeast rainfall with these large scale parameters;
2. the degree to which such large scale monthly or multi-monthly parameters can be measured, transmitted, and evaluated at Brazilian government institutions such that seasonal monthly forecasts can be made updated on a timely basis.

A variety of techniques is conceivable and their feasibility should be explored. The following recommendations are not meant to be comprehensive nor are they in order of priority.

RECOMMENDATIONS

1. Apart from the data described in section II and Appendix J very specific data sets will be needed for the actual applications of operational prediction schemes.

a. Predictores must be available on a timely basis.

b. Time series of predictors must be internally homogeneous, although calibration and absolute scale are not of essence;

c. Sufficiently long series ($\geq$ 10 years) are needed for reference;

d. Parameters should have a time resolution of about one month. A spatial resolution of about 2.5 - 5.0 degree squares, or individual station values are desired.

These simultaneous requirements could, for example, potentially be met by satellite cloud and wind data. The construction of a data base satisfying these requirements is a task of very high priority.

2. Further diagnostic studies and experimental seasonal forecasts for past years should be undertaken using the kind of data sets described in (a) above, as well as other data. Efforts should concentrate on predictions of the general character of the rainy season as a whole and for a large area (about 500,000 km^2) of the semi-arid interior of the northern Northeast as a whole. Initial predictions should be made with a lead time of 6 months. These will be followed by updated forecasts with shorter lead times.

3. The possibility of foreshadowing trends over intervals of more than a year to decades by time series and other techniques should be explored.

V - MODELLING AND SIMULATION

A. INTRODUCTION

Mathematical models of the Earth-climate system are tools used by meteorologists to develop, refine,and validate hypotheses for climatic variability. They are also used to suggest the data requirements for climate studies. Because they are based upon the fundamental laws of thermodynamics and hydrodynamics, they can give physical insight into the mechanisms that determine the climate system.

It is generally recognized that the mechanisms responsible for the variability of time averages can be put into two broad classes: (1) the effects of the slowly varying boundary conditions (sea surface temperature, soil moisture, sea ice/snow, etc.) and (2) internal dynamics (instabilities and non-linear interactions). Under these two broad classes we suggest specific modelling studies that may help to understand and predict Northeast Brazil drought. We recognize that this is an incomplete list since climatic variability is not well understood.

It is suggested that particular models may be used for the study of these hypotheses. The models are categorized as regional/process models, designed to study local effects, and global general circulation models that are designed to simulate and predict the Earth's climate. Research should be conducted with all of these models by the meteorological community in Brazil in order to understand the basic reasons for the Brazil climate in general,and that of Northeast Brazil in particular. However,it must be stressed that only certain of these modelling studies will be immediately feasible, because of limitations in computer capability and in highly experienced scientific manpower. We stress that in order to achieve complete understanding and predictability of the drought by numerical models, active resource development by the Brazilian government must be undertaken.

These modelling studies must be performed in close connection with the diagnostic studies and analysis of data since proper definition

of the problem will include the determination of time and space scales of anomalies. Some of the models will also have to be initialized with the proper initial conditions and all models must be eventually validated in terms of the data.

B. SENSITIVITY AND PREDICTABILITY STUDIES

In this section we list the possible sensitivity and predictability studies which might be carried out in order to understand the physical and dynamical mechanisms responsible for climatic variability over Northeast Brazil. We divide these studies into two broad categories, depending upon the role of slowly varying boundary conditions (sensitivity studies) or the role of internal dynamical interaction (predictability studies). The following lists are not written in order of importance nor are they all inclusive, as the relative effects of changes of slowly varying boundary conditions and the effect of the initial conditions are still poorly understood.

Sensitivity Studies

1. Relationship between sea surface temperature (SST) anomalies over tropical Atlantic and eastern Pacific oceans and precipitation over Northeast Brazil.

2. Effects of changes in soil moisture, vegetation and albedo on the circulation over Brazil.

3. Role of Amazon "heat source" in determining the mean circulation over the region. (Possible influence of Amazon deforestation on the local and global climate).

4. Sensitivity of local rainfall to changes in moisture flux convergence.

5. Role of Atlantic SST anomalies in determining the structure and

location of the ITCZ including the dynamical interactions between tropics and midlatitudes.

Predictability Studies

1. Determination of the limits of extended predictability (deterministic prediction of time averages) for the Northeast Brazil region.
2. Interaction between the tropics and the mid-latitudes (North and South Hemispheres) and their role in determining the variability over Northeast Brazil (fluctuations of ITCZ and subtropical highs).
3. Structure and dynamics of transient disturbances (cloud clusters and synoptic waves, etc.) in the region and their interactions with the ITCZ.
4. Structure and dynamics of trade wind inversion (over land and ocean) and its possible effects on precipitation variability.
5. Role of spatial variation of surface friction in determining the local circulation.

C. MODEL DEVELOPMENT

Dynamical models of the earth-ocean-atmosphere climate system consist of mathematical equations describing the physical properties of the relevant variables and their inter-relationships. They are helpful in determining the role of different physical and dynamical processes quantitatively. To properly understand and validate various hypotheses for climate variability suggested previously, several models with varying complexity must be developed and applied. We understand that a program for the development of numerical models for short range prediction is already underway. In this report we have concerned ourselves mainly with the development of climate models for the study of NE Brazil's drought problem. The models required to tackle the problems described in section 2, can be divided in the following broad categories:

1. Global General Circulation Models (GCM)
2. Regional/Process Models

Global General Circulation Models

The utilization of a global GCM should be one of the important components of a program for objective predictions of climate variability by dynamical methods. This should include global models for the atmosphere and simple mixed layer models for the oceans. For the time scale of the NE Brazil problem, it is not necessary to develop models for the deeper circulation of the oceans. Although the primary interest is the drought over NE Brazil, the physical causes of this problem are unquestionably global in character and, therefore, a global GCM is an indispensable tool to understand and predict the climate variability. Sensitivity and predictability studies involving air-sea interaction, land surface processes and dynamical interactions between tropics and extratropics can be carried out with global GCMs.

Regional/Process Models

The process models are simple models used to study quantitative details of various climate hypotheses and their mechanisms. For example, the radiative-convective models could be used to study the influence of local variations in albedo and soil moisture; the statistical-dynamical and energy balance models could be used to study the influence of remote regions such as the Amazon on Northeast Brazil; linear models could be used to study the influence of SST anomalies in the Pacific and Atlantic region and the effects of a changing zonal wind; and high spectrally truncated models could be used to study the influence of remote regions on Northeast Brazil Drought. Simplified general circulation models, which include regional and spectrally truncated models, might be used to study the influence of different initial conditions on the tropical disturbances that produce the precipitation in Northeast Brazil. They can also be used to study the remote region influence such as the strength and location of the midlatitude anomalies, the subtropical highs, and the intertropical convergence zone.

D. STRATEGY FOR UTILIZATION AND DEVELOPMENT OF MODELS

Since there already exist well developed GCM centers in the World, every effort should be made by the Brazilian meteorological community to collaborate with the existing centers. However, since it is not possible to rely completely on these foreign centers to study Brazil's climate problems, improved levels of expertise and facilities should be developed in Brazil. To accomplish this we suggest the following strategy.

The regional/process modelling studies should be immediately undertaken by the individual scientists with present computer facilities. The more complicated GCMs can be studied initially in collaboration with scientists at other institutions. As a number of these highly trained professionals become available to the meteorological community in Brazil, there should be consideration of developing facilities for GCM studies locally. Encouragement should also be given to develop regional collaboration among the South American countries for the application of modelling techniques to regional problems.

E. RESOURCE REQUIREMENTS

1. Scientific Personnel

To fully achieve the objectives outlined in the previous sections, a sizeable group of well trained scientific personnel is needed in the areas of atmospheric and oceanic modelling, computer sciences and related areas. Simultaneously, there should be established a close collaboration between the Brazilian institutions and existing foreign groups dedicated to climate modelling, so that initially, some studies can be performed in collaboration, while training the personnel. This point is further discussed in section VII.

2. Computing Facility

A fast and dedicated computing facility is very essential

to study the problems of climate variability and dynamical long range prediction. Absence of an adequate upper-air network in the Southern Hemisphere requires an increased dependence on satellite-derived meteorological data. In order to process the massive amount of satellite and conventional data in near real-time, so as to be useful for empirical forecasting and for integrating global models, it is very important to have available a dedicated, high speed, large memory computing facility. A conservative estimate would be to acquire a dedicated computer with a speed of about 10 MIPS for the Northeast Brazil climate problem. This should be accompanied by suitable peripheral and graphical facilities. However in order to tackle several other problems important to Brazil, such as those discussed above as well as numerical weather prediction and other climate problems, it is suggested that a somewhat larger computer be acquired, i.e. about 50 MIPS.

F. DATA REQUIREMENTS

In addition to the development of the physical hypotheses needed to perform climatic studies, the data must also be used to initialize and validate the numerical models. To do this we require first the characteristics of the precipitation variability over Northeast Brazil. This requires the climatic mean, standard deviation, and frequency distribution of the time and space scales of precipitation. Next, since precipitation is a particularly difficult meteorological parameter to model, the space and time scales of associated meteorological parameters such as wind, temperature, and water vapor are required. This becomes particularly important in evaluating the applicability of various theories. Finally, characteristics of various higher order terms such as momentum and heat fluxes are also needed. Modelling studies can be helpful, *inter alia*, in determining the data requirements for climate studies.

RECOMMENDATIONS

1. Carry out a program of sensitivity and predictability studies to determine the mechanisms responsible for climate variability over NE Brazil.

2. Develop and utilize regional/process and global models to simulate the mean climate and its variability over Northeast Brazil.

3. Develop a team of qualified scientific personnel in the area of modelling and simulation.

4. Make available a dedicated computing facility with a computer of speed 10 - 50 MIPS with adequate peripheral and graphical devices.

VI - BILATERAL AND INTERNATIONAL PROGRAMS

The Drought Forecasting Project for Northeast Brazil should be considered in the context of the overall Brazilian climate-related effort which includes the Semi-arid Tropics Program and the Humid Tropics Program.

The World Climate Program (WCP) comprises a wide range of activities including data, applications, impact studies and a research program. The WCP is being planned and implemented by the Member Countries of WMO and many international organizations (e.g. WMO, ICSU, UNEP, FAO, UNESCO, WHO, among others).

The following points, while directed primarily at the Drought Forecasting Project, may be applicable to other Brazilian problems as well (e.g. the climate aspects of the harvest of tropical forest). It is recommended that Brazil participate fully in the planning and implementation of the WCP.

Certain activities may best be undertaken through bilateral arrangements with another country facing similar problems or having technical or scientific resources needed by the Brazilian program. Another mode of the future may be the eventual establishment of a South American center with the participation of all nations of the continent.

Brazil might participate in the WCP in two ways:

1. Brazil may utilize data, information, methodologies, results and technological resources from other countries.
2. Brazil may contribute to the international program through the provision of data, information and results of its own programs.

The following are examples of possible participation in the four component programs of the WCP given to illustrate the type of international participation possible. It should be emphasized that the following list is not comprehensive.

World Climate Data Program (WCDP)

1. The Drought Forecasting Project should specify the data requirements needed and request the WCP to coordinate and facilitate the assembling of data required from international sources.

2. Brazil should organize and make available the Brazilian data required by the WCP. These data may include the following general classifications:

   a. data provided through the Global Telecommunications System (GTS) of the World Weather Watch. (This implies a continued expansion and improvement of the GTS);

   b. data provided in delayed mode to international centers;

   c. data collected and archived in Brazil and made available on request;

3. Brazil will need to comply with the WCP data organization conventions and formats.

World Climate Applications Program (WCAP)

1. The Drought Forecasting Project could be considered as a pilot project* within the WCAP. It will be a valuable test case for methodologies and techniques in the application of Climate Data to food production and water resources.

2. Application methodologies and training material developed by the Project will be useful for programs in other countries and should be exchanged through the WCAP.

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* *Several pilot projects in the developing world are being planned within the WCAP which entail an integrated approach including observational, data processing and applied services activities.*

World Climate Impact Studies Program (WCIP)

The Drought Forecasting Project is an excellent test case for the WCIP because it deals with a specific problem - Drought Forecasting. The impact of climate change on the socio-economic structure of the area may be more easily treated than in a more complex case (e.g. more than one country). This aspect of the program may be related more to Brazil's Semi-arid Tropics Program than to the limited Drought Forecasting Project.

World Climate Research Program (WCRP)

1. The Drought Forecasting Project should utilize, as much as possible, models developed by other countries participating in the WCP, adapting the models to suit the Project's needs. The following mechanisms are possible:

   a. post-doctoral training at foreign institutions;

   b. adapting models to computers available to the Project within Brazil;

   c. joint efforts with foreign scientists and institutions in developing models and running them on very large computer systems abroad.

2. Research should be undertaken in the Drought Forecasting Project which supplements the continuing Brazilian research efforts and these research results should be exposed to the World community through the WCP, as well as through scientific publications. This research activity might include:

   a. model development;

   b. sensitivity and predictability studies utilizing models;

   c. diagnostic studies.

VII - TRAINING

The necessity of training high quality personnel at all levels to guarantee the success of the Drought Forecasting Project was recognized. Concern was voiced that support facilities such as a technical library are needed. The main areas of emphasis are Atmospheric Sciences, Physical Oceanography and Hidrology. Here, one must take a look at the broad educational picture. The Drought Forecasting Project is only one of the many applications of the overall education.

A. RESEARCH SCIENTISTS AND UNIVERSITY FACULTY (Ph.D.)

Although there are presently a few institutions that can train at the Ph.D. level in Hydrology, there is only one institution which is able to train people at this level in the Atmospheric Sciences. Therefore, the National program requires increased manpower in these disciplines at a crucial level.

In order to alleviate the problem three concurrent strategies are proposed to produce the necessary Ph.D's in an early time frame:

- short term (aimed at producing results within a two-year period)- a program in which scientists with a Ph.D degree in Physics or Engineering should be trained abroad or at accredited Brazilian institutions at the post-doctoral level in Atmospheric Sciences, Physical Oceanography, or Hydrology. This step is mainly aimed at theoretical modelling efforts;
- medium term (expansion of current programs aimed at producing results within a 5-year period and continuing) - a program in which Brazilians with high quality M.Sc. or B.Sc. degrees in Meteorology, Mathematics, Physics or Engineering are sent abroad for Ph. D. training;
- long term (to become effective in 10 years and beyond) - to establish graduate programs at a few selected national institutions for training at the Ph.D. level.

It is recommended that post-doctoral opportunities abroad be provided at reasonable intervals for research scientists holding a Ph.D. degree.

B. RESEARCH SUPPORT SCIENTISTS (M.Sc. and B.Sc.)

There are several national institutions training personnel in various disciplines at these levels. It is recommended that special attention should be given to promote and guarantee training of high quality. It is important to maintain high entrance qualifications for the B.Sc. It is equally important to maintain a balance of the number of B.Sc.'s produced against the needs of the job market.

The employment potential for M.Sc. and B.Sc. personnel covers a wide spectrum of jobs. For example, experience has shown that physical sciences B.Sc. holders may be successfully trained to perform computer programming activities.

Whenever adequate training facilities in Brazil are not available in certain specialized areas provision should be made for on-the-job training abroad. An example is the area of data management.

C. TECHNICIANS

The present national educational infra-structure generally provides good quality personnel at this level. It is foreseen that in special cases on-the-job training should be pursued.

D. OBSERVERS

An adequate training facility to produce geophysical observers is necessary.

APPENDIX A

AVAILABILITY OF CLIMATOLOGICAL DATA

(contribution to the workshop
submitted by INPE)

Beginning in the 1950's, the upper air network over Brazil has gradually expanded until the addition of several stations in Northeast Brazil in 1969. Upper air data are currently being processed and placed on magnetic tape for ready access by investigators in the future.

Rainfall data for about 2000 stations in the Northeast are also being processed and placed on magnetic tape. Many stations were installed in the 1960's, though many others have records of up to 60 - 70 years in length, and a few have record lengths of over 100 years.

Surface data are also being processed, with the period 1961 - 1970 for all of Brazil already available on magnetic tape. In addition, data for the period prior to 1961 is gradually being processed and made available. Some stations in the Northeast, with surface data records of about 60 years are already available.

Polar orbiting satellite data have been received and archived since 1968. Recently, beginning in 1979, geoestationary satellite data have become available and are being archived.

Besides the data processed and available in Brazil, data have been purchased from other sources. Upper air and surface data for all of South America, for the period 1968-1976, have been purchased from the National Climatic Center, Ashville, N.C. These data originated from the teletype reports transmitted via the GTS in real time and, in general, have not been checked or corrected.

Microfilm copies of Southern and Northern Hemisphere surface and upper air charts have also been purchased from the NCC. In addition, microfilm copies of polar orbiting satellite data, in the form of mosaics, have recently been added to Brazil's archive of data.

Recognizing the importance that the availability of meteorological data has on research, the Brazilian National Research Council (CNPq) has set up a special commission to oversee the data processing. This commission will establish uniform criteria to control data quality and suggest means whereby rapid access to the data can be obtained by research groups.

APPENDIX B

METEOROLOGICAL RESEARCH IN BRAZIL

(contribution to the workshop
submitted by INPE)

The meteorological research community is rather small in Brazil. There are only 15 professionals holding a Ph.D. degree, and about 40 holding a M.Sc. degree in the country.

There are five major groups in Meteorology working on various aspects of Northeast Brazil climate:

- INPE/CNPq - The Institute for Space Research of the National Research Council has a Department of Meteorology with a research staff of 7 Ph.D. and 11 M.Sc. INPE also maintains an Engineering Division for Meteorological satellite applications, and a graduate program in Meteorology leading to M.Sc. and Ph.D. degrees (up to now 25 M.Sc. degrees have been conferred and there are currently 21 M.Sc. and 7 Ph.D. candidates).
- IAG/USP - The Institute of Astronomy and Geophysics of the University of São Paulo has a Department of Meteorology with a research staff of 5 Ph.D. and 3 M.Sc. in Meteorology. It maintains an undergraduate program and is also training students at the M.Sc. level.
- CCT/UFPb - The Science and Technology Center of the Federal University of Paraíba, in Campina Grande, has a staff of 2 Ph.D. and 10 M.Sc. in Meteorology, teaching an undergraduate course and also training some students at the M.Sc. level. The group is putting some effort on upper air data processing for Northeast(NE) Brazil.
- IAE/CTA - The Institute for Space Activities of the Aerospace Technical Center, of the Air Force Ministry, has a research

group of 5 M.Sc. in Meteorology, and is putting much effort into meteorological data processing. The Institute is also conducting a cloud seeding experiment in the Northeast.

- CETEC - The Technological Center of Minas Gerais State is beginning a research effort with a group of 1 Ph.D. and 3 M.Sc. in Meteorology.

In addition to these institutions, there are several Universities training undergraduates or conducting research in its incipient stages. They are:

- IPM/FEB - The Meteorological Research Institute of the Educational Foundation of Bauru is the only group working with Radar Meteorology.
- IGC/UFRJ - The Geosciences Institute of the Federal University of Rio de Janeiro has a Department of Meteorology with an undergraduate course in Meteorology, in operation since 1964.
- NCGG/UFPa - The Geophysics and Geological Sciences Nucleus of the Federal University of Pará started an undergraduate program in Meteorology in 1976. The research efforts are mainly devoted to the understanding of the Amazon climate.
- INPA/CNPq - The Amazonas Research Institute, of the National Research Council, is conducting some studies related to the exchange of mass, energy and momentum through the soil-forest-atmosphere system. For this purpose, the Institute has installed a 40 m high tower in the middle of the forest.

- UFV - The Federal University of Viçosa, with emphasis in Agrometeorology.
- ESALQ - The Luiz de Queiroz School of Agriculture, with a graduate program in agrometeorology.

The best known institutions with some involvemert in agrometeorological research are:

- IAC - The Campinas Institute for Agriculture Research, and
- IPAGRO - The Agriculture Research Institute of Rio Grande do Sul.

Institutions having just recently developed undergraduate programs in Meteorology:

- UFPel - The Federal University of Pelotas, and
- UFAl - The Federal University of Alagoas.

- UFC - The Federal University of Ceará, through its Departments of Physics and Mathematics is contributing with some statistical studies of rainfall distributions in Northeast Brazil.

- FUNCEME - The Ceará State Foundation for Meteorology and Artificial Precipitation has maintained an operational cloud-seeding program in the state of Ceará.

The organizations in charge of operational meteorology in Brazil are:

- INEMET - The National Institute of Meteorology of the Agriculture Ministry is in charge of daily weather forecasting, maintains a climatological surface network, supports an upper air network, and has been conducting climatological studies (e.g. the works of Serra).
- DEPV - The Directorate of Electronics and Flight Protection of the Air Force Ministry operates a network of upper air stations and issues aviation forecasts.

- DHN - The Directorate of Hydrography and Navigation of the Navy is in charge of issuing forecasts for the South Atlantic ocean region.

LIST OF RESEARCH STAFF

INPE/CNPq

- A.D.Moura, Ph.D., Massachusetts Institute of Technology, 1974
- C.M.Dixit, M.Sc., Nagpur University, India, 1941
- C.A.Nobre (currently in a Ph.D. Program at Massachusetts Institute of Technology
- K.Hada, M.Sc., Instituto de Pesquisas Espaciais, 1974 (currently at University of Michigan in a Ph.D. Program)
- L.C.B.Molion, Ph.D., University of Wisconsin, 1975
- L.G.Meira Filho, Ph.D. University of Colorado, 1969
- M.A.M.Lemes, M.Sc., University of Wisconsin, 1975
- M.Elias, M.Sc., University of Colorado, 1973
- M.T.Kagano, M.Sc., Instituto de Pesquisas Espaciais, 1979
- M. Fortune, M.Sc., University of Wisconsin, 1978
- N.J.Ferreira, M.Sc., Instituto de Pesquisas Espaciais,1978
- P. Satyamurty, M.Sc., Andhra University, 1965
- P. Bonatti, M.Sc., Instituto de Pesquisas Espaciais, 1979
- R.P.Santos, M.Sc., Instituto de Pesquisas Espaciais, 1973
- S.Srivatsangan, Ph.D., Colorado State University, 1975
- V.B.Rao, Ph.D., Andhra University, 1969
- V.E.Kousky, Ph.D., University of Washington, 1970
- Y.Viswanadham, Ph.D., Andhra University, 1965
- Y.Yamazaki, M.Sc., Instituto de Pesquisas Espaciais, 1974

IAG/USP

- C.L.Ting, Ph.D., McGuill University, 1974
- H.S.Chien, Ph.D., Purdue University, 1975
- E.S.Caetano, M.Sc., Universidade de Campinas,1978 (Física)

- M.A.Dias, Ph.D., Colorado State University, 1979
- M.Moraes, Ph.D., Universidade de São Paulo, 1979 (Hidrologia)
- O.Massambni, M.Sc., Centro de Rādio Astronomia e Astrofísica do Mackenze, 1977 (Rādio Ciência) presently at McGuill University, enrolled in a Ph.D. Program)
- P.L.S.Dias, Ph.D., Colorado State University, 1979
- P.M.Santos, M.Sc., Centro de Rādio Astronomia e Astrofísica do Mackenze, 1972 (Rādio Ciência)

CCT/UFPb

- G.O.Lucena, M.Sc., Universidade Federal da Paraíba, 1979 (Water Resources)
- G.N.Sobrinho, M.Sc., Instituto de Pesquisas Espaciais, 1975
- H.S.Rathor, Ph.D., University of Chicago, 1968
- J.Ceballos, Lic. Física, Universidade de Tucumã, 1966
- J.F.Lima, M.Sc., Instituto de Pesquisas Espaciais, 1975
- J.O.R.Aragão, M.Sc., Instituto de Pesquisas Espaciais, 1975
- K.Ragavan, B.Sc., India, 1944
- M.A.V.Silva, M.Sc., Instituto de Pesquisas Espaciais, 1976
- M.F.Gomes Filho, M.Sc.,Instituto de Pesquisas Espaciais,1979
- M.R.Aragão, M.Sc., Instituto de Pesquisas Espaciais, 1977
- P.Chamker, Ph.D., Andhra University, 1972
- P.V.Azevedo, M.Sc., Instituto de Pesquisas Espaciais, 1974
- T.V.R.Rao, M.Sc., Andhra University
- Z.R.Sobral, M.Sc., Instituto de Pesquisas Espaciais, 1979

IAE/CTA

- C.Girardi, Lic.Met., Universidad Buenos Aires, 1961
- D.M.G.Strang, B.Sc., University of California, 1948

- R.P.L.Ramos, M.Sc., Colorado State University, 1975
- U.Belculfinê, M.Sc., Colorado State University, 1973
- V.A.Perdiz, M.Sc., Instituto de Tecnologia Aeroespacial, 1973 (Ciência Aeroespacial)

CETEC/MG

- F.C.Almeida, Ph.D., University of Wisconsin, 1975
- G.S.S.Nunes, M.Sc.,Instituto de Pesquisas Espaciais, 1976
- H.M.T.Nunes, M.Sc., Florida State University, 1971
- T.Morimoto, M.Sc., Instituto de Pesquisas Espaciais, 1979

APPENDIX C

THE DRY CLIMATE OF NORTHEAST BRAZIL - A BRIEF SURVEY OF SOME STUDIES PERFORMED IN BRAZIL

(contribution to the workshop
submmitted by INPE)

Drought events in Northeast Brazil have been reported since the 17th Century. The interest in explaining its causes has grown since then. Several scientific studies have been published in Brazil (e.g. Derby, 1885; Hann, 1911; Hull, 1942; Oliveira, 1878; Pompeu, 1859; Sampaio Ferraz, 1925; Serra, 1946; Strang, 1972; Weber, 1911; Aragão, 1975; Gomes Filho, 1979), and in the international journals (e.g., Ackemann, 1900; Freise, 1938; Fukui, 1970; Hastenrath and Heller, 1977; Hastenrath, 1978; Cevas and Hastenrath, 1978; Kousky, 1979; Markham, 1973; Mossman, 1919; Namias, 1972; Ramos, 1975; Ratisbona, 1976; Walker, 1911; Yamazaki and Rao, 1977) but a complete understanding of the climate, its variability and the possible prediction of extreme events is still far from being achieved.

A dramatic account of the way of living of the *nordestinos* (the people who live in the Northeast) is found in the classic *Os Sertões* (The Hinterlands), by Euclides da Cunha.

Works of Denis (1909) and Hull (1942) have tried to establish a frequency relationship of sunspot minima and the occurence of droughts in the Northeast. Several works by Serra (1945, 1973) are along the same lines followed by Namias (1972), in establishing correlations between several variables (e.g., pressure) in certain locations over the globe, and the rainfall distribution in Northeast Brazil. Some local influences of orography and albedo on vertical motions may be found in Gomes Filho (1979); the influence of local winds and sea breeze is found in Kousky (1980, to be published); frontal influences upon Northeast rainfall can be found in Kousky (1979); and the penetration of cloud clusters from the Atlantic and rainfall in Northeast Brazil was

studied by Yamazaki and Rao (1977).

The Atmosphere of Northeast Brazil should not be isolated. The coupling of midlatitude synoptic systems and the atmospheric circulation over Northeast Brazil should be more explored. It is believed that General Circulation Models can play an important role in testing hypotheses, and in establishing correlations of meteorological variables in some areas of the globe, which lead to precipitation events in Northeast Brazil. Most important, as it has already been noted, is the availability of long records of data. Some effort is already being made to assemble these data.

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APPENDIX D

THE WORLD CLIMATE PROGRAM (WCP)

by J. Rasmussen, WMO

The Eighth World Meteorological Congress established the World Climate Program. This program is comprised of the following components:

- World Climate Data Program WCDP
- World Climate Applications Program WCAP
- World Climate Impact Studies Program WCIP
- World Climate Research Program WCRP

The outline plan and basis for the WCP are contained in WMO Publication 540, copies of which were distributed at the Workshop. The project of Drought Forecasting for Northeast Brazil is potentially an important element in the total Brazilian participation in the WCP.

WORLD CLIMATE RESEARCH PROGRAM (WCRP)

The objectives of this program are to determine:

1. To what extent the climate can be predicted
2. The extent of man's influences on climate.

This program is a further development of the internationally coordinated work done under the joint WMO/ICSU Global Atmospheric Research Program. It is guided by a Joint Scientific Committee.

Many of the objectives of the proposed project for Drought Forecasting of Northeast Brazil are research in nature and

fit within the WCRP framework . The various international scientific symposia, workshops, expert meetings, organized within the WCRP would help contribute to the Brazil program and in turn would benefit from the contributions of Brazilian scientists actually working in this field.

WORLD CLIMATE APPLICATIONS PROGRAM (WCAP)

This component of the WCP is aimed at the further development of applied climatic services. The application of climate data and information in the food, water, energy and health sectors of national activities can be an important contribution to development and to solutions to national problems. The following major lines of activity are foreseen within the WCAP:

1. To develop improved and new methodologies for the applications of climate data and information;
2. To increase the awareness of users to the potential benefits of utilizing climate, data and services;
3. To develop methods and techniques for international dissemination of information;
4. To develop international mechanisms for training of the technical personnel in applications, data handling, etc;
5. To organize a few pilot projects addressing specific problems in application of climate data and information with priority given to food production and water resources.

The Project for Northeast Brazil includes, in a very specific way, the objectives of the WCAP and the Project fits the concept of a pilot project from which information regarding its design, implementation, and results might find wider international applications.

The WMO has taken the lead in planning this component of the WCP but by virtue of its broad objectives many other international organizations must be involved (FAO, UNESCO, WHO, etc.).

WORLD CLIMATE IMPACT STUDIES PROGRAM (WCIP)

The objective of this component is to bring to light the importance of climatic considerations in the formulation of rational policy alternatives. The United National Environmental Program has taken the responsibility to plan and implement the international aspects of this program. It will involve regional as much as global studies. The Project certainly includes this impact dimension at the National level.

THE WORLD CLIMATE DATA PROGRAM (WCDP)

The objective of this program is to improve the availability of data for research applications and impact studies. International efforts to:

1. Determine data requirements for the WCAP, WCIP and WCRP;
2. Locate and assemble instrumental observation and making these data internationally available;
3. Organize the countries of the world to establish, maintain and improve observational networks, ocean observations and space based observing systems so that the stated data requirements are met;
4. To prepare and implement an international data management plan;
5. To promote new technology, including space programs which will contribute to the climate data base.

The Project will require some data from a wide (possibl global) area and other data only from Brazil. The international exchange of data may be coordinated through WCDP.

APPENDIX E

TOWARDS THE MONITORING AND PREDICTION OF NORTHEAST BRAZIL DROUGHTS

by Stefan Hastenrath, University of Wisconsin

A prominent feature of the surface circulation in the Brazil-Tropical Atlantic sector is a broad zonally oriented low pressure trough in which is embedded a confluence axis between the quasi-permanent North and South Atlantic anticyclones. The circulation complex migrates seasonally, reaching a southernmost location - still in the Northern hemisphere - during late March, coincident with the Northeast Brazil rainy season which is narrowly centered in March/April.

Drought years in Northeast Brazil are characterized by an equatorward expansion of the South and a poleward retraction of the North Atlantic highs, and associated with this an anomalously far northerly position of the near-equatorial trough of low pressure and convergence band. During years with abundant rainfall in Northeast Brazil anomaly patterns over the Atlantic are approximately inverse. Departure characteristics in the large-scale atmospheric and oceanic fields develop well in advance of the March/April rainy season. Spectral analysis identifies preferred time scales of variability and large-scale couplings.

Diagnostic studies form the basis for the selection of promising parameters for predictive endeavours. Among the most important indicators are the pressure distribution, especially over the South Atlantic and the equatorward side of the North Atlantic high, wind in the equatorial belt, cloudiness in the equatorial North Atlantic , and rainfall in the Guyanas. Monitoring of these fields, and systematic processing of data on a quasi real time basis will be prerequisite for operational forecasting schemes.

APPENDIX F

SUGGESTIONS FOR PLAN OF RESEARCH ON THE BRAZIL NORTHEAST DROUGHT PROBLEM

by Herbert Riehl, CIRES

Experience from other parts of the tropics may be utilized for the Northeast drought in two ways:

1. Identify processes as much as possible
2. Establish synoptic climatology of dry-wet periods.

1. Processes

Satellite photos suggest that the conventionally looking ITC is not present in Brazil. A forcing action of mid-Atlantic trough extension to the northwest is indicated; there is parallelism with the South Pacific trough and the equatorial zone there. At Canton Island, a reversal of the normal dry E Winds accompanies the onset of heavy rains. This suggests a formation of an equatorial trough zone to the South. The correlation T-RH along the vertical indicates cold core rain area in the low and middle troposphere, changing to warm cores in the high troposphere where anvils from hot towers spread out.

All of the foregoing (trough from extratropical, equatorial westerlies cold core rain areas) are typical of synoptic systems in other parts of the tropics.

The corresponding modeling and compositing is proposed as a practical step for Brazil.

2. Synoptic Climatology

Following the Caribbean example, the vertical wind

profile with lower westerlies and upper easterlies in the troposphere (a monsoon profile) is favorable for rainfall while the inverse basic current is unfavorable. The high troposphere during a rainy wet season has anticyclonic flow and warm temperatures on a monthly basis, east winds are located equatorward of subtropical anticyclones.

During suppressed rainy seasons (drought) the upper (200 mb) flow is cyclonic, very cold, convergent with descent. Upper westerlies lie over the equatorial zone. Note similar statements for the Amazon basin made by Ratisbona (Surface only).

A suggested quantitative step: establish the basic current and monthly maps of the active and suppressed dry season in Brazil. The differences from the basic current would be indicated by models.

APPENDIX G

LIKELY PHYSICAL PROCESSES RELEVANT TO THE NE BRAZIL DRY ZONE AND SUGGESTED RESEARCH STRATEGY

by William M. Gray, Atmospheric Science Dept., Colorado State University

The rain-produced condensation energy release from tropical weather systems goes primarily to balance the troposphere's average daily radiation of cooling of about $1^{o}C/d$. This is accomplished primarily from an up-moist and down-dry vertical circulation which, when averaged over the whole global tropical belt, is largely constant. Areas with heavy rain produce enough condensation energy release in the form of potential energy export by mass divergence at upper levels to balance the radiational loss for the much larger tropical regions with little or no precipitation. The total amount of rain falling in the tropics is largely invariant with time. Regions with above normal precipitation are compensated by areas with below normal precipitation.

Evidence from many sources is beginning to indicate that there is a good likelihood for the development of reasonable skillful seasonal precipitation forecasting at a number of tropical locations. This requires treatment of the seasonal forecast from a broad-scale general circulation point of view. Variability of NE Brazil seasonal precipitation has been shown by a number of authors to be related to the latitude position of the ITCZ, strength of the Atlantic trade winds, middle latitude circulations, Atlantic and Pacific SST's, and other features.

Seasonal rainfall variability in the NE is also related to more local Brazilian features such as the strength of the subsidence temperature inversion over the NE, special return flow subsidence indicative of variations in precipitation at other Brazilian locations, character of the on-shore trade wind flow along the NE Brazil coast, etc.

Precipitation in the NE appears to be primarily produced by 10-15 weather systems which move from East to West across this region, or by occasional cold front penetration from higher latitudes. It seems that seasonal precipitation variability in the NE is determined by the general strength of the NE seasonal subsidence into which these westward travelling disturbances or cold fronts move. Subsidence adversely dries out and stabilizes the middle trophosfere layers, and parcel ascent in deep rain clouds is inhibited by dry air entrainment and subsidence stability. If this subsidence and resulting middle troposphere dryness is strong, as is typically the case when the Western Atlantic ITCZ is further North than normal, then the traveling weather systems produce little rain. On the other hand, if the ITCZ should be displaced more southward of its normal position off the Amazon river estuary, then subsidence will be weaker and the middle troposphere not so dry. Westward travelling individual systems or cold front penetration will then be more able to overcome the inhibiting influences of stability and dryness. These latter weather systems will produce significantly more rain than the former ones. It appears that it is not the number of travelling weather systems which is so important for NE Brazil rainfall but rather the environment into which these weather systems move.

Seasonal Prognosis. The essence of the seasonal forecast of precipitation for the northern portion of the NE appears to rest with:

1. the degree of correlation of the time lag of the NE rainfall with these large scale parameters and
2. the degree to which such large scale monthly and multi-monthly parameters can be measured, transmitted, and evaluated at Brazilian government institutions such that seasonal monthly forecasts can be made and updated on a timely basis.

To study the NE seasonal prediction problem properly it is necessary that large quantities of non-Brazilian data be gathered and evaluated. As a first step in this direction it is recommended that

some Brazil research center (such as INPE) act as the central archive for such needed extra-Brazil data sets.

Types of Research Programs to be Instituted. Distinctions need to be made between : 1) the requirements necessary for the implementation of NE seasonal forecast schemes and 2) those requirements necessary for a broadly based and long term climate research program. The first program requirements are much less extensive in human and economic needs than the second program needs.

Development of NE Brazil seasonal forecast schemes generally require only conventional meteorological and satellite data, meteorological processing facilities, and trained meteorological personnel. Successful forecast schemes do not necessarily require a complete physical knowledge of the processes involved with such seasonal forecasts.

The initiation of a broadly based climatological research program will require the services of a variety of trained research specialists in hydrology, oceanography, soil, radiation, tree-rings, agriculture, etc. Special training programs will have to be instituted to meet such requirements. Although the data and modeling needs will be quite varied and extensive, the long term knowledge gains will likely be quite substantial and very worthy of such a commitment as resources are available.

Recommendations

1) There appears to be a critical economical need for the development of new NE Brazil seasonal precipitation forecasting schemes as fast as possible. It is recommended that the highest priority be given to the development of such new schemes.

2) It is recommended that a broadly based climatological Research Program also be instituted in Brazil to the extent that National

APPENDIX M

PREDICTABILITY OF TIME AVERAGES

by Jagadish Shukla
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It is well known that the deterministic prediction of synoptic scales of atmospheric motions is limited to about 2 weeks. This is mainly due to hydrodynamic instabilities and their nonlinear interactions. There is, however, a possibility that the time averages may be predictable for longer periods. A basis for such a possibility is the existence of low frequency long wave components which carry most of the variance. For considering the predictability of time averages, the day to day fluctuations due to instabilities act as noise in estimating the time mean.

Interannual variability of time averages (monthly and seasonal means) can be due to the following three processes: a) Internal dynamics including the instabilities and their nonlinear interactions; b) Influence of slowly varying boundary conditions (viz: see surface temperature, soil moisture and vegetation, snow and sea ice etc.); c) sampling error (noise) due to averaging over a correlated time series.

One of the most outstanding problems of the climate variability is to understand the relative contribution of these different mechanism in explaining the variability of monthly and seasonal means.

A comprehensive study of the analysis of data and application of global general circulation models for sensitivity and predictability studies may help understand the relative contribution of each of the processes towards interannual variability.

A survey of available published literature on the problem of drought in NE - Brazil suggests that the following mechanisms may be operating, individually or collectively, in determining the fluctuations of monthly and seasonal rainfall over NE - Brazil:

a) Sea surface temperature anomalies over tropical Atlantic and eastern tropical Pacific.

b) Location and intensity of ITCZ (most of the drought years seem to coincide with the years when ITCZ does not move sufficiently southward).

c) Interaction of tropical circulation with extratropics (Northern and Southern Hemisphere). There seems to be possible relationships between the position and intensity of the subtropical highs and large scale circulation in middle latitudes. For example, there seems to be apparent relationships between the blocking situations in the mid and high latitudes and drought over Brazil. Similarly, there appears to be some connection between the seesaw patterns of North and tropical Atlantic circulation.

d) There appears to be a significant component of quasi-biennial oscillation in the convergence of Atlantic trade winds and Atlantic seesaw. There also appears to be relationship between the "Atlantic Walker circulation", "Pacific Walker circulation" and NE Brazil fluctuations.

e) Protrusion of Southern hemispheric mid-latitude perturbations seems to be an important factor in determining rainfall in different areas.

f) Rainfall events over NE Brazil suggest that time average rainfall consists of rainfall produced by individual cloud clusters and synoptic waves. It may be useful to study the structure and dynamics of tropical disturbances over this region and their interaction with the ITCZ.

g) It can be hypothesized that the mean climate of NE Brazil may be related to heavy precipitation over Amazon. If this is true, there might be significant implications of deforestation in the Amazon.

h) Finally, since the rainy seasons and dry seasons over NE Brazil appear to be two quasi-stable situations which occur at different times, is it possible that these may be manifestations of multiple quasi-equilibrium states for an interacting tropical-mid latitude flow system.

A systematic study of the space and time scales of monthly and seasonal anomalies and their relationship with slowly varying boundary conditions and extratropical circulations may suggest development of possible empirical and dynamical methods of predicting the variability of precipitation over NE Brazil.

APPENDIX I

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APPENDIX J

DATA REQUIREMENTS FOR A BROADLY BASED CLIMATE PROGRAM

Parameter/Data Set.	Coverage	Density	Frequency	Source
Upper Air Data (Rawinsondes, Pibals)	Global	Synoptic	12 Hrly	Brazil WWW WDC-A
Surface Data Temp., Humidity, Pressure	Global	Synoptic Brazil	6 Hrly	Brazil WWW WDC-A
Special Precipitation Data	Brazil	Very Dense	Daily	Brazil WDC-A
Hydrological Data Runoff, Storage	Brazil	Major Rivers	Monthly	Brazil
Surface Radiation	Brazil	200 km	Daily	Brazil
Satellite Data Images, winds	$20^{0}N - 90^{S}$ $30^{0}E - 180^{0}W$	500 km	12 Hrly	Brazil USA
Sea Surface Data	W. Pacific Atlantic	500 km	Weekly	WWW USA
Soil Moisture	Brazil	?	Weekly	Brazil
Satellite SST	W. Pacific Atlantic	500 km	Weekly	WWW USA
Ship Data	W. Pacific Atlantic	Synoptic	12 Hrly	