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Applications of Climate Forecasting for Better Decision-making Processes in Agriculture

Edited by

G. R. CUNHA, J. C. HAAS and M. A. BERLATO

Embrapa

360

APPLICATIONS OF CLIMATE FORECASTING FOR BETTER DECISION-MAKING PROCESSES IN AGRICULTURE

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Applications of Climate Forecasting for Better Decision-making Processes in Agriculture

The contribution from the 12th Regional Climate Outlook Forum for Southeastern South America, held in Passo Fundo, RS, Brazil, April 24-25, 2001

Edited by

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Preface

There are many jokes concerning weather/climate and its predictions. Among them, there is a special one that I faced about 40 years ago. I asked to one of my family farm's employee "how is the weather going to be the next days?" He promptly answered: *"If someone wants to lie, he should talk about the weather."*

Mostly everyone talks about the weather/climate, but how many of them really know something about it? Worst than that, those that are supposed to know something about the subject, do not even talk about the same thing! What does weather/climate prediction really mean to each one? What does weather/climate forecasting really mean? Can we trust it?

Another important point to consider is that weather/climate information has an immense impact on people's behavior. It affects people's mood. It changes people's plans. And, not last important than the human behavior, it certainly, affects the general economy.

Finding consensus' in climate forecasting is becoming a truly valuable good. The fact is that climate forecasting is becoming an economic indicator, because it is a powerful tool for production prediction and consequently, business interest. It should not be seen only for its economic value, but, also for its social consequences.

Reliable climate information means secure decision making. Food production, rural development, agribusiness growth, job offer, consumers' food costs, farm migration, urbanization, environment protection and natural disasters prevention, are the reasons to understand and to use efficiently climate forecasting.

This 12th Regional Climate Outlook Forum for Southeastern South America, held in Passo Fundo, Rio Grande do Sul, Brazil from April 24 to 25 of 2001 was designed to seek for a consensus in climate forecasting. Well known scholars, invited to deliver speeches

during the event, are the best the Forum's organizers could gather. We hope that after this Forum, we can offer to the climate information users, the utmost state of the art, for a true agricultural sustainable development. To society, to reach that consensus, means the ability to predict a better future.

To further improve the value of this Forum we present this book with the contribution of the invited guests that lectured during the event.

The book gathers the contribution of scientists, planners, administrators and users of climate forecast from Brazil, Argentina, Uruguay, Paraguay and United States of America. They belong to different Universities, Research Centers, Agriculture Ministries, Environmental Agencies, National Institutes, Agriculture Agencies and Rural Insurance Organizations.

For Embrapa Trigo – The National Wheat Research Center, it was a great honor to be host of this 12th Regional Climate Outlook Forum for Southeastern South America. It was a pleasure to receive all distinguished guests that contributed to update knowledge and additionally promoted the Wheat Research Center internationally.

Benami Bacaltchuk
Head of Embrapa Trigo

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OVERVIEW OF REGIONAL CLIMATE OUTLOOK FORA FOR SOUTHEASTERN SOUTH AMERICA

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Abstract

This chapter summarizes the history of Regional Climate Outlook Fora for Southeastern South America and makes available all releases of consensus-based seasonal forecasts for Southeastern South America, from the 1st COF to the 11th COF, nowadays available at Internet, mainly in the IRI's site (http://iri.ldeo.columbia.edu/climate/forecast/sup/).

1. Introduction

The Regional Climate Outlook Fora (COF) for Southeastern South America were organized as part of a large world effort based on the application of climate forecasts developed since the 1997-98 El Niño event. The first COF was held in Montevideo, Uruguay, in December 1997. Up to April 2001, eleven meetings were regularly

held every few months in different places in Brazil, Argentina, Paraguay, and Uruguay, as follows:

- 2nd COF: Foz do Iguaçu, Brazil, June 1998;
- 3rd COF: Buenos Aires, Argentina, August 1998;
- 4th COF: Salto Grande, Uruguay, December, 1998;
- 5th COF: Mariano Roque Alonso, Paraguay, April, 1999;
- 6th COF: Buenos Aires, Argentina, September, 1999;
- 7th COF: Montevideo, Uruguay, December, 1999;
- 8th COF: Cachoeira Paulista-SP/Brasília-DF, Brazil, March 2000;
- 9th COF: Mariano Roque Alonso, Paraguay, June 2000;
- 10th COF: Buenos Aires, Argentina, September 2000;
- 11th COF: Montevideo, Uruguay, December, 2000.

The primary objectives of the Outlook Fora included (USA, 1999):

- Developing and communicating a consensus seasonal Climate Outlook;
- Facilitating research cooperation and data exchange within and between regions;
- Improving coordination within the climate forecasting community; and
- Creating and enhancing a regular dialogue between producers and users of the climate information.

The Regional Climate Outlook Fora for Southeastern of South America involved specialists in climate forecast, scientists, meteorologists and representatives of National Meteorological and Hydrological Services, government organizations, international institutes, and users from sectors such as agriculture, water resource, disaster awareness, fisheries, food supply, public health etc., creating an unique opportunity to prepare for related climatic anomalies

impacts, aimed to reduce socioeconomic damages or, in some cases, to gain benefits.

On the other hand, an intensive broadcast of seasonal consensual forecast and its applications was established using Internet sites of institutes from different countries, and conventional media (e.g newspaper, radio, and TV).

At each Outlook Forum, a consensus-based seasonal forecast or climate Outlooks for Southeastern South America was designed to produce, disseminate, and apply climate forecast technologies to real environmental, economic, and public security issues.

The forecast products were presented as tercile probabilistic rainfall forecasts- that is, the probability that rainfall would fall into the wettest-third (above normal), driest-third (below-normal), or middle-third (near-normal) of historically-observed values for a given area.

This chapter summarizes the history of Regional Climate Outlook Fora for Southeastern South America and makes available all releases of consensus-based seasonal forecasts for Southeastern South America, from the 1st COF to the 11th COF, nowadays available at Internet, mainly in the IRI's site (http://iri.ldeo.columbia.edu/climate/forecast/sup/). The original release of consensus-based forecasts are maintained in english versions, except for the 3rd COF, 4th COF, and 9th COF, which are only available in spanish.

Reference

UNITED STATES OF AMERICA. Department of Commerce. National Oceanic and Atmosphere Administration. **An experiment in the application of**

climate forecasts: NOAA-OGP activities, related to the 1997-98 El Niño event. Washington, 1999. 134p.

Climate Outlook - Rainfall
Statement From The South-Eastern South America Regional Climate Outlook Forum
December 10, 1997, Montevideo, Uruguay
El Niño-Related Climate Forecast South-eastern South America Outlook
January 1998 - March 1998

Summary

Wetter than average conditions over the period January-March 1998 are expected over much of the central parts of south-eastern South America, including north-eastern Argentina, southern Paraguay and parts of southern Brazil and western Uruguay. Dry conditions are expected only in areas further north and close to the Andes. Stronger impacts in the year following El Niño events typically occur only in autumn and early winter, after the period covered in this Outlook.

The Climate Outlook Forum

On 10 December 1997 a South-eastern South American Climate Outlook Forum convened to formulate consensus guidance for the early 1998 season in the region. The Forum was attended by Meteorological Services from South- eastern South American countries, and climate scientists from universities and national and international research institutes. These specialists reviewed the state of the global climate system and its implications for South-eastern South America. One of the principal factors taken

into account is the major El Niño event occurring in the tropical Pacific Ocean. Although much stronger impacts in the year following El Niño events typically occur only in autumn and early winter, after the period covered in this Outlook, recent El Niño occurrences have had significant impacts on rainfall across much of the region south of 20°S during January-March.

The Forum was co-sponsored by the Association Rural del Uruguay, the Inter-American Institute for Global Change Research (IAI), the National Oceanic and Atmospheric Administration (NOAA), the International Research Institute for Climate Prediction (IRI) and the World Meteorological Organization (WMO). Participants at the Forum included representatives of Meteorological Services from four countries (Argentina, Brazil, Paraguay and Uruguay) and climate scientists and other experts from national, regional and international institutes and organizations (University of Buenos Aires, Department of Atmospheric Sciences; CIMA/CONICET/UBA; Federal University of Parana, Department of Physics; INPE/CPTEC; National University of Asuncion, Faculty of Exact and Natural Sciences; University of the Republic, Uruguay; World Meteorological Organization; International Research Institute for Climate Prediction; U.S. National Oceanic and Atmospheric Administration Office of Global Programs).

Methodology

The regional climate assessment began with consensus agreement that the current El Niño will remain over the forecast period (January-March 1998). The sea-surface temperature (SST) forecasts were based on coupled

ocean- atmosphere models, physically-based statistical models and expert interpretation. The region considered included continental areas bounded from 20 to 40°S and east of the Andes to 47°W. This area was divided into sub-regions according to previous statistical analyses of the impact of El Niño events in the region. The outlook was based on dynamical forecasts presented by INPE/CPTEC and IRI models as well as results of detailed studies of El Niño impacts in this region.

The current status of seasonal to inter-annual forecasting allows prediction of spatial and temporal averages, and may not fully account for all factors that influence regional and national climate variability. This Outlook is relevant only to seasonal timescales and relatively large areas, and local variations may occur.

Outlook

'The experts provided probability distributions to indicate the likelihood of below-, near- or above-normal rainfall for each sub-region (see Map). Above-normal rainfall is defined as within the wettest third of historically recorded precipitation totals in each region; below-normal rainfall is defined as within the driest third of precipitation totals; near-normal is the third centered around the climatological median. Users are strongly advised to contact participating institutions and other climate information sources for interpretation of this Outlook and for additional guidance.

Above-normal rainfall is expected in southern Paraguay, the south-western part of southern Brazil, western Uruguay and north-eastern Argentina. Normal to above-

normal rainfall is expected in central eastern Argentina. In Brazil, normal rainfall in the south is considered most likely, however, north of about 22°S, normal to below-normal rainfall may occur. Near the Andes, dry conditions are expected in north-western Argentina, and there is a zone immediately to the east where average conditions are anticipated. Further south, in central western Argentina, rainfall prospects are uncertain.

Temperatures during January-March are expected to be cooler than average where above-average rainfall is indicated.

The confidence that can be placed in a three-month outlook is relatively high. Beyond three months the reliability of statements about rainfall prospects for the region decreases because of uncertainty in the evolution of SSTs at longer time-scales. However, there are no signs that widespread dry conditions will occur in April-June, and there are indications of wet conditions in the south-eastern part of southern Brazil, Uruguay and eastern Paraguay.

Map Caption

The numbers indicate the probabilities of rainfall in each of the three categories. The first number indicates the probability of rainfall occurring in the above-normal category, the second number is for near-normal and the third for below-normal. In the case of north-western Argentina near the Andes, for example, there is a 20 % probability of rainfall occurring in the above-normal category (i.e., within the range of the driest third of historically-recorded rainfall); a 40 % chance in the near-normal category; and a 40 % chance in the below-normal category. Boundaries between

sub-regions should be considered as transition zones. A "C" stands for "climatology", which indicates that there is no clear scientific basis for favoring a prediction of below-normal or above-normal rainfall.

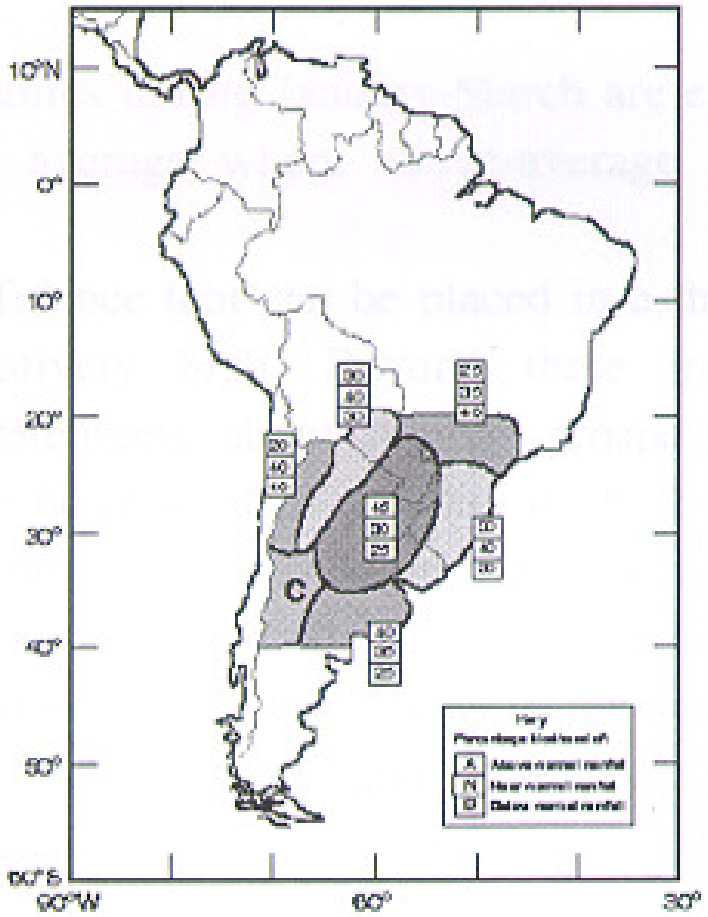
Consensus Climate Guidance

South-eastern South America Regional Climate Outlook Forum

December 10, 1997 *Montevideo, Uruguay*

(for list of participants and explanatory text see associated discussion)

January - March 1998



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Climate Outlook - Rainfall
Statement from the South-eastern South America Regional Climate Outlook Forum
June 16, 1998, Foz do Iguaçu, Brazil
Climate Forecast South-eastern South AmericaOutlook
July 1998 - September 1998

Summary

A transition from El Niño to La Niña conditions appears likely during the period July-August-September 1998. Climatological probabilities for rainfall are expected during the upcoming July-August-September, with enhanced probabilities of below normal amounts expected for October-November-December throughout much of the region (20°S-40°S; east of Andes- 47°W) in response to La Niña onset. The highest probabilities of below normal precipitation are expected in southwestern Rio Grande do Sul, Uruguay and Northeastern Argentina for October-November-December.

The Climate Outlook Forum

On 16 June 1998 a South-eastern South American Climate Outlook Forum convened to formulate consensus guidance for the late 1998 season in the region. The Forum was attended by Meteorological Services from South-eastern South American countries, and climate scientists from universities and national and international research institutes. These specialists reviewed the state of the global

climate system and its implications for South eastern South America. The principal factors taken into account are: (1) the demise of the 1997-98 El Niño event, (2) the likely onset of La Niña conditions for the second semester of 1998, and (3) the increased likelihood of drier than normal conditions for the period October-November-December. The period of transition from El Niño to La Niña conditions does not favour either dry or wet continental climate response for southeastern South America. However, the period following the La Niña onset is typically associated with drier than normal conditions for most of the region south of 25°S. Further indications of enhanced probabilities of below normal precipitation are given by the presence of below normal SSTs in the south Atlantic off the coast of southern South America.

The Forum was co-sponsored by the Itaipu Binacional; Brazilian Ministry of Science and Technology, the Inter-American Institute for Global Change Research (IAI), and the International Research Institute for climate prediction (IRI). Participants at the Forum included representatives of Meteorological Services from the region and climate scientists and other experts from national, regional and international institutes and organizations (SIMEPAR; Univ. Nac. Asunción, Fac. De Ciencias Exactas y Naturales; Univ. Nac. Litoral, Unidad de Investigaciones Hidroclimáticas; INPE/CPTEC; Universidad de la República, Facultad de Ingeniería (IMFIA); International Research Institute for climate prediction (IRI); Instituto Nacional de Meteorologia- INMET, Brazil; Univ. de Buenos Aires, Departamento de Ciências de la Atmosfera; Entidad Binacional YACYRETA, Comisión Técnica Mixta de Salto Grande).

Methodology

The regional climate assessment began with consensus agreement that El Niño conditions no longer prevail and that La Niña conditions will evolve during much of the second semester of 1998. The sea-surface temperature (SST) forecasts were based on coupled ocean-atmosphere models, physically-based statisical models and expert interpretation. The region considered included continental areas bounded from 20 to 40°S and east of the Andes to 47°W. This area was divided into sub-regions according to previous statistical analyses of the impact of La Niña events in the region. The outlook was based on dynamical and statistical forecasts presented by INPE/CPTEC and IRI, as well as results of detailed studies of El Niño and La Niña impacts in this region.

The current status of seasonal to inter-annual forecasting allows prediction of spatial and temporal averages, and may not fully account for all factors that influence regional and national climate variability. This Outlook is relevant only to seasonal timescales and relatively large areas, and local variations may occur.

Outlook

The experts provided probability distributions to indicate the likelihood of below-, near- or above-normal rainfall for each sub-region (see maps). Above- normal rainfall is defined as within the wettest third of historically recorded precipitation totals in each region; below-normal rainfall is defined as within the driest third of precipitation

totals, near-normal is the third centered around the climatological median. Users are strongly advised to contact participating institutions and other climate information sources for interpretation of this Outlook and for additional guidance.

Climatological probabilities are expected for the rainfall regime over the July -August-September period for the entire region (see map), with enhanced probabilities of below-normal temperatures for most of the region, except the southern section of Rio Grande do Sul(see map).

With the likely onset of La Niña conditions, the guidance calls for enhanced probabilities of below-normal rainfall for late 1998 (October-November -December) for most of region except in the extreme northeastern part (north of 25°S) where climatological probabilities are indicated. Probabilities of below-normal conditions are most enhanced in the southwestern part of Rio Grande do Sul, Uruguay and Northeastern Argentina for October-November-December 1998 (see map).

Beyond six months the reliability of statements about rainfall prospects for the region decreases because of uncertainty in the evolution of SSTs at longer time-scales. However, there are no indications of enhanced probabilities of above-normal rainfall for the region during the three months following December 1998.

Note: This guidance is based on the expected evolution of La Niña conditions during the second half of 1998. Should this not occur, users should seek updated information from participating institutions.

Map Caption

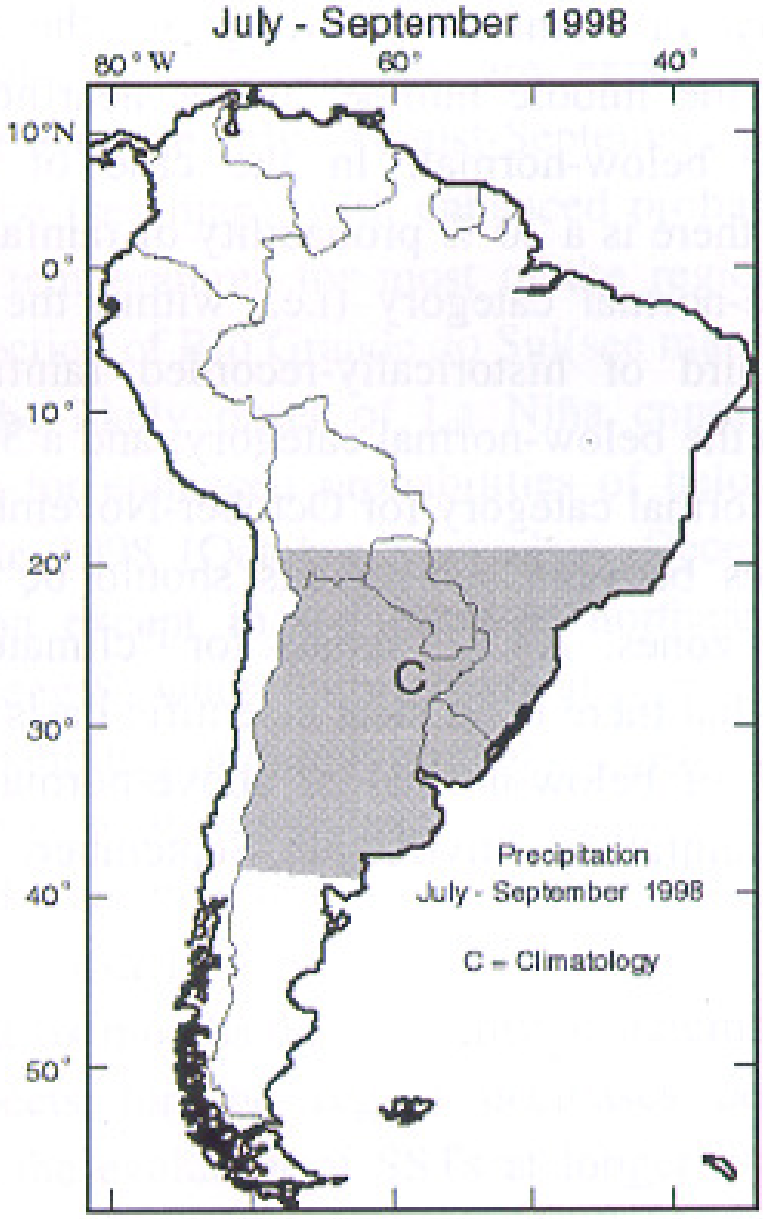
The numbers indicate the probabilities of rainfall in each of the three categories. The upper number indicates the probability of rainfall occurring in the above-normal category, the middle number is for near-normal and the lower for below-normal. In the case of Uruguay, for example, there is a 20 % probability of rainfall occurring in the above-normal category (i.e., within the range of the wettest third of historically-recorded rainfall); a 50 % chance in the below-normal category; and a 30 % chance in the near-normal category for October-November-December. Boundaries between sub-regions should be considered as transition zones. A "C" stands for "climatology", which indicates that there is no clear scientific basis for favoring a prediction of below-normal or above-normal rainfall, e.g. expected rainfall for July-August-September.

Consensus Climate Guidance

South-eastern South America Regional Climate Outlook Forum

16 June 1998 *Foz do Iguaçu, Brazil*

(for list of participants and explanatory text see associated discussion)



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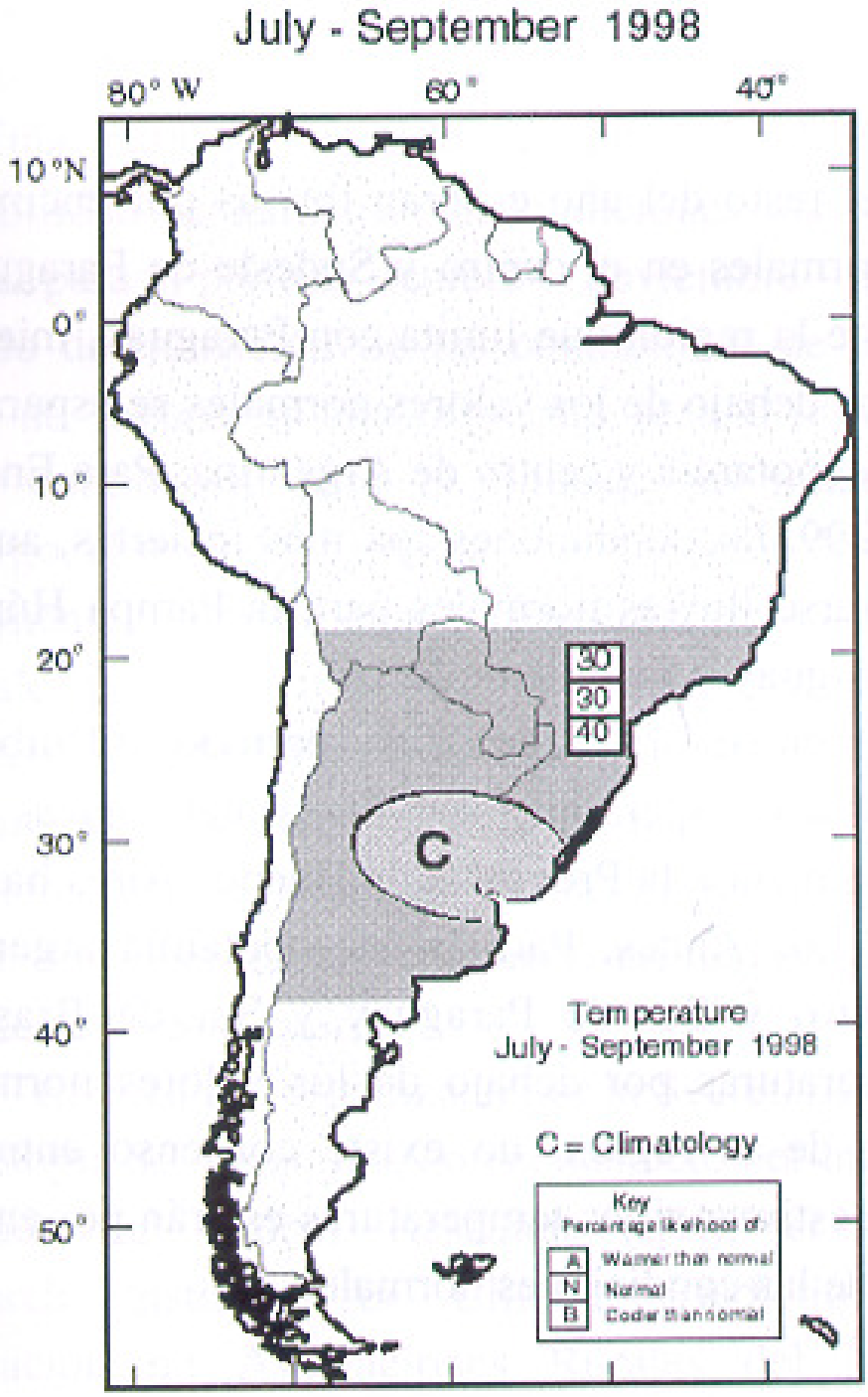
Consensus Climate Guidance

South-eastern South America Regional Climate Outlook Forum

16 June 1998 *Foz do Iguaçu, Brazil*

(for list of participants and explanatory text see associated discussion)



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Tercer Foro Regional de Perspectiva Climatica para El Sudeste de Sudamérica
Agosto 27 de 1998; Buenos Aires – Argentina

Resumen

Para el resto del año esperan lluvias por encima de los valores normales en el centro y Sudeste de Paraguay y en Brasil sobre la región que limita con Paraguay, mientras que lluvias por debajo de los valores normales se esperan en Uruguay, Mesopotamia y centro de Argentina. Para Enero y Febrero de 1999, las condiciones son más inciertas, aunque podrían esperarse lluvias normales para la Pampa Húmeda Argentina, Uruguay y Sudeste de Brasil.

Las temperaturas para el período Octubre - Diciembre 1998 se espera que sean las climatológicas en la franja que comprende la Provincia de Buenos Aires hasta la cordillera de Los Andes. Para la Mesopotamia argentina, Uruguay, centro y Sur de Paraguay y Sur de Brasil se esperan temperaturas por debajo de los valores normales. Para el resto de la región, no existe consenso entre los expertos para estimar si las temperaturas estarán por encima o por debajo de las condiciones normales.

Foro De Pronostico Climatico

El 27 de Agosto de 1998, el Foro de Pronóstico Climático para el Sudeste de Sudamérica convino en formular por consenso una guía para la siguiente estación en la región. El Foro estuvo integrado por Servicios Meteorológicos de países del Sudeste de Sudamérica,

expertos de climatología pertenecientes a Universidades e Institutos Nacionales e Internacionales. Los especialistas revisaron el estado del sistema climático global y sus implicancias para el Sudeste de Sudamérica. Los principales factores tomados en cuenta son: (1) el decaimiento del evento El Niño 1997-1998, (2) la iniciación de condiciones La Niña para el segundo semestre de 1998, y (3) la probabilidad de aumento de condiciones más secas que la normal para el período octubre – noviembre - diciembre. El período de transición de las condiciones de El Niño a la Niña, no favorecen una respuesta seca o húmeda para el clima continental para el Sudeste de Sudamérica. Sin embargo, el período siguiente a la iniciación de La Niña está típicamente asociado con condiciones más secas que las normales para la mayor parte de la región al sur de los 25° S. Además, indicaciones de aumento de la probabilidad de precipitación por debajo de lo normal están dadas por la presencia de temperaturas de la superficie del mar por debajo de lo normal en Atlántico Sur, fuera de las costas en el Sudeste de Sudamérica.

El Foro fue organizado por la Secretaría de Ciencia y Tecnología de Argentina, con el auspicio del Inter American Institute for Global Research (IAI), el International Research Institute for Climate Prediction (IRI), la Federación de Asociaciones Rurales del Mercosur, el Instituto de Pesquisas Espaciaes de Brasil, la National Oceanic and Atmospheric Administration (USA), la Secretaría de Ciencia y Técnica de la Universidad de Buenos Aires y el Departamento de Ciencias de la Atmósfera de la Universidad de Buenos Aires. Los participantes al Foro incluyen representantes de los Servicios Meteorológicos de Argentina, Paraguay y Uruguay, científicos y otros expertos del Clima de

Universidades, Institutos y Organizaciones Regionales, Nacionales e Internacionales: Departamento de Ciencias de la Atmósfera de la Universidad de Buenos Aires, Laboratorio de Climatología Regional, CIMA (CONICET/UBA) de Argentina, Universidad Federal de Paraná (Brasil), CPTEC/INPE (Brasil), IRI (USA), Facultad Politécnica y Facultad de Ciencias Exactas y Naturales de la Universidad Nacional de Asunción (Paraguay) y Facultad de Ingeniería y Facultad de Ciencias de la Universidad de la República de Uruguay.

Metodologia

La estimación regional del clima comenzó con un acuerdo por consenso de que las condiciones de la Niña se han iniciado y continuará su desarrollo durante el resto del año 1998.

Las temperaturas de la superficie del mar pronosticadas (SST) que se tomó en consideración, estuvieron basadas en los resultados de modelos acoplados océano - atmósfera, modelos estadísticos con base física e interpretación de expertos. La región considerada incluye las áreas continentales comprendidas entre 20º S a 40º S y el este de los Andes hasta 47º W. Esta área se dividió en subregiones de acuerdo a análisis estadísticos previos del impacto de La Niña en la región. El pronóstico se basó en pronósticos dinámicos y estadísticos presentados por INPE/CPTEC e IRI, así como los resultados de estudios detallados de impacto de El Niño y La Niña realizados por expertos climatólogos de la región.

En la actualidad, los pronósticos estacionales a interanuales, muestran la *predicción de promedios*

espaciales y temporales y pueden estas predicciones no contener totalmente, para todos los factores, la influencia de la variabilidad climática regional. Este pronóstico es relevante solamente a escalas de tiempo estacional y áreas relativamente grandes, pudiendo ocurrir variaciones locales.

Pronostico

Los expertos proveyeron la distribución de probabilidades para indicar la posibilidad de precipitaciones debajo, cerca o encima de lo normal para cada subregión (ver mapas).

Precipitaciones encima de lo normal se definen dentro del tercio más húmedo de los registros históricos de totales de precipitación en cada región; lluvias por debajo de lo normal están definidas como dentro del tercio más seco de las precipitaciones totales; cercana a lo normal, es el tercio centrado alrededor de la mediana climatológica. Los usuarios están fuertemente advertidos para que contacten a las instituciones participantes y otras fuentes de información climática, para la interpretación de este pronóstico y por guía adicional.

Para el mes de Setiembre se esperan lluvias por encima de los valores normales en el centro y Sudeste de Paraguay, en Brasil sobre la región que limita con Paraguay, Noroeste de Uruguay y litoral y centro de Argentina. En el Sudeste de Brasil y Noreste de Uruguay, las precipitaciones esperadas serian normales o ligeramente menores que los valores normales. Para la franja comprendida entre la costa Argentina y la Cordillera de Los Andes, y entre unos 38º y el paralelo de 40º de latitud Sur, se esperan condiciones por debajo de los valores normales. En

climatológicas. Para los meses octubre, noviembre y diciembre, lluvias por encima de los valores normales son esperadas en el Norte y centro de Paraguay y en el Sudoeste de Brasil. En el centro Sur y centro Este de Brasil, Sur de Paraguay, Noroeste, Centro - Oeste y Sur de Buenos Aires, se esperan condiciones climatológicas. Lluvias por debajo o próximo a los valores normales son esperadas en el Sudeste de Brasil, Sur de Paraguay, Misiones y Norte de Buenos Aires, mientras que lluvias por debajo de los valores normales se esperan en Uruguay, Mesopotamia y centro de Argentina. Para Enero y Febrero de 1999, las condiciones son más inciertas, aunque podrían esperarse lluvias normales para la Pampa húmeda argentina, Uruguay y Sudeste de Brasil.

Las temperaturas para el mes de Setiembre podrán ser menores que los valores normales en el Noreste de Argentina, Paraguay, Uruguay y Las temperaturas para el período Octubre - Diciembre 1998 se espera que sean las climatológicas en la franja que comprende la Provincia de Buenos Aires hasta la cordillera de Los Andes. Para la Mesopotamia argentina, Uruguay, centro y Sur de Paraguay y Sur de Brasil se esperan temperaturas por debajo de los valores normales. Para el resto de la región, no existe consenso entre los expertos para estimar si las temperaturas estarán por encima o por debajo de las condiciones normales.

En la Pampa húmeda y centro de la Argentina las presentes condiciones de disponibilidad de agua en los suelos junto con posibles lluvias por encima de lo normal en Septiembre atemperaran los efectos de la menor precipitación en el último trimestre del año.

Leyenda Del Mapa.

Los números indican las probabilidades de precipitación en cada una de las tres categorías. El número superior indica la probabilidad de ocurrencia de lluvias en la categoría por encima de lo normal, el número central es para cercano a lo normal y el número inferior, para más bajo de lo normal. Los límites entre las subregiones deberían ser considerados como zonas de transición. La C significa condiciones climáticas normales, las cuales indican que no hay bases científicas claras para favorecer la predicción debajo de lo normal o encima de lo normal para las precipitaciones. El significado es el mismo para la temperatura.

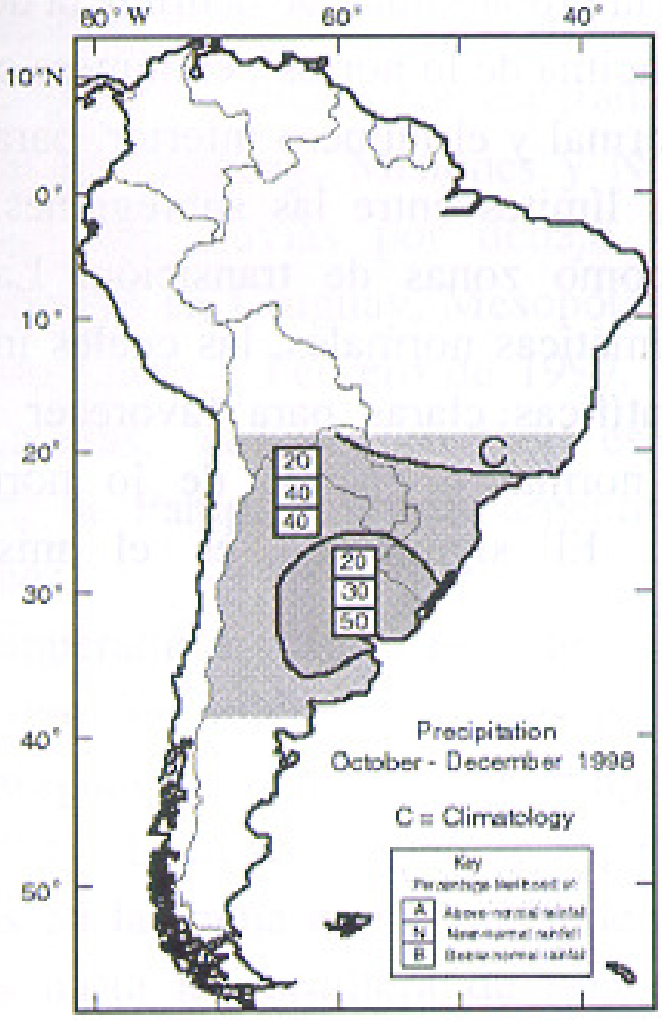
Consensus Climate Guidance

South-eastern South America Regional Climate Outlook Forum

18 June 1998 *Foz do Iguaçu, Brazil*

(for list of participants and explanatory text see associated discussion)

October - December 1998



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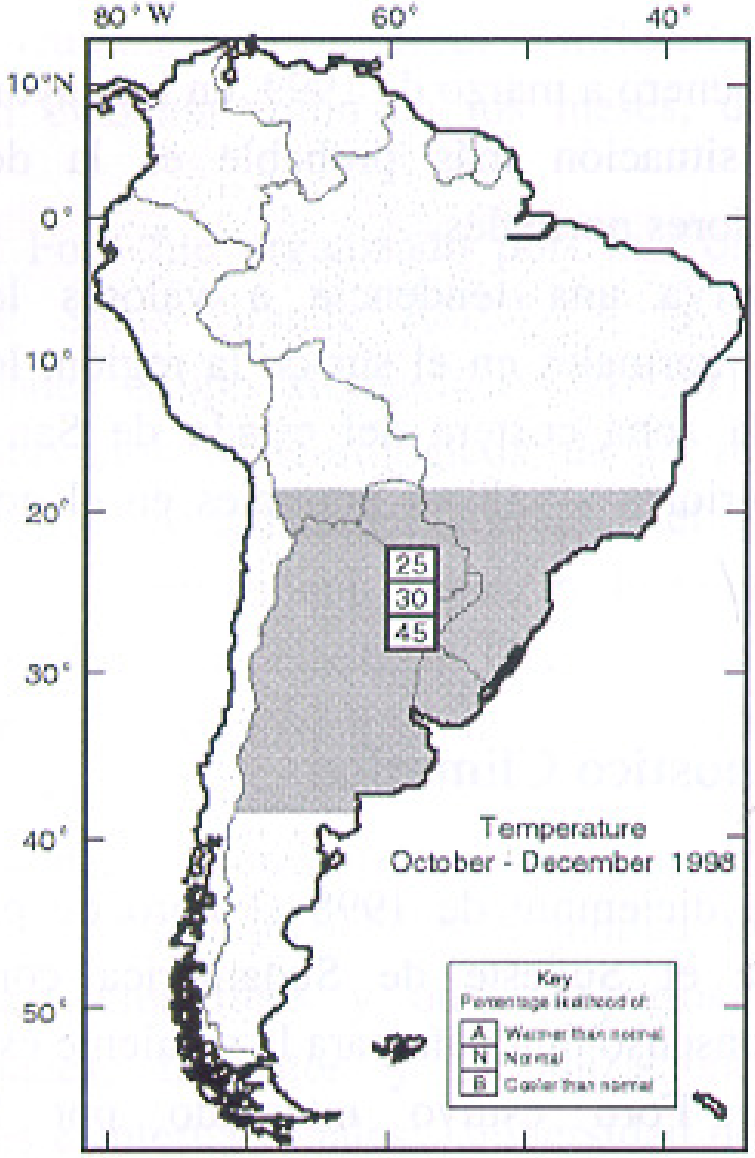
Consensus Climate Guidance

South-eastern South America Regional Climate Outlook Forum

16 June 1998 Foz do Iguaçu, Brazil

(for list of participants and explanatory text see associated discussion)

October - December 1998



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IV Foro Regional de Perspectiva Climatica para El Sudeste de Sudamerica Enero a Marzo/1999 Diciembre 4 de 1998, Salto Grande

Resumen

Durante enero a marzo de 1999, en la mayor parte de la región, la situación más probable es la de lluvias alrededor de valores normales.

Se observa una tendencia a valores levemente inferiores a los normales en el sur de la región, levemente inferiores en la zona costera del estado de San Pablo y levemente superiores a valores normales en el norte de la región.

Foro de Pronostico Climatico

El 4 de diciembre de 1998 el Foro de pronóstico Climático para el Sudeste de Sudamérica convino en formular por consenso una guía para la siguiente estación en la región. El Foro estuvo integrado por Servicios Meteorológicos de países del Sudeste de Sudamérica, expertos de climatología pertenecientes a Universidades e Institutos Nacionales y se recibieron los aporte de institutos internacionales en particular a través del IRI.

Los especialistas revisaron el estado del sistema climático global y sus implicancias para el Sudeste de Sudamérica. Los principales factores tomados en cuenta son:

1) La persistencia de condiciones frías en el océano Pacifico ecuatorial, consistente con el desarrollo de un evento "La Niña".

2) No se evidencia un sesgo marcado en las precipitaciones del periodo, asociados a las anomalías de temperatura del Océano Pacífico.

3) Durante enero-febrero, la influencia de "La Niña" no es tan evidente como en los meses, de diciembre y marzo.

El Foro fue organizado por- la Comisión Técnica Mixta de Salto Grande (CTM) y la Asociación de Universidades Grupo Montevideo (AUGM), con el apoyo de los Servicios Meteorológicos de la región y de la Federación de Asociaciones Rurales del Mercosur y el auspicio del International Research Institute for Climate Prediction (IRI), la National Oceanic and Atmospheric Administration (NOAA) y el Inter American Institute for Global Research (IAI).

Los participantes al Foro incluyen representantes de los Servicios Meteorológicos de Argentina, Brasil, Paraguay y Uruguay, científicos y otros expertos del clima de Universidades, Institutos y Organizaciones Regionales, Nacionales e Internacionales: Universidad de Buenos Aires (Argentina), Universidad Federal de Paraná (Brasil), Universidad Nacional del Litoral (Argentina), Universidad Federal de Río Grande do Sur (Brasil), Fundación Universidad de Río Grande (Brasil), Universidad Nacional de Asunción (Paraguay), Universidad de la República (Uruguay) y el Instituto Nacional de Pesquisas Espaciales (INPE, Brasil).

Metodología

La estimación regional del clima comenzó con un acuerdo de que las condiciones de "La Niña" se han consolidado y continuará su desarrollo durante los primeros meses de 1999.

Las temperaturas de la superficie del mar pronosticadas (SST) que se tomó en consideración, estuvieron basadas en los resultados de modelos acoplados oceano-atmósfera, modelos estadísticos con base física e interpretación de expertos. La región considerada incluye las áreas continentales comprendidas entre 20° S a 40° S y al este de los Andes hasta el océano Atlántico.

El Consenso se basó en los pronósticos dinámicos y estadísticos presentados por los expertos climatólogos de la región. Se dispuso para el consenso de los resultados de los modelos NCAR (ccm3), NCEP, ECHAM, aportados vía Internet por el IRI y del modelo del CPTEC/INPE.

En la actualidad, los pronósticos estacionales a interanuales, muestran la predicción de promedios espaciales y temporales y pueden estas predicciones no contener totalmente, para todos los factores, la influencia de la variabilidad climática regional.

Este pronóstico es relevante solamente a escalas de tiempo estacional y áreas relativamente grandes, pudiendo ocurrir variaciones locales.

Pronostico

Los expertos proveyeron la distribución de probabilidades, a partir de los registros históricos de totales de precipitación en cada región, para indicar la posibilidad

de precipitaciones: dentro del tercio más húmedo, dentro del tercio más seco y dentro del tercio centrado alrededor de la mediana climatológica (ver mapa).

Los usuarios están fuertemente advertidos para que contacten a las instituciones participantes y otras fuentes de información climática, para la interpretación de este pronóstico y por guía adicional.

Analisis de las Precipitaciones en las Subregiones

I La región extendida entre el Noroeste argentino, sur de Bolivia y oeste del Gran Chaco, mostró un elevado nivel de consenso,, con altas probabilidades de producirse precipitaciones dentro del tercil superior (40%), si bien, dado que las lluvias del trimestre dependen de la instalación de la Alta Boliviana que está asociada con "La Niña", un comienzo tardío de dichas lluvias en enero pueden producir totales normales (40%).

El Gran Chaco americano, en plena temporada lluviosa, experimentará lluvias normales o por encima de lo normal

II La región central de la Argentina forma parte de una banda donde el consenso mostró una supremacía de que las precipitaciones se ubiquen dentro de la normal (50%). Sin embargo debe tenerse presente que la suma trimestral puede estar formada por una gran variabilidad en el tiempo (intermensual o intersemanal) y en el espacio. Hacia el oeste de la Argentina no se puede descartar un menor peso de la probabilidad normal, aumentando la probabilidad de ambos extremos.

III La región centro-sur de la Argentina que se incluye con el Uruguay mostró, dentro del consenso, un leve predominio de las precipitaciones inferiores a las normales (40%).

Es necesario aclarar que esa señal negativa está regida preferentemente por el mes de marzo. Así como en la región central, esta suma trimestral puede estar afectada por grandes variabilidades temporales y espaciales que se suavizan en el resultado final.

Para gran parte de Uruguay (centro, nordeste y suroeste), parte de Río Grande do Sul, Provincia de Buenos Aires y La Pampa, los acumulados de precipitaciones en el trimestre enero-febrero-marzo, tendrían probabilidades ligeramente mayores de situarse en el tercil inferior. No obstante esta relación no es estadísticamente significativa, lo que estaría asociado a una pérdida de señal en relación fenómeno de ENSO, en especial durante el mes de enero.

Asimismo durante enero y febrero ocurren precipitaciones geográficamente dispersas debidas a convección local, por lo cual pueden suceder precipitaciones intensas en puntos muy localizados.

IV Hacia el sudoeste argentino, es decir norte de la Patagonia se pueden acentuar las probabilidades de ubicarse en el tercil inferior, como un claro efecto, en este caso más persistente durante todo el período, del fenómeno de "La Niña".

V La región Oriental del Paraguay y los estados de Paraná y Matto Grosso tendrá una fuerte tendencia a lluvias normales alguna con ligera tendencia a lluvioso si se apartara de lo normal.

VI Para la región sudeste de Brasil, se esperan lluvias que serían entre normales y ligeramente menores que los valores normales, para el periodo Enero-Marzo 1999.

Los sistemas frontales tenderán a pasar más rápidamente y producirán lluvias al norte de Sao Paulo. Previsiones del CPTEC - INPE de Brasil para el sur del país indican posibilidades de ocurrencia de un ligero exceso de precipitación en la región litoral. En la parte central de los estados del sur de Brasil y norte de Paraná se va a tener un leve déficit de precipitación.

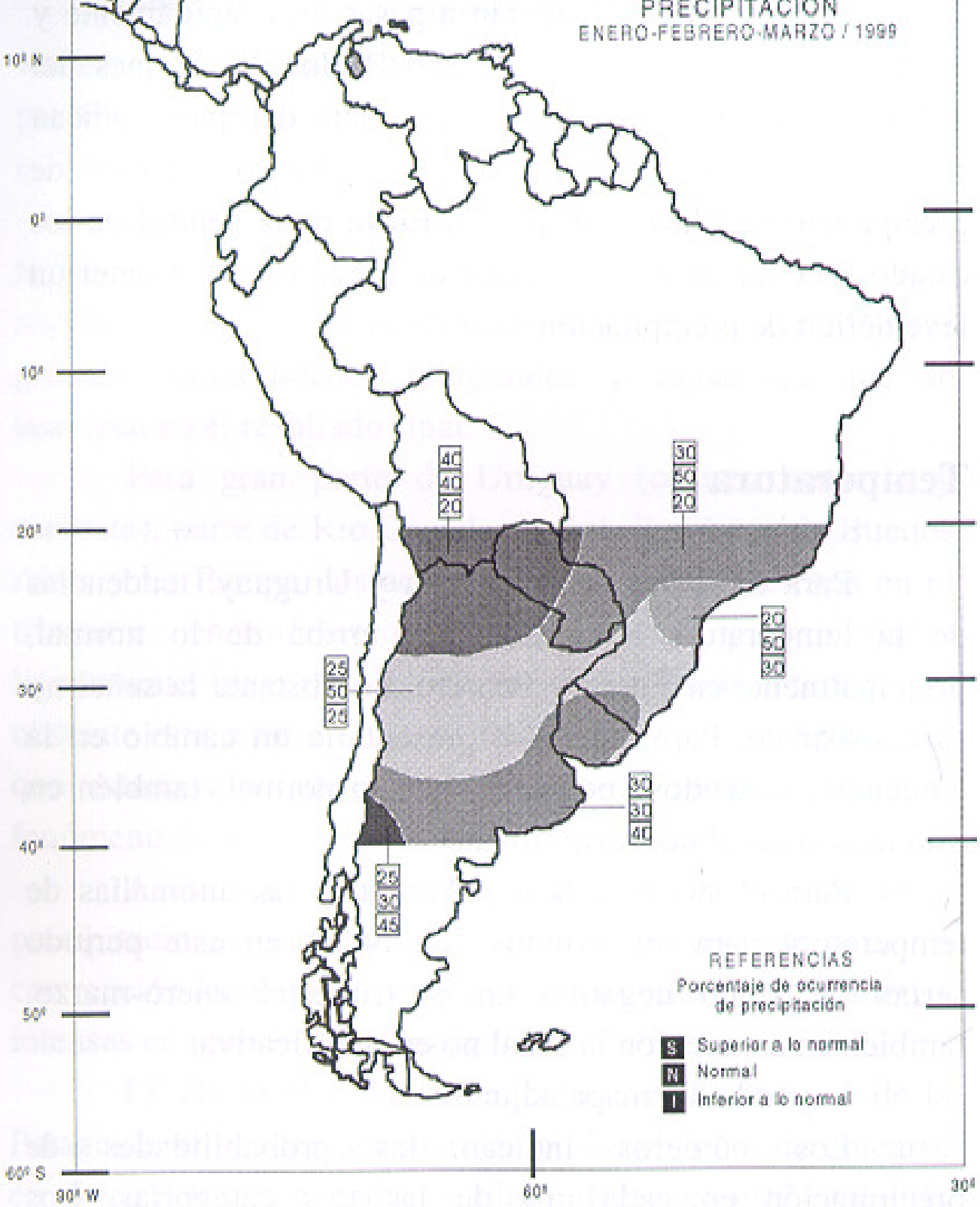
Temperatura

Para el centro de Argentina y Uruguay: tendencias de la temperatura a situarse por arriba de lo normal, principalmente en Enero y Febrero, no obstante la señal no es consistente. Para marzo se presentaría un cambio en la tendencia, situándose por debajo de lo normal, también en este mes la señal no es significativa.

Para el sur de Brasil y Paraguay las anomalías de temperatura para los eventos "La Niña" en este periodo serian de signo negativo en el trimestre enero-marzo, también en esta región la señal no es significativa.

Leyenda del mapa adjunto

Los números indican las probabilidades de precipitación en cada una de las tres categorías. Los números indican la probabilidad de ocurrencia de lluvias en cada categoría: por encima de lo normal o tercil superior, cercano a lo nominal, o tercil central y por debajo de lo normal o tercil inferior. Los limites entre las subregiones deberían ser considerados como zonas de transición.


PRECIPITACION
ENERO-FEBRERO-MARZO / 1999
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
40
40
20
30
30
20
20
30
30
25
50
25
30
30
40
25
30
45
REFERENCIAS
Porcentaje de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal

V Regional Climate Outlook Forum for Southeastern South America April-June 1999 Mariano Roque Alonso, Paraguay, April 15-16, 1999

Summary

For the period of April through June of 1999, the most likely expected situation for most of the region is precipitation values around normal or slightly above normal, except in the west and center of the region.

Temperature values are estimated to be normal to slightly below normal in the south and slightly higher than normal in southern coastal region of Brazil, as well as the northeast of Argentina and western Paraguay.

Climate Outlook Forum

On the April 15, 1999 the V Climate Outlook Forum for southeastern South America met in the headquarters of the Asociación Rural del Paraguay in the city of Mariano Roque Alonso, Paraguay, and put together a consensus forecast for the period of April through June 1999 for southestern South America. This region is defined as between 20°S to 40°S, from the coast to the eastern Andes. The forum incorporated experts in climatology from meteorological services, universities and regional and national institutions and received support from the International Research Institute for Climate Prediction (IRI).

The specialists reviewed the state of global climate and its implications for southestern South America. The principle factors taken into account are:

1) The persistence of cold water in the equatorial Pacific Ocean, consistent with a "La Niña" event of moderate intensity.

2) There is preliminary evidence of a shift from normal precipitation values in the period considered, associated with the Pacific Ocean temperature anomalies.

3) From April to June, 1999 the influence of La Niña on the weather of the region will persist.

The V Forum was organized by the Paraguay Rural Association and the Rural Associations of Mercosur, under the auspices of the Polytechnic Department of the National University of the Asunción, National Board of Civil Aeronautics, World Meteorological Organization, International Research Institute for Climate Prediction (IRI), Itaipu Binacional, Banco Nacional de Fomento, CAPECO, and the Entidad Nacional Yacyretá.

The participants in the V Forum include experts from the Meteorological Sevices of Argentina, Brazil, Paraguay and Uruguay and scientists from the University of Buenos Aires (Argentina), Federal University of Paraná (Brazil), Universidad Nacional del Litoral (Argentina), National University of the Assumption (Paraguay), University of the Republic (Uruguay), Center for Weather Forecast and Climate Studies (CPTEC, Brazil), and the International Research Institute for Climate Prediction (IRI).

Methodology

The experts assumed a continuation of the La Niña event in the next few months with a tendency to decay in the austral spring. The forecast area covers the southeast of South America from 20°S to 40°S to the eastern Andes. The consensus forecast is based on various studies carried out in the region, as well as the results from IRI and CPTEC climate models.

The consensus attempt to balance the limitations of the spatial resolution of the models with the results of the available studies on climate variability. Finally, different aspects of the climate were considered, including dynamic and physical aspects as determined by recent observations, such as the heat of the Atlantic Ocean and the residual humidity of central and northern Argentina, among other factors.

It is anticipated that each region identified will have a distinct matrix. For that reason, the forecast should be interpreted as a mean condition for each region.

Forecast

The experts decided to express the forecast in terms of a probabilistic terms. For this purpose, three categories were identified: Above Normal, Normal, and Below Normal, coinciding with a tercile distribution of historic temperature and precipitation records.

The probability of occurrence of each of the three categories is represented in Figure 1 and Figure 2, corresponding to the precipitation and temperature, respectively.

participating institutions for more detailed information and explanation.

Analysis of the Precipitation Forecast, Figure 1

I. For the eastern region of the states of São Paulo, Paraná, Santa Catarina and Río Grande do Sul, normal to slightly above normal precipitation is predicted.

II. For the central and western region of Paraná, Santa Catarina and Río Grande do Sul in Brazil; central and western region of Uruguay; central and northern region of Chaco and the northeastern Oriental region in Paraguay; the provinces of Entre Ríos, central and southern regions of Santa Fé, north and northeastern Buenos Aires in Argentina, normal precipitation is predicted.

III. For Bajo Chaco, central and southern Paraguay; eastern region of the provinces Formosa and Chaco, northern region of Santa Fé, Corrientes and Misiones in Argentina, normal to slightly below normal precipitation is predicted.

IV. For the far east of paraguayan Chaco and in central to northern central Argentina, eastern La Pampa, western and southern Buenos Aires, normal to slightly above normal precipitation is predicted.

V. For the region from the Puna Jujeña and the eastern Andean provinces of Argentina, normal precipitation is predicted.

VI. For the cordillera cuyana region in Argentina, below normal precipitation is predicted.

VII. For northern Patagonia, including the extreme southeast of Buenos Aires, higher than normal precipitation is predicted.

Analysis of the Temperature Forecast, Figure 2

I. For the coastal region of the states of Rio Grande do Sul, Paraná and Santa Catarina, normal to slightly above normal temperatures are predicted.

II. For the states of São Paulo, Mato Grosso do Sul, eastern Paraná, Santa Catarina and Río Grande do Sul in Brazil; eastern Uruguay; central and eastern Paraguay; Mision province, eastern Formosa, central and cuyana regions of Argentina, normal temperatures are predicted.

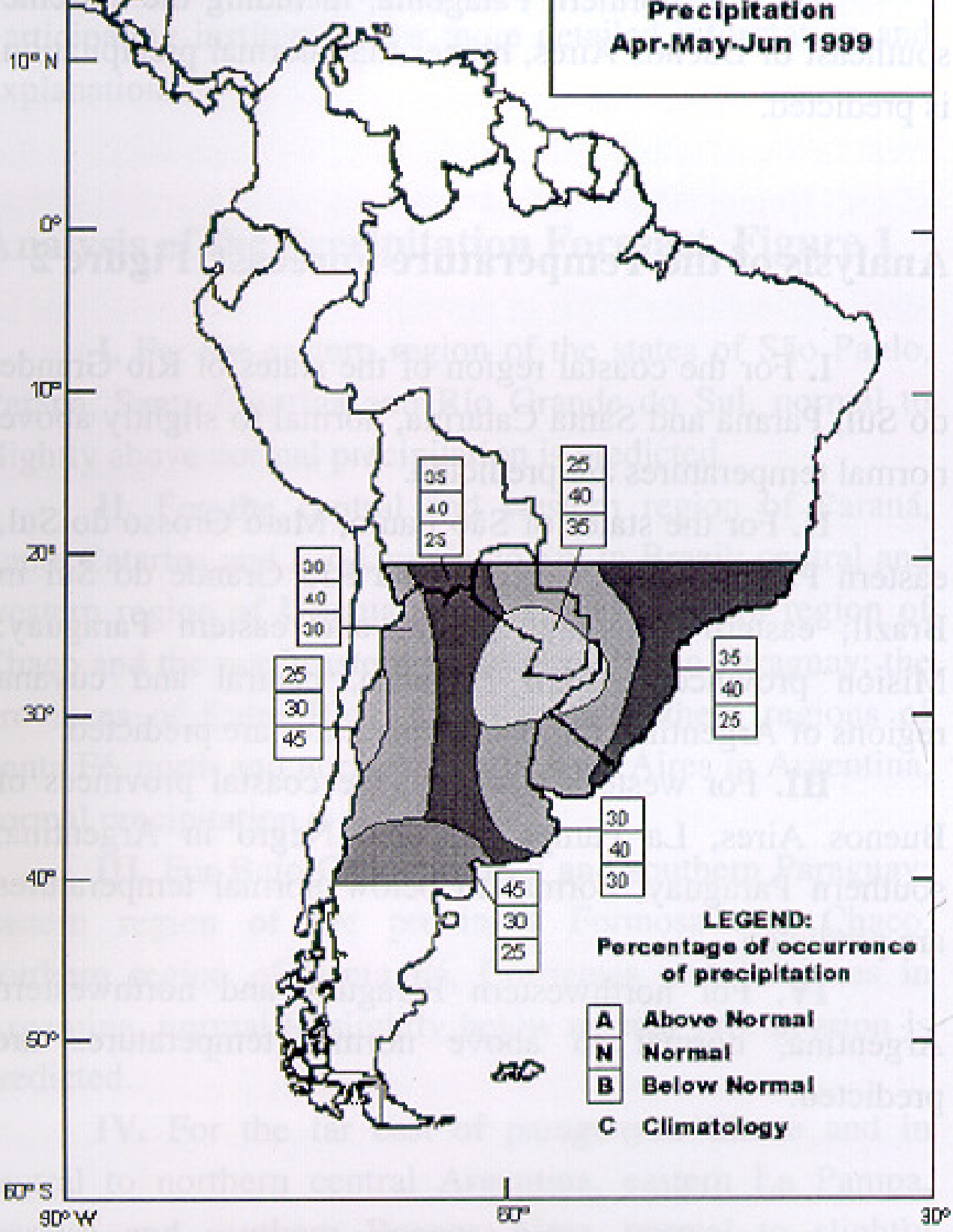
III. For western Uruguay; the coastal provinces of Buenos Aires, La Pampa and Río Negro in Argentina; southern Paraguay, normal to below normal temperatures are predicted.

IV. For northwestern Paraguay and northwestern Argentina, normal to above normal temperatures are predicted.

Additional Aspects of the V Forum

I. It was discussed and agreed upon that there is a need to continue the activities of Climate Outlook Fora for the region.

II. A methodology for the verification of climate predictions was proposed.


Precipitation
Apr-May-Jun 1999
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
35
40
25
25
40
35
30
40
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25
30
45
35
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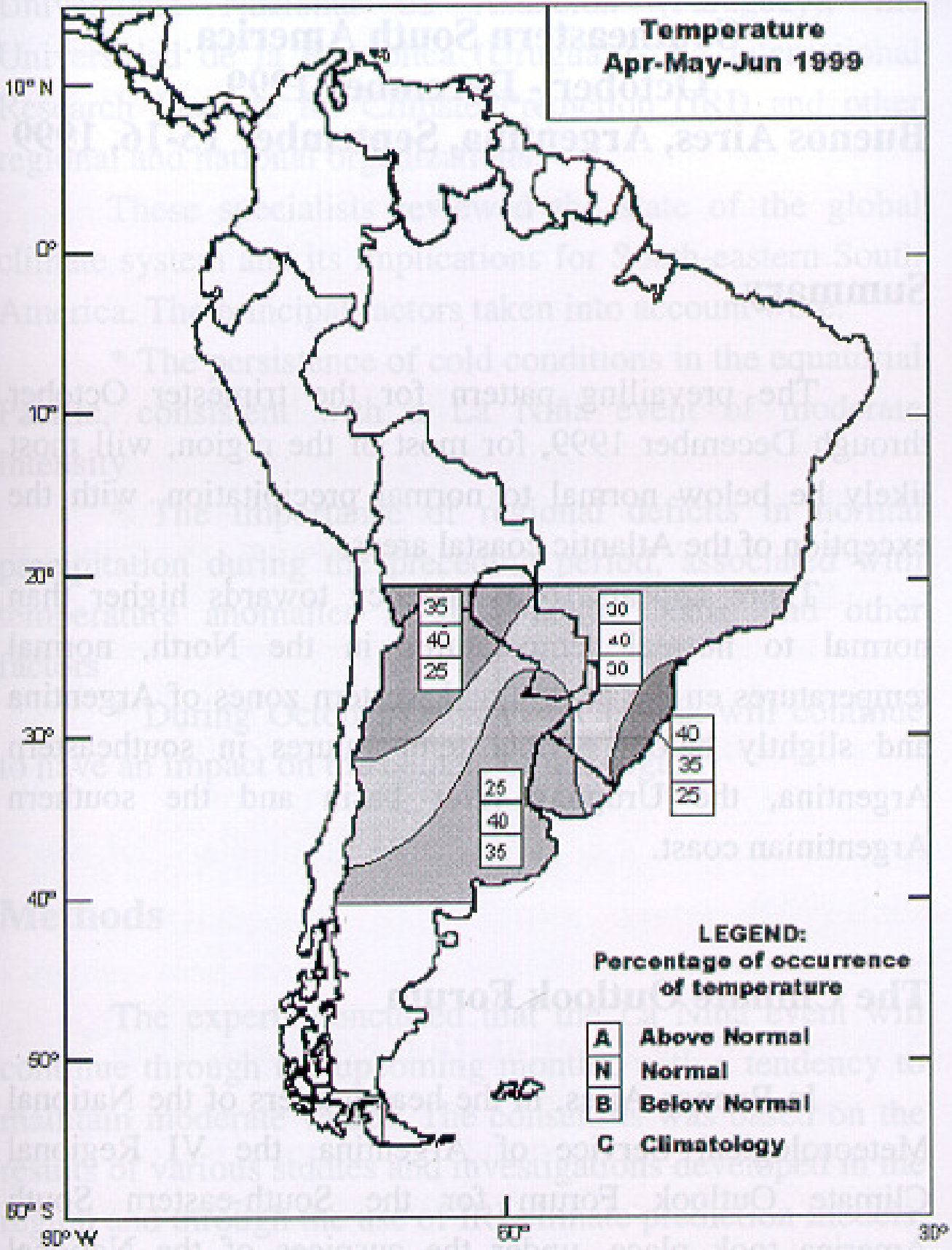
40
30
45
30
25
LEGEND:
Percentage of occurrence of precipitation
A Above Normal
N Normal
B Below Normal
C Climatology


Temperature
Apr-May-Jun 1999
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
35
40
25
30
40
30
40
35
25
25
40
35
LEGEND:
Percentage of occurrence
of temperature
A Above Normal
N Normal
B Below Normal
C Climatology

VI Regional Climate Outlook Forum for Southeastern South America
October - December 1999
Buenos Aires, Argentina, September 15-16, 1999

Summary

The prevailing pattern for the trimester October through December 1999, for most of the region, will most likely be below normal to normal precipitation, with the exception of the Atlantic coastal areas.

There appears to a tendency towards higher than normal to normal temperatures in the North, normal temperatures en the central and western zones of Argentina and slightly below normal temperatures in southeastern Argentina, the Uruguay river basin and the southern Argentinian coast.

The Climate Outlook Forum

In Buenos Aires, in the headquarters of the National Meteorological Service of Argentina, the VI Regional Climate Outlook Forum for the South-eastern South America took place, under the auspices of the National Meteorological Organization (OMN). The objective was to formulate, by consensus, a climate prediction for the period October-December 1999, for South-eastern South America, from 20°S to 40°S, from the Eastern coast to the Andes. The Forum was attended by climate scientists from the Meteorological Services of Argentina, Brazil, Paraguay and Uruguay, with the support of scientists from the la

Universidad Nacional de Asunción (Paraguay), the Universidad de la República (Uruguay), the International Research Institute for Climate Prediction (IRI) and other regional and national organizations.

These specialists reviewed the state of the global climate system and its implications for South-eastern South America. The principal factors taken into account were:

* The persistence of cold conditions in the equatorial Pacific, consistent with a La Niña event of moderate intensity

* The importance of regional deficits in normal precipitation during the preceding period, associated with temperature anomalies in the Pacific Ocean and other factors

* During October-December La Niña will continue to have an impact on the climate of this region

Methods

The experts concurred that the La Niña event will continue through the upcoming months, with a tendency to maintain moderate values. The consensus was based on the results of various studies and investigations developed in the region and through the use of IRI climate prediction models. In the same way, limitations of the spatial resolution of the climate models were balanced with the results of the available climate variability studies. Finally, different aspects of the climate, dynamic and physical, were considered in relation to recent observations. These observations include the cooling of the southern Atlantic Ocean adjacent to the forecast region and the expected low humidity from the North, among others.

Aires and the northern portion of Patagonia (Argentina), normal precipitation is predicted.

IV. For the rest of São Paulo, Paraná, Santa Catarina and Río Grande do Sul (Brazil), southern and eastern Paraguay, northern and western Uruguay, and central Argentina, including Mesopotamia and Cuyo, moderately below normal precipitation is predicted.

V. For southeastern Mato Grosso do Sul in Brazil, northern and western Paraguay, and the Formosa province in Argentina, below normal precipitation is predicted

VI. For northeastern Argentina, slightly above normal precipitation is predicted.

Analysis of the Temperature Forecast, Map 2

I. For the states of Río de Janeiro, Espíritu Santo, eastern São Paulo, coastal region of Paraná, Santa Catarina and Río Grande do Sul (Brazil), central and eastern Uruguay, and central and western Argentina, close to normal temperatures are predicted.

II. For northern Argentina, southern and eastern Paraguay, Mato Grosso do Sul, Santa Catarina, Paraná and Río Grande do Sul (Brazil) moderately above normal temperatures are predicted.

III. For the region including northern and western Paraguay, Formosa province (Argentina) and southeastern Mato Grosso do Sul (Brazil), above normal temperatures are predicted.

IV. For two regions, one situated in the south of Mesopotamia, Argentina and the western coast of Uruguay and the other situated in northeastern Patagonia (Argentina), slightly below normal temperatures are predicted.

Aires and the northern portion of Patagonia (Argentina), normal precipitation is predicted.

IV. For the rest of São Paulo, Paraná, Santa Catarina and Río Grande do Sul (Brazil), southern and eastern Paraguay, northern and western Uruguay, and central Argentina, including Mesopotamia and Cuyo, moderately below normal precipitation is predicted.

V. For southeastern Mato Grosso do Sul in Brazil, northern and western Paraguay, and the Formosa province in Argentina, below normal precipitation is predicted

VI. For northeastern Argentina, slightly above normal precipitation is predicted.

Analysis of the Temperature Forecast, Map 2

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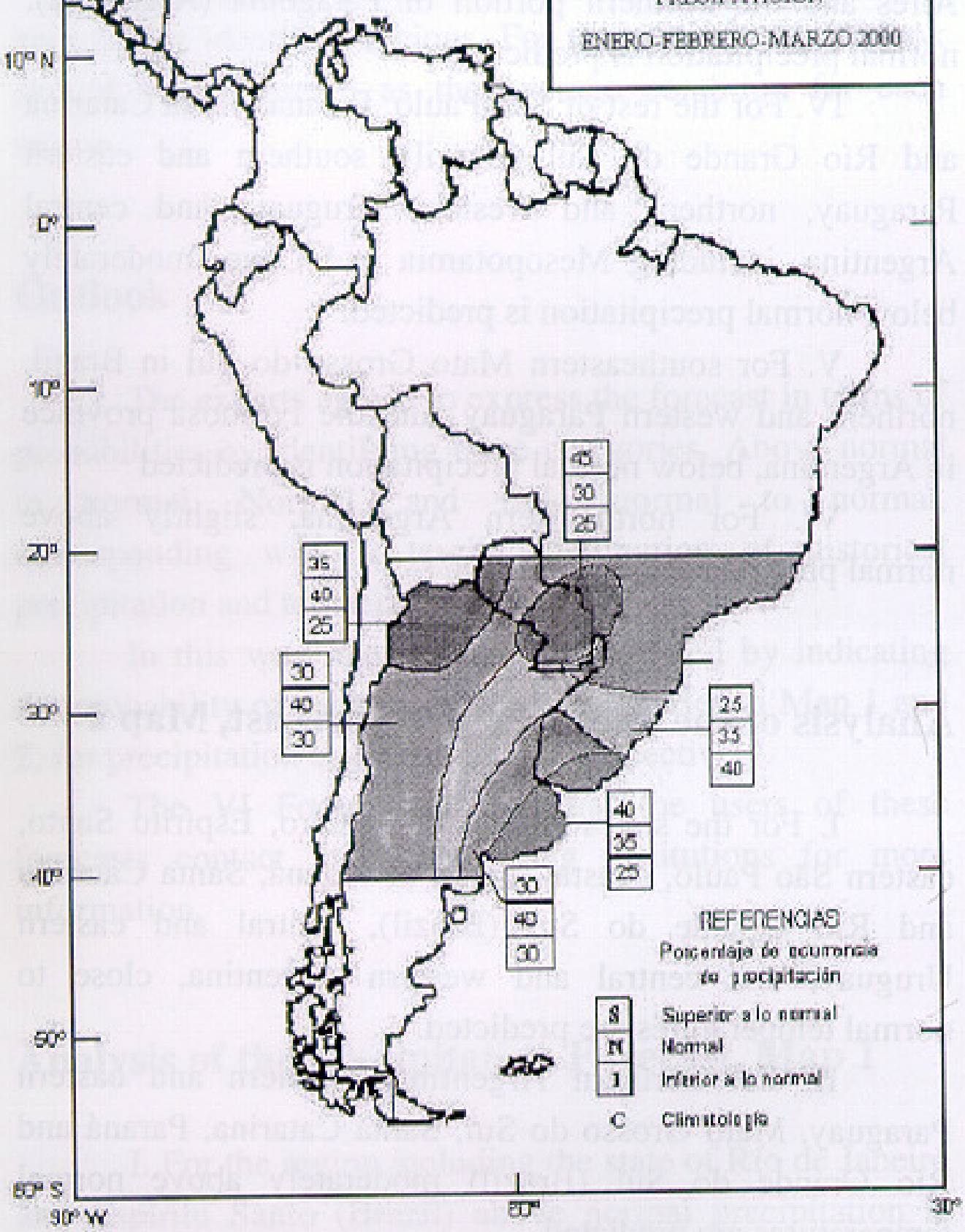
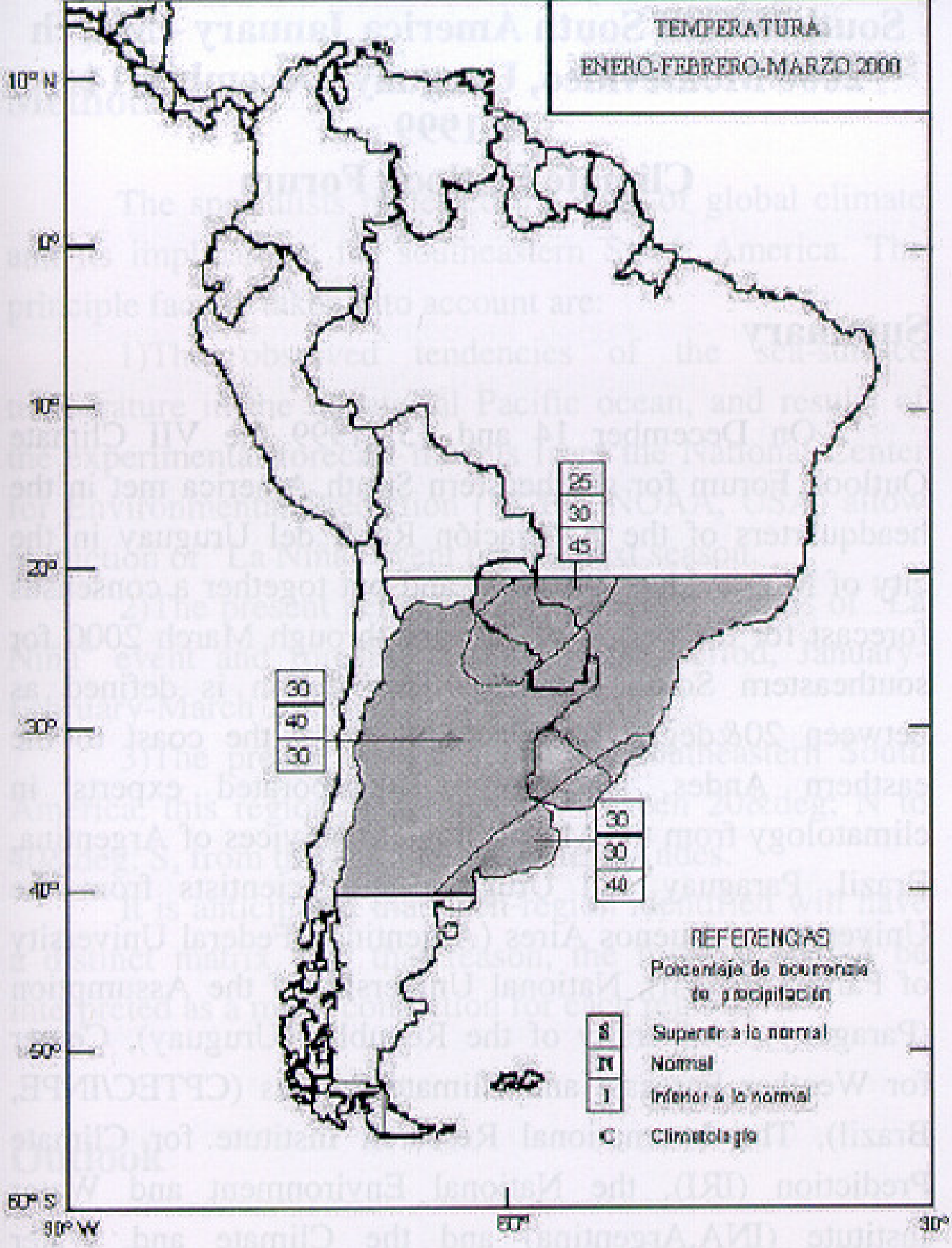
II. For northern Argentina, southern and eastern Paraguay, Mato Grosso do Sul, Santa Catarina, Paraná and Río Grande do Sul (Brazil) moderately above normal temperatures are predicted.

III. For the region including northern and western Paraguay, Formosa province (Argentina) and southeastern Mato Grosso do Sul (Brazil), above normal temperatures are predicted.

IV. For two regions, one situated in the south of Mesopotamia, Argentina and the western coast of Uruguay and the other situated in northeastern Patagonia (Argentina), slightly below normal temperatures are predicted.


ENERO-FEBRERO-MARZO 2000
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
45
30
25
35
40
25
30
40
30
25
35
40
40
35
25
30
40
30
REFERENCIAS
Porcentaje de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal
C Climatología


TEMPERATURA
ENERO-FEBRERO-MARZO 2000
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
25
30
45
30
40
30
30
30
40
REFERENCIAS
Porcentaje de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal
C Climatología

Southeastern South America January - March 2000 Montevideo, Uruguay, December 14-15,1999
Climate Outlook Forum

Summary

On December 14 and 15, 1999 the VII Climate Outlook Forum for southeastern South America met in the headquarters of the Asociación Rural del Uruguay in the city of Montevideo, Uruguay, and put together a consensus forecast for the period of January through March 2000 for southeastern South America. This region is defined as between 20°N to 40°S, from the coast to the easthern Andes. The forum incorporated experts in climatology from the Meteorological Services of Argentina, Brazil, Paraguay and Uruguay and scientists from the University of Buenos Aires (Argentina), Federal University of Paraná (Brazil), National University of the Assumption (Paraguay), University of the Republic (Uruguay), Center for Weather Forecast and Climate Studies (CPTEC/INPE, Brazil), The International Research Institute for Climate Prediction (IRI), the National Environment and Water Institute (INA,Argentina) and the Climate and Water Institute (INTA - Castelar, Argentina).

During the past months, the cold phase of "ENSO" was in the registered the equatorial Pacific. This lead to below normal precipitation for southeastern Brazil, Coastal region of Argentina and an extensive regions of Paraguay and Uruguay. In the central-western Argentina (Córdoba, San Luis, eastern Cuyo) above-normal rainfall was present.

Methodology

The specialists reviewed the state of global climate and its implications for southeastern South America. The principle factors taken into account are:

1)The observed tendencies of the sea-surface temperature in the equatorial Pacific ocean, and results of the experimental forecast models from the National Center for Environmental Prediction (NCEP, NOAA, USA) allow prediction of "La Niña" event for the next season.

2)The present perspective is based on studies of "La Niña" event and forecast models of the period, January-February-March 2000.

3)The prediction was made for southeastern South America, this region is defined as between 20° N to 40° S, from the coast to the eastern Andes.

It is anticipated that each region identified will have a distinct matrix. For that reason, the forecast should be interpreted as a mean condiction for each region.

Outlook

The experts agreed to express the forecast in terms of probabilities by identifying three categories, Above-normal to normal, Normal, and Below-normal to normal, corresponding with a tercile distribution of historical precipitation and temperatures.

In this way, the forecast is presented by indicating the probability of each of the three categories in Map1 and 2, for precipitation and temperature, respectively.

forecasts contact the participating institutions for more information.

Analysis of the Preciptation Forecast, Map 1

I. For the region including central Paraguay and south-western portion of Brazil, above normal precipitation is predicted.

II. For the southern region of Rio Grande do Sul (Brazil), northeastern and central Argentina, moderately below normal precipitation is predicted.

III. For the southern region of Uruguay and eastern province of Buenos Aires (Argentina), slightly above normal precipitation is predicted.

IV. For the northwestern Argentina, normal to slightly above normal precipitation is predicted.

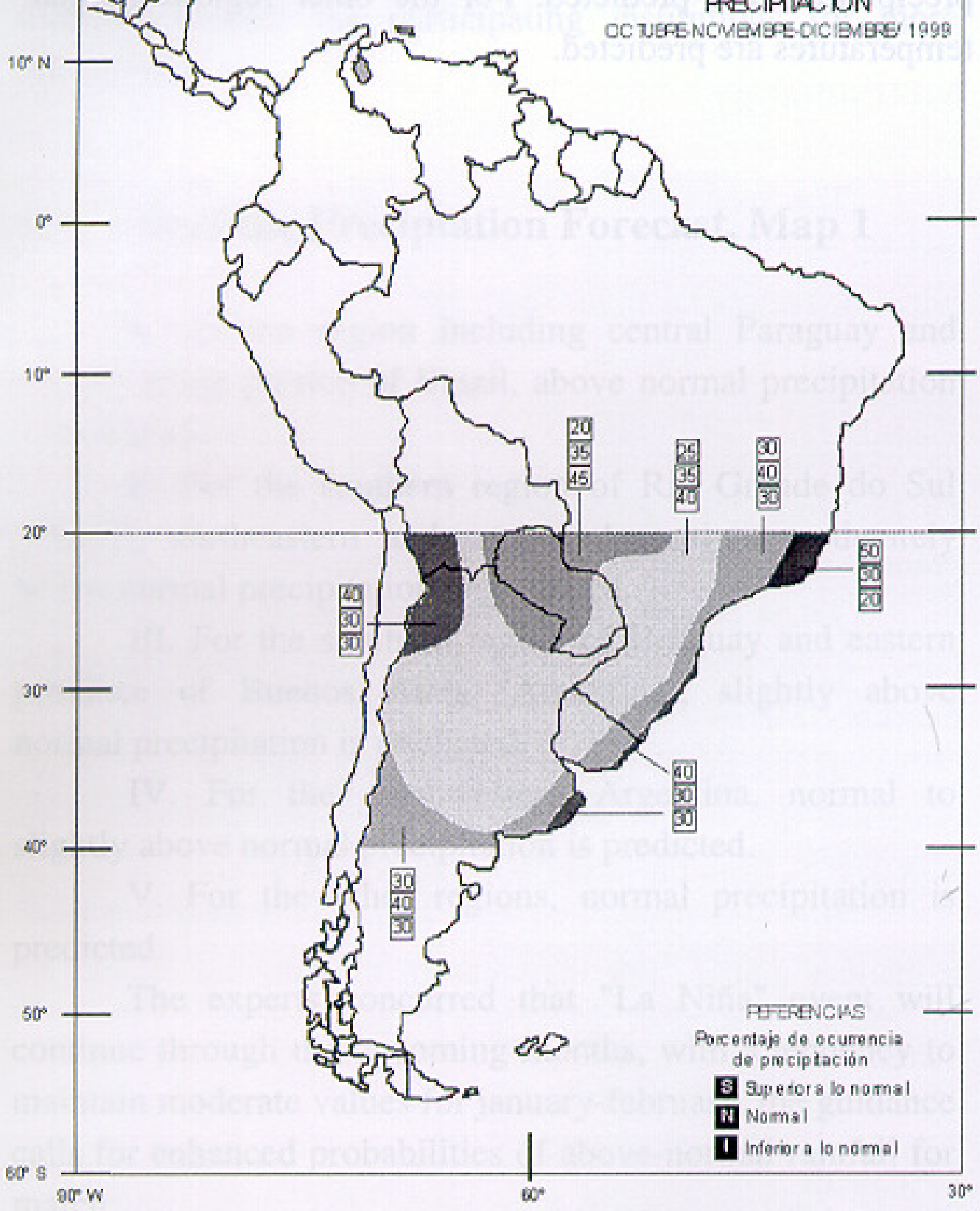
V. For the other regions, normal precipitation is predicted.

The experts concurred that "La Niña" event will continue through the upcoming months, with a tendency to maintain moderate values for january-february, the guidance calls for enhanced probabilities of above-normal rainfall for march.

Analysis of the Temperature Forecast, Map 2

For the central region of Paraguay, southeastern Uruguay, and coastal province of Buenos Aires (Argentina), below normal temperature associated with above normal

precipitation are predicted. For the other regions normal temperatures are predicted.


PRECIPITACION
OCTUBRE-NOVIEMBRE-DICIEMBRE/ 1999
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
20
35
45
25
35
40
30
40
30
30
40
30
40
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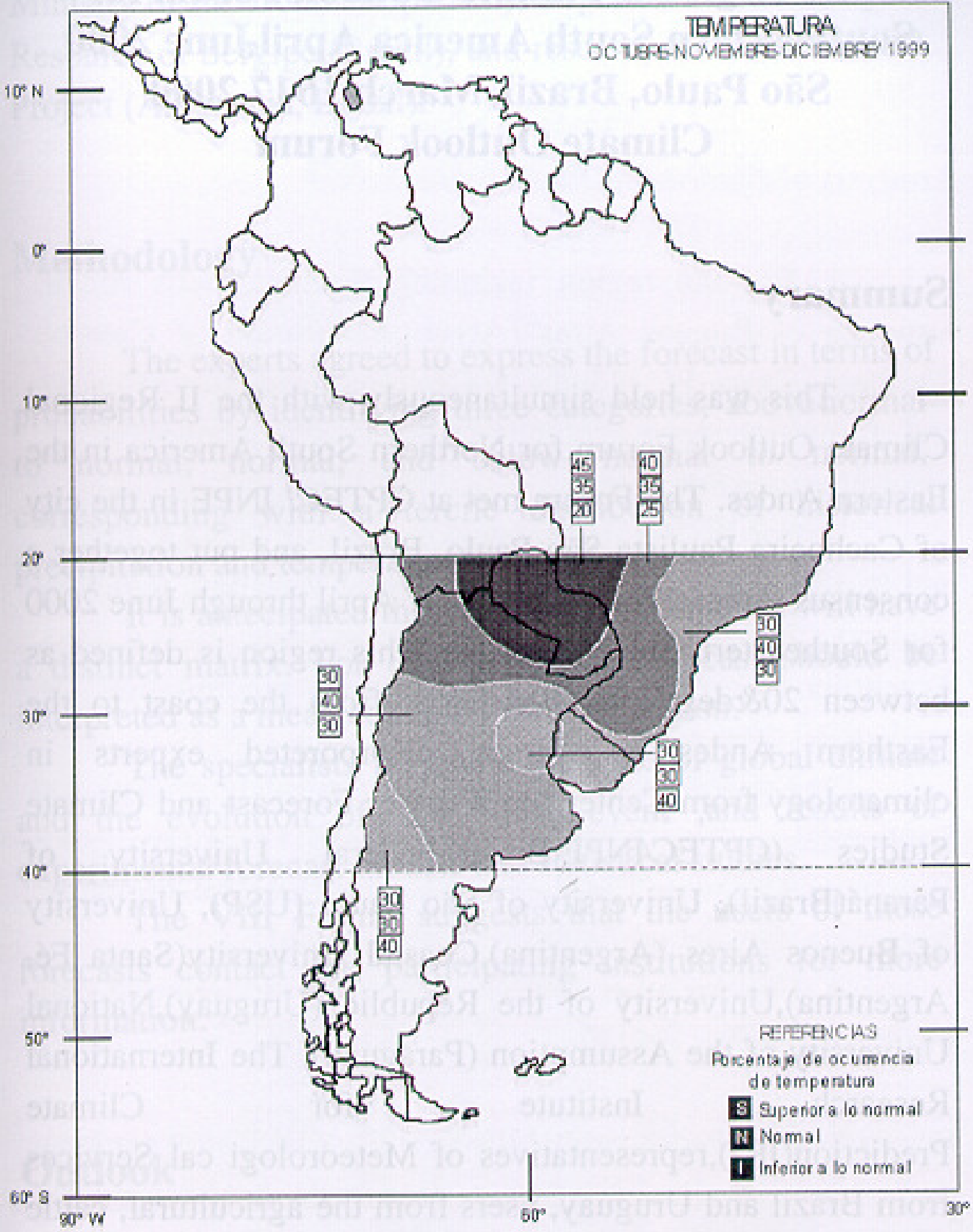
40
30
PEFERENCIAS
Porcentaje de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal


TEMPERATURA
OCTUBRE-NOVIEMBRE-DICIEMBRE/ 1999
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
45
35
20
40
35
25
30
40
30
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REFERENCIAS
Porcentaje de ocurrencia de temperatura
S Superior a lo normal
N Normal
I Inferior a lo normal

VIII Regional Climate Outlook Forum for Southeastern South America April-June 2000 São Paulo, Brazil, March 16-17,2000 Climate Outlook Forum

Summary

This was held simultaneously with the II Regional Climate Outlook Forum for Northern South America in the Eastern Andes. The Forum met at CPTEC/ INPE in the city of Cachoeira Paulista São Paulo, Brazil, and put together a consensus forecast for the period of April through June 2000 for Southeastern South America. This region is defined as between 20°N to 40°S, from the coast to the Easthern Andes.The forum incorporeted experts in climatology from Center for Weather Forecast and Climate Studies (CPTEC/INPE,Brazil),Federal University of Paraná(Brazil), University of São Paulo (USP), University of Buenos Aires (Argentina),Coastal University(Santa Fé, Argentina),University of the Republic (Uruguay),National University of the Assumption (Paraguay), The International Research Institute for Climate Prediction(IRI),representatives of Meteorologi cal Services from Brazil and Uruguay, users from the agricultural, cattle rai sing and energy generation sectors,between them Itaipu Binacional,the National Environment and Water Institute (INA, Argentina), National Committee of Space Activities(Argentina),Technical Committee of Salto Grande(Argentina),São Paulo State Ministry of Environment (Brazil), Paraguay Chamber of Cereal(Paraguay), University of Andes (Venezuela), FUNCEME(Fortaleza,Ceara, Brazil), Pernambuco State

Ministry of Environment (Brazil), Superintendence of Hydro Resource of Sergipe (Brazil), and researchers from the LBA Project (Amazonia, Brazil).

Methodology

The experts agreed to express the forecast in terms of probabilities by identifying three categories, above-normal to normal, normal, and below- normal to normal, corresponding with a tercile distribution of historical precipitation and temperatures.

It is antecipated that each region identified will have a distinct matrix. For that reason,the forecast should be interpreted as a mean condition for each region.

The specialists reviewed the state of global climate and the evolution of "La Niña" event ,and results of experimental forecast models and statistical studies.

The VIII Forum suggests that the users of these forecasts contact the participating institutions for more information.

Outlook

Analysis of the Temperature Forecast

Sea surface temperature (SST) anomalies in the tropical Pacific and Atlantic oceans show a weakness for "La Niña" event for the next season.For the northern region of the Equatorial Atlantic Ocean below-normal temperature

the other regions normal temperature are predicted.

Analysis of the Preciptation Forecast

1. For the region including Southeasthern Brazil, province of Buenos Aires (Argentina), South of Coastal, Southern Santa Fé, Southern Cordoba, and Northwestern and Central-western Argentina,normal and above-normal preci-pitation is predicted.

2. For the Central-western region of Santa Catarina and Rio Grande do Sul (Brazil), Central Uruguay, region of lowland Chaco (Paraguay) and extreme Northern region of Argentina, normal and below-normal precipitation is predicted.

3. For the other regions of Rio Grande do Sul and Southeastern Brazil, other regions of Paraguay, other regions of Uruguay, Central-Northern and Coastal-northern Argentina, normal precipitation are predicted.

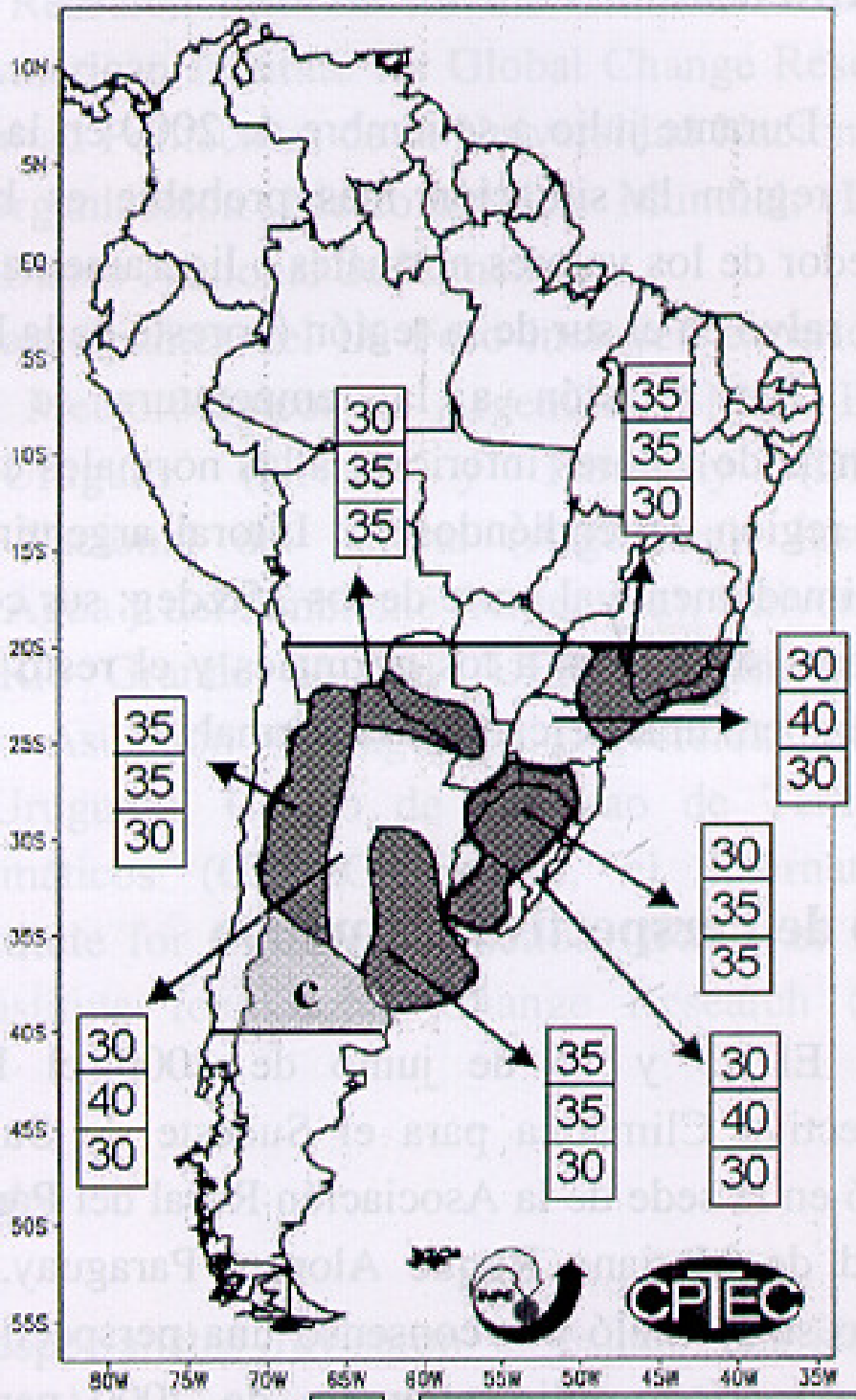
4. For the other regions , there are not enough data available.

Figura 1: Resultados probabilísticos do VIII fórum regional de perspectiva climática para o sudeste da América do Sul \226 cptec/inpe-16/17 março de 2000.

VIII Forum Previsão Climática

REGIÃO SUDESTE DA AMÉRICA DO SUL

Precipitação AMJ 2000



Probabilidade de ocorrência		
A	→	ACIMA do NORMAL
N	→	NORMAL
B	→	ABAIXO do NORMAL

para El Sudeste de Sudamérica
Julio-Agosto-Setiembre 2000

Resumen

Durante julio a setiembre de 2000 en la mayor parte de la región la situación más probable es la de lluvias alrededor de los valores normales o ligeramente superiores a estos, salvo en el sur de la región (noreste de la Patagonia).

Con relación a la temperatura se estima una tendencia de valores inferiores a los normales en el suroeste de la región, extendiéndose al Litoral argentino; las áreas aproximadamente al norte de los 25° sur con tendencia a valores superiores a los normales y el resto de la región con temperaturas cercanas a la normal.

Foro de Perspectiva Climática

El 15 y 16 de junio de 2000 el IX Foro de Perspectiva Climática para el Sudeste de Sudamérica se reunió en la sede de la Asociación Rural del Paraguay, en la ciudad de Mariano Roque Alonso, Paraguay. Durante el mismo se formuló por consenso una perspectiva climática para el período julio-setiembre de 2000 para la región sudeste de Sudamérica comprendida entre las latitudes de 20º S y 40º S y al este de la cordillera de los Andes.

El Evento fue organizado por la Asociación Rural del Paraguay, la Dirección de Meteorología e Hidrología de la DINAC, la Federación de Asociaciones Rurales del

Mercosur, la Organización Meteorológica Mundial, la Universidad Nacional de Asunción y la Cámara Paraguaya de Cereales y Oleaginosas (CAPECO), con el auspicio del Instituto Interamericano de Cooperación para la Agricultura (IICA), Ministerio de Agricultura y Ganadería (MAG), International Research Institute for the Climate Prediction (IRI), Inter-American Institute for Global Change Research (IAI), la Facultad Politécnica de la Universidad Nacional de Asunción, Organización Meteorológica Mundial, Itaipu Binacional y Banco Nacional de Fomento.

Los participantes del IX Foro incluyen expertos de los Servicios Meteorológicos de Argentina (SMN), Brasil (INMET), Uruguay (DNM) y Paraguay (DMH), Universidad Nacional del Litoral (Argentina), Instituto Nacional del Agua y del Ambiente (Argentina), Universidad Federal de Río Grande do Sul (UFRGS), Universidad Nacional de Asunción (Paraguay), Universidad de la República (Uruguay), Centro de Previsao de Tempo y Estudos Climáticos (CPTEC, Brasil), el International Research Institute for Climate Prediction (IRI) y el Inter-American Institute for Global Change Research (IAI).

Metodología

Los especialistas revisaron el estado del sistema climático global y sus implicancias para el sudeste de Sudamérica. Los principales factores tomados en cuenta fueron:Revisión de la perspectiva del VIII Foro.

- Las tendencias observadas en las anomalías de la temperatura superficial del mar (TSM) en la región ecuatorial del océano Pacífico y en el Atlántico sur.

previsión de anomalías de la temperatura superficial del mar (TSM) provenientes del National Center for Environmental Prediction (NCEP,NOAA-USA) y del ECMWF, que indican la tendencia a la desaparición de las condiciones frías en el océano Pacífico ecuatorial (La Niña).

- Los resultados de los modelos climáticos del International Institute Research for Climate Prediction (IRI), Instituto Nacional de Pesquisas Espaciais (INPE-CPTEC) y del UKMO.
- Los resultados de los modelos estadísticos y empíricos elaborados por el SMN de Argentina y la Universidad de la República de Uruguay.
- En menor grado se tomaron en cuenta los estudios-diagnósticos de impactos de los eventos "La Niña" sobre los campos de lluvia y temperatura sobre la región, a causa de la ausencia de una señal consistente en esta época del año.

El consenso se obtuvo balanceando los resultados de los modelos climáticos con los de diversos estudios de variabilidad climática. Por último se consideraron aspectos dinamicos y fisicos del clima, inferidos a través de observaciones recientes.

Perspectiva

Los expertos coincidieron en expresar la previsión en términos probabilísticos. Para ello se identificaron tres categorías, a saber: Superior a lo Normal, Normal e Inferior a lo Normal, coincidentes con los terciles de la distribución histórica de la precipitación y la temperatura.

De este modo la previsión se presenta indicando la probabilidad de ocurrencia de cada una de estas tres categorías en los Mapas 1 y 2, que corresponden a la precipitación y la temperatura respectivamente.

Debido a la condición probabilística de las previsiones y tomando en cuenta la variabilidad espacial y temporal de los parámetros considerados, se recomienda a los usuarios de estos pronósticos que para mayor información, se contacten con las Instituciones participantes.

Análisis de la Previsión de la Precipitación, Mapa 1

I. Para el este del Chaco paraguayo, la región oriental del Paraguay y el este de la provincia de Formosa en Argentina, se prevé una mayor probabilidad de precipitación alrededor de lo normal.

II. Para la región central de la Argentina se prevé mayor probabilidad de precipitaciones iguales o superiores a lo normal.

III. Para el extremo suroeste de la región, junto a la Cordillera de los Andes, aproximadamente entre 35 y 40° sur se preve una mayor probabilidad de precipitaciones por encima de lo normal.

IV. Para la región comprendida en el noreste de la Patagonia, se prevén mayores probabilidades de precipitaciones por debajo de lo normal.

V. Para la región comprendida por gran parte de la Provincia de Buenos Aires, República Oriental del Uruguay y el litoral sur de Río Grande do Sul se prevé una mayor probabilidad de precipitaciones normales o levemente superiores a las normales.

mayor probabilidad de precipitaciones cercanas a lo normal.

Análisis de la Previsión de la Temperatura, Mapa 2

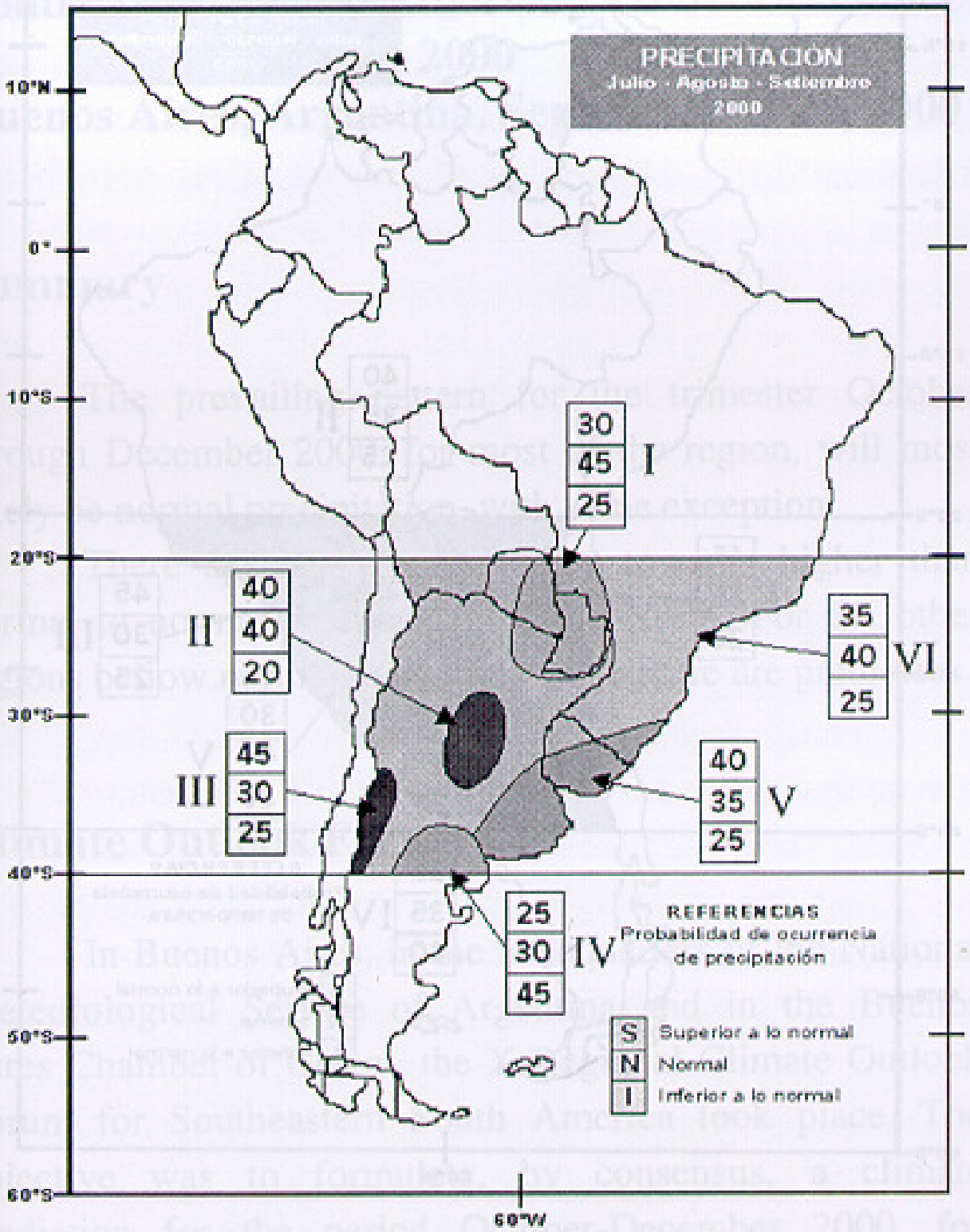
I, II, III. Para los estados de Sao Paulo, Mato Grosso do Sul, Paraná, y provincia de Misiones, así como la región del extremo noroeste de Argentina y Paraguay se prevé una mayor probabilidad de temperaturas por encima de lo normal.

IV. Desde el extremo sudoeste a 40° sur hacia el centro del Litoral argentino y oeste del Uruguay se prevé una mayor probabilidad de temperaturas levemente inferiores a la normal.

V. Para el resto de las áreas se prevén mayores probabilidades de temperaturas cercanas a los valores normales.

Para más informes referentes al IX Foro, favor contactar con los Organismos participantes o la Asociación Rural del Paraguay (ARP), Km 14, Ruta Transchaco, Mariano Roque Alonso, PARAGUAY.

Teléfonos: (595-21) 291061 / 292011, E-mail: farm@rieder.net.py.


PRECIPITACION
Julio - Agosto - Setiembre
2000
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
60°W
30
45
25
I
40
40
20
II
45
30
25
III
35
40
25
VI
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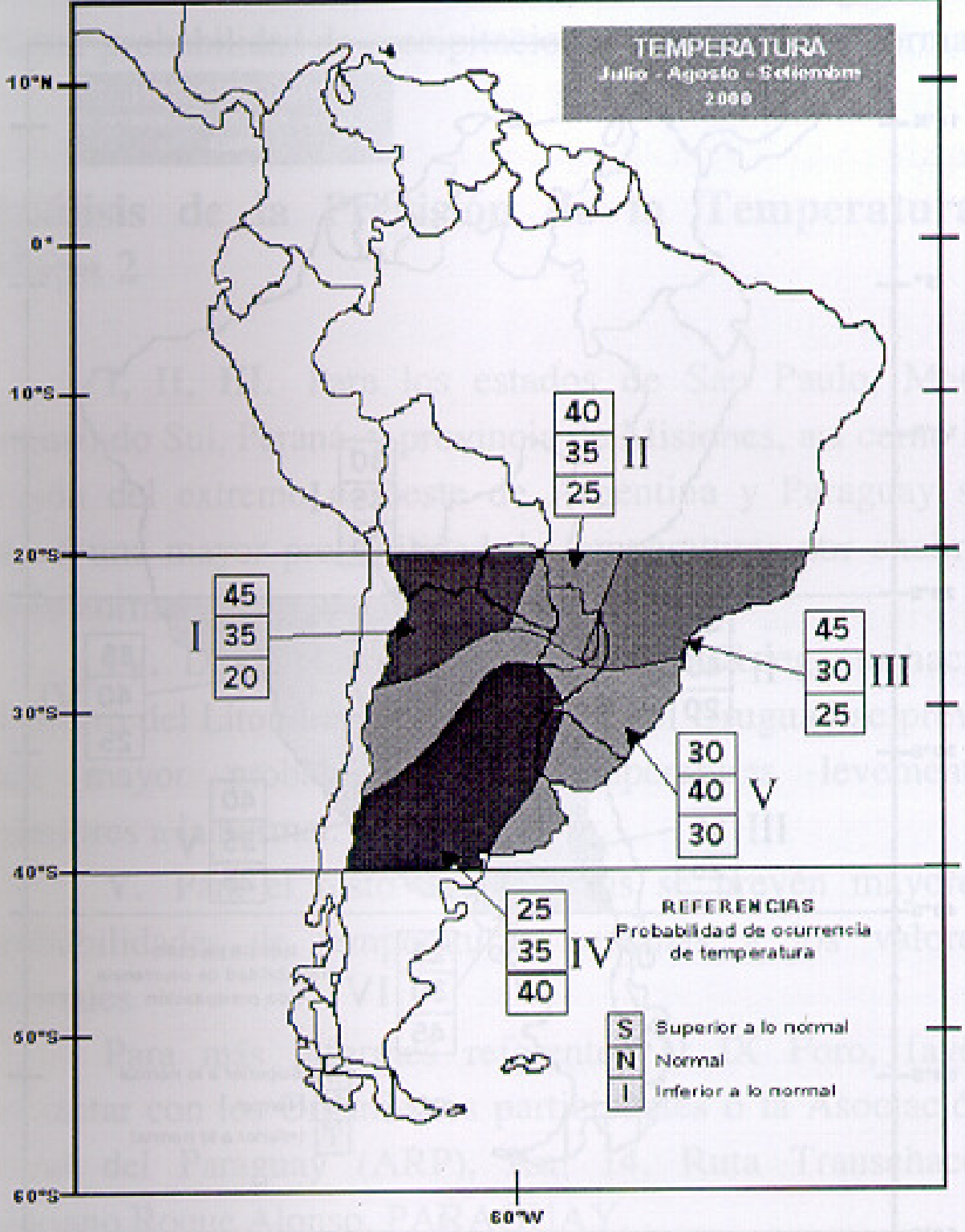
45
IV
REFERENCIAS
Probabilidad de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal


TEMPERATURA
Julio - Agosto - Setiembre
2000
10°N
0°
10°S
20°S
30°S
40°S
50°S
60°S
60°W
40
35
25
II
45
35
20
I
45
30
25
III
30
40
30
V
25
35
40
IV
REFERENCIAS
Probabilidad de ocurrencia de temperatura
S Superior a lo normal
N Normal
I Inferior a lo normal

Southeastern South America October-December 2000

Buenos Aires, Argentina, September 19-20, 2000

Summary

The prevailing pattern for the trimester October through December 2000, for most of the region, will most likely be normal precipitation, with some exception.

There appears to a tendency towards higher than normal to normal temperature in the North. For the other regions bellow normal to normal temperature are predicted.

Climate Outlook Forum

In Buenos Aires, in the headquarters of the National Meteorological Service of Argentina and in the Buenos Aires Chamber of Cereal, the X Regional Climate Outlook Forum for Southeastern South America took place. The objective was to formulate, by consensus, a climate prediction for the period October-December 2000, for Southeastern South America, from 20°N to 40°S, from the Eastern coast to the Andes. The Forum was organized by the Buenos Aires Chamber of Cereal, the Ocean and Atmosphere Research Center(CIMA),the National Commission for Global Change(CNCG&41;,The Department of Ocean and Atmosphere Science(DCAyO) incorporeted experts in climatology from and the Meteorological Services of Argentina(SMN),under the auspices of World Meteorological Organization(OMM) and

Innovation(SeTCIP).Participants at the Forum included representatives of Meteorological Services from Brazil,(INMET), Uruguay(DMN), Paraguay(DMH) and Argentina(SMN), University of Buenos Aires(Argentina), Coastal University(Santa Fé, Argentina), National University of the Assumption(Paraguay), University of the Republic(Uruguay), Center for Weather Forecast and Climate Studies(CPTEC/INPE, Brazil)and International Research Institute for Climate Prediction(IRI).

Methodology

These specialists reviewed the state of the global climate system and its implications for Southeastern South America. The principal factors taken into account were:

1. The observed temperature anomalies in the Equatorial Pacific and Southern Atlantic Oceans.

2. The sea-surface temperature (SST) were based on coupled ocean-atmosphere models (NCEP-NOAA) and indicates near-normal temperatures for the Equatorial Pacific Ocean.

3. The results of various studies and investigations developed in the region and through the use of climate prediction models from IRI and CPTEC-INPE.

4. The results of statistical models from SMN(Argentina), CIMA(Argentina),CPTEC-INPE (Brazil), and University of Republic (Uruguay).

The specialists reviewed the state of global climate, the results of experimental forecast models and statistical studies, there is no evidence to predict "El Niño" event for summer of 2001.

Outlook

The experts agreed to express the forecast in terms of probabilities by identifying three categories, above-normal to normal, Normal, and Below-normal, corresponding with a tercile distribution of historical precipitation and temperature.

In this way, the forecast is presented by indicating the probability of each of the three categories in Map 1 and 2, for precipitation and temperature, respectively.

The X Forum suggests that the users of these forecasts contact the participating institutions for more information.

Analysis of the Precipitation Forecast, Map 1

I. For the region including Central-western portion of Argentina, slightly above-normal precipitation is predicted.

II.For the Northwestern Argentina and Western Paraguay climatological probabilities are predicted.

III. For most of Paraguay, Eastern Argentina, Western Uruguay and Central-western Brazil, normal precipitation is predicted.

IV. For Northwestern Uruguay and Southern Brazil, slightly above-normal precipitation is predicted.

V. For Southeastern Brazil, below-normal precipitation is predicted.

Analysis of the Temperature Forecast, Map 2

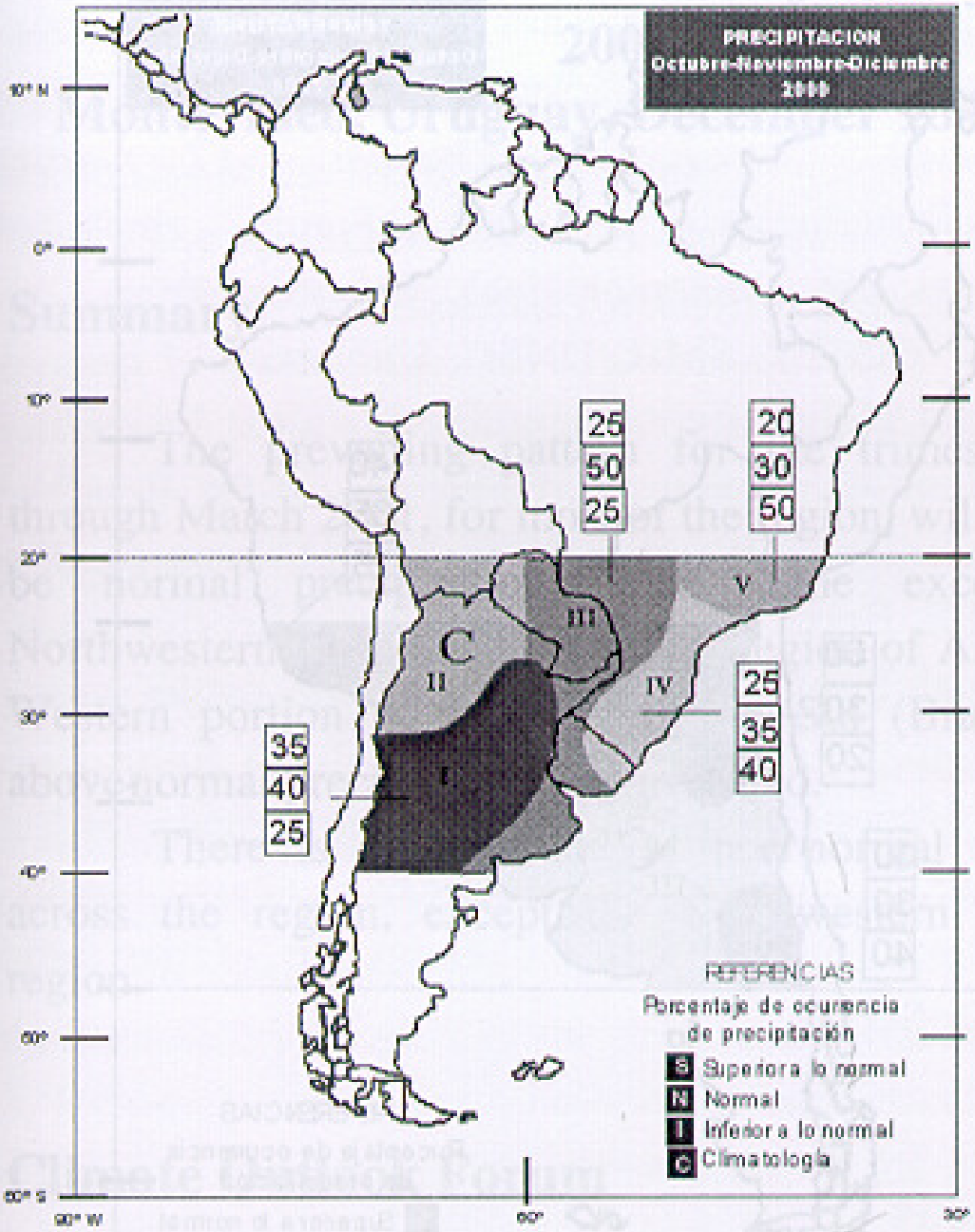
I. For Northwestern Argentina, above-normal temperatures are predicted.

II. For the region including Northern Argentina, Central-northern Paraguay and Northern Brazil, slightly above-normal temperatures are predicted.

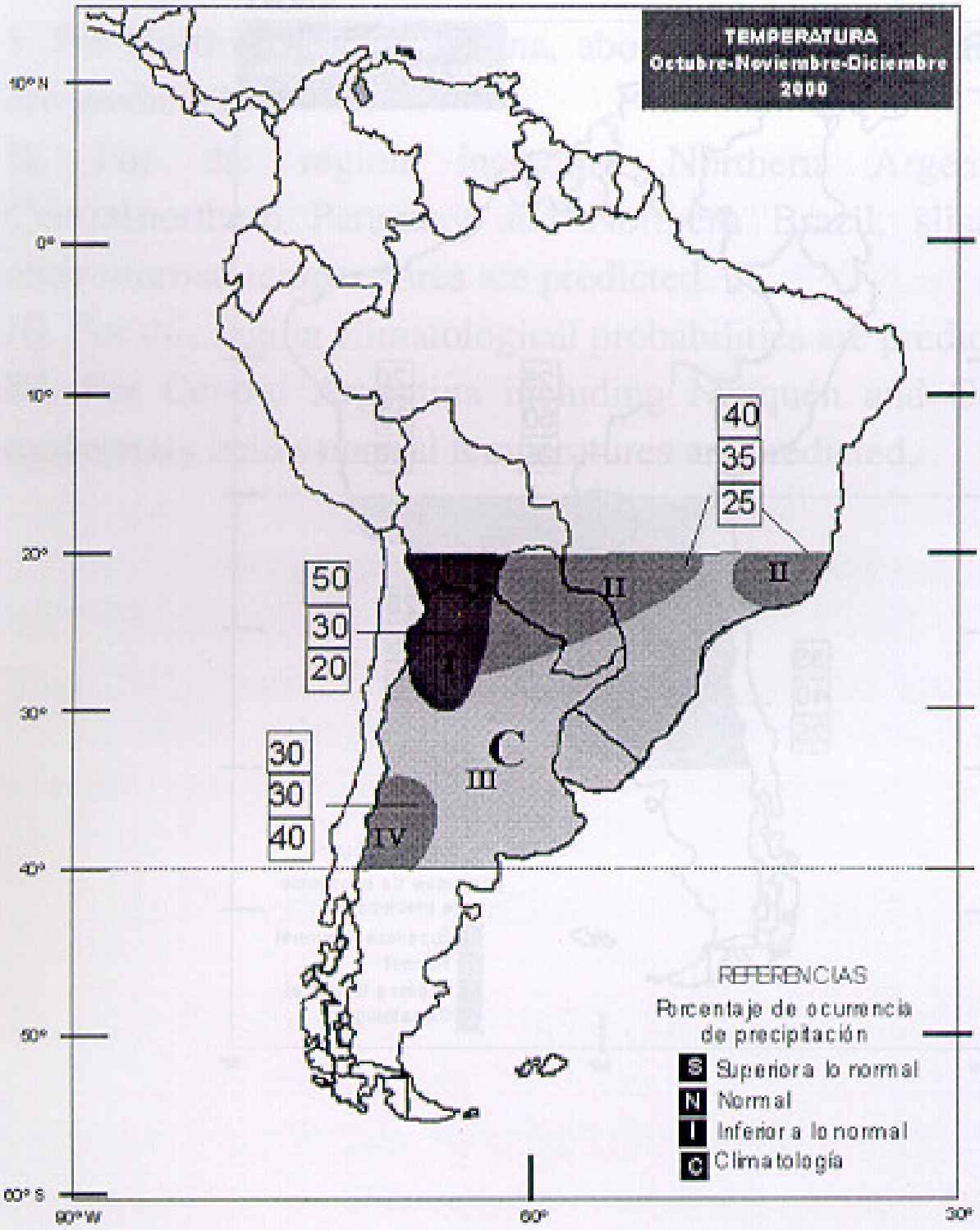
III. For this region climatological probabilities are predicted.

IV. For Central Argentina including Neuquén and Cuyo, moderately below-normal temperatures are predicted.

MAPA Nº 1


PRECIPITACION
Octubre-Noviembre-Diciembre
2000
10° N
0°
10°
20°
30°
40°
50°
50° S
90° W
60°
30°
25
50
25
20
30
50
25
35
40
35
40
25
C
I
II
III
IV
V
REFERENCIAS
Porcentaje de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal
C Climatología

MAPA Nº 2


TEMPERATURA
Octubre-Noviembre-Diciembre
2000
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
40
35
25
50
30
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30
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40
II
II
III
IV
C
REFERENCIAS
Porcentaje de ocurrencia de precipitación
S Superior a lo normal
N Normal
I Inferior a lo normal
C Climatología

XI Regional Climate Outlook Forum for Southeastern South America January-March 2001
Montevideo, Uruguay, December 18-19, 2000

Summary

The prevailing pattern for the trimester January through March 2001, for most of the region, will most likely be normal precipitation, with some exceptions for Northwestern Uruguay, the Coastal region of Argentina and Western portion of Rio Grande do Sul (Brazil) slightly above-normal precipitation are predicted.

There is a likelihood of near-normal temperature across the region, except the Northwestern part of the region.

Climate Outlook Forum

On December 18 and 19, 2000 the XI Climate Outlook Forum for Southeastern South America met in the National Administration for Electric power generation and Transmission Training Center (UTE), Montevideo, Uruguay.The objective was to formulate, by consensus, a climate prediction for the period January-February-March 2001, for Southeastern South America, from 20°N, to 40°S, from the Eastern coast to the Andes.

The Forum was organized by the University of the Republic and The Application Project for Climate Prediction in Agricultural and cattle raising Sectors(INIA-IFDC) and cosponsored by the World Meteorological

National Administration for Electric power generation and Transmission Training Center (UTE),the National Administration for Telecommunications(ANTEL), INAVI,Channel 4 and Channel 12 from Montevideo.Participants at the Forum included representatives of Metereological Services from the region(SMN, INMET, SMH, DNM), University of Buenos Aires, Coastal University (Argentina), National University of the Assumption (Paraguay), University of the Republic (Uruguay), Center for Weather Forecast and Climate Studies (CPTEC-INPE, Brazil). Also the Forum included specialists from National Institute for Agricultural and cattle raising studies (Uruguay), National University of the Entre Rios (Argentina) National University of the Rio Grande do Sul (Porto Alegre, RS, Brazil) EMBRAPA-trigo (Passo Fundo, RS, Brasil) and the Technical Commission of the Salto Grande (CTMSG).

Methodology

These specialists reviewed the state of the global climate system and its implications for Southeastern South America. The principal factors taken into account were:

1.The precipitation and temperature prediction for the period of January through March 2001 from INMET (Brazil), SMN (Argentina) and DNM (Uruguay).

2. The observed temperature anomalies in the Equatorial Pacific and Southern Atlantic Oceans.

3.The results of experimental forecast models, coupled ocean-atmosphere models (CPTEC, ECMWF, UKMO) and the results of CCM3 and ECHAM models

from The International Research Institute for Climate Prediction (IRI).

4.The results of statistical models from SMN (Argentina), CPTEC-INPE (Brazil), INMET (Brazil) and University of the Republic (Uruguay).

The specialists reviewed the state of global climate, the results of experimental forecast models and statistical studies.

Outlook

The experts established pobability distributions to indicate the likelihood of Above-normal to normal, Normal, and Below-normal to normal, corresponding with a tercile distribution of historical precipitation and temperatures.

In this way, the forecast is presented by indicating the probability of each of the three categories in Map1 and 2, for precipitation and temperature, respectively. The C is defined as climatological probabilities, is the 33.3% of the recorded amounts.

The XI Forum suggests that the users of these forecasts contact the participating institutions for more information.

Analysis of the Precipitation Forecast, Map 1

For the January-March 2001 period, the precipitation outlook for each zone within the region is given below.

Zone I: (Western Argentina) Likelihood of climatological probabilities.

America, except Northeastern Uruguay and the Coastal region of Argentina) Likelihood of normal precipitation.

Zone III: (Northeastern Uruguay, the Coastal region of Argentina and Western Rio Grande do Sul (Brazil)) Likelihood of below-normal precipitation.

Zone IV: (Western region of Chaco (Paraguay) and Northeastern Argentina including Northern portion of Mendoza) Likelihood of below-normal precipitation.

Zone V: (Southeastern Brazil (Rio de Janeiro, São Paulo and Easthern Paraná)) Likelihood of climatological probabilities.

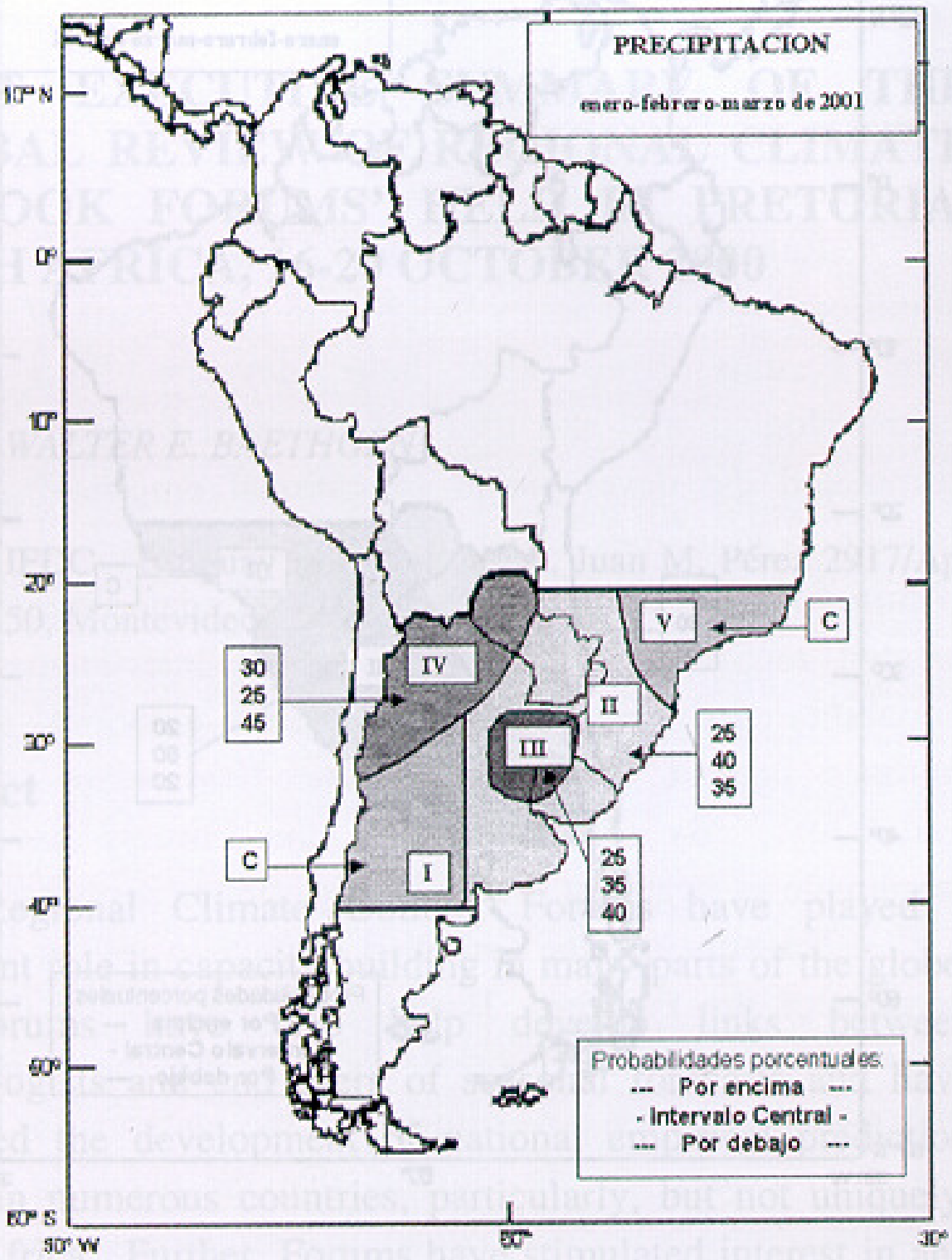
Analysis of the Temperature Forecast, Map 2

For the January-March period, the temperature outlook for each zone within the region is given below.

Zone I: (Western region of Chaco (Paraguay) and Northeastern Argentina including Northern portion of Mendoza) Likelihood of normal temperature.

Zone II: (Central region of of Southeastern South America) Likelihood of normal temperature.

Zone III: (Southeastern Brazil (São Paulo and Easthern Paraná)) Likelihood of climatological probabilities.


PRECIPITACION
enero-febrero-marzo de 2001
10° N
0°
10°
20°
30°
40°
50°
60° S
50° W
50°
30°
30
25
45
IV
C
I
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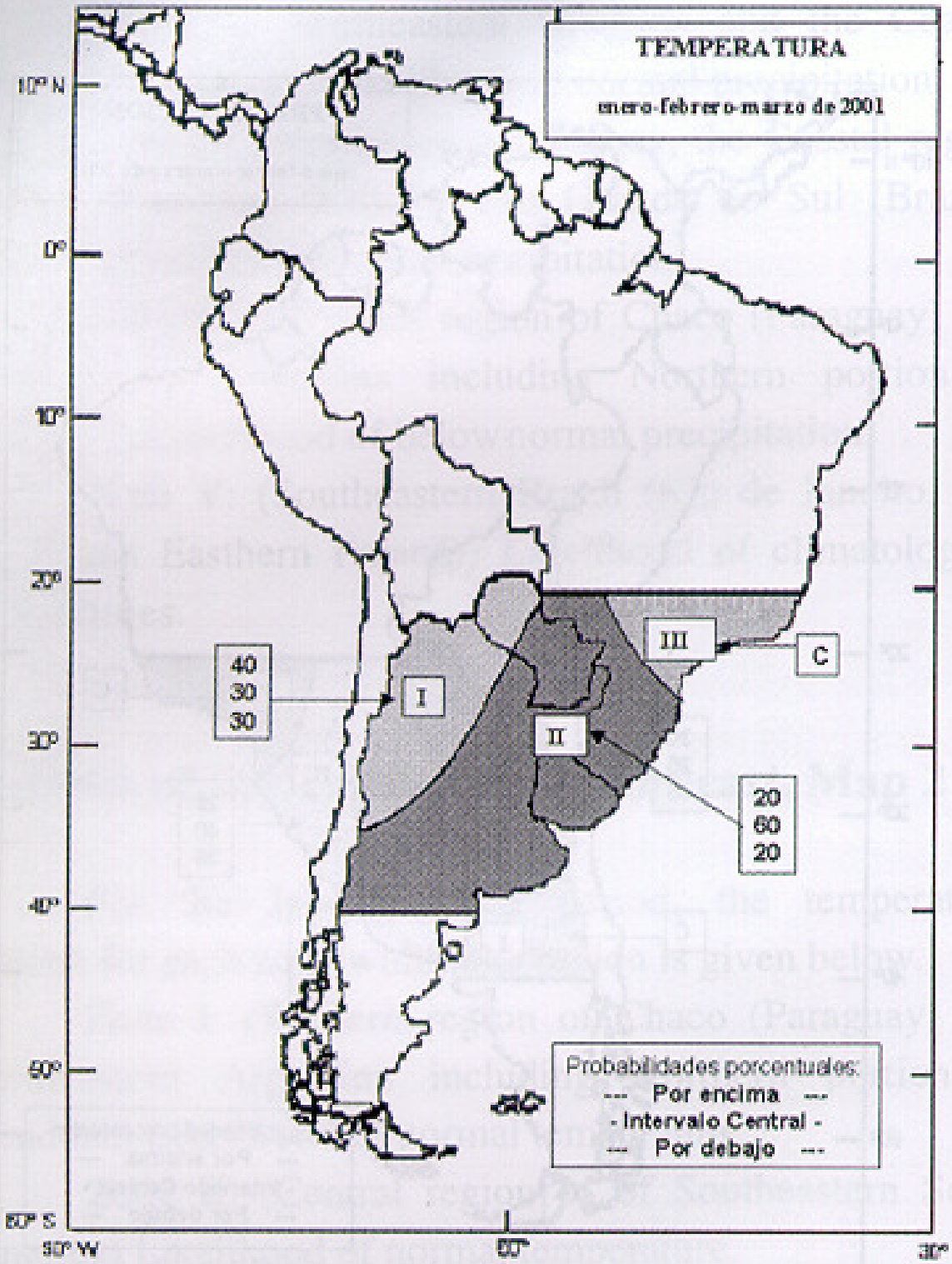
II
V
C
25
40
35
25
35
40
Probabilidades porcentuales:
--- Por encima ---
- Intervalo Central -
--- Por debajo ---


TEMPERATURA
enero-febrero-marzo de 2001
10° N
0°
10°
20°
30°
40°
50°
60° S
90° W
60°
30°
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I
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Probabilidades porcentuales:
--- Por encima ---
- Intervalo Central -
--- Por debajo ---

DRAFT EXECUTIVE SUMMARY OF THE 'GLOBAL REVIEW OF REGIONAL CLIMATE OUTLOOK FORUMS' HELD IN PRETORIA, SOUTH AFRICA, 16-20 OCTOBER 2000

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Abstract

Regional Climate Outlook Forums have played a significant role in capacity building in many parts of the globe. The Forums have also help develop links between meteorologists and end users of seasonal forecasts and have stimulated the development of national empirical prediction models in numerous countries, particularly, but not uniquely, within Africa. Further, Forums have stimulated interest in and created recognition of the impacts of inter-annual climate variability and assisted in developing activities that both mitigate against these impacts and help adapt to climate variability. By many measures the Forums have proved invaluable as a catalyst to developing climate services.

This chapter is a draft executive summary of the 'Global Review of Regional Climate Outlook Forums' held in Pretoria, South Africa, 16-20 October 2000.

1. Introduction

Regional Climate Outlook Forums have played a significant role in capacity building in many parts of the globe. The Forums have also help develop links between meteorologists and end users of seasonal forecasts and have stimulated the development of national empirical prediction models in numerous countries, particularly, but not uniquely, within Africa. Further, Forums have stimulated interest in and created recognition of the impacts of inter-annual climate variability and assisted in developing activities that both mitigate against these impacts and help adapt to climate variability. By many measures the Forums have proved invaluable as a catalyst to developing climate services.

Nevertheless the time had arrived to review the entire process of the Forums. Background reasons for the review were that the science of prediction was moving forward, that understanding of the possibilities and the methods for using the Forum forecasts was developing, that the needs of the users were becoming better understood, that an improved approach to training was required, and that the cost of the Forums was causing concern in terms of long-term sustainability. Thus the Review was organised to consider two major questions, which together encapsulated the above:

a) to what extent, and how, might the outputs of the Forums be improved for the benefit of end users of the information; and
b) how might the process of developing and delivering forecast information and training be made sustainable?

In order to address these two questions, the meeting was required to review the entire Forum process and to consider ways in which improvements could be made and costs reduced or made sustainable. There was no restriction on limiting proposals simply to adjusting the current Forum process, with innovative and radical solutions sought throughout.

Representatives from all regions in which Forums had been held or had been considered attended the Workshop. At least two delegates attended from each region, one representing the meteorological side and the second an applications area. Further experts in applications were invited, with a balance maintained to incorporate all major applications areas. Additional experts in various meteorological disciplines also participated. Members of the media were invited to provide advice on communications with end users. In total 60 delegates attended the meeting.

The first day was spent in plenary review of the current status of various aspects of the Forum process and of important associated issues. Representatives of all regions made solicited presentations, from both the meteorological and applications perspectives. Further reports were presented on technical issues of forecasting, interfacing with users, sustainability of the Forums, and dissemination and the role of the media. Working Group sessions, with plenary feedback, occupied all remaining days.

On the Tuesday Working Groups considered *Alternative Forecast Products and Processes*; *Marketing and Demand Stimulation*; and *User/Forecaster Interaction*. Topics on the Wednesday included *Climate Forecasting and Information*

and *Climate Forecasting and Applications Research and Development.*

The final set of Working Groups on the Thursday considered **Regional Issues, including Sustainability**, for *Africa*, for *Latin America*, and for the *Caribbean, the Pacific Islands and Southeast Asia.* Other Working Groups examined **The Delivery of Products**, including the necessary *Networking and Communications*, infrastructure developments in terms of proposals for a *Climate Forecasting and Information System*, and also developed a *Media Strategy.* A further Working Group examined ***Capacity Building***, while **Technical Issues** were handled under *Climate Forecasting and Applications Research and Development* and *Verification.*

2. Overarching conclusions

Various common themes recurred throughout the discussions. These included:

a) the recognition of three Forum stakeholders partners, that is, forecasters, intermediaries, and end users;
b) the need for new end-user products such as start of rainy season, occurrence of dry spells, and improved spatial and temporal resolution;
c) the Forum as a process of regional and national meetings, perhaps linking to existing national organizations such as agriculture, health, water resources and disaster mitigation;
d) the need for research pilot programs to address many of the unanswered questions concerning end-to-end forecasting.

A Climate Outlook Forum may be seen as a three-part process of:

(1) a regional meeting to develop and discuss a regional forecast;

(2) a regional training meeting for forecasters and intermediaries and;

(3) a national meeting to disseminate the forecast to intermediaries and those end-users with enough knowledge to use the forecast directly.

Not all regions have implemented all three parts of the Forum process. One of the many advantages of this process is that it allows national forecasters to interact with international and other national forecasters at the regional meeting to verify that their forecasts are consistent with those of others.

The final objective of the Forum process is to meet end-user needs. For success of the process, there is need to clearly define the characteristics and needs of intermediaries and end users. Though there have been many successes in the parts of the Forum process, shortcomings of the process in the various regions, as recognised during the meeting, need to be addressed.

The process might be improved if there was more systematic organisation of the roles and responsibilities of Forum partners including users, researchers, and operational organisations. It was felt that participants in Forums should also build upon existing relationships to accomplish the objectives of the process. Systematic management is also needed to organise and keep track of regional and national forums to ensure they are coordinated and receive the necessary financial and managerial support.

There are other considerations in the Forum process. Complex numerical models run at major prediction centres are essential parts of the forecasting process as many Forums start from their output and their use will also eventually allow forecasters to provide more detailed predictions than those of the present tercile system with its broad spatial scale. There is also the need to carry out hindcast studies to test forecasting capabilities.

In order to carry the process forward partnerships are needed at all levels. These include partnerships between the research and operational communities (such as National Meteorological Services) to define research needs, and the operational and user communities to define end products. If these partnerships are to lead to improved data exchange between National Meteorological Services and other meteorological organisations, the value of sharing data among partners needs to be demonstrated. The availability of data was, perhaps, the single most important concern linking all discussions, an issue raised in many sessions, by a variety of delegates and in a number of contexts. There was full agreement that most activities in the development of climate information and prediction services required adequate access to the data by all involved, the data being both meteorological/climatological as well as applications-related. There was also full agreement that a satisfactory level of access was not available to any individual worker or group. No specific and achievable recommendations to handle the data issue were made during the course of the Workshop.

The Regional Climate Outlook Forum review workshop identified a comprehensive and rich set of follow-up actions

along both thematic and regional lines. Implementation of these actions would significantly enhance the application of climate information in regions affected by seasonal to inter-annual climate variability. A common characteristic was the need for vertical and horizontal integration and coordination from the national through the regional to the international (global) level and as well as across thematic areas in order for the identified actions to be fully implemented and the benefits realised.

Consequently, four overarching measures were proposed.

O1. The Regional Climate Outlook Forum Review follow-up actions should be pursued systematically and in an organised fashion.

O2. Based on the strength of the Forum Review findings, organisations that did not participate directly in the Review should also be enlisted in pursuit of a common agenda.

O3. The process of development initiated in the Pretoria Review meeting should be continued in a methodological manner through regular sessions at all future Forums.

O4. There should be continuing and expanding interaction between Forums to ensure information transfer and to intercompare outcomes.

In order to manage the process of making the required linkages and mobilising the required resources, an appropriate, flexible follow-up organisational structure is required. According to the outcomes of the review, this organisational structure should have both thematic and regional components. Furthermore, owing to the numerous linkages, particularly

organisational elements need to be able to call upon one another to assist with the research, development and implementation of the various actions identified. For clarity, transparency and accountability, the organisational elements should be sufficiently formalised to be able to identify and fulfil mutual expectations. In this way the elements would function together as a single enterprise working towards a common goal.

3. Main Recommendations

In addition to the overarching conclusions outlined above, the final nine Working Groups developed a series of more specific conclusions. Broadly these Working Groups covered a) Regional Issues, including Sustainability, b) The Delivery of Products, c) Capacity Building, and d) Technical Issues. Key conclusions from these Groups are provided in the following; a full list of recommendations is provided in each Working Group Report..

4. Regional Issues, including Sustainability

All regional Working Groups concurred on the need for sustainability, but no specific solutions to the immediate sustainability problem were forthcoming. A variety of proposals for future infrastructures were developed, with differences in regional characteristics and needs prominent. In Africa, for example, there was recognition that 'ownership now lies squarely with national and regional players' and indicated

that 'the new vision is to move towards increased national responsibility'. The Caribbean, Pacific Islands and Southeast Asia group stated, on the other hand, that 'the climate forecasting and information needs of all three sub-regions can only be met through the enhancement or establishment of regional climate and information centres', in recognition of limited national capabilities. An improved regional structure was also recommended within Latin America.

All regions recognised the necessity to improve the infrastructure, regional and national capacity and expertise, products and delivery methods. Further institutional support is necessary, however, to achieve these objectives, which currently do not necessarily lie within the grasp of the regions themselves. Regional management teams or task forces have been proposed to examine in more detail the outcomes of the Workshop and to identify routes for future development; one such group, for Latin America, was established in an *ad hoc* manner during the Workshop itself.

Specific recommendations from these Working Groups follow. An attempt has been made to integrate similar recommendations from different groups into a single recommendation. Recommendations specific to a particular region have been identified as such.

R1. Continue capacity building, ensuring maintenance of expertise at cutting edge. Hold national training workshops for all involved, from meteorologists through the chain to end users.

R2. Develop a research and implementation agenda appropriate for all regions, including issues such as downscaling for specific locations, sectors and applications.

R3. Conduct end-to-end demonstration projects in all areas and applications sectors.

R4. Prepare training materials.

R5. Select and train {intermediary} trainers.

R6. Create user demand and awareness, including holding Workshops for policy makers.

R7. In Africa, plan the transition of the Forum process to the NMHSs, with mandating of regional centres during the transfer process

R8. Improve access to GCMs and statistical model predictions at regional and national levels.

R9. Explore virtual forums, video conferencing, and any other options for using new technologies etc., as possible methods for reducing costs.

R10. In Africa establish regional management teams to prepare a strategy on development of the entire process, including funding.

R11. In the Caribbean, Pacific and Southeast Asia, enhance or establish regional climate and information centres. Specifically in Southeast Asia develop an integrated and comprehensive Southeast Asian Climate Forecast Information System.

5. The Delivery of Products

One point made by several of the Working Groups is that long-term sustainability of climate information and prediction services is unlikely to be achievable until it can be demonstrated that the information and predictions are being used. In some respects sustainability becomes an issue of

providing improvements in services, as well as information and training on these services, and that issue in turn links into the need for focused research and development activities.

Specific recommendations from the *Climate Forecasting and Information System*, *Networking and Communications*, and *Networking and Communications* Working Groups follow.

D1. Recent climate anomalies are an important factor in affecting current variability, and therefore the monitoring capabilities and climatological databases of national and regional climate centres should be strengthened. Computing and related software facilities need to be improved consistent with the requirement.

D2. Discriminate periods into those in which major climate events are taking place from the rest, and focus long-term development activities into the latter.

D3. Establish regional networks of researchers for both climate and applications working within, at least in part, regional research programmes.

D4. Establish research and development methods for applications, enabling, amongst other things, the undertaking of in-depth economic studies to quantify forecast value.

D5. Develop a new pro-active media strategy on International, Regional and National levels. Base this strategy, including immediate and long-term components, around the networking capabilities of the WMO Information and Public Affairs Office.

D6. Ensure the participation of a media expert at each Forum to assist Forum managers in promoting the meeting and

its outcomes and for developing news items. Provide training for these experts.

D7. Develop a "communication culture" within scientific communities.

6. Capacity Building

The Capacity Building Working Group made the observation that sustainability will come about especially if national producers and users see themselves as full, qualified partners in the production/interpretation/usage chain, and a feeling of ownership is engendered. The Group also noted that investment is the key to future success for both information producers and users and that the greatest return on investment will be gained from strengthening the interface between the national producers and the intermediaries that help translate forecast products.

Specific recommendations from the *Capacity Building* Working Group follow.

C1. Supplement Forum-type training with a range of on-going professional development courses and activities, while ensuring institutional commitment to the training and deployment of personnel.

C2. Re-examine national needs for computing technology.

C3. Develop a cadre of sector-specific intermediaries for improved, sector-specific product translation and dissemination.

C4. Develop sector-specific databases, research capabilities and dissemination through specific products based on translated predictions.

7. Technical Issues

A major part of the solution to the issues raised in the Workshop lies in the development of technical aspects of the entire Forum process, with the objectives of providing improvements to the products themselves. To the manner in which they are produced, and to the manner in which their quality is broadcast. Specific recommendations from the *Climate Forecasting and Applications Research and Development* and *Verification* Working Groups follow.

T1. Shape and implement a research agenda for applications, informed by user needs.

T2. Shape and implement a research agenda for forecasts, informed by scientific developments.

T3. Identify and address gaps that constrain the wider use of climate information.

T4. Examine the extent to which current Forum predictions can be downscaled to a $2^{o}x2^{o}$ region.

T5. Develop a 30-year historical set of Forum products for estimation of the quality and value of the products using a statistical combinatory process on predictions created using current models.

T6. Examine on a regular basis whether or not the progress of a season is consistent with the Forum product.

T7. Develop a summary of the performance of all Forums to date using a consistent methodology.

T8. Undertake further analyses of the value obtained through use of Forum products.

8. Some concluding remarks from the Organising Committee

The Review of Regional Climate Outlook Forums was a successful, stimulating meeting at which many ideas were proposed and accessed. In terms of the first of the two major questions to be addresses – to what extent, and how, might the outputs of the Forums be improved for the benefit of end users of the information? – many recommendations were made. Further attention to the frequently-stated needs of the user community through research provided a common response to this question, but more importantly perhaps were the recommendations on education and verification. Without doubt impediments to the uptake of climate forecasts include the complexity of the presentation methods, the limited understanding of probabilities, and the difficulties of interpretation of the forecasts in terms of leading to beneficial decisions for users. The combined proposals for research, education and improved forecast assessment will together move the process towards the elimination of such impediments. Many of the activities recommended in this context can be handled on a regional basis, but it is clear that international assistance and coordination will be required to a certain extent. Continuing exposure of these issues at Forums, and the closer linking together of Forums through information exchange as proposed at the Meeting, will also play significant roles in achieving elimination of these impediments.

In terms of the second major question - how might the process of developing and delivering forecast information and

training be made sustainable? – the outcomes were less immediately clear, although the issue was recognised in all regions and initial steps taken to progress discussion. Incorporation of additional stakeholders through development of ownership, translation of ownership to national levels, and use of new technology, were just three of the proposals made within the context of sustainability. None of these approaches can be made within a brief period of time and it is clear that the Forums will continue in essentially their current forms for the immediate future – provided funding can be arranged. The funding situation varies substantially between regions, with some well placed for the time being, and others reaching the end of their current resources. A prime objective of the regional management activities proposed for all areas must be to address this issue.

The level of success achieved by the Forum process in many respects is noteworthy. Many of those involved around the World appear convinced that the Forums and their successor mechanisms will play a substantive role in approaches to managing climate variability for years to come. The Organising Committee will formulate actions at the international level to address many of the recommendations made. Most success is likely to be gained, however, through organisers and attendees of individual Forums taking ownership of the issues and recommendations of the Review Meeting and responding proactively to the challenges presented.

THE IRI's PRECIPITATION PREDICTIONS FOR 2001 FOR SOUTHEASTERN SOUTH AMERICA, AND HOW THEY WERE DEVELOPED

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Abstract

Every month, the IRI makes forecasts for the global temperature and precipitation for the coming two 3-month periods. Due to the substantial uncertainty of the forecasts, they are given in a probabilistic format with respect to the three terciles of the climatological distribution. Here we present IRI's precipitation forecast for the period of May-June-July 2001 in southeastern South America.

The IRI's forecasts are based mainly on the indications of three dynamical general circulation models forced by predicted as well as persisted global SST. For the April-May-June period, these forecasts show a weak tendency for above-normal precipitation in northern Argentina, and below normal precipitation in central Argentina in the southern portion of Zone II (as defined by past southeastern South American

below normal SST predicted for off the southeastern coast of Argentina, and above normal SST farther north off the coast of southeast Brazil.

1. The IRI Forecast Process

Starting in late 1997, the IRI has made near-global forecasts of anomalies of temperature and precipitation four times per year. Each forecast contains an outlook for the coming 3-month season and for the 3-month season following that one. Forecasts are issued in late March, June, September, and December. The forecast made in late June, for example, would contain outlooks for the periods of July-September and October-December. In the discussions that follow, the two seasons being forecast are called the two target seasons.

Because anomalies of SST--particularly tropical SST--are known to be a basic cause of atmospheric climate anomalies, forecasting the SST anomalies for the two target seasons is the first part of the climate forecasting task. Since SST anomalies usually change slowly, persistence of the observed SST anomalies for the most recent month is done for the first forecast period, in addition to using forecast SST anomalies. The version using persisted SST anomalies can be thought of as a control forecast that is roughly representative, and in fact may be weighted fairly highly for certain regions that are governed by the SST in locations where the forecast SST is known to be very uncertain. Sometimes cases the persisted and the forecast SST are found to differ by only small amounts over appreciable areas of the globe, and by moderate

amounts only in a minority of locations. However, the second target season cannot be approximated using persisted SST anomalies because the anomalies may change significantly in many regions over 4 to 6 months.

2. SST Forecasts

The SST forecasts are made using a dynamical model for the tropical Pacific SST, and statistical models for the Indian Ocean and tropical Atlantic Ocean. From 1997 to the time of this writing in April 2001, the model given the most weight for tropical Pacific SST is that of the National Centers for Environmental Prediction (NCEP). The NCEP forecasts cover the area from 30N to 25S, and 70W to 120E. Predictions from other dynamical models are also examined, such as the COLA model and the model run at the European Center for Medium Range Weather Forecasts (ECMWF). Forecasts of the tropical Atlantic SST are made using the statistical canonical correlation analysis (CCA) model of CPTEC/INPE in Brazil, using the tropical Atlantic and Pacific SST fields as predictors. Similarly, forecasts of the Indian Ocean are presently done at the IRI using a CCA model, using the observed Indo-Pacific SST anomalies, and the forecasts of the Pacific SST field, as predictors. This Indian Ocean CCA model makes use of, among other things, the observed tendency for the Indian Oceans SST anomalies to approximately follow the ENSO-related SST anomalies of the tropical Pacific, with a lag time of a few months. Prediction of the Indian, and especially the tropical

Examination of the dynamical model forecasts of the global SST run at the ECMWF indicates that they may have sufficient skill to replace the statistical predictions now used for the Atlantic and Indian oceans. For the extratropical latitudes of all of the oceans, the SST anomalies of the most recent month are slowly damped toward the target period's observed climatological normals, such that the anomalies become about 0.7 of their observed value by the middle month of the initial target period and about 0.2 of that value by the middle month of the second target period. This very simple forecasting procedure for extratropical SST is based on the fact that extratropical SST is often unable to be predicted with adequate skill, and also that the SST outside the tropics has a less significant influence on the continental climate than does tropical SST.

3. Using the predicted SST to forecast the global climate

The second step of the two-tiered forecasting consists of using the SST as a prescribed condition for the running of several atmospheric general circulation models (GCMs) to predict the global climate. The GCMs predict, among other things, the surface air temperature and precipitation. Three models are currently (as of early 2001) run for each forecast: The MRF9 from the NCEP, the ECHAM3 from Max Planck Institute, and the CCM3 from the National Center for Atmospheric Research (NCAR). These models are run at T42 spatial resolution, which is approximately 2.8 degrees of

longitude and latitude, and using about 18 vertical levels. During the years 2001 and 2002, more refined versions of these models (e.g. higher spatial resolution [such as T63], or improved physical representations), and perhaps additional models to the current three, may be used. For example, the models of COLA in Calverton, Maryland and NASA/Goddard in Greenbelt, Maryland, are now being examined in addition to the original three models. Ensembles of 10 runs are produced from each of the models, where the ensemble members are exposed to the same predicted (or persisted) SST but initialized with differing atmospheric initial conditions. The use of several GCMs helps achieve a greater area of the globe that has some reliable forecast indications, given that each model's strengths and weaknesses differ and the weaknesses of one may be counterbalanced by the strengths of another. In total, there are thus 30 runs from the original three models, and 50 for the first target period if the persisted SST runs are included also. (The persisted SST scenario is not run for the NCEP model.)

A schematic diagram showing the IRI's forecasting procedure is shown in Figure 1.

4. The Forecasts Made in Mid-March 2001

4.1. Forecast for April-May-June 2001

The SST forecast for April through June 2001 is shown in Figure 2. The long-lived La Nina is finally expected to

later in the year; this may be an El Nino or it may be only a mild warming tendency. The warm Atlantic SST currently off the southeastern Brazil coast, as well as the Pacific SST off the southern coast of Chile, are expected to continue but weaken somewhat. The cool SST currently off the southeastern Argentina coast and off the southern coast of Chile are also expected to continue but weaken. The above SST anomalies are among the factors leading to a very slight forecast tendency toward above-normal precipitation in northern Argentina, and a somewhat stronger indication for below normal precipitation in central Argentina in the southern portion of Zone II (as defined by past southeastern South American Climate Outlook Fora). The neutral ENSO situation probably cannot be held responsible for these precipitation anomalies. The precipitation forecast for the globe for April-May-June 2001, in terms of a weighted multi-model ensemble from the three original GCMs mentioned above, is shown in Figure 3. The colors in Fig. 3 indicate the probability of the tercile forecast to have the highest probability of occurrence. The green and blue indicate enhanced wetness, while the yellow, orange, brown and red show enhanced dryness.

4.2. Forecast for July-August-September 2001

The SST forecast for July through September 2001 is shown in Figure 4. The tropical Pacific SST is expected to be warmer than normal, with anomalies of 0.5 to 1.0C. The Atlantic SST anomalies bordering southern Brazil, Uruguay and Argentina, as well as the Pacific SST anomalies off the coast of

Chile, are predicted to be similar to those predicted for April-May-June except that they are much weaker. These extratropical SST anomalies, in conjunction with the predicted warmish ENSO situation, help produce a forecast for enhanced probabilities of below-normal precipitation in southern Brazil and southern Paraguay, and very slightly enhanced probabilities for above normal precipitation in parts of northern Argentina and extreme southern Uruguay. The weighted multi-model ensemble precipitation forecast for the globe for July-August-September is shown in Figure 5.

5. Dominant Models in Shaping the Southeastern South American Forecasts

The precipitation forecasts shown in Figs. 3 and 5 are based on multi-model consolidations of the three dynamical models, where the weights of the models are based on their historical performance in simulations using simultaneous observed global SST. Thus, 30 ensemble forecasts (10 from each model) are taken into account. For southeastern South American region of concern, the models having the most influence in April-May-June are ECHAM and CCM3 in southeastern Brazil and mainly the ECHAM in southern Uruguay and adjacent coastal Argentina. In July-August-September the ECHAM model has the highest performance record throughout most of the region, and is thus weighted most heavily. The NCEP model generally has the lowest weight in both seasons over much of the region, although its historical

model weights, while likely approximately correct, has some error based on the fact that in an actual forecast the SST is also being forecast, and is therefore not "perfect" as it is in the simulations (mentioned above) used to estimate model performance over a long period. It is possible that the imperfection of the SST forecast will reduce the skill by a greater proportion in one model than in another. Research is currently underway at the IRI to estimate model skills based on imperfectly forecast SST rather than observed SST. The problem is complicated by the fact that the skills are based on the climate circumstances as well as the degree of imperfection in the forecasts of SSTs in the regions that are most relevant to a given land location.

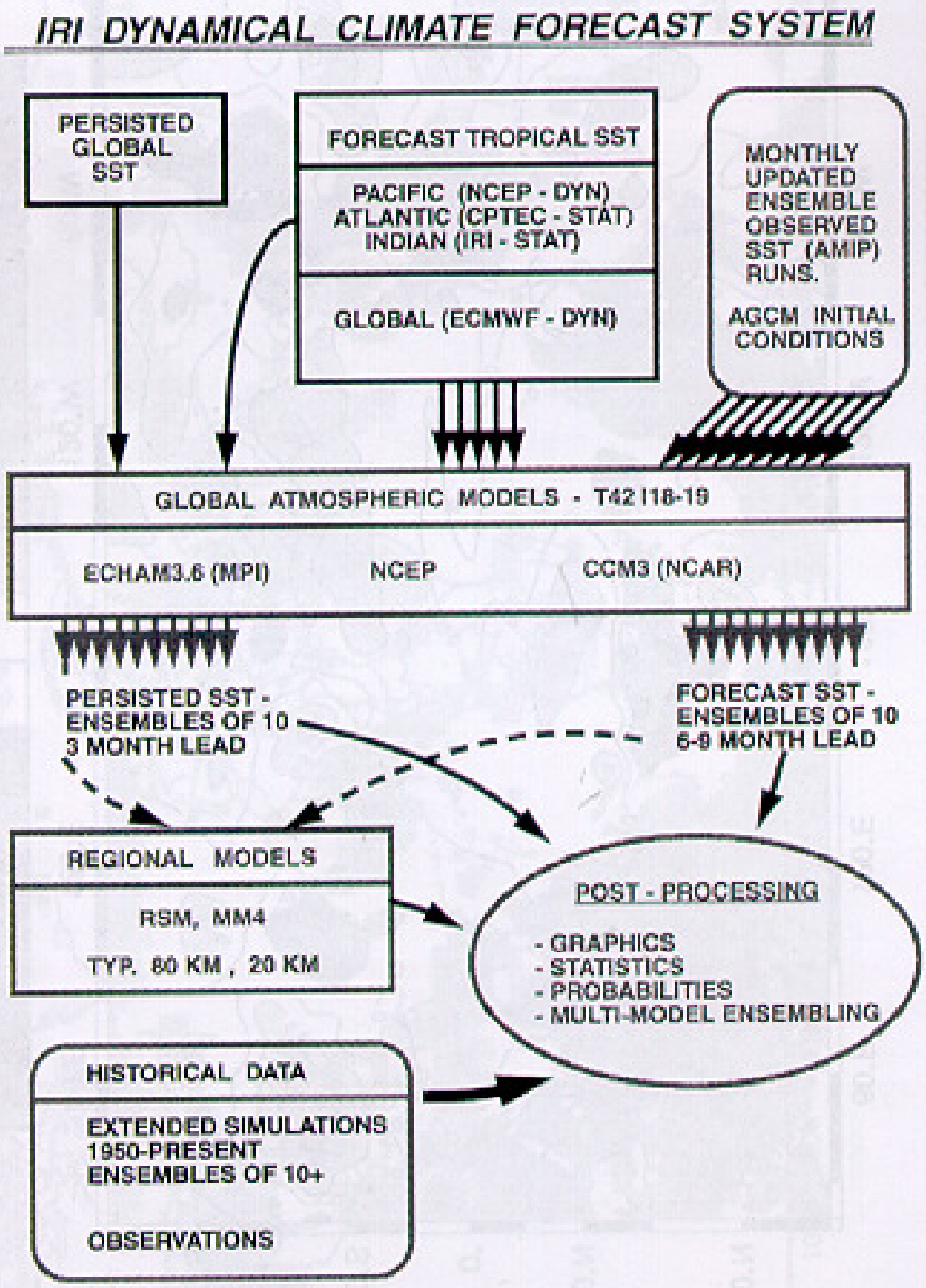

IRI DYNAMICAL CLIMATE FORECAST SYSTEM
PERSISTED GLOBAL SST
FORECAST TROPICAL SST
PACIFIC (NCEP - DYN)
ATLANTIC (CPTEC - STAT)
INDIAN (IRI - STAT)
GLOBAL (ECMWF - DYN)
MONTHLY UPDATED ENSEMBLE OBSERVED SST (AMIP) RUNS.
AGCM INITIAL CONDITIONS
GLOBAL ATMOSPHERIC MODELS - T42 L18-19
ECHAM3.6 (MPI)
NCEP
CCM3 (NCAR)
PERSISTED SST - ENSEMBLES OF 10 3 MONTH LEAD
FORECAST SST - ENSEMBLES OF 10 6-9 MONTH LEAD
REGIONAL MODELS
RSM, MM4
TYP. 80 KM , 20 KM
POST - PROCESSING
- GRAPHICS
- STATISTICS
- PROBABILITIES
- MULTI-MODEL ENSEMBLING
HISTORICAL DATA
EXTENDED SIMULATIONS 1950-PRESENT ENSEMBLES OF 10+
OBSERVATIONS

Figure 1.

Figure 2.

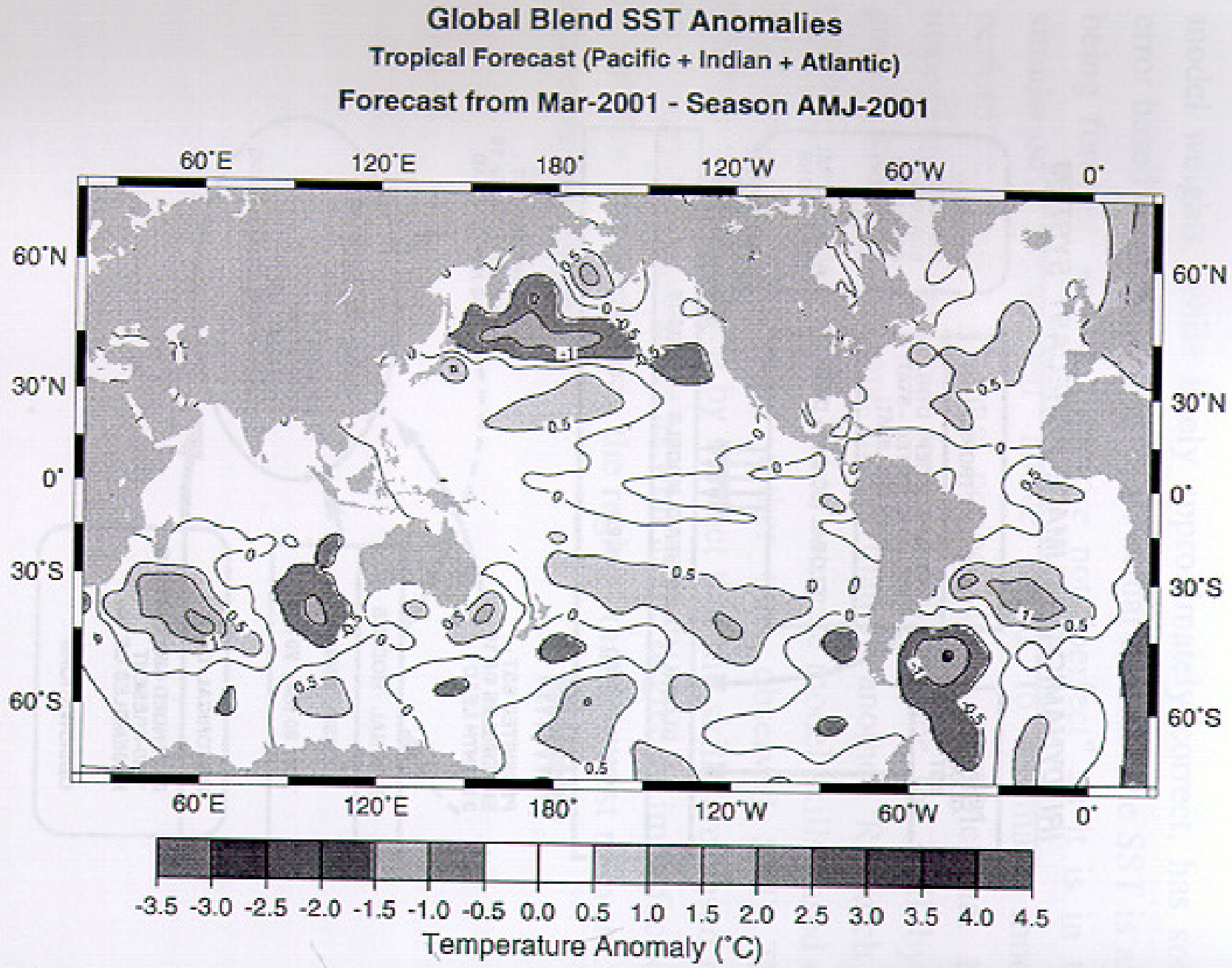

Global Blend SST Anomalies
Tropical Forecast (Pacific + Indian + Atlantic)
Forecast from Mar-2001 - Season AMJ-2001
60°E
120°E
180°
120°W
60°W
0°
60°N
30°N
0°
30°S
60°S
-3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
Temperature Anomaly (°C)
IRI

Figure 3

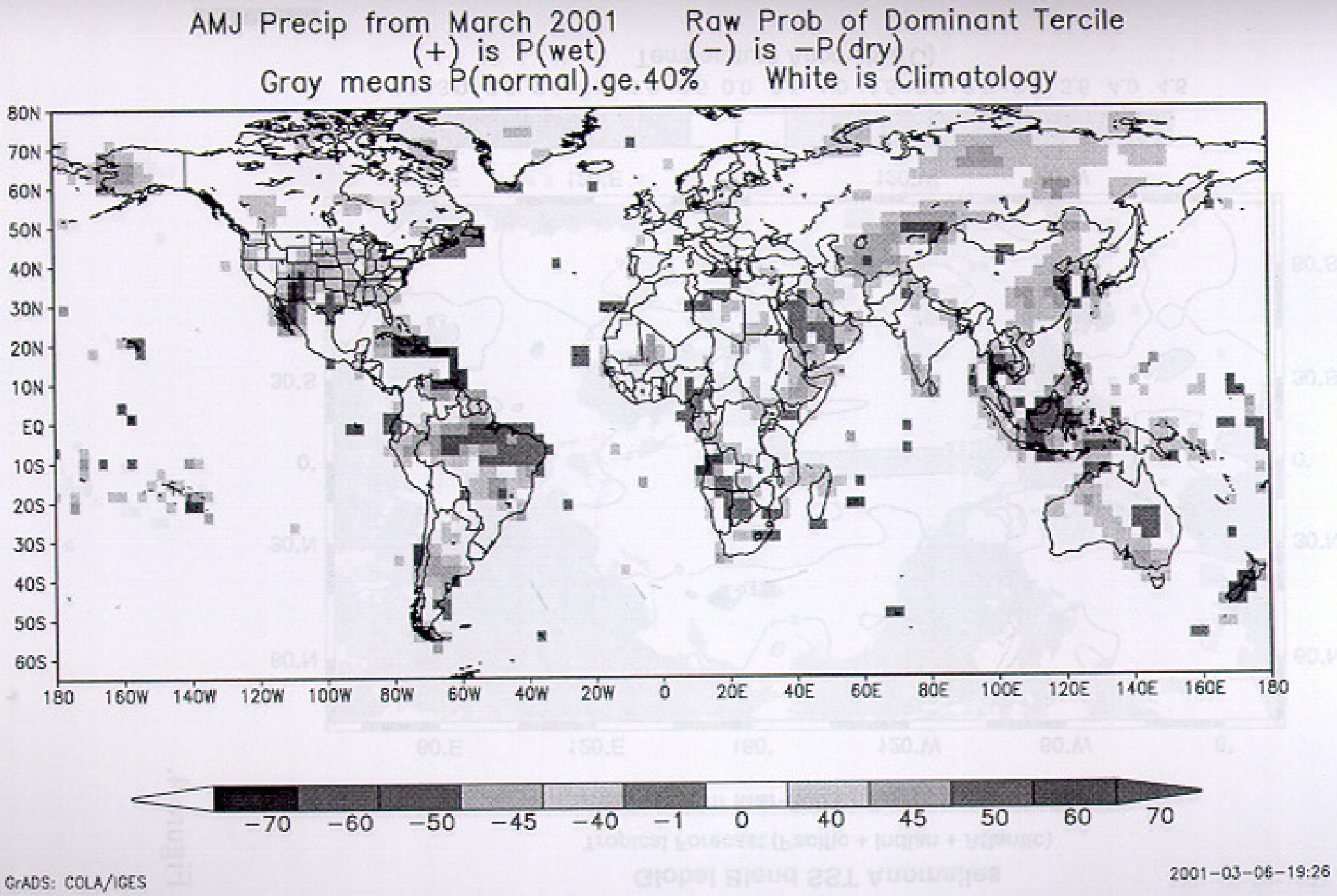

AMJ Precip from March 2001
Raw Prob of Dominant Tercile
(+) is P(wet)
(−) is −P(dry)
Gray means P(normal).ge.40%
White is Climatology
80N
70N
60N
50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
60S
180
160W
140W
120W
100W
80W
60W
40W
20W
0
20E
40E
60E
80E
100E
120E
140E
160E
180
−70
−60
−50
−45
−40
−1
0
40
45
50
60
70
GrADS: COLA/IGES
2001-03-06-19:26

Figure 4.

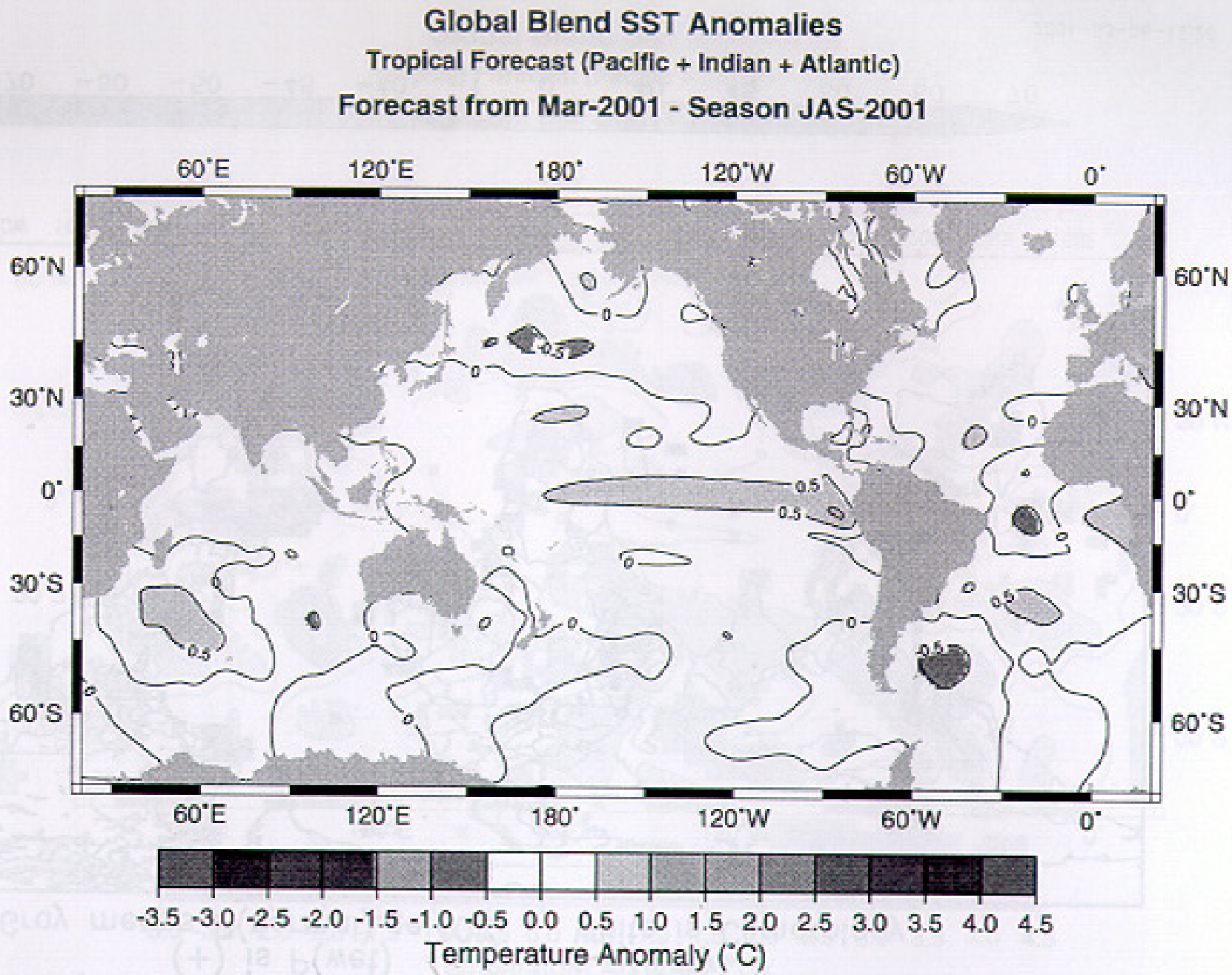
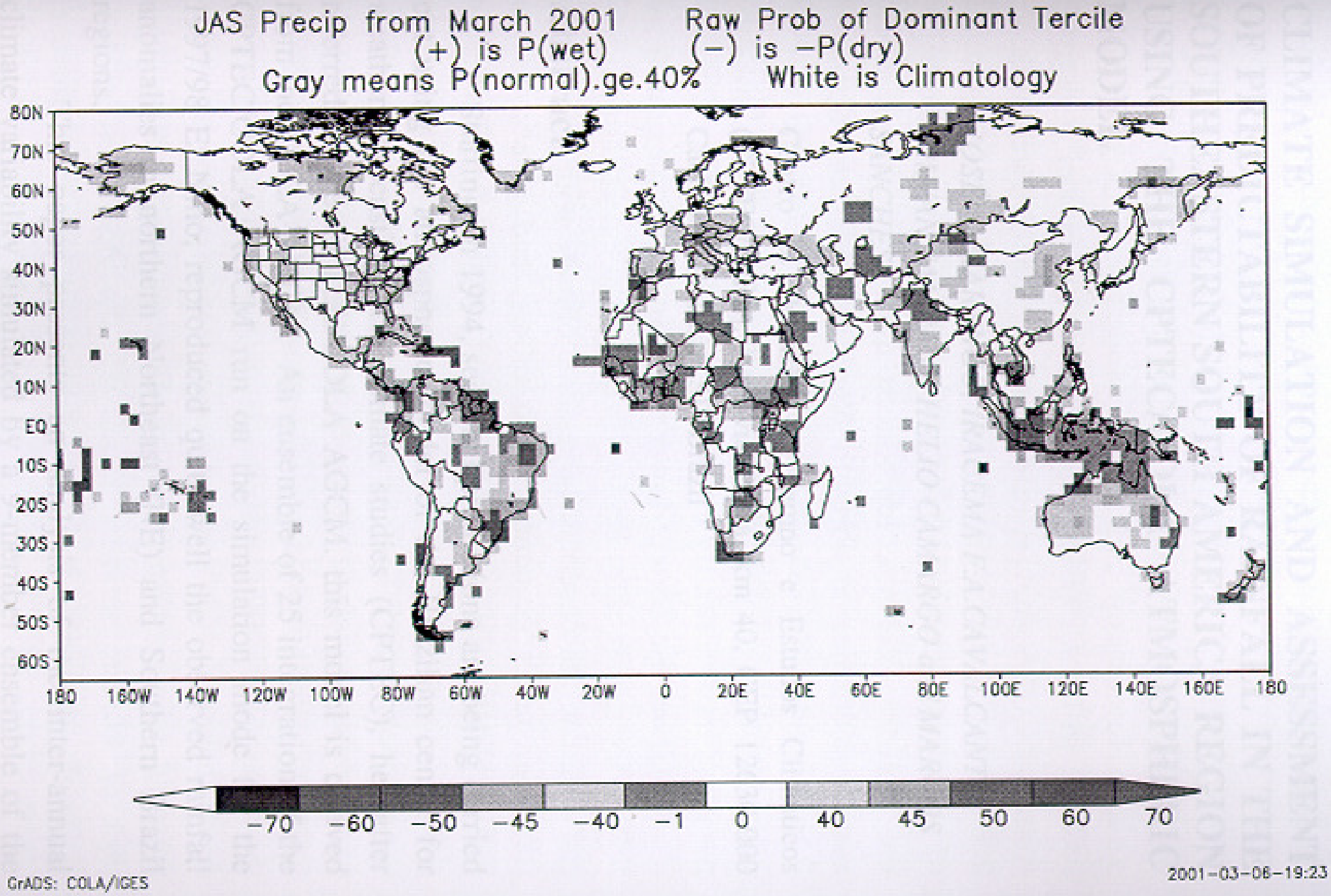

Global Blend SST Anomalies
Tropical Forecast (Pacific + Indian + Atlantic)
Forecast from Mar-2001 - Season JAS-2001
60°E
120°E
180°
120°W
60°W
0°
60°N
30°N
0°
30°S
60°S
0.5
0
-3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5
Temperature Anomaly (°C)

Figure 5


JAS Precip from March 2001
(+) is P(wet)
Gray means P(normal).ge.40%
Raw Prob of Dominant Tercile
(−) is −P(dry)
White is Climatology
80N
70N
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50N
40N
30N
20N
10N
EQ
10S
20S
30S
40S
50S
60S
180
160W
140W
120W
100W
80W
60W
40W
20W
0
20E
40E
60E
80E
100E
120E
140E
160E
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−45
−40
−1
0
40
45
50
60
70
GrADS: COLA/IGES
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CLIMATE SIMULATION AND ASSESSMENT OF PREDICTABILITY OF RAINFALL IN THE SOUTHEASTERN SOUTH AMERICA REGION USING THE CPTEC/COLA ATMOSPHERIC MODEL

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Abstract

Starting on 1994, seasonal predictions are being carried out using the atmospheric model of the Brazilian center for weather forecasting and climate studies (CPTEC), hereafter referred as the CPTEC/COLA AGCM. this model is derived from the COLA AGCM. An ensemble of 25 integration of the CPTEC/COLA AGCM run on the simulation mode for the 1997/98 El Niño, reproduced quite well the observed rainfall anomalies in northern Northeast (NE) and Southern Brazil regions.

This paper presents an analysis of the inter-annual climate variability simulated by a 9-member ensemble of the

1. Introduction

Starting on 1994, seasonal predictions are being carried out using the atmospheric model of the Brazilian center for weather forecasting and climate studies (CPTEC), hereafter referred as the CPTEC/COLA AGCM. this model is derived from the COLA AGCM (Shukla et al., 2000, Marengo et al. 2001, Cavalcanti et al. 2001). An ensemble of 25 integrations of the CPTEC/COLA AGCM run on the simulation mode for the 1997/98 El Niño, reproduced quite well the observed rainfall anomalies in northern Northeast (NE) and Southern Brazil regions (Cavalcanti et al. 1999). Local and central governments, and society in general are taking these forecasts more and more seriously into their planning activities.

Given the correct lower boundary conditions, such as SST or ice extent, most atmospheric general circulation models can simulate the observed large-scale climate with better skill for some areas as compared to others, and give a useful indication of some of the observed regional and global inter-annual climate variations and long-term trends. Simulations using specified SST have an extensive history. Several studies on these issues include Shukla et al. (2000); and Sperber et al. (1999). Using the technique of ensemble of simulations from the same model, or simulations from an ensemble of models, dynamical seasonal and inter-annual predictions have the potential to provide probabilistic forecasts and to assess the skill of climate models. Based on the dispersion of the ensemble members it is possible to establish confidence

thresholds on the seasonal forecast and to determine the skill of the model at seasonal and inter-annual scales. For some regions in Brazil, such as southeast Brazil, it is possible that predictability may be limited due to the chaotic variability on sub-seasonal time scales (Goddard et al. 2001).

This paper presents an analysis of the inter-annual climate variability simulated by a 9-member ensemble of the model, with prescribed SST covering the period 1981-92. This period was characterized by moderate to strong El Niño Southern Oscillation (ENSO) events in 1982/93 and 1986/87, and two La Niña events in 1985/86 and 1988/89, which provide an attractive opportunity to evaluate the model's depiction of inter-annual variability and ENSO teleconnections and their link to rainfall variability in Southeastern South America. We assess model skill and the predictability at regional scale, aimed at identifying the deficiencies and uncertainties of the model in the region, compared to other regions of the tropics and extra-tropics during their rainy season. Several aspects of simulation of climate and prediction of precipitation in Southern Brazil and southeastern South American have been discussed in several papers (Cavalcanti et al., 2001, Marengo et al. 2001), using either dynamic or statistical modeling, such as SIMOC. Recent work by Pezzi and Cavalcanti (2000) have shown the important role of SST anomalies in the tropical Atlantic and in the Pacific (ENSO mode), and they found that the southeastern South America region the intensity of rainfall anomalies is affected by the Atlantic conditions only during La Niña conditions, whereas during El Niño this region is influenced only by conditions in the Pacific Ocean.

2. The CPTEC/COLA GCM And Implementation Of Climate Simulations

The dynamical core of the CPTEC/COLA AGCM is based on that of the COLA AGCM, and is described by Cavalcanti et al. (2001). With the ensemble technique, the Brier Skill Score (BSS, Marengo et al. 2001) has been estimated to assess the predictability of seasonal climate in the NE Brazil region. The ensemble is considered to be a collection of 9 independent simulations of the December 1982 to November 1991 model climate that are physically consistent with observed worldwide SST and sea-ice extent in this period. The model's seasonal and annual climatology is defined as the mean of all ensemble members of the experiment, and are defined relative to the 1982-91-model climatology, and the observed field anomalies are determined relative to the 1982-91 climatology of the NCEP reanalysis, and the CMAP rainfall data sets

3. Results

3.1. Simulation of rainfall and its seasonal and interannual climate variability in Southeastern South America

Previous modeling experiences on seasonal and inter-annual variations in the region show that the CPTEC/COLA AGCM exhibits underestimation of observed rainfall in the area that comprises southern Brazil, Uruguay and Eastern Paraguay in all months except of October (Fig. 1a). Another area, which presents lower values than the observations, is the southernmost region of Brazil, Uruguay and eastern Argentina (Fig. 1b), but the values are very close. The ensemble mean represents well the observed values over northern and southern Argentina (Fig. 1c, d).

The inter-annual variability of rain on this region and in the South American monsoon areas (central-southeast Brazil) in general show that the spread among members of the ensemble is large, as compared to other regions such as Northeast Brazil and Amazonia, and the observed and modeled inter-annual variability are sometimes in contradiction. In fact, in southern-Brazil-Uruguay the intramodel spread is larger than 2 standard deviations from the ensemble mean. The model captures well the positive rainfall anomalies during the fall boreal of 1983, and with less intensity, the negative departures during the 1988/89 La Niña. For the South American monsoon (Fig. 2a) there is also a large spread among members of the

anomalies shown in the observations are not well reproduced by the model.

3.2. Predictability assessments of climate in southern South America

It is also clear, as pointed out by Cavalcanti et al. (2001) and Marengo et al. (2001) that the model reacts very well to large SST forcing in the tropical Pacific, typical of El Niño and La Niña events 1982/83, and this was also observed during the 1997/98 El Niño, which is reflected in the inter-annual variability of rainfall in southern Brazil-Uruguay-Northern Argentina. This indicates the impacts of very strong El Niño or La Niña in this region, while on the rest of Normal or "neutral" years the Pacific shows a more passive role, dominating now the Atlantic Ocean, especially the southern basin.

The skill of the CPTEC/COLA AGCM is assessed using the Brier Score Skill or BSS (Marengo et al. 2001, Sperber et al., 1999). We assess only precipitation anomalies to derive scores in some regions of the globe: Southern Brazil-Uruguay-Northern Argentina and the South American monsoon area. BSS may range from 0.0 (a perfect score) to 2.0 (total disagreement with observations). The Brier score of climatological forecast is 0.5. The assessment of the BSS is implemented for the rainy season of each analyzed region. Table 1 shows the BSS values for southern Brazil-Uruguay-Northern Argentina Brazil and the South American monsoon. It indicates that the CPTEC/COLA AGCM is more capable of

capturing inter-annual variations of the peak rainy season in Southern Brazil-Uruguay-N. Argentina, which is much better than the monsoon region of South America, but with an skill lower than in regions such as Northeast Brazil.

These regions, especially the monsoon area show relatively low predictability, as compared to Northeast Brazil (that show a BSS less than 0.18). In southern Brazil-Uruguay-Northern Argentina, the simulation of inter-annual variations of rainfall still remains problematic, possible due to land-surface feedback mechanisms, or to a features that are not well depicted by models, such as the representation of the low level jet east of the Andes, or the land surface characteristics and topography of regions such as southeastern Brazil.

Other indicators of model predictability shown by Cavalcanti et al. (2001), such as the Root Mean Square (RMS) indicate hat the largest errors are related to overestimated precipitation, seen as systematic errors in DJF and JJA, with large errors in southeastern South America. The correlation of seasonal anomalies between model and result and the observational CMAP data sets, show regions with large positive correlation in MAM in northeastern and southern Brazil. In JJA correlation higher than 0.3 is seen over southern Brazil. However, negative correlations are found over central South America and northern Argentina. The reproducibility is another method of validation, which measures the model's ability to respond consistently to the imposed boundary forcing. The southeastern South America section does not show large does not show large reproducibility, as compared to Northeast Brazil.

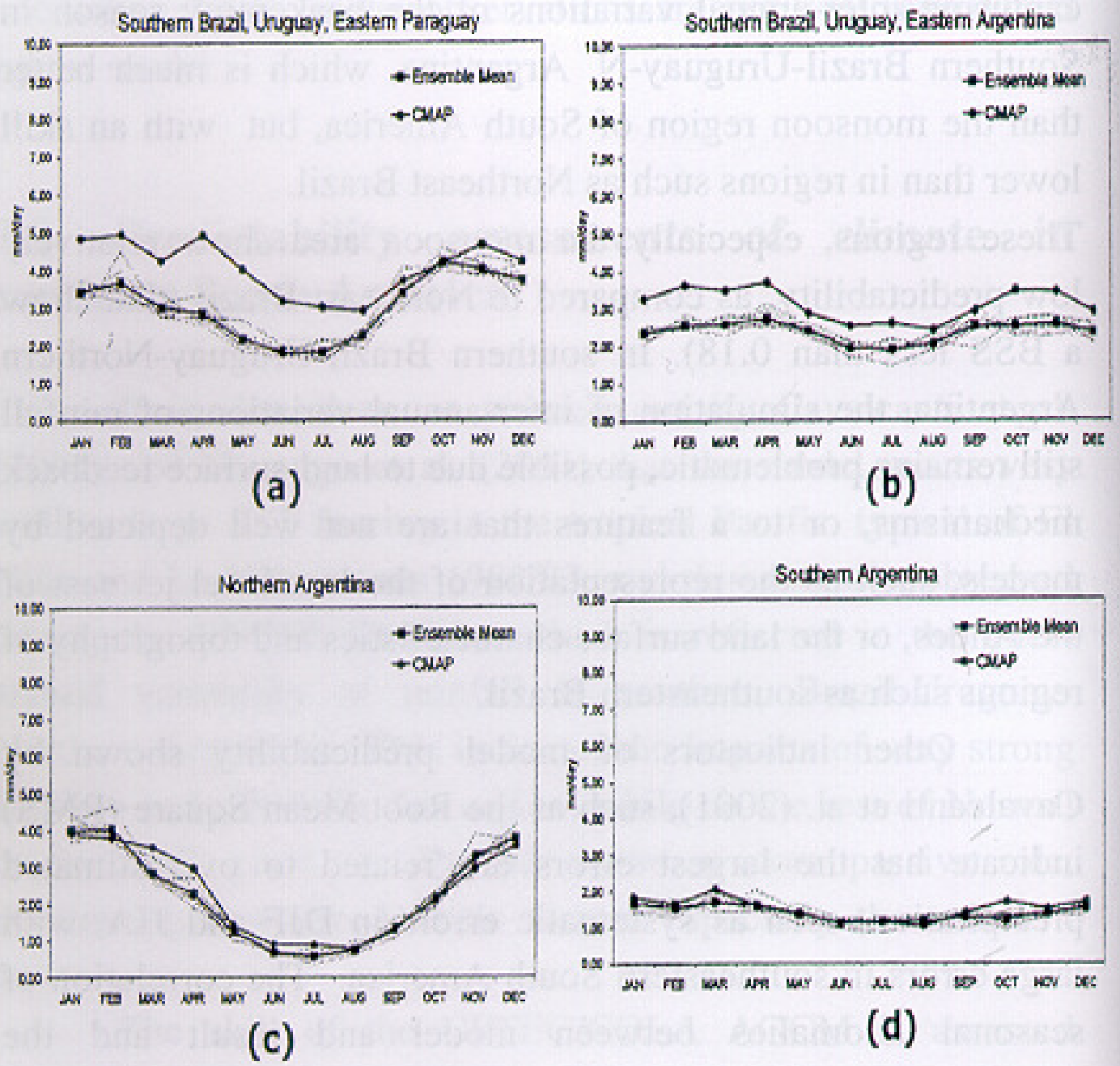
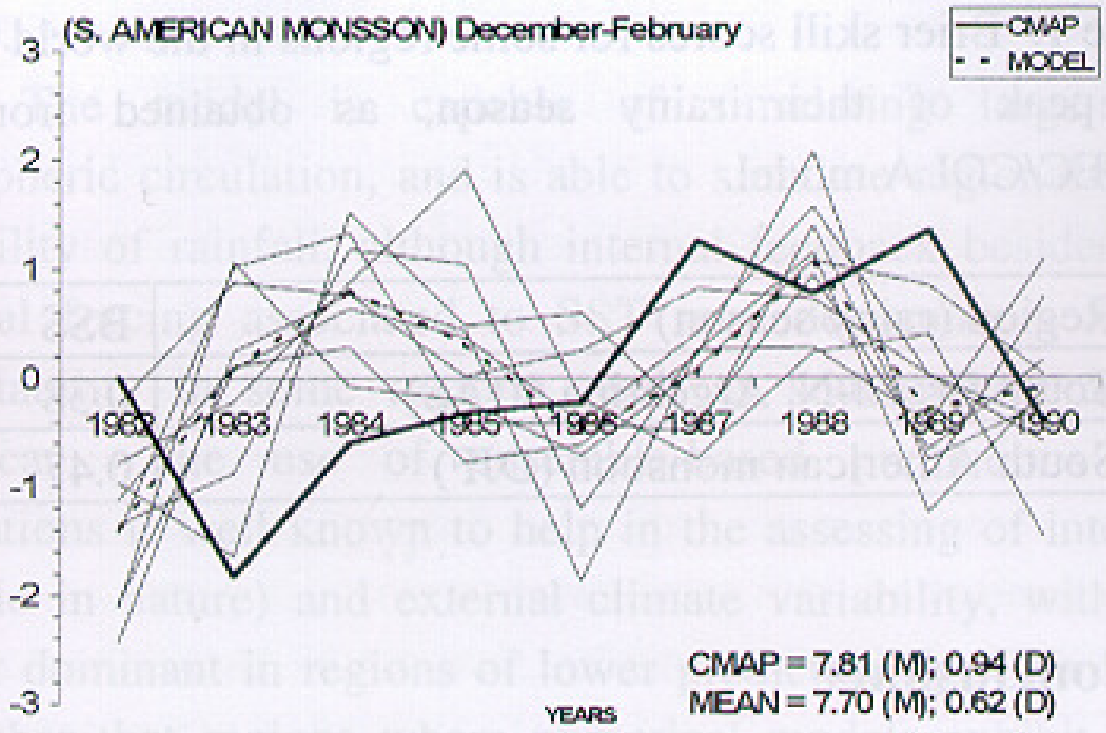


Figure 1. Annual cycle of rainfall in southeastern south America (Cavalcanti et al. 2001). Broken lines represent the ensemble mean, and fine lines represent each of the ensembles. Full line is the CMAP observed rain for the region.



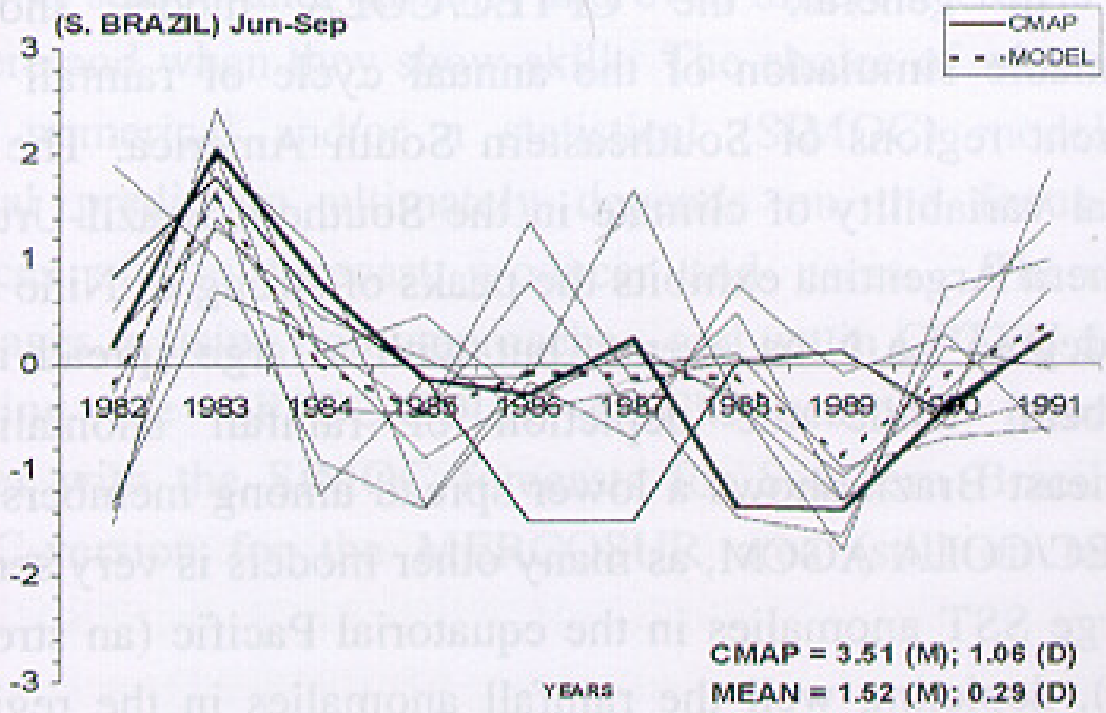


Figure 2. Inter-annual variability of rainfall for the DJF rainy season in the South American monsoon area (above) and Southern Brazil-Uruguay-Northern Argentina (below) during 1982-91. Broken lines represent the ensemble mean, and fine lines represent each of the ensembles. Full line is the CMAP observed rain for the region. Rainfall values are expressed as normalized departures.

Table 1. Brier skill scores for some regions in the world during the peak of their rainy season, as obtained from the CPTEC/COLA model.

Region (rainy season)	BSS
South Brazil-N. Argentina (JJAS)	0.38
South American monsoon (DJF)	0.47

4. Conclusions

In general, the CPTEC/COLA model shows a reasonable simulation of the annual cycle of rainfall in the different regions of Southeastern South America. The inter-annual variability of climate in the Southern Brazil-Uruguay-Northern Argentina exhibits the peaks of strong El Niño and in less degree La Niña events, but with a large spread among members, while the depiction of rainfall anomalies in Northeast Brazil shows a lower spread among members. The CPTEC/COLA AGCM, as many other models is very sensitive to large SST anomalies in the equatorial Pacific (an strong El Niño), depicting well the rainfall anomalies in the region of southeastern South America. During Normal years this is not so obvious, and the Atlantic assumes an active role. The BSS is much lower (higher predictability of climate in the region) in Northeast Brazil, while in southern Brazil-Uruguay-Northern Argentina the BSS is a bit larger, showing a relatively lower predictability of seasonal climate in this region. These skill measurements indicate that forecasts skill outside tropical

ENSO.

The model is capable of simulating large-scale atmospheric circulation, and is able to simulate regional-scale variability of rainfall, although internal feedback besides the external forcing associated to SST may determine a lower predictability in some regions, such as southeastern South America. The use of ensemble-based predictions and simulations is well known to help in the assessing of internal (chaotic in nature) and external climate variability, with the former dominant in regions of lower predictability. We must remember that regions where numerical models exhibit skill vary with season and variable, and even different GCMs vary in where and when they show skill. The choice of whether to use a numerical and/or a statistical (SIMOC) model for seasonal prediction ultimately depends on the focus and resources of the forecast producer and users. There are advantages to using both approaches, and we in CPTEC do so, by using the CPTEC/COLA AGCM seasonal forecasts, together with the SIMOC forecasts for Southern Brazil and SIMOC-version for the MERCOSUR area (still on testing phase).

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ON THE RELATIONSHIP BETWEEN SKILL (EX-POST) AND STATISTICAL SIGNIFICANCE (EX-ANTE) FOR AN ENSEMBLE OF REGIONAL-SEASONAL RAINFALL FORECASTS ISSUED BY IMFIA-UR (URUGUAY)

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Abstract

Based on the influence of El Niño – Southern Oscillation (ENSO) on interannual rainfall variability in Uruguay, statistically based seasonal-regional rainfall forecast are isuued at IMFIA from 1996. A global evaluation and the relationship between statistical significance and fraction of "rightness" for an ensemble of 54 issued forecasts, is described in order to establish useful meaning and interpretation of the significance as an indicator of the level of risk of an user when it is going to use it as a guide for made decisions.

1. Introduction

Rainfall in Uruguay (30-35° S, 54-58°W) occurs during the 12 months of the year. The complex interaction of several mechanisms which generates rainfall produces a wet climate with a relatively "flat" annual cycle. This is the case particularly in southern Uruguay, while in the northern part, fall and spring average exceed those of winter and summer (Pisciottano et al. 1994, Terra and Pisciottano 1994). In a regional scale (southeastern South America, SESA), the rainfall regime in Uruguay is a show of a transition between maritime influences, particularly to southeastern Uruguay, and mixed summertime processes to the northwest part of the country which continuates gradually changing to subtropical summer rains to the interior part of Argentina (see Prohaska, 1976).

Various studies have confirmed a significant influence of El Niño – Southern Oscillation (ENSO) on interannual rainfall variability in Uruguay, with a tendency for above normal rainfall during warm events in the Pacific Ocean (El Niño), especially in November and December and also in the next fall / early winter (March to July) (Ropelewski and Halpert 1987, Aceituno 1988, Pisciottano et al. 1994, Bidegain and Caffera 1991, Díaz et al. 1998, Montecinos et al. 2000). During cold episodes (La Niña), there is a tendency for below normal precipitation during October to December, and also during next March to July. A slight reversion of the signal has been described for January-February associated to cold, La Niña, episodes, particularly for southern Uruguay. All these documented features allow to develop statistically based forecast techniques for seasonal rainfall which should

differences in the different seasons and subregions of Uruguay, by using an ENSO index as "predictor", understood as a continuos variable adecquately conditioned, and not only as two different extreme phases . (Atlantic Ocean sea surface temperature impacts have been also studied as a conditioner of rainfall in the region, see, Diaz et al 1998 and also, Díaz 2000, but several technical dificulties prevent the use of that variables as a simple "predictor" to the present)

During 1996, 97, 98 and 99, IMFIA-UR has issued both, i) experimental regional-seasonal forecasts for subregions in Uruguay, as a scientific product to be tested and improved (see Pisciottano et al. 1997, 1998ª, 1998b, 1999 and 2000); and also 2) several regional-seasonal rainfall forecasts as technical advise in order to be used as a guide for decisionmakers in Uruguay (IMFIATech. Reports 1991, 1993 and 1996-2000). The second type of forecast have been requested by "users" for regions, seasons and dates, which can or can not agree with the "best" (or at least "good"), from a scientific point of view, in order to have a "good" degree of predictability. Actually the forecasts were requested when the applied needs indicated (but filtered by IMFIA in order to have at least a minimal scientific foundation).

In this work we focus in an ensemble of the sencond type of forecasts (made for technical use, in real time) for regional-seasonal (2 to 5 months) rainfall in three regions of Uruguay, founded on the ENSO-rainfall statistical relationships but even when there are not an extreme event in the Pacific Ocean (El Niño, EN, or La Niña, LN). A priori we know that, besides the user´s interest, there are regions, seasons and opportunities (dates) for which the issued forecasts will be more

"reliable" and other for which this is not the case. When the forecast technique is statistical in nature, an adecquate indicator of that "reliability" is the "statistical significance" associated to a certain test for the hypotesis that the issued forecast is (statistically) different from the climatology (in a technical sense to be precised). ***These values of significance are given together with the statistical forecast***, and it is assumed that high values (e. g. 99% or 0.99) indicate a certain "strength" of that individual forecast, at least in a relative sense in comparison to other with a smaller (i.e. 95%) or much smaller statistical significance.

Even when the statistical significance would be not so high, a particular user can have some interest in use a particular forecast (but he need to have some indication of the risk, as it is the significance, actually 1 minus significance). Also, the notion of which is a "high" significance is arbitrary to some degree. What is "high", more than 99% or 95% is enough??, a forecast acompained by 90,5% of significance is useful or not??

In this presentation we use the previous work done in an ensemble of forecasts which includes enough cases in order to allow to evaluate the skill of the technique and to ***determine the degree of association found (a posteriori, based in the observed values) between the significance level (given with the forecast) and the percentage of rightness*** (in some sense to be precised). Then we will learn which is the actual meaning of a particular value of significance, at least for this ensemble of predictions.

2. The issued forecasts. Methodology and their presentation

We focus on regionally averaged seasonally acumulated rainfall, based on three sites in each one of the three regions which are aprox. 150 to 200 Km N-S and W-E, which are not overlaped and located from NW Uruguay to SE Uruguay following the Uruguay-Brazil borderline. Seasons focused are from two to five months (not isoleted months and sites were predicted because we know there are nòt enough skill, even when strong global climate features are ongoing /as El Niño). The forecast were built by doing estimations of the statistical parameters of each case (rainfall for an individual region and season, for ex. NW-Uruguay, Sept.-Dec/97). We estimate and compare the statistical parameters (we estimate medians m and quartiles q and Q) of the "whole population" (in the example, the NW-Uy rainfall for any Nov-Dec included in the data available), which is representative of the **"clima"** for that region and season, and those parameters (m', q' and Q') of the "subpopulation", obtained by selecting only cases for which, in a previous period (in the ex. July-August), a predictor index (ex. NIÑO3 or similar) take a certain range of values (which is considered similar to that which was occurring in the year and date when the forecast was issued, in order to be useful as a **"forecast"**). Detailed explanation of the technique can be read in Pisciottano et al. 1997.

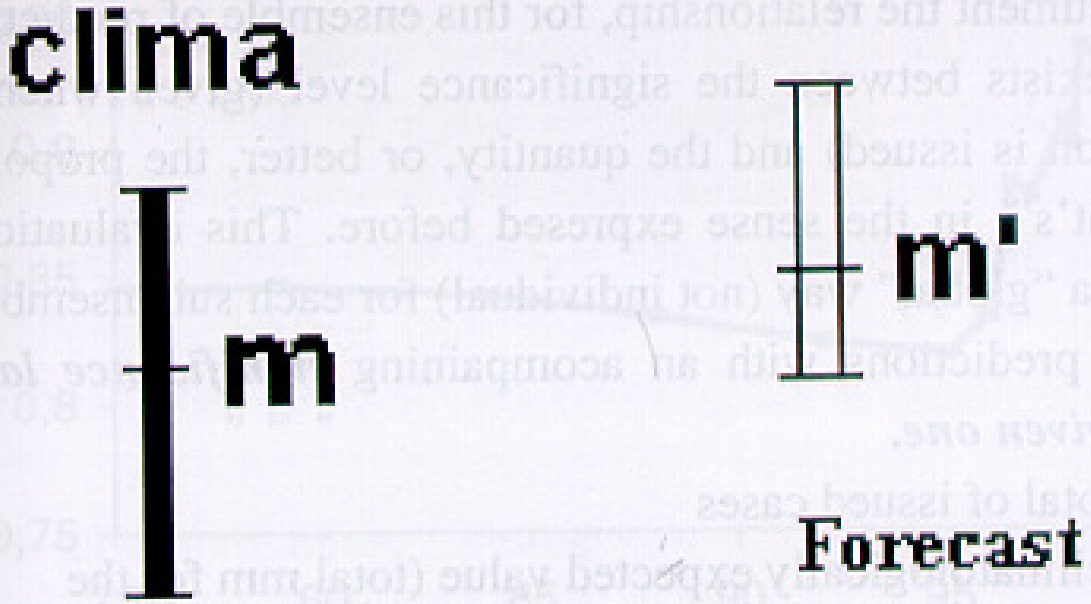
Roughly speaking, it can be said that ussually we expect m milimeters of rainfall (for the region and season), that is the "normal" or "climatology" ("clima" in the figure). Also it can be said that for the current year it can be expected rainfall

"around" m' milimeters ("forecast" in the figure). (The estimations of the quartiles, the bars in the figure, can be understood as indications of the dispersion, but we do not focus that in this work).

The next figure sketch a forecast issued. When m' is larger than m, "it is expected" rainfall larger "than normal" (and similar when m' smaller than m). However small differences between m and m' does not make sense. By definition, in the "whole population", for that case (region/season), half of the years are above m and the other half below m. This is not the case (with regards m) for the "subpopulation" (conditioned to some values of the predictor index) because those values are (almost) half and half above and below m'. Suppose that m´ is larger than m, i.e. the forecast is to "rainfall above normal". As more cases (in the subpopulation) are above m, more "founded" would be the announcement to "rainfall above normal". That is exactly what the statistical significance (s) means, which is given together with m' as forecast. In the extreme case, when all cases in the subpopulation (data of the past cases similar to the current case) would be above m, then the statistical significance would be very high (close to 100% or 1, if there were enough cases). In other case, the values will be similarly above and below m' but there were more above m than below, and based on that numbers a statistical significance can be calculated (actually an hypergeometric probability must be calculated to have s; see Pisciottano et al. 1994).

Figure. The usual graphical presentation of an IMFIA regional-seasonal rainfall forecast. The black bar represent the "climatological" expected values expressed as a value (m) and a

in conditioned expected values) as a value (m') and a dispersion bar (conditioned quartiles). The sketch is for a forecast for above normal rainfall. The forecast issued (ex - ante) is completed with the respective value of s=statistical significance as explained in the text.



3. Evaluation of the issued forecasts

In order to evaluate the forecasts the first natural comparison is between the "forecast" issued (m') and the actual observed value (obs), ex - post, after the forecasted season pass (i.e. a posteriori).

Besides of the "bias" of an individual prediction (for example an m' much larger than m) and how high have been the associated significance, an individual forecast always can be "erroneous", whichsoever be the meaning given to the notion of "erroneous". In this work we will consider "right" those cases for which "obs" (the observed value) is deviated from "m" (the

climatological or "normal" value) to the same side than "m' " (the forecast). In other cases the result will be counted as an "erroneous" forecast.

For this work we will use an ensemble of 54 forecasts issued by IMFIA-UR in the before explined format requested for several seasons for the same three regions in Uruguay. We will document the relationship, for this ensemble of predictions, which exists between the significance level (given when the prediction is issued) and the quantity, or better, the proportion of "right's", in the sense expresed before. This evaluation is done in a "global" way (not individual) for each subensemble of issued predictions with an acompaining ***significance larger than a given one.***

N=54 total of issued cases

m climatologically expected value (total mm for the region/season)

m' predicted value (total mm for the region/season)

obs observed value (total mm for the region/season)

s significance

the forecast is issued as (m' , s)

If (obs – m) and (m' – m) have the same sign → Right

If (obs – m) and (m' – m) have different sign → Error

K (s)=Number of cases of issued predictions with significance larger than s

K*(s)=Number of "Rights" in the K(s) cases

K*(s)/K(s) is plotted as a function of s ; it gives the fracction of "Rights" in the K(s) cases with significance larger than s.

of s starting from which the fraction of "Rights" is important. That is shown in the next Figure.

(Note that for s close to 1, or 100%, we have few cases; and for s very low all the cases are taken in consideration).

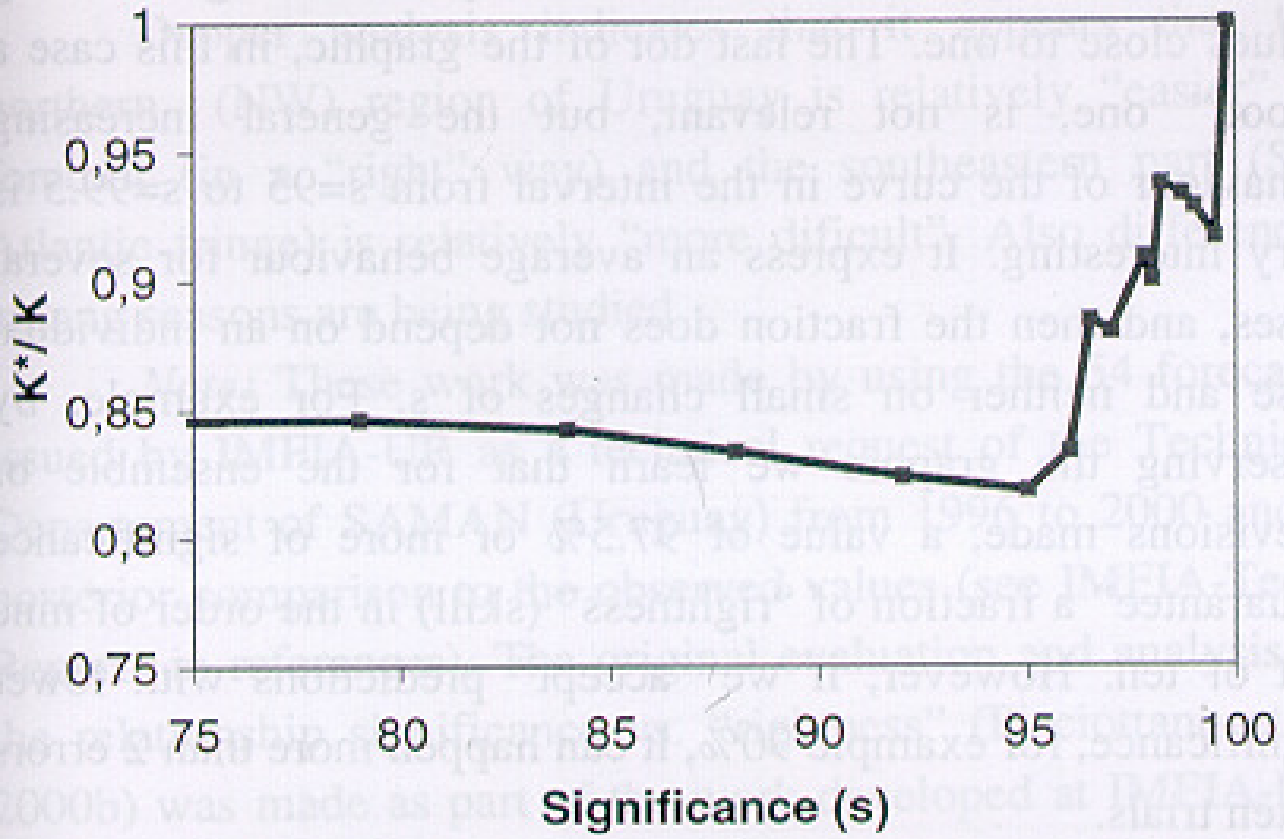


Figure. Relationship between statistical significance and fraction of "Right" cases, for the ensemble of IMFIA-UR predictions evaluated.

K is the N° of cases whose significance is larger than a value S,

K* are the "Right"cases whose significance is larger than a value S.

"Right" case is understood as that for which (m'-m)*(obs-m) >0.

4. Results and remarks

Based on the former figure and table, it can be noted that starting from some values of significance s (and higer), the fraction of "Right" cases becomes very interesting, reaching values close to one. The last dot of the graphic, in this case a "good" one, is not relevant, but the general increasing behaviour of the curve in the interval from s=95 to s=99.5 is very interesting. It express an average behaviour for several cases, and then the fraction does not depend on an individual case and neither on small changes of s. For example, by observing the graphic we learn that for the ensemble of previsions made, a value of 97.5% or more of significance "guarantee" a fraction of "rightness" (skill) in the order of nine out of ten. However, if we "accept" predictions with lower significance, for example 90%, it can happen more than 2 errors in ten trials.

In this way, significance becomes an indicator of the risk (global, not individual) assumed when using predictions with a certain minimal value of significance.

However, besides the technical analysis, it can be useful for a particular user, to use or to know, some predictions or forecasts with a "low" significance, even with the associated risk of "error", because the importance of the decisions to be made, or other reasons. What does not make sense is to risk the use of this kind of predictions or forecasts in a "blind" way, ignoring the type of global evaluation shown here, which allows to rationalize the assumed risk. Anyway, an individual, statistically based, prediction always can be erroneous and the

evaluation, for a larger number of cases, would be adecquate. Another limitation for the use of this type of prediction techniques came from the long term trends detected in the region for rainfall, as those documented by Genta et al. 1998 (for streamflow).

Depper analysis indicates that it appears that the northern (NW) region of Uruguay is relatively "easier" to forecast (in a "right" way) and the southeastern part (SE, Atlantic fringe) is relatively "more dificult". Also differences among seasons are being studied.

Note: These work was made by using the 54 forecasts issued by IMFIA-UR as a technical request of the Technical Departament of SAMAN (Uruguay) from 1996 to 2000 and a posterior comparison to the observed values (see IMFIA-Tech. Reports in references). The original evaluation and analysis of the relationship significance vs. "rightness" (Pisciottano et al 2000b) was made as part of the work developed at IMFIA-UR in the activities of the Project INIA-UR-IFDC (see Baethghen, 1999).

Significance	99,8	99,5	99,0	98,7	98,2	98,0	97,8	97,0	96,5	96,0	95,0	92,0	88,0	84,0	79,0	50,0
N° of cases	1	11	2	1	1	4	2	3	1	4	3	1	2	2	1	6
N° of right cases	1	10	2	1	1	3	2	2	1	2	2	1	2	2	1	5
K	1	12	14	15	16	20	22	25	26	30	33	34	36	38	39	45
K*	1	11	13	14	15	18	20	22	23	25	27	28	30	32	33	38

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POTENTIAL APPLICATIONS OF CLIMATE FORECAST TO WATER RESOURCES MANAGEMENT IN SOUTH AMERICA

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Abstract

A series of climate outlook Fora for Southeast South America begun in Montevideo, Uruguay in December 1997, in the middle of the last strong El Niño 1997/98. Participation included specialists of the four countries of the Mercosur region, i.e. Argentina, Brazil, Paraguay and Uruguay. The motivation was the concern about the ongoing El Niño in mid 1997, the availability of experimental climate forecast, and the knowledge about the impact of past El Niño in the region. In three years, a total of 12 meetings were conducted in the region.

This chapter presents a preliminary evaluation of the first nine forecasts analyses using categorical agreement between precipitation forecasts and observations. It also shows an example of practical application of climate prediction to decision-making in water resources management in Argentina.

1. Introduction

A series of climate outlook Fora for Southeast South America begun in Montevideo, Uruguay in December 1997, in the middle of the last strong El Niño 1997/98. Participation included specialists of the four countries of the Mercosur region, i.e. Argentina, Brazil, Paraguay and Uruguay. The motivation was the concern about the ongoing El Niño in mid 1997, the availability of experimental climate forecast, and the knowledge about the impact of past El Niño in the region. In three years, a total of 12 meetings were conducted in the region.

Participation in the Fora included researchers in meteorology, agronomy, hydrology, oceanography, related environmental sciences, public health and social sciences, as well as users of agriculture, water resources management, hydroelectric generation, civil defense and emergencies. Sponsorship was received from different international organizations and research institutes in climate variability and short-term climate prediction, as well as universities, research institutes and research centers in the region, national weather services, water resources centers and hydropower plants, national and regional rural societies and other national and regional organizations.

The economic resources for the meetings were provided mostly by local and regional sources. The Fora produce seasonal forecasts of the averaged precipitation and temperature anomaly expected for the upcoming 3-month period.

The backbone of the regional climate assessment is the consensus agreement between coupled ocean-atmosphere

diagnosis analysis and published research on climate variability over the region and expert interpretation of this information in the context of the current situation. The region considered for the forecast includes continental areas bounded between 20°S to 40°S and to the east of the Andes Mountains.

Seasonal climate forecasts of precipitation are expressed in probabilistic terms. For this purpose, three categories are identified: *above-normal*, *normal*, and *below-normal*, which are associated to a tercile distribution of precipitation. Homogeneous regions are identified in each case and the seasonal climate forecast is presented as the probability of occurrence of each category during the upcoming 3-month period. The probabilities assigned to each category are determined by consensus agreement among the specialists.

2. Preliminary Evaluation of Southeast South America Climate Outlook Fora

A preliminary evaluation of the first 9 forecasts analyzes the categorical agreement between precipitation forecasts and observations (Berri and Hordij, 2000). Due to the limited number of cases to verify, the analysis considers that the forecast corresponds to the most likely category, i.e. the category having the highest probability.

Figure 1 presents a summary of results of the first 9 forecast. Regions with red shading represent 0 out of 9 categorical agreements, while regions with dark blue shading represent 9 out of 9 categorical agreements. Considering that a 3-category forecast has a one third chance to be correct (3 out

of 9), only regions with at least 6 or more categorical agreements could be considered with a minimal degree of skill.

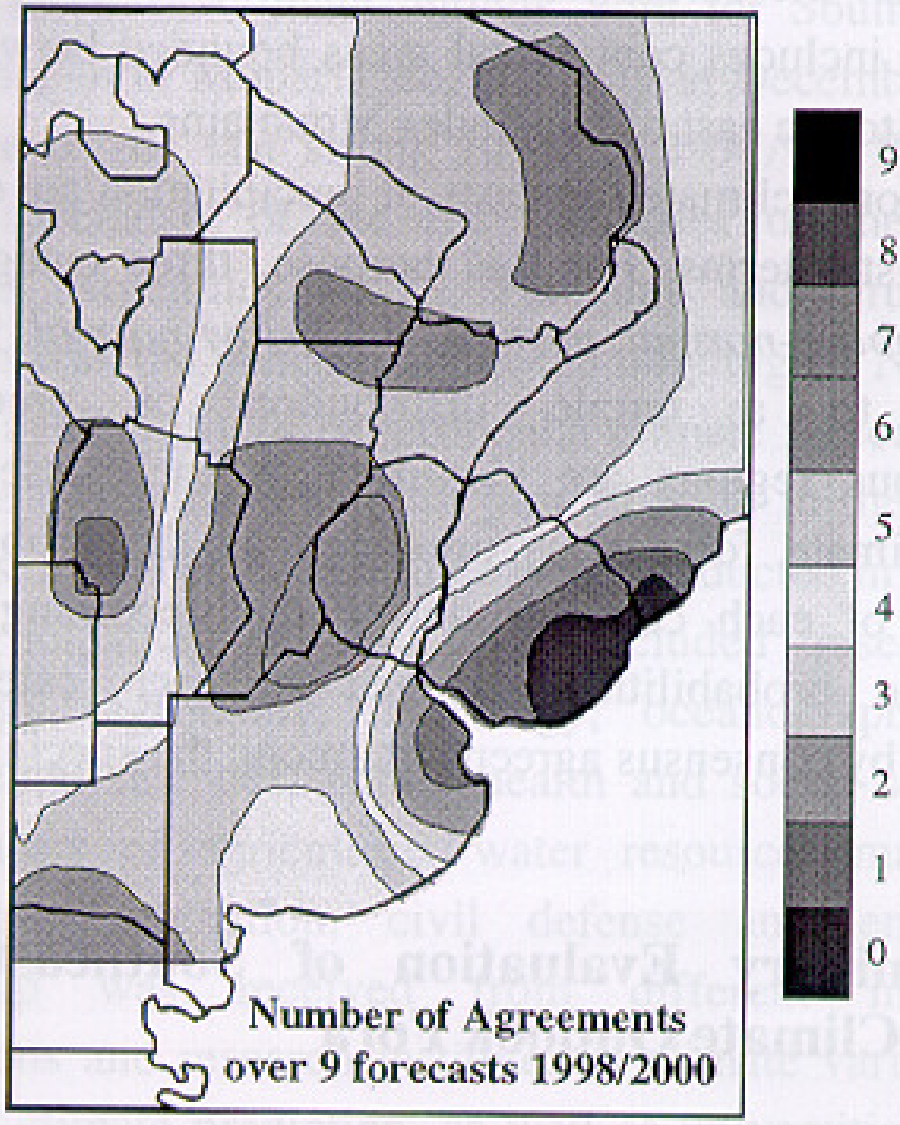

Figure 1

Figure 1 shows that the central part of the analyzed region would satisfy that condition, which includes a smaller region with 7 out of 9 agreements. These areas are located over Northeastern Argentina, within the region where statistically significant correlation between ENSO and precipitation has been reported by different authors. It should be stressed that during the analyzed period, 1998 until mid 2000, there was a very strong El Niño at the beginning, followed immediately by a strong La Niña event. Both situations provided good grounds

for the skill obtained. On the other hand, the areas where there was disagreement do not show such strong association with ENSO.

Moreover, these areas are affected by local factors such as the vicinity to the Atlantic Ocean, for example in the case of eastern Uruguay where 9 out of 9 categorical disagreements are found. Orographic effects and different degrees of seasonal feedback between the atmosphere and the underlying surface affect some regions as for example Central-Western Argentina. Also, the rapid change of ENSO phase in early 1998 from El Niño to La Niña contributed to the uncertainty of the climate community as to whether classifying that year as a late El Niño or early La Niña part of the cycle. This situation conspired against a proper utilization of the results obtained in climate diagnostic studies based on ENSO ensembles.

3. An example of practical application of climate prediction to decision-making in water resources management in Argentina

3.1 The Diamante River case

The Diamante River, located in western Argentina approximately between 34°S-35°S and 69°W-70°W, has its source in the high ranges of the central Andes Mountains. The hydrological regime, measured at the flowgauge station La Jaula (34°40'S, 69°19'W), during the period 1946-1994, presents a well-defined spring and summer maximum, when the

melting of the snow accumulated during wintertime takes place. A simple calculation concludes that the period October-March accounts for 70% of the annual water volume. The total drainage area upstream the flowgauge station is 2,750 km^2.

Downstream the station are located the Agua del Toro and Los Reyunos hydropower plants, with a combined power of 500 Mw. Important irrigation areas totaling 800 km^2 are located downstream these water reservoirs, which are dedicated to vegetables crops, grapes and other fruits that represent an important economic activity in the region.

For the purpose of hydroelectricity management, it is convenient to define the accumulated water volume flowing during the period October-March, which it is referred to as the seasonal volume. At the end of the winter, in September, an estimate of the snow volume in the catchment is made and the first seasonal volume prediction is issued. The snowpack thickness model in use by the water resources operator converts the snow volume into an equivalent water volume that will flow during the period October-March. The power utility company uses this prediction to produce future electricity generation estimates.

3.2 Relationship between Diamante River streamflows and sea surface temperatures of the Pacific Ocean

The relationship between the Diamante River streamflows and the sea surface temperatures (SST) of the equatorial Pacific Ocean is studied by means of a linear

correlation analysis between the seasonal volume, and monthly mean simultaneous SST and lagged SST up to 9 months. In order to make comparable the variability of such different numerical values as seasonal water volume (of the order of 10^9 m^3), and SST (of the order of 10^1 °C), normalized anomalies are calculated. Subtracting the mean value of the period and dividing by the standard deviation, normalized the original 1949-1994 seasonal volume time series. Similarly, the original monthly SST time series are normalized by subtracting the monthly mean value and dividing by the monthly standard deviation. Hereafter, the term seasonal volume and SST will refer to normalized anomalies.

3.3 A simple regression model for seasonal volume forecast

A statistically significant relationship is found between seasonal volume October(t)-March(t+1) in the Diamante River and SST anomalies observed in the equatorial Pacific Ocean, where t identifies a calendar year and t+1 the following one. The relationship peaks during March(t)-April(t) and November(t)-December(t), when considering the region known as Niño3 (5°S-5°N, 90°W-150°W). The relationship is such that Niño3 SST anomalies are positively correlated with seasonal volume anomalies.

A multiple linear regression model is developed, employing Niño3 SST anomalies during March(t)-April(t) and November(t)-December(t) and two auto-regressive components, i.e. seasonal volume observed 1 and 2 years before. The model

produces 3-category forecast (above normal, normal and below normal), of the October(t)-March(t+1) seasonal volume anomalies. A cross-validation analysis carried on comparing model predictions with observations for the period 1951-1994, achieve statistically significant correlations.

The result of the cross-validation analysis is shown in the figure 2, where the thick line represents the standardized anomalies of October(t)-March(t+1) seasonal volume observed in the Diamante River basin, and the thin line represents the calculated standardized anomalies with the regression model.

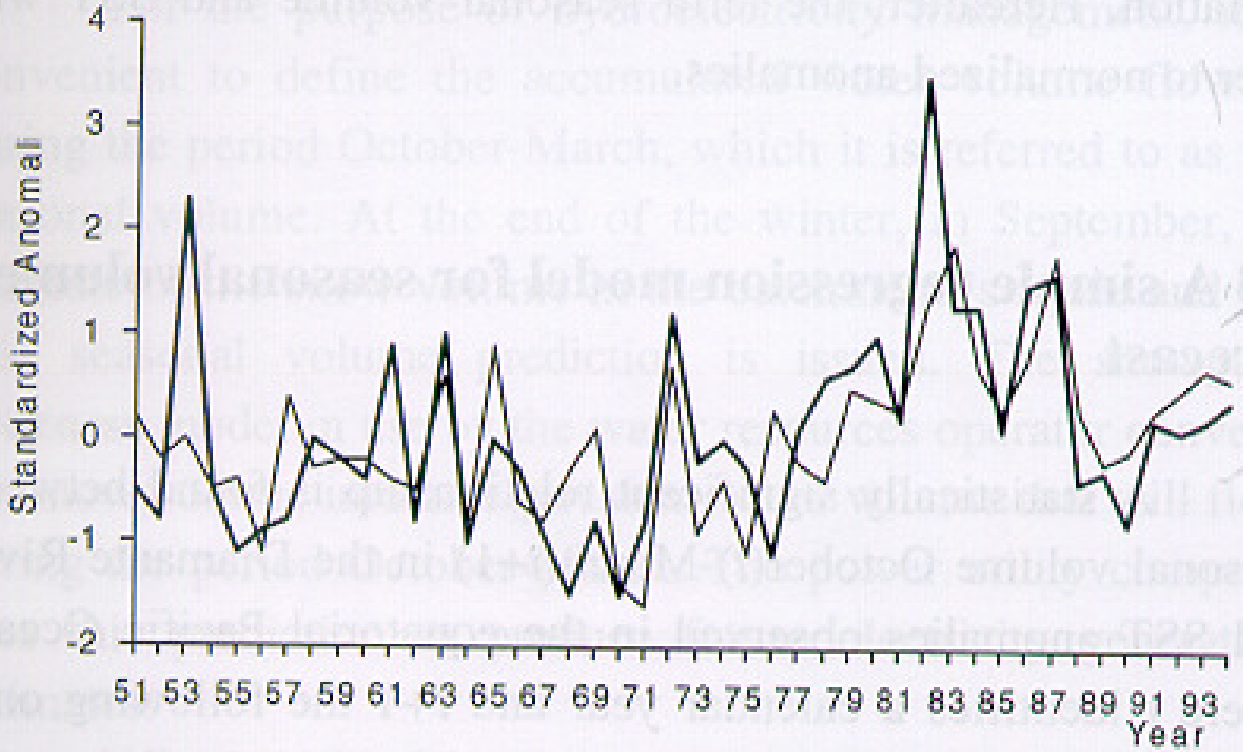

Figure 2.

Since November(t)-December(t) Niño3 SST anomalies are input to the model, they are replaced with 6-month Cane and Zebiak model predictions (Chen et al., 1995), performed in May(t). A cross-validation analysis of the SST model predictions for the period 1980-1994, achieves a categorical skill of 73 %, equal to that of the

same period. The following table shows the result of the contingency analysis.

		Predicted		
		Below	Normal	Above
Observed	Below	3	2	0
	Normal	2	3	0
	Above	0	0	5

3.4 Practical use of the model

The advantage of the SST model resides in the ability to produce a forecast in May, before the main snowfalls, with a similar result to that obtained with the snowpack model. The snowpack model can only be applied in October when the maximum snow cover is reached. On the other hand, the snow volume deposited in the catchment is estimated from few point measurements and, therefore, it represents an approximation. The SST model is able to provide the water resources operator information about the amount of water available in the system during the following summer, even before the wintertime snowfalls that feed the system.

The availability of the forecast in May can be of utility to the water resources operator for a better planning of the system. For example, irrigation downstream the dam begins in July and it is operated without any knowledge of the water replacement in the system. Advance knowledge of the surpluses

following season, could certainly help a better planning of the water resources.

Another example is related to the value of the hydroelectricity generated by the power plants in the system. In August, representatives of all sectors involved in generation and distribution of electricity in the interconnected system in Argentina, discuss the price of the kilowatt to be delivered by each plant during the following 12-month period. Normally, the price is agreed considering mean seasonal offer and demand patterns. Thus, advance knowledge of water availability in the dam could help the local operation to discuss a fairer price.

Obviously, a sample of 15 seasonal predictions (1980-1994) is not large enough to draw definitive conclusions about the SST model ability. Nevertheless, the results can be considered sufficiently positive to continue the investigation in order to improve the skill of the methodology.

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INMET: SYNONYMOUS OF TECHNOLOGICAL PROGRESS IN THE BRAZILIAN METEOROLOGY

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Abstract

The National Meteorological Institute (INMET), NHMS of Brazil, holder of the quality certification ISO 9001, is the meteorology leader of Latin America in this millenium beginning by high technology recently installed to improve weather forecast. In the last March, INMET opened High Performance Center for Meteorological Computation, with the two new and powerful supercomputers for the numerical modelling plans of Institute. In order of upgrade, there are other projects like automatization of surface observation network, meteorological database together with Navy, Air Force and Aneel (Brazilian Electricity Regulatory Agency), all operational organisms of meteorology in the country, with Brazil.

1. Introduction

In the last 22 of March, as celebration of the World Meteorological Day, the National Meteorological Institute - INMET had the great honor to open, with Minister of Agriculture and Supply, Pratini de Moraes, the High Performance Center for Meteorological Computation - CCMAD in Portuguese, the major computation center on Numerical Weather Prediction of the Latin America.

The Center was a memorable acquisition for the modernization of the Brazilian meteorology representing a technological achievement occurred at INMET in the last years. Two powers computers, Cray SV1 and Origin 2400, manufactured at USA, are operating and they are responsible for numerical modeling at INMET. The processing capacity of CCMAD is 32 Gygaflops.

Currently the main product is the Brazilian High Resolution Model (MBAR in Portuguese), regional model for numerical weather forecasting which produces meteorological variables prognoses at a 25 km of grid, the highest resolution of the Latin America. So far, the performance has been assess within expected limits.

With new supercomputers, INMET aims to run the current regional model on a more fine grid, seeking to obtain even more accuracy on its prognoses. Moreover, INMET is planning to run other numerical models, as well as to cooperate with others operational and research institutions.

The High Performance Center for Meteorological Computation reached the efficiency operation, due to the

Ph.D, graduated in the United States and England, with expertise either in NWP or Applied Mathematics. The Center counts also with well prepared computer experts.

CCMAD also comprises the Hydrometeorological Information System (S.I.M.), database created by INMET jointly with operational institutions of Brazilian meteorology such as the Directorate of Hydrography and Navigation (DHN), of Navy, Diretoria de Eletrônica e Proteção ao Vôo (DEPV), of Air Force, Brazilian Electricity Regulatory Agency (ANEEL), all of them, partners of INMET in achieving technological improvement.

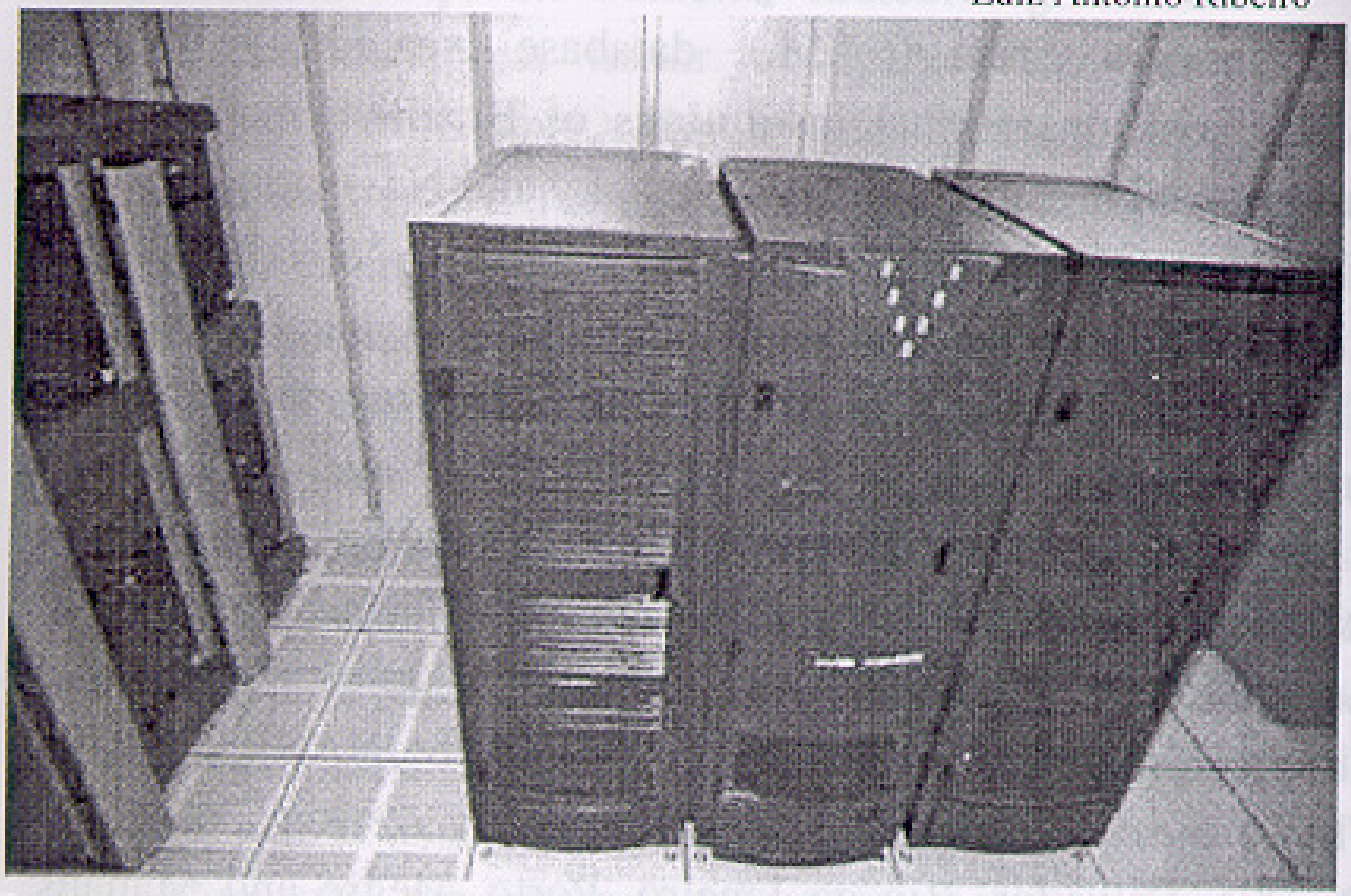
Having the opportunity of assessing the Europe experience in the automatization area, INMET has expanded its surface observational network, through a joint project with Finnish Meteorological Institute - FMI, the SONABRA Project. This project has started with 5 automatic stations, placed at Brasilia, Salvador, Rio de Janeiro, Porto Alegre and Manaus. Although, the system has just begun INMET has acquired expertise to install more 50 automatic stations throughout Brazil, increasing the current database.

This is INMET, holder of the quality certification ISO 9001, on national and international level, at the headquarters as well as at the 10 Districts and meteorological stations, showing total quality of the products and services offered to Brazilian citizens. The quality program involves all staff in a standardization procedure, based on training and calibration of equipments, essential requisite for ISO 9001.

INMET, official organism of the meteorology in the country, has almost one century of experience within its 92

community, with essential information for the urban and rural societies. This factor has a major impact in the development and in the social economic aspects of Brazil.

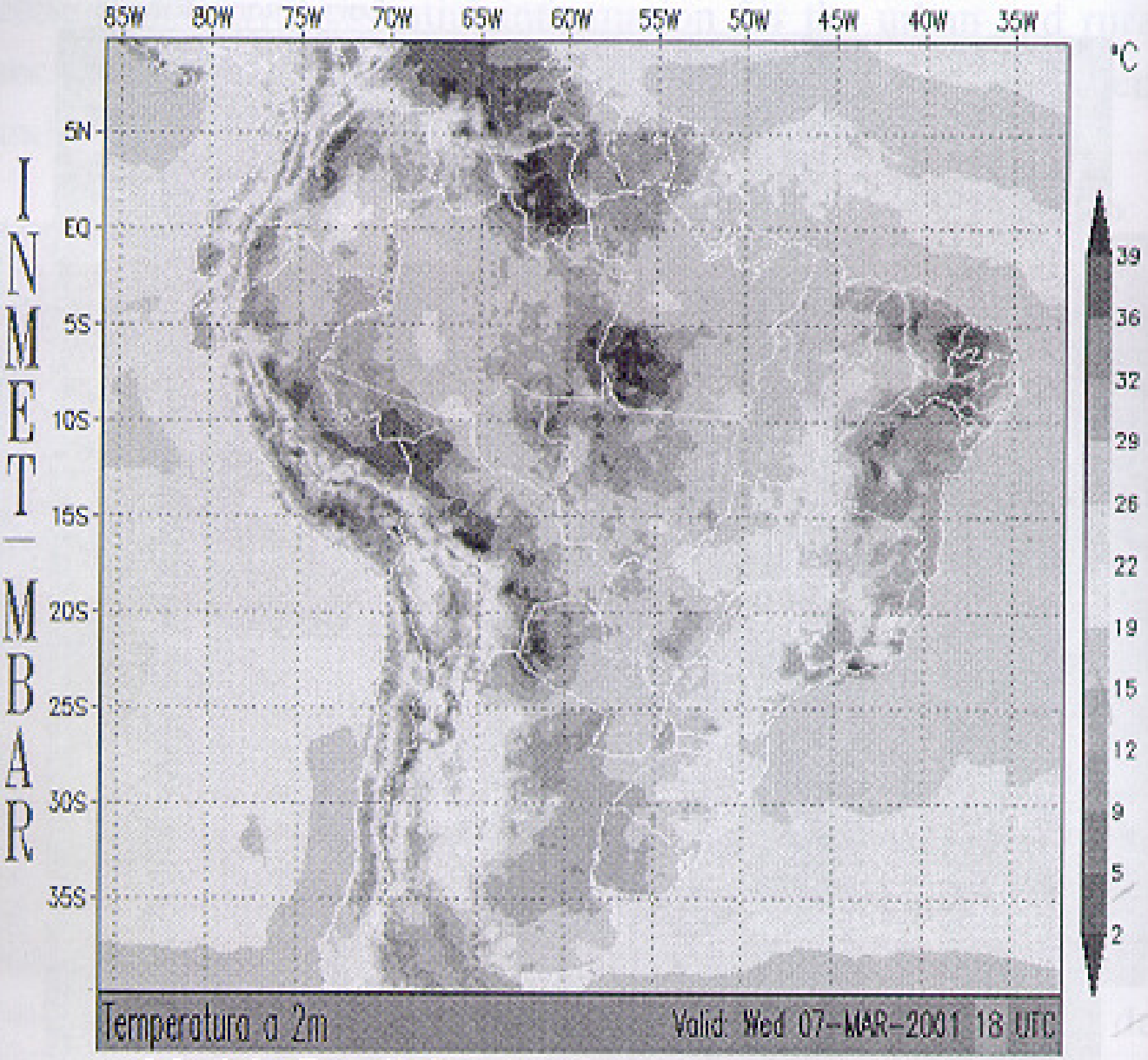
Luiz Antonio Ribeiro



Supercomputador Cray SVI - (CCMAD - Centro de Computação Meteorológica de Alto Desempenho).

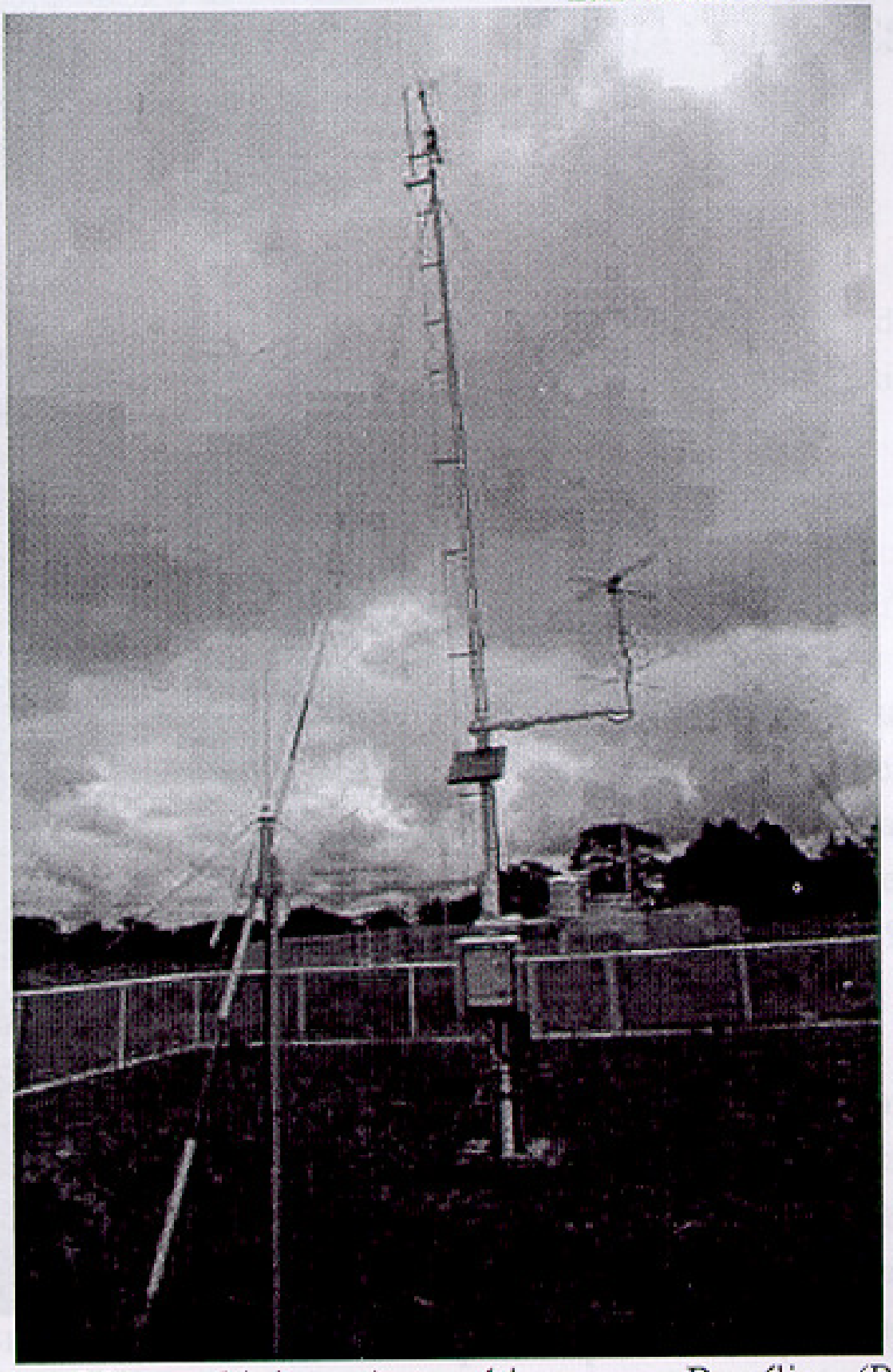
Luiz Antonio Ribeiro

Supercomputador Origin 2400 - (CCMAD - Centro de Computação Meteorológica de Alto Desempenho).



Modelo Brasileiro de Alta Resolução (MBAR).

Luiz Antonio Ribeiro



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FORECAST APPLICATIONS IN AGRICULTURE: APPROACHES, ISSUES, AND CHALLENGES

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Abstract

We discuss the path along which agricultural applications research has evolved, and current approaches that attempt to meet the challenge of utilizing seasonal forecasts in farm management. Approaches used have evolved over the period since they first become available in the mid 1980's. From an early phase of searching for locations around the world where predictable inter-annual variability influenced crop outcomes and improving our understanding of the physical interactions between climate and crop growth, our current interest rests more in the human-oriented issues of perception of probabilistic information and implications for decision making. For small-scale and commercial farmers alike, we argue that improving the comprehension of uncertainties associated with climate outcomes and their implications holds the largest hope for successful applications of forecasts to farm management.

1. Introduction

Applications of seasonal climate forecasts have been contemplated for a number of years now in many places around the world, with the agricultural sector considered one of the most likely to receive benefits. Approaches to the promotion and improved use of forecasts in farm management have evolved over that time, yet a number of obstacles remain. From an early stage of optimism about "revolutionizing" agriculture, when anticipated benefits to dryland agricultural production were heralded as "the next Green Revolution" (Cusack, 1983; Sah, 1987), we now have a more realistic understanding of the opportunities and limitations to applying seasonal forecasts, and have more clearly identified the challenges.

Given the ubiquitous nature of the farming enterprise, experience can be drawn from a wide range of farming systems applications, across many continents, cultures, and levels of development. Although details of the uses of seasonal forecasts may differ from system to system, we will argue here that many of the challenges are common to all. All farmers are faced with managing a complex production system under a range of constraints. Decisions are made with imperfect information regarding future states of a number of variables, often dominated by the uncertainty regarding weather outcomes. Seasonal climate forecasts *constrain* the distribution of possible outcomes of weather more narrowly than the climatological distribution in the absence of forecasts. Yet the decision-making process remains the same (or should remain the same, as we argue), if the new information is correctly understood. One of the biggest challenges, then, is ensuring that decision

makers have a solid understanding of the expected distribution of climate outcomes and its implications for their production options.

In this paper, we present some background on the path that has led us to the current focus of research, then expand on the issue of communication and approaches being developed to address the technology transfer challenge.

2. Early Approaches in Agricultural Applications

Early insights into the potential ramifications of El Niño-related inter-annual climate variability were discovered through simple correlation analysis. Given the large-scale nature of the influence of Pacific sea-surface temperatures (SSTs) on global climate, teleconnections with seasonal variation in precipitation at the regional or national scale could easily be detected through straightforward statistical tools. The earliest, and now famous, example of this was Sir Gilbert Walker's work attempting to understand the causes of the massive drought and ensuing famine in India at the end of the 19th century. Walker was the first to make the connection between inter-annual oscillations in sea-level atmospheric pressure in the southern Pacific and the episodic failure of the Indian monsoon.

Since then, many others have confirmed the ocean-atmosphere links, but the next step toward understanding implications for crop production was slow in coming. Early correlation work between SSTs and crop production in the United States (Handler and Handler, 1983) and Australia

(Nicholls, 1985), went unnoticed until late 1980's and early 1990's, when evidence of predictability of ENSO was confirmed (Cane, Zebiak and Dolan, 1986). In 1994, Mark Cane recognized the ENSO signal in a time series of national maize yields in Zimbabwe, gaining international attention with a publication in the journal *Nature* (Cane et al., 1994). If future states of ocean surface temperature were predictable, then crop production (and by extension food shortfalls) would also be predictable, with large implications for food security management.

In that early phase of applications work, such analyses were used mainly as an exploratory tool, looking for ENSO impacts where they were not easily found by looking only at the meteorological records (Hansen et al., 2000), or to identify areas of potential ENSO forecast applications (e.g. Carlson et al., 1996; Posestá et al., 1999; Zubair and Somasundea, 2000). It has been argued (e.g., Rosenzweig, 1994), somewhat successfully, that examination of ENSO signals in monthly or seasonal mean climate statistics can miss agriculturally-important climatic responses to ENSO. This is because plant growth can integrate precipitation and temperature sequences thereby revealing impacts of global circulation anomalies through regional yields that might otherwise go undetected. This turned out to be useful both for revealing regions where ENSO has an influence, and also for pointing out some of the complexities of plant-environment-human interactions (e.g. the difficulties of finding a "signal" in the yields of paddy rice). In order to move beyond descriptive studies to understanding implications for management, other tools were needed.

3. Experimenting with Decision Scenarios Using Crop Simulation Models

Approaches originally developed in the context of climate change impacts on agriculture using crop simulation modeling were soon adopted by the research community interested in inter-annual climate prediction. At the simplest level, crop models could be driven with historical time series of observed climate data and results sorted by ENSO phase to gain insight into the mechanisms of ENSO impacts. For example, Phillips et al. (1999) combined statistical and modeling approaches to investigate the impacts of El Niño and La Niña phases on maize yields in the United States Cornbelt. The statistical analysis revealed an association between regional maize yields and Pacific SSTs ($R^2 = 0.39$), but mapping of the district-level yields by ENSO phase showed high spatial variability in the response. The use of crop growth simulations revealed that lower maize yields in La Niña years were associated with both accelerated development resulting from higher temperatures in July and August, and also with water stress during grainfill. As a number of other studies have pointed out (e.g. Meinke and Hochman, 2000), soil type, depth, and initial soil moisture influence the severity of the impact. Studies of this sort carried implications for management but were not explicitly designed to test decision alternatives.

Other studies have taken this approach one step further, using simulation models explicitly to investigate potential management strategies. This approach has been used extensively in Australia to assess alternative cropping strategies (e.g. Meinke et al. 1996 (peanut); Hammer et al. 1996

(wheat); Meinke and Hochman, 2000 (wheat and sorghum)). One important conclusion from this body of work is that variation in a number of factors, from the temporal distribution of rainfall to spatial distribution of soil type or initial moisture conditions, lead to a wide range of yield outcomes within any given ENSO phase. This recognition has helped to foster awareness of the importance of the probabilistic nature of forecasts to making appropriate farm management decisions (e.g. Meinke and Hochman, 2000; Ferreyra et al., 2001).

In additional to the ability to investigate production outcomes as a function of ENSO phase and alternatives such as planting date (Phillips et al., 1998), cultivar (Phillips and Rajagopalan, 1999), or land allocation (Messina et al., 1999), simulation allows for cost/benefit analysis and risk assessment. Hansen (2000) shows the importance of identifying one's risk tolerance in evaluating outcomes of alternatives under a range of climate scenarios. Using the example of farm land allocation between maize, soybean, and sunflower based on the work of Messina et al. (1999), he compares the risk-adjusted value of forecast information between risk neutral decision makers and those that are risk averse, varying their perception of the uncertainty in the forecast. He shows that for risk averse farmers who interpret the forecast deterministically – that is, assuming the mean tendency of an ENSO phase is the expected outcome - the value of forecast information is negative over the long run due to exposure to excessive income risk. In comparison, a risk averse farmer correctly considering the probabilistic nature of the forecast information responds with decisions that result in a net positive value over the long run.

4. Communicating Forecast Uncertainty and Implications for Farm Decision Making

Analyses of historic agricultural data, simulation experiments with decision scenarios, and experience working with farmers has clearly highlighted the importance of (1) the variability of impacts of climate fluctuations both in space and time, and (2) understanding the resulting forecast uncertainties associated with any skillful but imperfect forecasts, and their implications for how forecast information is used in farm management (Phillips et al., 2001; Hansen, 2000; Jones et al., 2000; Hammer et al., In press).

With respect to forecast uncertainty, the issue is not one of "poor" forecasts – we are assuming that forecast quality is high. Rather, it is the intrinsically probabilistic nature of the forecast, and of climate in general, that is crucial to the decision making process. We have found that the concept of a "prediction" is often taken to mean a deterministic indication of a future event (Letson et al., 2000; Phillips et al, 2001); this interpretation is what often leads to poor decisions. Farmers are generally concerned not only with averages, but with the stability of production and reliability of income. This is particularly true of smallholder, resource-poor farmers in climate-sensitive environments. Farmers employ a range of risk management strategies to reduce their vulnerability to consequences of a poor year, generally at the cost of some reduction of average production, resource use efficiency, and sometimes sustainability of natural resources. In the absence of seasonal climate forecasts, farmers clearly factor into their decisions some mental representation of the distribution of

possible weather outcomes derived from their understanding of local climate. Although there is evidence that this mental representation can be distorted from the "real" distribution (Weber, 1997), it none the less considers a range of outcomes rather than a single expected event. Thus, in order to support the appropriate use of seasonal climate forecasts, our task is to present them clearly as shifts from the climatological distribution.

Regarding variation in impacts across space and time, it can be argued that prescriptive advice regarding the "correct" usage of a forecast may be difficult to provide (Jones et al., 2000). More importantly, conveying the range of possible climate outcomes, and implications for the potential impacts on crop response may be the most effective aspect to communicate. Helping farmers become aware of the importance of climate variability, and equipping them with the tools to analyze and assess their own farm condition, preferences and risk tolerance will help them make use of probabilistic climate forecasts and manage climate variability.

Although most of the crop simulation studies mentioned above are based on scenarios depicting large-scale commercial farmers, the points of greatest concern are arguably relevant to all scales of farming. While some argue that large-scale, better-endowed farmers are likely to reap most of the benefit from seasonal forecasts because they have greater access to resources and information, and hence, greater decision capacity (e.g., Broad and Agrawala, 2000), others argue that resource-poor smallholder farmers will potentially benefit more due to their greater vulnerability to impacts of climate variability, leading

Barrett, 1998). The issue of risk may be of greater importance for small-scale, resource-limited farmers, who appropriately tend to be more risk averse than relatively wealthy farmers. Where conditions allow, resource-poor farmers seek to spread risk by cultivating a wider variety of crops and utilizing off-farm employment more frequently than large-sale farmers, making their decision environment even more complex. A focus on communicating the probabilistic nature of the information seems therefore to be particularly critical in the case of smallholder farmers.

Communicating a basic understanding of the uncertainties in forecast information is a current focus of research on applications of seasonal climate forecasts to agricultural management at the IRI. To achieve this we are developing hands-on training materials that address the topic of understanding climate variability in general, decision making in the face of climate uncertainty, and the implications of seasonal forecasts within that probabilistic framework. Crop simulation modeling is seen as one of the tools that can help convey this understanding by making potential crop management outcomes explicit. Moving beyond simple ENSO-based climate scenarios, we are working on developing methods to express model-based forecasts of seasonal climate in the format necessary to drive crop simulations (see IRI, 2000). Understanding how people perceive uncertainty and make decisions under risk is a necessary ingredient in developing training programs to help people use seasonal forecasts wisely.

5. Summary

Research on the application of seasonal climate forecasts has progressed from a focus on the physical impacts of inter-annual climate variability on crop production to a more human-centered consideration of how farmers can incorporate this probabilistic information into decisions to minimize production risks. It has become clear over the last few years of working in this field that misinterpretation of what the forecast represents can actually lead to poorer decisions and increased exposure to risk. However, it can be shown that correct interpretation of forecasts, and their wise use in farm management will lead to improvements in overall agricultural productivity, with likely benefits to resource use efficiency and environmental sustainability. The greatest task before us is to learn, along with the farm community, how to express forecast information in such a way that the full range of possible outcomes of various decision alternatives are made explicit, and that farmers have the tools to apply that information to their own specific decision context. Increasing awareness of climate interactions with the farming enterprise will help farmers better manage climate variability with or without a strong forecast. A partnership between climate scientists, the agricultural research community, and farmers on the ground will be necessary to achieve this goal.

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El NIÑO – SOUTHERN OSCILLATION AND CLIMATE FORECASTS APPLIED TO CROPS MANAGEMENT SOUTHERN BRAZIL

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Abstract

The El Niño-Southern Oscillation phenomenon (ENSO) or just El Niño as referred by the communication media, has two phases: warm (El Niño) and cold (La Niña). The behavior of the tropical Pacific Ocean water temperature (central part and in the west coast of South America) associated to the pressure fields (represented by the Southern Oscillation Index) alters the general circulating pattern of the atmosphere. With that, ends up influentiating on the climate of different regions of the world, being responsible for the deviations related to the climatological normal, that is, by the so called persistent climatic anomalies, that last 6 - 18 months, for example. Particularly in Southern Brazil, there is an excess of rainfall in El Niño years and drought in La Niña years. Although the influence occurs during the whole acting period of these events, there are two periods of the year that are more affected by the phases of ENSO. They are spring and early summer (October, November and December), in the initial year of the event, and

in late fall and early winter (April, May, and June), in the following year to the begging of the event. Therefore, on those periods the chances of higher rainfall level increase, in El Niño years (as occurred in 1997/98), and rainfall bellow normal, in La Niña years (example, event of 1998/99). Based on the known impacts of the ENSO phenomenon over the climate in Southern Brazil it is possible to adopt a series of strategies in the crop management area, that make possible the reduction of climatic risks, and optimize the use of the favorable conditions. For agriculture in Southern Brazil, both El Niño and La Niña don't cause exclusively losses. In the El Niño years, due to the fact that there is not a lack of water in the spring-summer period, in general, the summer crops (soybeans and maize, in particular) are beneficiated. In La Niña years, the typical example is the wheat crop that is favored by a dry spring. This meteorological condition is favorable to the wheat crop, because it reduces the occurrence of spike diseases and improves the quality characteristics of the grain. In other hand, droughts, which are not exclusively from La Niña, as in 1990/91, cause serious problems to the summer crops. Maize and soybean are the most affected. In those crops, as shown, the El Niño phenomenon (due to the rains above normal favors the yields in spring and summer). Finally, it is necessary to highlight that the ENSO events (El Niño and La Niña) do not occur exactly the same way. The impacts on the climate will depend on the intensity of the events. That's why the reflex in agriculture of the South of Brazil can differ between the occurrence of El Niño or La Niña episodes. But, in a general way, it is valid to expect a tendency in the pattern of response as described.

1. Introduction

The El Niño-Southern Oscillation phenomenon (ENSO) or just El Niño as referred by the communication media, has two phases: warm (El Niño) and cold (La Niña). The behavior of the tropical Pacific Ocean temperature (central part and in the west coast of South America) associated to the pressure fields (represented by the Southern Oscillation Index) alters the general circulating pattern of the atmosphere. With that, ends up influentiating on the climate of different regions of the world, being responsible for the deviations related to the climatological normal, that is, by the so called persistent climatic anomalies, that last 6 to 18 months for example.

It is admitted that around 20 regions of the world are affected by the phases of ENSO. Among those, in Brazil, the north part of the Northeast Region, the east of the Amazon (tropical part) and the Southern Region (extratropical part). The best known climatic anomalies and of greater impact are related to the rainfall regime, although the thermic regime can also be affected. In a general way the anomalies related to El Niño (warm tropical pacific waters and negative Southern Oscillation Index) and to La Niña (cold tropical pacific waters and positive Southern Oscillation Index) hit the same regions in the same period of the year (a bit out of phase) but in opposite forms. That is, on those regions where in El Niño years there is an excess of rainfall, in La Niña years can occur droughts.

Particularly in Southern Brazil, there is an excess of rainfall in the El Niño years and drought in La Niña years. Even though the influence occurs during the whole acting period of these events, there are two periods of the year that are more

affected by the ENSO phases. They are spring and early summer (October, November, and December), in the initial year of the event, and in the late fall and early winter (April, May, and June), in the following year to the beginning of the event. Therefore in those periods, the chances of higher rainfall level increase in El Niño years (as occurred in 1997/98), and rain bellow normal, in La Niña years (example, event of 1998/99).

In this century, the following El Niño events were registered: 1900/1901, 1902/1903, 1905/1906, 1911/1912, 1914/1915, 1918/1919, 1923/1924, 1925/1926, 1930/1931, 1932/1933, 1939/1940, 1940/1941, 1941/1942, 1946/1947, 1951/1952, 1953/1954, 1957/1958, 1963/1964, 1965/1966, 1969/1970, 1972/1973, 1976/1977, 1977/1978, 1982/1983, 1986/1987, 1991/1992, 1992/1993, 1994/1995, and 1997/1998.

As for the La Niña events, the following occurrences were registered: 1903/1904, 1906/1907, 1908/1909, 1916/1917, 1920/1921, 1924/1925, 1928/1929, 1931/1932, 1938/1939, 1942/1943, 1949/1950, 1954/1955, 1964/1965, 1970/1971, 1973/1974, 1975/1976, 1988/1989, 1995/1996, 1998/1999, and 1999/2000.

When the communication media publish that an El Niño or La Niña event that might occur in the following months, it creates worries and expectations in Southern Brazil. At least for those who work in activities that are sensible to the climatic anomalies, for example, in agriculture. The objective of this article is to make a series of elucidations over the El Niño-Southern Oscillation phenomenon and its impact over the climate of the Southern Region, and to give advise over the use of the available information to reduce the risks associated to

agriculture of Southern Brazil and optimize the use of the favorable climatic conditions, when that is the case.

2. El Niño, La Niña, and Southern Oscillation

The El Niño - Southern Oscillation phenomenon, also designated by the expression ENSO, constitutes a two components phenomenon: one of sea nature, in the case of El Niño/La Niña; and one of atmospheric nature represented by the Southern Oscillation.

The El Niño denomination ages back to the 18th century which was first used by Peruvian fishermen to designate a hot water stream that appeared from the Pacific Ocean, on the coast of South America in the end of December. In reference to Christmas and "Baby Jesus" this hot water stream was called "El Niño" a Spanish word that means "the boy".

As for the atmospheric component, the works by sir Gilbert Walker in the beginning of the 20th century showed a negative correlation between the pressure at the surface of the Pacific and Indic Ocean, denominated Southern Oscillation: when high in the Pacific Ocean, pressure tends to be low in the Indic Ocean. These works tried to correlate the Southern Oscillation with the monsoons in India.

In the 60's the Norwegian meteorologist Jacob Bjerknes living in the USA, was who idealized the link between the two fluids - the ocean and the atmosphere - in the tropical Pacific Ocean. The atmosphere acts mechanically over the ocean surface, redistributing temperature anomalies. And by its turn,

changes in the wind fields. The ENSO is a manifestation of instability of the coupled system ocean-atmosphere.

Various indexes have been used to measure the intensity of ENSO. One of them is the Southern Oscillation Index (SOI), that reflects the standartized differences in atmospheric pressure between two key sitesfor the phenomenon (Darwin AU and Tahiti) and the sea surface temperature (SST) in a region called Niño 3 (5°N - 5°S and 90° - 150°W). The SOI measures the intensity of the Southern Oscillation (atmospheric component) and the SST from the Niño 3 region measures the El Niño (oceanic component).

The ENSO has a time of return that can be considered irregular and involves strong, moderate, weak, or even the total absence of events, when neutral years occur.

3. ENSO mechanisms

The ENSO phenomenon has as place of origin the tropical Pacific Ocean where in virtue of the trade winds that predominantly blows Southeast on the Southern Hemisphere, there is a pattern in oceanic circulation which in the coast of South America, the water is usually cold and in the extreme opposite, region of Indonesia and coast of Australia the water is usually hot.

The Pacific Ocean water temperature associated to the superficial atmospheric pressure fields, influenciates the zonal atmospheric circulation, in a Walker type cell, that is, from east to west, where there is air rising in the west of the tropical Pacific and sinking of air in the extreme east of this ocean. That

makes the west part of the Pacific Ocean a region of frequent rainfalls, and in opposite form the east coast or the coast of South America a region of low rainfall.

In El Niño years, previously to its establishment a reduction on the trade winds can be detected in the Equatorial Pacific region. This alters the pattern in oceanic circulation, reducing the upwelling of cold waters on the coast of South America and shifting the hot waters of the Pacific west to a position east of the International Date Line. With that there is a change in the ascending branch of the Walkers circulating cell to the central part of the Pacific Ocean that makes the islands of this region experience an excess of rainfalls where they are originally rare.

With the movement towards the east, the abnormal warm waters from the tropical Pacific Ocean reach the coast of South America in Peru and Equator. That ascends the air current on that region making the coast of South America experience rainfalls above climatological mean. This ascending branch of the Walker type circulating cell, becomes descendant in reason of the dry air over the north of the Amazon and the northeast part of Brazil, determining accentuated dry seasons on this region.

In terms of behavior of the atmospheric fields the SOI reflects the anomalies in surface pressure by the differences in pressures between Tahiti, in the central Pacific, and Darwin in Australia.

In the years in which the surface pressure is high in Darwin and low in Tahiti the SOI is negative (El Niño episode); inversely, when the surface pressure is low in Darwin and high in Tahiti the SOI is positive; when the SOI is strongly positive

water colder than normal appear in the central region and in the east part of the Equatorial Pacific Ocean. This cold episode is called La Niña, and implicates the climate anomalies generally inverse to the warm episode denominated El Niño. Another aspect of the atmosphere that is disturbed during the El Niño period is a circulating cell with north-south direction of Hadley type, that intensifies and ends up inducing in the "jet stream", that are really strong winds from the west at about 10,000 m high. The intensified jet stream determines atmosphere barriers, making the cold fronts stay semi-stationary over the extreme South of Brazil, causing excess in rainfalls verified during El Niño years, recent example is 1997/98 event.

In the La Niña years, the Hadley circulating cell (north-south direction) weakens. With that, the atmosphere barriers are reduced, making the cold fronts (main rain mechanism cause in South of Brazil) pass rapidly over the South Region, or even, change its route, passing over the ocean, consequently reducing the rainfall quantity. As example the La Niña event of 1998/99.

4. El Niño and recomendations for crops management

4.1. General orientations for summer crops

Based on the known impacts of the El Niño phenomenon over the South Region, causing rainfalls above normal levels, that implicates, other than the amount of water, a higher number of rainy days, the general order is:

- Stat sowing on the beginning of the recommended period, especially in large areas;
- Have all sowing structures ready. Clean, adjust and repair equipments, have inputs ready, to start the operation as soon as the weather allow;
- Do not sow seeds with soil too wet. Avoid the risk of compactation and degradation of the soil structure. Even though there are abundant rainfalls, there are enough periods of sun for sowing, during the recommended period;
- Follow crop rotation schedules, since in years of high humidity the environment is favorable for disease development;
- Adopt no till system, in function of the soil conservation characteristics and practicability in the sowing operation;
- Avoid use of areas subject to long flood periods.

4.1.1. Soybean

In general, the El Niño years, by the availability of water, are of good yield for the soybean crop in Southern Brazil. There are several issues that should be taken care in order to optimize the favorable hidric condition:

- Choose varieties with resistance to fungic diseases that occur in the region. El Niño years implicate in high soil humidy for Southern Brazil, consequently, favorable environment for disease development;
- Be careful about sanity and seed treatment for the same reasons as exposed above;

- Choose varieties that are not susceptible to lodging. In years of high humidity there is a tendency of the soybean to grow a lot, and that facilitates the lodging of some cultivares. The lodging in soybean plant, especially in the pre-flowering period, determines great losses of the yield potential;
- Adjust the sowing machine so that it doesn't put a plant population of over 400 thousand per hectare or over the specified recommendation for the cultivar in use. In years of high humidity and with high plant population on the fields, the favorable conditions lead to the appearance of diseases and to lodging of plants;
- Invest on technology, because, in general, they are considered good years for soybean crop in Southern Brazil.

4.1.2. Maize

For the same reason as the soybean crop (good availability of water), in El Niño years, in Southern Brazil, the maize yield have been good. Some care must be taken though:

- Observe sanitary conditions and treat seeds. Year of high humidity, is a favorable environment for diseases;
- Avoid sowing in areas subject to accumulation of water (low lands). Maize is highly sensitive to ground flooding, specially in the beginning of the cycle;
- Take care with nitrogen fertilization on cover. In years of excess rainfalls, the lixiviation of nitrogen (N) is high and the symptoms of N deficiency on the maize crop are evident. Observe the rain forecasts to avoid fertilizing the

soil before strong rains, by nitrogen's mobility this nutrient ends up being lost;

- Invest in technology. In general, they are considered good years for maize crop in Southern Brazil.

4.1.3. Paddy Rice

In function of the great quantity of rainfall that can occur in spring (October and November) in the El Niño years, there can be operational difficulties for sowing in some parts of Rio Grande do Sul. In general, there is the benefit of the farmer having the reservoirs full in the beginning of sowing, avoiding problems of lack of water to adequately cover the hole cultivated area. Important points to be considered by rice producers are:

- Heave sowing structures ready for sowing (inputs, machinery clean and adjusted). Due to the excess in rainfall there can be few days suitable for sowing in the period considered preferential;
- Unblock draining trenches;
- Choose short cycle cultivares, particularly when sowing in the end of the reccomended period, having in mind avoiding low temperatures at flowering;
- Special attention must be given to diseases, specially blast;
- Be aware of possible low light in the field, and for nitrogen fertilization consult a specialized technician on rice crop for orientation;

- Opt for no tillage system or sowing pre-germinated rice for faster sowing operation on the preferential period. Both systems require specialized technical assistance.

4.2. General orientation for winter crops (wheat, barley, triticale, and oat)

In the El Niño years there is an excess of rains in the South of Brazil, particularly in spring (October and November). With that, for the winter cereals, for coinciding with the flowering period, grain filling, maturing and harvest, depending on the region, the atmospheric conditions are unfavorable. The situation of high humidity propitiates the development of spike diseases, like, fusarium head blight, also causing loss in grain quality, that reflects in low test weight and, even, in some cases, sprouting. As general recommendations to reduce risks:

- Apply recommended fitosanitary treatments for the crop in question. Years of high humidity present favorable environmental conditions for diseases development;
- Harvest as soon as the humidity is adequate for the operation. The faster the crop is removed from the field, less chance of having losses in quantity and quality due to the frequent rains in El Niño years;
- Do the so-called anticipated harvest, product with around 20 % humidity, as long as there is disponibility of drying structure. This practice requires a specialized technician, in both regulating of harvester and in the drying;
- The meteorological effects on the quality of winter cereals harvest are not valid for regional generalization, in El Niño

years. There is great local variability within the Southern Region of Brazil, in terms of time of sowing, crop development and rainfall quantity occurred. Therefore crop fields are affected differently by the meteorological conditions.

- Special attention must be given to seed producing fields.

5. La Niña and recomendations for agriculture

Based on the known impacts of the La Niña phenomenon over the Southern Region of Brazil, causing rainfall below normal levels, as orientation to minimize the drought impact (circular SAA nº 03/98, Secretaria da Agricultura e Abastecimento do Rio Grande do Sul, Porto Alegre, RS, October, 1st, 1998), emphasis should be placed on:

5.1. General orientations for summer crops

These orientations must be adjusted, according to the specification of each crop and the farmers' reality.

- Soil subsoiling;
- Move the soil less possible, while preparing it;
- Prefer the no tillage system;
- Do not use higher plant population than the recommended for the crop;
- Schedule the sowing and/or planting season, using cultivares of different cycles;

- Sowing the crops over adequate conditions of humidity and soil temperature;
- Avoid emptying water reservoirs;
- Rationalize the use of water, irrigating when necessary, preferentially in critical periods;
- Observe agricultural zoning;
- Follow informations on the subject and consult technical assistance.

5.1.1. Paddy Rice

- Dimension sowing area according to availability of water;
- Observe the recommended time of sowing by the agroclimatic zoning, considering:
  - Start the sowing in the beginning of recommended time;
  - Schedule sowing periods using different cycle cultivares;
  - Sow first cultivares of medium cycle, then short cycle;
- Give priority to preparing and beginning of sowing using the minimum tillage and/or no tillage, having in mind the use of the soil conditions on the right time;
- In conventional systems use preferably line planting, avoiding superficial sowing;
- Try to seed when there is enough water for fermination, to save irrigation, especially in the no tillage and minimum tillage systems.

5.1.2. Soybean

- Schedule the sowing time and cultivar cycle. When sowing in October use late or semi-late cycle cultivars;
- Use seed treatment.

5.1.3. Maize

- Schedule the sowing with different cycle cultivares to avoid the drought on the critical period (flowering) to the whole field;
- Do not use plant population above the recommended for low rainfall conditions.

5.1.4. Bean (recommended sowing time)

- Use cultivars with deeper root system, such as Rio Tibagi, Guapo Brilhante, FT Nobre, and Iapar 44;
- Avoid multiple-croping practical.

5.1.5. Horticulture

- In greenhouses, give preference to dripping irrigation system, as measure to rationalize water use;
- Increase water reservoir capacity;
- Use dry matter to cover soil, whenever possible;

- Use shading for large leaf plants; if using plastic screen for shading, the index must be 30 %.

5.1.6. Fruit crops

- Use vegetation dissecation in orchard or the rolling of winter vegetation earlier;
- Use fruit thinning out as indispensable practice.

5.1.7. Forage crops

- Increase the forage stock in the property. In the field, by adjusting load (reduce animal load) and rotate the corrals from the end of winter, when possible, by the use of forage conservation (silage and hay). For rotation in spring: close the corral (absence of animals) from the end of August to the end of November;
- On summer cultivated forage crops, anticipate the sowing/planting the most and use seeds/seedlings of high vigor;
- For grazing forages, maintain good soil cover, by residue (stubble) relatively high.

Other than those, the greater need for attention by the farmer and technical assistance on the field conducting, having in mind the favorable environment conditions for the development of ground pests in corn, and disfavorable for natural control of pests in soybean (attention to the level of economic loss). It can be also added that sowing a little deeper

and the use of coulters can help the crops have deeper roots and consequently explore a greater volume of soil, having a greater quantity of water at their disposition; what can be important for short drought periods.

6. Final Considerations

The excess of rainfalls and dry spells in the spring-summer period is not rare in the South of Brazil. Sometimes they are related to the El Niño and La Niña phenomenon, sometimes not.

For agriculture in Southern Brazil, can be said that both El Niño and La Niña don't cause exclusively losses. In El Niño years, there is not a lack of rains in the spring-summer period, in general, summer crops (soybean and maize particularly) are beneficiated. In La Niña years, the typical example is the wheat crop. For La Niña years, are characterized by dry springs. That type of meteorological condition is favorable for wheat crop, because it reduces the occurrence of spike diseases and improves the grain quality.

On the other hand, dry spells that are not exclusively due to La Niña, 1990/91 example, and cause serious problems to summer crops. Maize and soybean are the most affected. On these crops, as said before, the yield is favored by the El Niño phenomenon (due to the rainfall level above normal, in the spring-summer period).

Finally, its worth saying that the ENSO events (El Niño and La Niña) do not occur exactly the same. The impacts on the meteorological conditions will depend on the intensity of the

events. That is why the results on agriculture of Southern Brazil can differ between El Niño and La Niña episodes. But, in general, it is valid to expect an average response to the models described in this article.

Additional information can be found on works listed on the bibliographic references item.

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ACTIVITIES AIMED TO IMPROVE PUBLIC PERCEPTION ABOUT THE RELATIONSHIP BETWEEN CLIMATE FORECASTING AND FARM MANAGEMENT IN SOUTHERN BRAZIL

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Abstract

Several activities are affected by climatic variability. To be incorporated into the practical decision-making processes, the climate forecasting must be available not only on scientific journal but reach the public though conventional media.

This chapter describe a serie of activities done by Embrapa Trigo aimed to increase the public perception about climate forecasting.

1. Introduction

A great worldwide effort over climate forecasting application was developed based on 1997-98 El Niño event. Information related to climate forecasting, done on the seasonal and inter-annual scales were attempted to incorporate in the

practical decision making process. For that, all sectors of human activities that are sensitive to the impacts caused by climatic variability were considered and involved, like: agriculture, food supply, energy, public health, water resource, disaster awareness.

The intense publication of information, using the powerful resource of the Internet, on web-pages maintained by institutions involved on the atmospherical science in various countries, and the great amount of space dedicated to the theme by the conventional communication media (newspaper, magazines, radio, and TV), made the general public aware, almost simultaneously to the scientific community, of a series of information, many still in experimental phase, related to the predictions of the El Niño - Southern Oscillation (ENSO) and its possible reflexes on the climatic variability and social economic impacts in some regions of the world. This fact in spite of the realization of meetings with scientific specialists of climate forecasting, and representatives of the users sectors, at the time of divulgation on the communication media, has caused many doubts, leading to equivocated and abrupt interpretations over what was effectively being predicted, whose impacts on the regional climatic variability can be expected and which is the best form of using this type of information to reduce the risks from the adverse conditions or optimize the use of favorable situations.

Among the sector of the human activity that can profit from climatic predictions, agriculture stands out. Particularly on those regions of the world in which there are signs of climatic variability associated to the phases of the ENSO phenomenon. El Niño and La Niña, warm and cold phases of the ENSO

respectively, influenciate specially the rainfall regime of the Southern region of Brazil. In general, El Niño causing rains above normal levels and La Niña being responsible for the reduction of rain. This knowledge, by itself does not assure any utility for the information related to the divulgation of predictions of the ENSO phenomenon.

Embrapa Trigo, aware of the need to aggregate value to the information related to the predictions on the ENSO phenomenon phases, developed various activities on the agricultural meteorological area, having in mind understanding the impacts of the regional climatic variability associated to the ENSO phenomenon phases and advising the farmers on its applications on agriculture in the southern of Brazil.

The objective of this article is to synthesize the activities conducted by Embrapa Trigo related to the application of the weather forecasts for agriculture in the southern Brazil.

2. Results

The incorporation of climate forecasting on the decision making process of agriculture is not as simple as it may seem at first sight. The credibility of the information, the clear notion of the strong aspects and the uncertain points of the predictions, the knowledge of the impacts of climatic variability over the economic yield of the crops, the identification of plant management practices that can be done differently, according to the scenery of climatic variability, and, above all, the consciousness that the expected results, when dealing with future, will always be probabilistic, are questions that require an

intense process of education of users and diffusion of results, having in mind transforming scientific knowledge and information in technology with pragmatic characteristics, as demanded by the agribusiness segments, specially the producer.

In the last years, the effort dedicated by Embrapa Trigo in the climate forecasting applications on agriculture in the South of Brazil included: lectures, newspaper articles, technical-cientifical articles for bulletins, scientific papers for specialized journals and congress proceedings, presentation of results in scientific events, participation in public hearings of the deputy house and in interviews for newspapers, radio and television.

2.1. Lectures

Between 1997 and 2000, 56 lectures about the applications of the El Niño - Southern Oscillation phenomenon on agriculture were given. Agronomists, agriculture technicians, farmers, authorities, local leaders and general public from 33 cities of the grain producing region of South of Brazil, attended these events, reaching, directly, 7551 people (Table 1).

2.2. Newspaper articles

Opinion articles were published, in regional, state and nacional circulating newspapers related to climate forecast applications for agriculture. Particularly about El Niño and La

Niña. Many of these articles were published in various newspapers. The following shows a relation of articles, with only one reference of publication per article (titles in Portuguese).

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CUNHA, G.R. O El Niño no Sudeste da América do Sul. **Gazeta Mercantil**, Porto Alegre, RS, p. 2, 23-25 de janeiro de 1998.

CUNHA, G.R. El Niño: bandido ou mocinho? **Gazeta Mercantil**, Porto Alegre, RS, p. 2, 13 de outubro de 1997.

CUNHA, G.R. Ciclo hidroilógico. **Zero Hora-Campo & Lavoura**, p.2, 07 de novembro de 1997.

CUNHA, G. R. Meteorologia aplicada à agricultura. **O Nacional**, Passo Fundo, RS, p. 8, 19 de junho de 1996.

CUNHA, G.R. As previsões meteorológicas de longo prazo. **O Nacional**, Passo Fundo, RS, p. 2, 9 de dezembro de 1996.

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CUNHA, G.R. O fenômeno ENSO e suas anomalias climáticas. **O Nacional**, Passo Fundo, RS, p. 2, 22 de janeiro de 1996.

2.3. Articles in Bulletins

In the Plantio Direto, Lavoura Arrozeira and Amanhã magazines, were published the following articles (titles in Portuguese):

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CUNHA, G.R. Esperando La Nina. **Revista Plantio Direto**, Passo Fundo, n. 46, p. 22, 1998.

CUNHA, G.R. Esperando La Nina. **Amanhã-Guia Empresarial Rio Grande do Sul**, Porto Alegre, Agosto de 1998, p. 8, 1998.

CUNHA, G.R. O fenômeno El Nino - Oscilação do Sul e suas aplicações na agricultura no sul do Brasil. **Lavoura Arrozeira**, Porto Alegre, v. 50, n. 433, p. 3-12, 1997.

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Table 1: Lectures on climate forecasting applications on agriculture. Embrapa Trigo 1997 - 2000.

Place (city, state)	Date (dd/mm/yy)	Public (nº of people)
Passo Fundo, RS	26/06/1997	42
Chapada, RS	10/09/1997	300
Carazinho, RS	20/10/1997	50
Espumoso, RS	27/07/1998	120
Santa Rosa, RS	29/07/1998	650
Cruz Alta, RS	30/07/1998	200
Ijuí, RS	31/07/1998	350
Lagoa Vermelha, RS	04/08/1998	550
Erechim, RS	05/08/1998	120
Sarandi, RS	07/09/1998	80
Frederico Westphalen, RS	07/08/1998	200
Ibirubá, RS	10/08/1998	50
Santa Bárbara, RS	10/08/1998	120
São Miguel da Missões, RS	11/08/1998	60
Lajeado, RS	12/08/1998	180
Sananduva, RS	13/08/1998	120
Passo Fundo, RS	17/08/1998	150
Bagé, RS	18/08/1998	40
Passo Fundo, RS	19/08/1998	350
Marau, RS	21/08/1998	120
São José do Ouro, RS	02/09/1998	120
Serafina Corrêa, RS	09/09/1998	150
Tapera, RS	10/09/1998	80
Palmeira das Missões, RS	10/11/1998	38

Passo Fundo, RS	13/04/1999	96
Passo Fundo, RS	24/05/1999	52
Erechim, RS	11/06/1999	37
Chapada, RS	13/07/1999	165
Ijuí, RS	14/07/1999	280
Campo Novo, RS	10/08/1999	200
Passo Fundo, RS	20/08/1999	155
São Miguel das Missões, RS	25/08/1999	80
Getúlio Vargas, RS	31/08/1999	150
Lagoa Vermelha, RS	09/09/1999	203
Sananduva, RS	14/09/1999	81
Cruz Alta, RS	28/09/1999	70
Passo Fundo, RS	30/09/1999	100
Espumoso, RS	08/10/1999	187
Passo Fundo, RS	14/10/1999	25
Passo Fundo, RS	25/10/1999	154
Vacaria, RS	04/11/1999	156
Passo Fundo, RS	09/11/1999	34
Londrina, PR	21/02/2000	200
Passo Fundo, RS	30/03/2000	21
Toledo, PR	19/04/2000	170
Passo Fundo, RS	25/04/2000	78
Castro, PR	10/05/2000	36
Guarapuava, PR	11/05/2000	89
Ijuí, RS	16/05/2000	39
Sarandi, RS	17/05/2000	30
Treze Tílias, SC	10/10/2000	70
Maringá, PR	17/10/2000	75
Cascavel, PR	18/10/2000	60

Giruá, RS	31/10/2000	120
Passo Fundo, RS	20/11/2000	18
Ijuí, RS	23/11/2000	80
Total of lectures = 56		7551

2.4. Articles in scientific journals, in congress proceedings, in books and in documents of Embrapa Trigo

The following articles are cited (titles in Portuguese):

CUNHA, G.R. **Meteorologia: Fatos & Mitos 2**. Passo Fundo: EMBRAPA-CNPT, 294p., 2000.

CUNHA, G.R. El Niño-Oscilação do Sul e perspectivas climáticas aplicadas no manejo de culturas no sul do Brasil. **Revista Brasileira de Agrometeorologia**, Santa Maria, v. 7, n. 2, 1999.

CUNHA, G.R.; DALMAGO, G.A. ESTEFANEL, V. Enso influences on wheat crop in Brazil. **Revista Brasileira de Agrometeorologia**, Santa Maria, v. 7, n. 1, p. 127-138, 1999.

CUNHA, G.R.; DALMAGO, G.A.; ESTEFANEL, V. Influências do fenômeno ENSO sobre a cultura de trigo no Brasil. In: XI CONGRESSO BRASILEIRO DE AGROMETEOROLOGIA, 1999, Florianópolis, SC, Brasil. **Anais XI Congresso Brasileiro de Agrometeorologia**, Epagri, p. 1622 -1628, 1999.

CUNHA, G.R. El Niño-Oscilação do sul e perspectivas climáticas aplicadas no manejo de culturas no sul do Brasil. In: XI CONGRESSO BRASILEIRO DE

AGROMETEOROLOGIA , 1999 , Florianópolis, RS, Brasil. **Anais XI Congresso Brasileiro de Agrometeorologia**, Epagri, p. 1340 -1346, 1999.

CUNHA, G. R. La Niña e suas influências na agricultura do sul do Brasil, safra 1999-2000. In: IV CONFERÊNCIA ANUAL DA REVISTA PLANTIO DIRETO, 1999, Passo Fundo, RS, Brasil. **IV Conferência Anual da Revista Plantio Direto**, Aldeia Norte Editora, p. 33-43, 1999.

CUNHA, G.R. Riscos climáticos e cultivo de trigo no Brasil. In: XVIII REUNIÃO NACIONAL DE PESQUISA DE TRIGO, 1999, Passo Fundo, Embrapa Trigo, **Anais XVIII Reunião Nacional de Pesquisa de Trigo**, v. 1, p. 85 -103, 1999.

CUNHA, G. R. El Niño e a safra de cevada cervejeira de 1997. In: XVIII REUNIÃO ANUAL DE PESQUISA DE CEVADA, 1998, Passo Fundo, RS, Brasil. **Anais XVIII Reunião Anual de Pesquisa de Cevada** , Embrapa Trigo, p. 30 -36, 1988.

CUNHA, G.R. **Meteorologia: Fatos & Mitos**. Passo Fundo: EMBRAPA-CNPT, 267p., 1997.

CUNHA, G.R. Sustentabilidade: a redução de riscos climáticos e o contexto de sustentabilidade em agricultura. In: REUNIÃO TÉCNICA ANUAL DO MILHO, 41. / REUNIÃO TÉCNICA DO SORGO, 24., 1996, Passo Fundo. **Anais...** Passo Fundo: EMBRAPA-CNPT, p. 241-247, 1996.

CUNHA, G.R. Meteorologia aplicada à agricultura. In: SEMINÁRIO SUL-BRASILEIRO DE INFORMÁTICA NA AGRICULTURA, 1., 1996, Passo Fundo. **Anais...** Passo Fundo: EMBRAPA-CNPT, p. 30-33, 1996.

CUNHA, G.R.; FERNANDES, J.M.C. Meteorologia aplicada à tomada de decisão em agricultura. In: EMBRAPA. Centro Nacional de Pesquisa de Trigo (Passo Fundo, RS). **Dia de campo do Centro Nacional de Pesquisa de Trigo-1995**. Passo Fundo, 1995. p. 18. (EMBRAPA-CNPT. Documentos, 23).

Internet

Information and articles about the El Niño and La Niña and its aplications on agriculture of southern Brazil can be found on the site of Embrapa Trigo: http://www.cnpt.embrapa.br/agromet.htm (Figure 1).

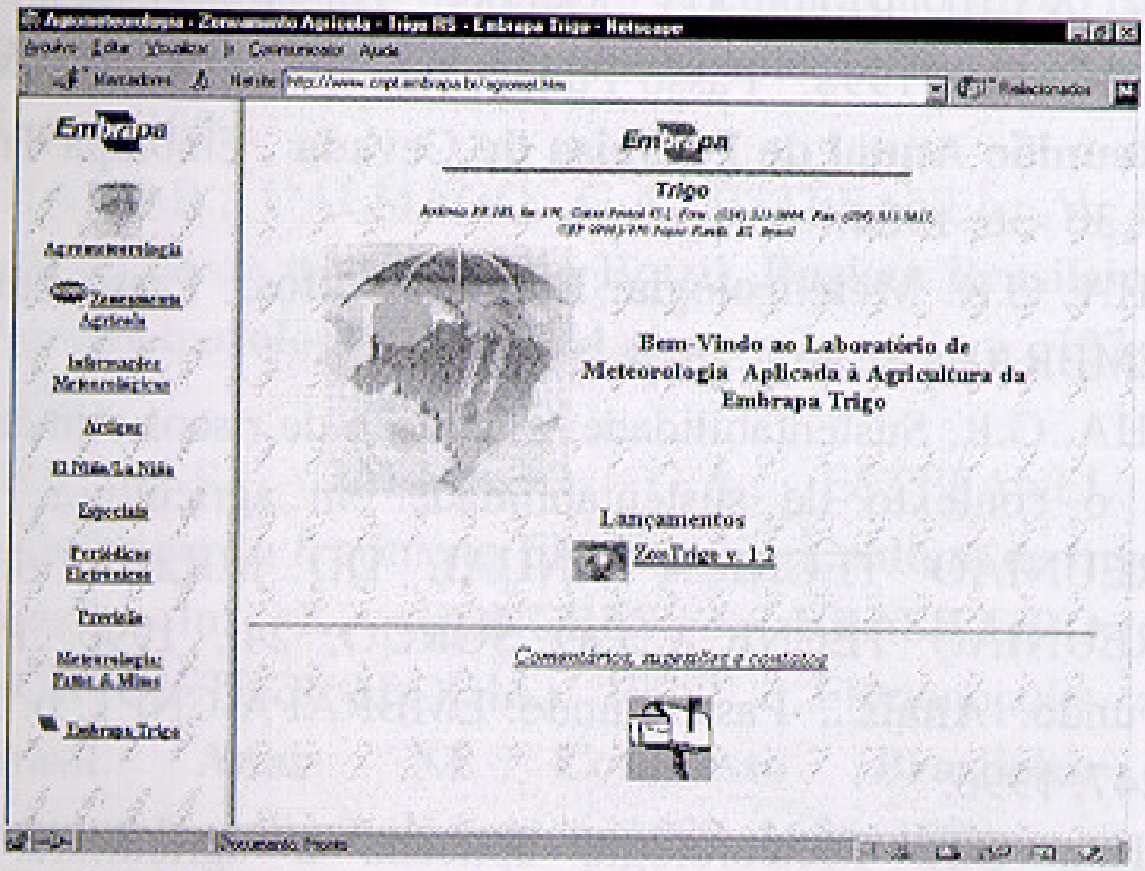

Figure 1. Homepage of Embrapa Trigo "Laboratory of Meteorology Applied to Agriculture".

2.6. Others

Beside the opinion articles for newspapers, scientific articles and technical bulletins, lectures and disponibilization of information on the Internet, emphasis was given on participation in public hearings on the house of deputies (Brasilia, DF, October 22, 1997, meeting of "Comissão da Agricultura e Política Agricola sobre os impactos do fenômeno El Niño") and in interviews for radio, TVs and newspapers, involving the theme of climate forecast for agriculture. The following example can be listed (titles in Portuguese):

- Estiagem volta a assustar na hora do plantio, **Zero Hora-Campo & Lavoura**, Porto Alegre, p. 4, 1° de outubro de 1999.
- Clima favorável para a safra de inverno, **O Nacional**, Passo Fundo, p. 9, 27 de agosto de 1999.
- Frio favorece rendimento e qualidade de trigo no RS, **Diário da Manhã**, Passo Fundo, p. 2, 7 de julho de 1999.
- Clima favorece cultivo de trigo na Região Sul, **O Estado de São Paulo**, São Paulo, p. 4, 30 de junho de 1999.
- Cereal serve para forragem e farinha, **Zero Hora-Campo & Lavoura**, Porto Alegre, p. 5, 25 de junho de 1999.
- Safra de trigo do sul é beneficiada pelo clima, **Gazeta Mercantil**, São Paulo, 14 de junho de 1999.
- Perspectivas climáticas são favoráveis para o trigo, **O Nacional**, Passo Fundo, p. 5, 12-13 de junho de 1999.
- Perspectivas climáticas são favoráveis para o trigo, **Diário da Manhã**, Passo Fundo, p. 16, 17 de junho de 1999.
- Seguro é opção para enfrentar La Niña, **Zero Hora-Campo & Lavoura**, Porto Alegre, p. 40, 16 de julho de 1998.

- Fenômeno El Niño também traz benefícios, **Gazeta Mercantil**, Porto Alegre, p. 1, 10 a 12 de outubro de 1997.
- O que fazer para enfrentar o El Niño, **Zero Hora**, Porto Alegre, p. 30, 30 de setembro de 1997.

IMPACTS OF EL NIÑO AND LA NIÑA ON AGRICULTURAL PRODUCTION IN SOUTHERN BRAZIL AND THE USE OF CLIMATE FORECASTS IN AGRICULTURE

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Abstract

In southern Brazil the warm episodes of ENSO (El Niño) produce rainfall above the climatological mean, and the cold episodes of ENSO (La Niña) produce rainfall below the climatological mean. The period of the year with the greatest impact on rainfall, both for El Niño and La Niña, is spring and early summer. The study of the impacts of El Niño and La Niña on agriculture in the South Region of Brazil (Rio Grande do Sul) shows that El Niño is favorable to the non-irrigated spring-summer crops, such as soybean and maize, raising their mean yields, whereas the La Niña phenomenon is responsible for harvest losses of these two main grain-producing crops in the state. On the other hand, the La Niña phenomenon is favorable to the production of wheat and other winter cereals, and, in several cases, is favorable also to irrigated rice. El Niño may be unfavorable to the spring-summer crops (soybean, maize and rice, for instance) when there is a rainfall above

climatological mean in April and May of the second year of the phenomenon (the maturation and harvest time) as occurred during the great El Niño of 1982/1983. These initial results of the relationship between El Niño and La Niña, rainfall and agricultural production are encouraging. They indicate that seasonal climate forecasts may provide invaluable information for the management of crops, soil and water, and minimize risks in unfavorable situations, making better use of favorable situations. However, in order to make the best use of long-term forecasts, such as those based on El Niño and La Niña, it is necessary to perform further studies of the phenomenon and its impacts on the climate and agriculture in the region, as well as to establish mechanisms to evaluate the effects of decision-making on the agricultural productive process.

1. Introduction

The South Region of Brazil (Paraná, Santa Catarina and Rio Grande do Sul) produces approximately 50 % of the country's grain, 81 % of the fruit, 25 % of the meat, 25 % of the vegetables and 25 % of the milk. The state of Rio Grande do Sul, alone, accounts for around 23 % of the Brazilian grain production, the most important crops being soybean, maize, rice and wheat, with a mean production of 16.3 million tons during the 1993-1995 period (IBGE, 1996).

Although the mean climatic conditions in the South Region of Brazil (subtropical and temperate climates) are favorable to agriculture in general, the seasonal and annual variability of some meteorological elements, especially rainfall

are responsible for the great variability in yields and production in most of this region (Berlato, 1987; Bergamaschi, 1989; Berlato, 1992; Berlato and Fontana, 1999).

As was showed for the first time by Ropelewski and Halpert (1987; 1989), in southeastern South America (southern Brazil, northeastern Argentina, Uruguay and southern Paraguay) there are clear signs of climatic variability associated with the El Niño-Southern Oscillation (ENSO) phenomenon, producing mainly rainfall anomalies.

Several other authors have confirmed and amplified the initial observations by Ropelewski and Halpert for the South Region of Brazil (Rao and Hada, 1990; Studzinski and Diaz, 1994; Studzinski, 1995; Fontana e Berlato, 1997; Grimm et al., 1996 a,b; Diaz et al., 1998). In this region, the warm episodes of ENSO (El Niño) produce rainfall above the climatological mean and the cold episodes of ENSO (La Niña) rainfall below the climatological mean. The greatest impact on rainfall, both in the case of El Niño and La Niña, occurs in spring and early summer.

This paper begins by presenting the impacts of climate variability on agricultural production in the far south of Brazil, especially the effects associated to El Niño and La Niña in grain production. It ends with some considerations regarding the use of climate forecasts in the decision-making process in agriculture.

2. Effects associated with El Niño and La Niña on Rio Grande do Sul agriculture

2.1. Soybean and maize

Soybean and maize are the two main crops in Rio Grande do Sul. Together, they cover 70 % of the cultivated area and account for 65 % of the total grain production in the State. Practically all these crops are farmed without irrigation (dry-farming) and their yields and production, consequently, depend on rainfall.

Figure 1 shows the function of the relationship between rainfall and soybean yield in the state of Rio Grande do Sul. It is found that the quadratic function has a good fit to the data observed, showing that rainfall from December to March accounts for almost 80 % (r^2=0.79) of the interannual variation in soybean yields. It is stressed that mean rainfall (6 stations) in the significant area of production (northwest of the state) accounts for much of the variability of soybean yields in the state. Through this function, the maximum soybean yield is achieved with a 848 mm rainfall, equivalent to 213 mm, on average, per month. This value is much higher than the monthly mean in the December-March period, even for the regions with the heaviest rainfalls in the state (Ávila, 1994).

A study of the water use of soybean carried out for several years in the climatic region of the Depressão Central (Berlato et al., 1986), shows that soybean require an average of approximately 827 mm of water for the whole cycle (approximately 4.5 months). Therefore, the 848 mm of rainfall

over 4 months (December to March) needed to achieve the maximum soybean yield is quite realistic, taking into account that total rainfall, not effective rainfall was used in this study.

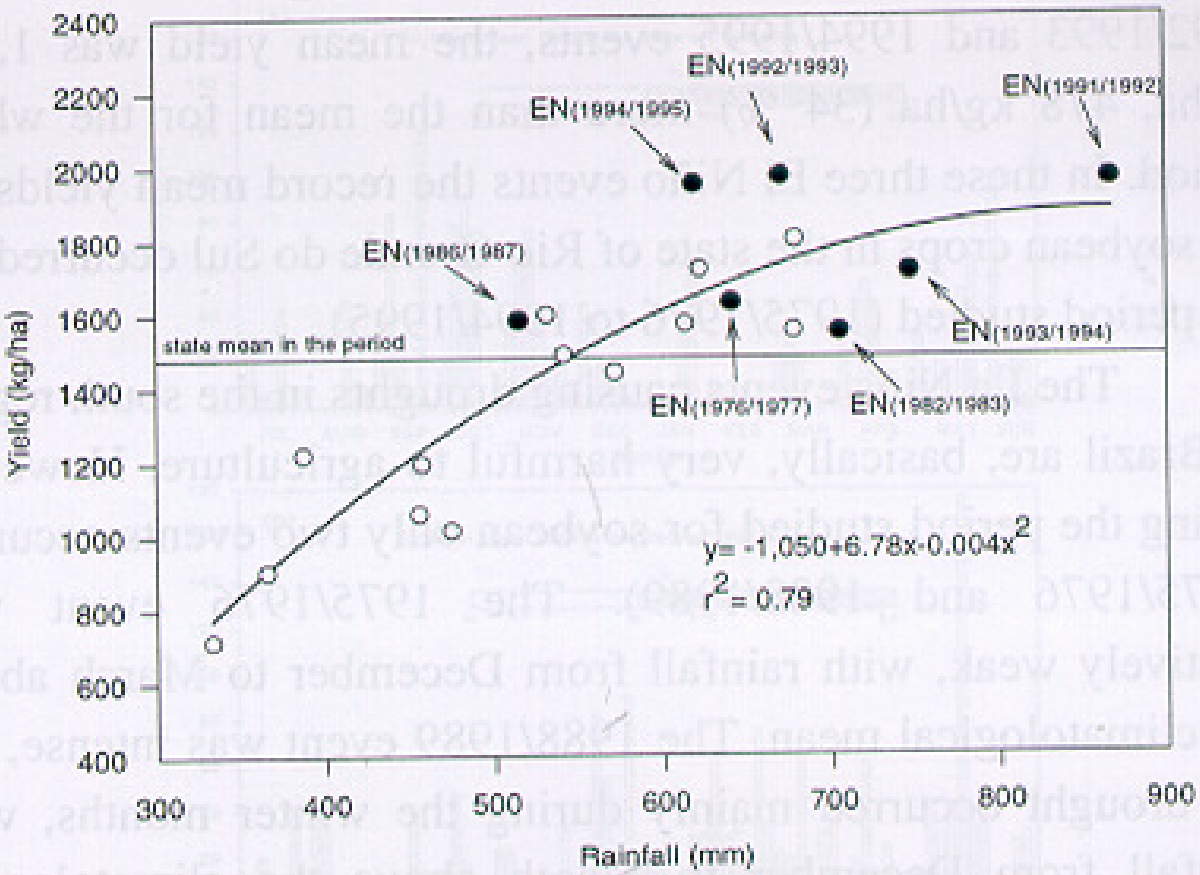

Figure 1. Relationship between the rainfall from December to March (mm) and soybean grain yield (kg/ha) in the state of Rio Grande do Sul, 1975/1976-1994/1995 period (Berlato and Fontana, 1999). EN- Years of occurrence of EL Niño.

Matzenauer and Fontana (1987), relating rainfall to data from experiments concerning maize yields in the Depressão Central region of the State, had already shown that the quadratic function is well fitted to the data observed, and that the rainfall that occurred during the reproductive period (tasseling-silking), accounts for much of the variability in the yields of this crop.

In Figure 1 are shown the El Niño events that occurred during the period from 1975/1966 to 1994/1995 (7 events). The mean soybean yields in the state during the 7 years when El Niño occurred was 1,763 kg/ha, 283 kg/ha (16 %) more than the average for the whole period. During the 1991/1992, 1992/1993 and 1994/1995 events, the mean yield was 1,958 kg/ha, 478 kg/ha (34 %) more than the mean for the whole period. In these three El Niño events the record mean yields for the soybean crops in the state of Rio Grande do Sul occurred for the period studied (1975/1976 to 1994/1995).

The La Niña events causing droughts in the south region of Brazil are, basically, very harmful to agriculture. However, during the period studied for soybean only two events occurred (1975/1976 and 1988/1989). The 1975/1976 event was relatively weak, with rainfall from December to March above the climatological mean. The 1988/1989 event was intense, but the drought occurred mainly during the winter months, with rainfall from December to March above the climatological mean.

Figure 2 shows the time distribution of rainfall in five-day periods, the means of six locations in the northwestern region of the state for the agricultural years of 1990/1991 and 1991/1992, as well as part of the average agricultural calendar for soybean. In 1990/1991 a drought occurred in the region, mainly during the period from end of December to March, coinciding with the whole period of flowering and a great part of the soybean grain filling period (critical periods for the crop as regards water) (Figure 2a). The mean soybean yield for that year was 712 kg/ha, one of the lowest in the history of this crop in the state. The following year, 1991/1992, thanks to the El

Niño phenomenon, there was plenty of rainfall in the region and in the same period and the mean yield in the state rose to 1,957 kg/ha (Figure 2b).

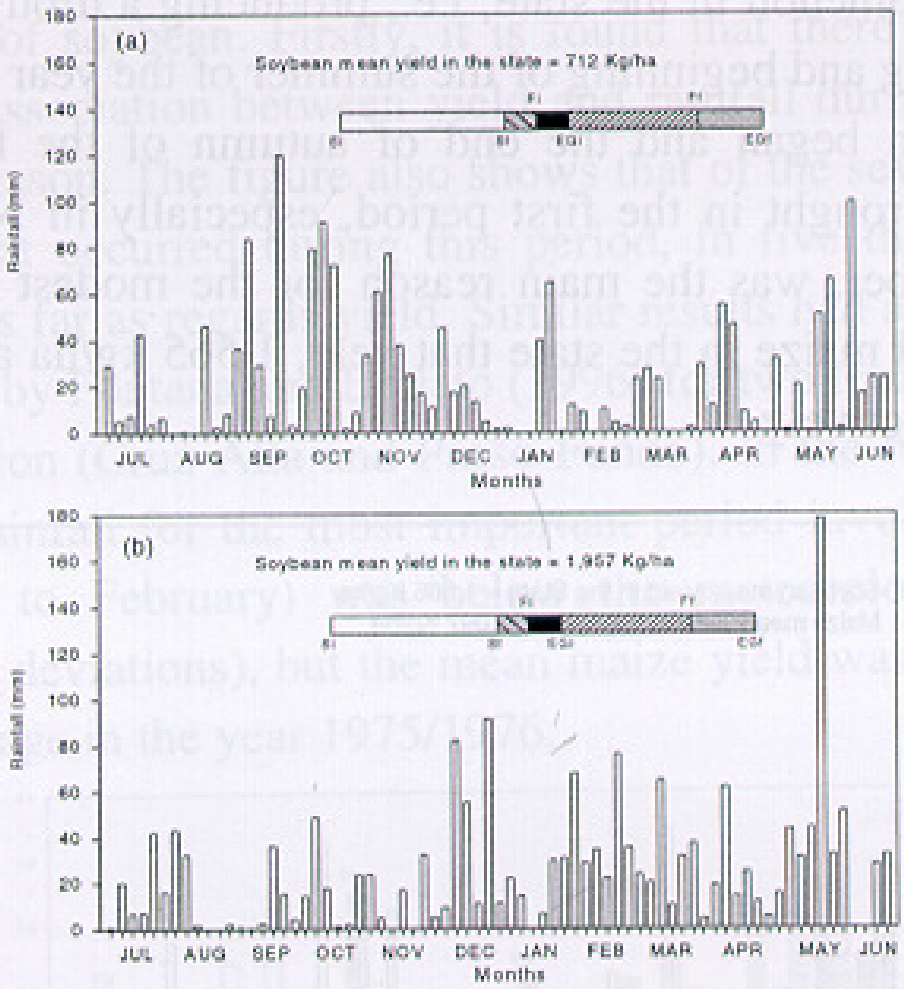

Figure 2. Rainfall (mm) for five-day periods in the northwest of the state of Rio Grande do Sul (mean of 6 localities) in 1990/1991(drought) (a), in 1991/1992 (El Niño) (b) and mean soybean yield in the state. Source of data: 8th DISME/FEPAGRO/EMATER-RS. The horizontal bar represents part of the mean agricultural calendar of soybean. Si and Sf represent the beginning and end of the sowing, respectively; Fi and Ff, represent the beginning and end of flowering, respectively; Egi and Egf represent the beginning and end of grain filling, respectively.

Figure 3 shows the time distribution of rainfall in the same region previously mentioned (northwest of the state) for the La Niña year of 1995/1996. This La Niña, considered weak, was very similar, in terms of rainfall, to the climatological mean of the phenomenon in the state, i.e., producing a drought at the end of spring and beginning of the summer of the year when the phenomenon began and the end of autumn of the following year. The drought in the first period, especially in November and December, was the main reason for the modest yields of soybean and maize in the state that year, 1,565 kg/ha and 2,097 kg/ha, respectively.

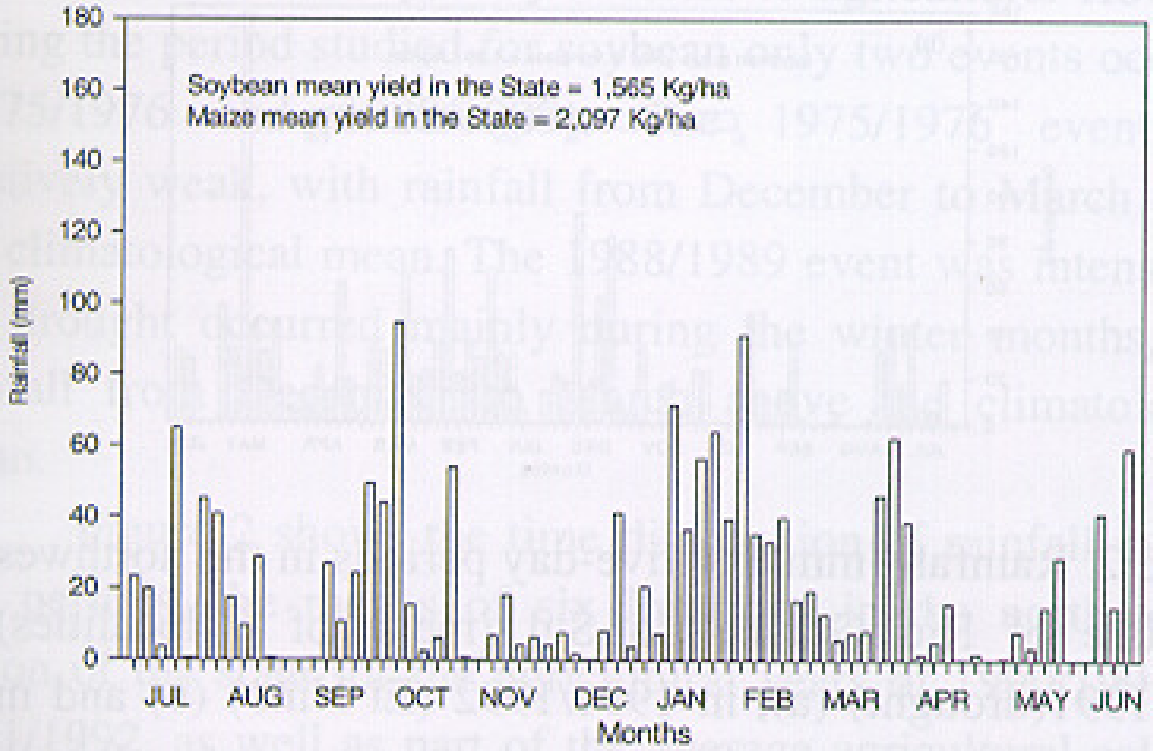

Figure 3. Rainfall (mm) for five-day periods in the northwest of the state of Rio Grande do Sul (mean of 6 localities) during the La Niña phenomenon of 1995/1996 (July to June) and mean yield of soybean and maize in the state of Rio Grande do Sul. Source of data: 8th DISME/FEPAGRO/EMATER-RS.

Figure 4 shows the standard deviations of the maize

yields in the state and the rainfall of the period from October to February, an average of 17 meteorological stations located in the most significant region for the production of that crop (northern region of Rio Grande do Sul), for the same period of 20 years of soybean. Firstly, it is found that there is a strong positive association between yield and rainfall during the crop growth season. The figure also shows that of the seven El Niño events that occurred during this period, in five the crop was favored as far as regards yield. Similar results had already been observed by Fontana and Berlato (1996) for two localities in the same region (Cruz Alta and Passo Fundo). In the two La Niña events, rainfall for the most important period involving maize (October to February) was below the meteorological mean (negative deviations), but the mean maize yield was only lower than average in the year 1975/1976.

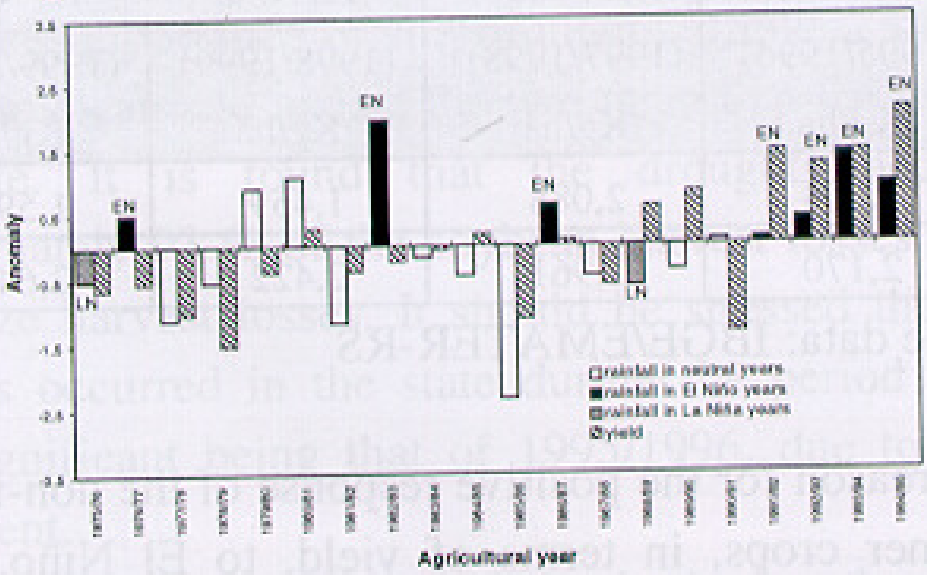

Figure 4. Anomalies standardized (by standard deviation) of maize yield and rainfall from October to February in the state of Rio Grande do Sul, 1975/1976-1994/1995 period (Fontana and Berlato, 1996). EL-years of occurrence of El Niño: LN-years of occurrence of La Niña.

Table 1 shows the mean yields of soybean and maize in Rio Grande do Sul in the last four events of El Niño and La Niña, not included in Figures 1 and 4. These data confirm the tendency for modest yields in these crops in the La Niña years (1995/1996, 1998/1999 and 1999/2000), but they also confirm the gains in mean yields of the state obtained in the El Niño years. In the case of soybean, for instance, the mean yield of 2,088 kg/ha and the total production of 6,605,743 tons in the El Niño year 1997/1998, represent, in physical terms, the best result of the whole history of this crop in Rio Grande do Sul.

Table 1. Mean soybean and maize yields in the state of Rio Grande do Sul, during the most recent El Niño and La Niña events.

Crop	La Niña (1995/1996) Kg/ha	El Niño (1997/1998) Kg/ha	La Niña (1998/1999) Kg/ha	La Niña (1999/2000) Kg/ha
Soybean	1,704	2,088	1,459	1,593
Maize	2,170	2,961	2,422	2,644

Source of the data: IBGE/EMATER-RS

The reason for the positive response of the non-irrigated spring-summer crops, in terms of yield, to El Niño, is that normal rainfall at the end of spring and summer in the state is generally insufficient to cover the water needs of these crops, limiting their yields (Berlato et al., 1986; Berlato, 1992; Fontana and Berlato, 1996; Berlato and Fontana,1999). This also goes for some forage plants such as, for instance, alfalfa, as shown by Bergamaschi et al. (1997).

In addition to the fact that normal summer rainfall is insufficient for non-irrigated agriculture, the droughts with rainfall well below the mean, that occur more frequently in spring and summer, make the situation worse.

Table 2 shows the "big numbers" of the physical and economic impacts of droughts on agricultural production in the state of Rio Grande do Sul. The last six droughts caused losses on the order of 19.1 million tons of grain, for the soybean and maize crops, a total value of more than 3 billion dollars. This loss of 19.1 million tons of soybean and maize represents more than the total production of all grain obtained in a normal year (no drought) in the state of Rio Grande do Sul.

An interesting study by the Empresa de Assistência Técnica e Extensão Rural (EMATER-RS, 1998) on the reasons for harvest losses in the State during the 1992-1997 period, shows the importance of the droughts. Table 3 illustrates the case of soybean and maize, the two main non-irrigated crops in the state. It is found that the droughts accounted for approximately 93 % of the soybean harvest losses and 88% of the maize harvest losses. It should be stressed that no severe droughts occurred in the state during the period studied, the most significant being that of 1995/1996, due to a weak La Niña event.

The soybean yields statistics in the last three decades (a large part of the history of this crop in the State), showed a frequency of 32 % reduction of yield due to drought. In other words, on average, approximately for one out of every three crops there is loss of yield due to this climatic adversity.

Table 2: Physical and economic impacts of droughts on agricultural production in the state of Rio Grande do Sul (soybean and maize).

Agricultural year	Losses of grain (millions of tons)	Value US$ millions
1987/1988	3.6	709.3
1990/1991	5.5	797.0
* 1995/1996	2.8	522.5
1996/1997	2.1	402.8
* 1998/1999	2.8	335.4
* 1999/2000	2.3	307.8
Total	19.1	3,074.8

Source of data: EMATER-RS * Years of La Niña

Table 3. Causes of losses in harvests in the State of Rio Grande do Sul (1992/1997 period)

Crop	Total loss (millions of tons)	Causes	
		Drought	Excessive rainfall, hail, pests, diseases etc.
Soybean	3,3	92,6 %	7,4 %
Maize	3,5	88,4 %	11,6 %

Source of data: EMATER-RS

In the El Niño years, there is no possibility of the occurrence of long periods of drought and the spring-summer rainfall is generally higher than the climatological mean,

leading to higher yields and, thus, higher production.

The risk that El Niño could be harmful to the non-irrigated summer crops is limited to autumn of the second year of phenomenon , especially if April and May are very rainy, and could create problems for the end of the maturation process and harvesting activities. During the intense El Niño in 1982/1983, the frequent excessive rainfall, beginning in April, determined losses of approximately 994 thousand tons of soybean and 196 thousand tons of maize. The negative impact of the intense 1982/1983 event could have been significantly reduced if, at the time, there had been the knowledge and forecasts of the phenomenon, that are already available to decision-makers in agriculture and to the farmers themselves, before sowing began.

2.2. Paddy Rice

Figure 5 shows the anomalies of irrigated rice yields as compared to the historical mean in the last five decades (1944/1945 to 1999/2000) in the State, where we can also see the years when El Niño and La Niña occurred. This figure was constructed after removing the technological trend of the original series that is highly significant in the case of rice. After removing the effects of new technologies (cultivars, management etc.), deviations from the mean of the new series are due to the environmental elements, especially meteorological ones. In Figure 5 it is seen that of the 17 El Niño events, 9 were harmful (53 %) in terms of yield (negative deviations) and 8 (47 %) were beneficial (positive deviations).

One of the possible reasons why El Niño is harmful to irrigated rice is the smaller amount of hours of sunlight caused by this phenomenon during the growing season of this crop, especially from October to February (Figure 6). As regards the La Niña event, of the 10 events that occurred during the period in 6 (60 %) yields were higher than average and in 4 (40 %) lower. These data show that there is a tendency for El Niño events to lower the yield of irrigated rice and a stronger tendency for La Niña events to be favorable.

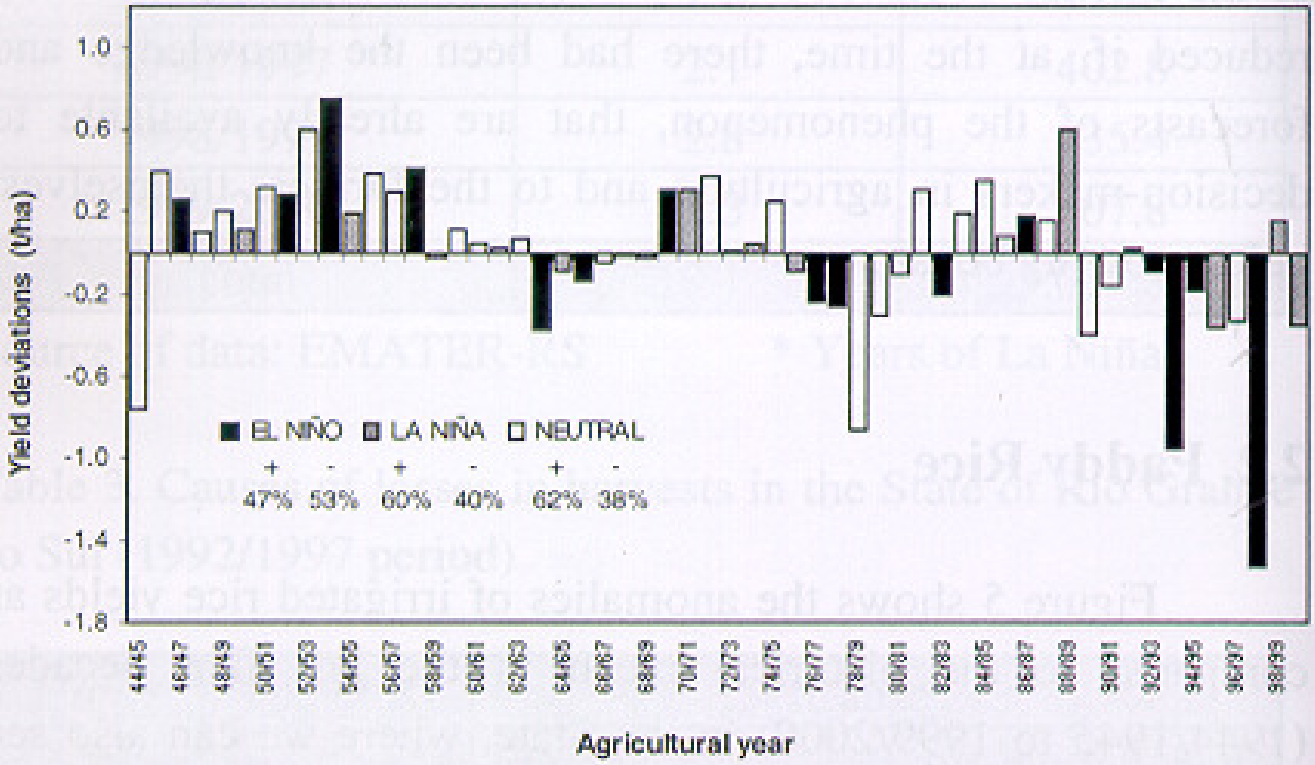

Figure 5. Anomalies in irrigated rice yields (t/ha) in the state of Rio Grande do Sul, 1944/1945-1999/2000 period (Carmona and Berlato,2001). Source of data: IRGA-RS.

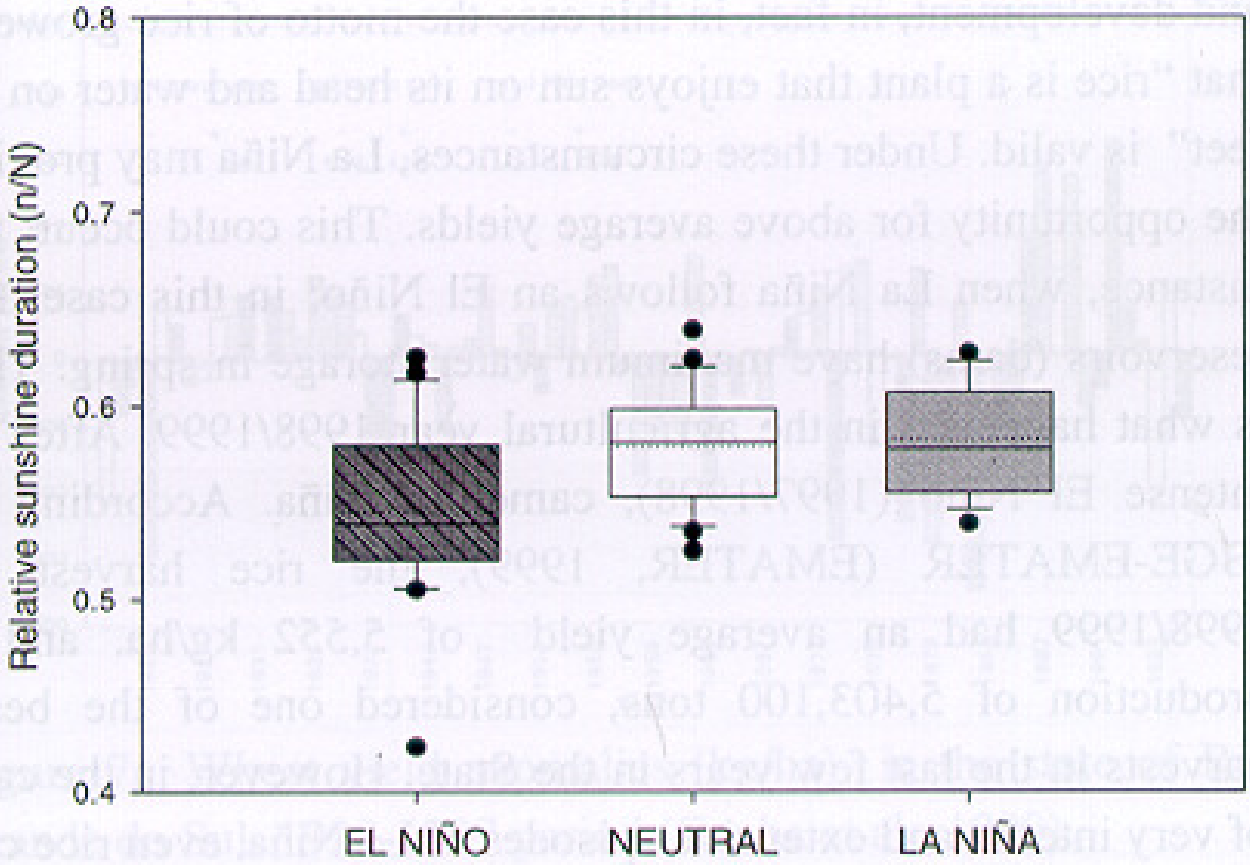

Figure 6. Distribution of relative sunshine duration (n/N), from October to February, associated to the years of El Niño, La Niña and neutrals, 1944/2000 period, for the rice-growing region of the state of Rio Grande do Sul (Carmona and Berlato, 2001). The full horizontal line inside the boxes represents the percentile 50 (median), the dashed line represents the mean, the end of the boxes the percentiles 25 and 75, the bar the percentiles 10 and 90, and the full circles the extreme values. Source of data: FEPAGRO/RS and 8th DISME/INMET.

The La Niña years in the State are characterized by below normal rainfall, especially in spring and the beginning of summer, as has already been seen, but also by less nebulosity, more hours of sunlight (Figure 6) and, possibly, more solar radiation. If there is no lack of water in the reservoirs (dams),

these meteorological conditions are excellent for rice growth and development, in fact, in this case the motto of rice growers, that "rice is a plant that enjoys sun on its head and water on its feet" is valid. Under these circumstances, La Niña may provide the opportunity for above average yields. This could occur, for instance, when La Niña follows an El Niño; in this case, the reservoirs (dams) have maximum water storage in spring. This is what happened in the agricultural year 1998/1999. After an intense El Niño (1997/1998), came La Niña. According to IBGE-EMATER (EMATER, 1999), the rice harvest of 1998/1999 had an average yield of 5,552 kg/ha, and a production of 5,403,100 tons, considered one of the bests harvests in the last few years in the State. However, in the case of very intense and extensive episodes of La Niña, even rice can be harmed by lack of water.

2.3. Wheat

Figure 7 shows the deviation from the mean of wheat yields in the state of Rio Grande do Sul over a 78-year period, after the removal of the technology trend (Cunha et al., 1999). During this period, 23 events of El Niño and 15 events of La Niña occurred (marked on the graph). In 57 % of the El Niño years the deviations were negative, and in 43 % they were positive. Of the La Niña events, 67 % presented positive deviations and 33 %, negative deviations. These results of observations show a strong tendency of the La Niña years to favor wheat crops in the State, whereas the El Niño years are generally unfavorable.

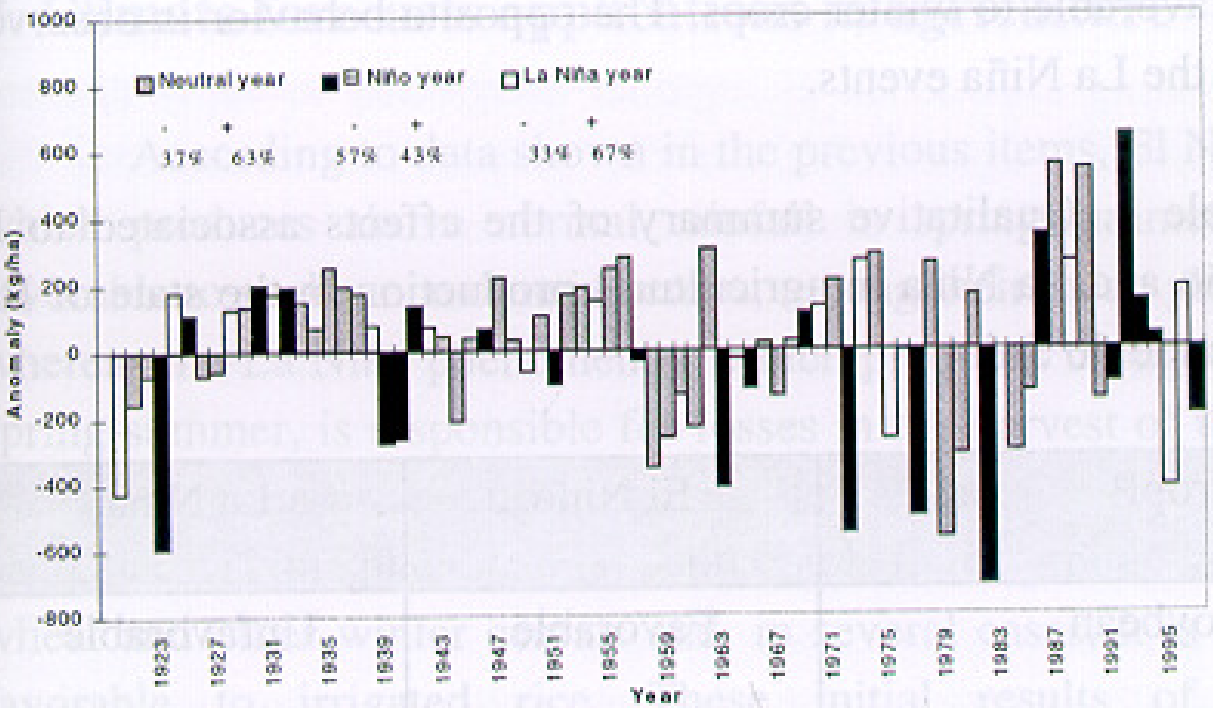

Figure 7. Wheat yield anomalies (kg/ha) in the state of Rio Grande do Sul, 1920-1997 period (Cunha et al., 1999).

El Niño is unfavorable to wheat and, certainly, to the other winter cereals, especially considering that the intense, frequent rainfalls provoked by this phenomenon at the end of spring coincide with the period of maturation and harvesting of these cereals. According to data from the official agencies that perform surveys of Rio Grande do Sul agriculture (IBGE/EMATER-RS), the loss of wheat production attributed to the last El Niño in 1997/1998, was on the order of 316 thousand tons, representing 35 % less than estimated for the state at the beginning of the harvest. The winter crops, however, represent less than 10 % of the total grain production of Rio Grande do Sul.

Table 4 shows a qualitative summary of the effects associated to El Niño and La Niña in the main Rio Grande do Sul crops. As discussed previously, El Niño tends to be

favorable to the spring-summer crops, except for rice, and unfavorable to winter crops. The opposite behavior is observed for the La Niña events.

Table 4. Qualitative summary of the effects associated to El Niño and La Niña in agricultural production in the state of Rio Grande do Sul.

CropP	El Niño	La Niña
Soybean	Favorable	Unfavorable
Maize	Favorable	Unfavorable
Rice	Unfavorable (intense event)	Favorable (weak event)
Wheat and other winter cereals	Unfavorable	Favorable
Forage plants	Favorable	Unfavorable

In order to minimize the impacts of the climatic adversities on agriculture, climate risk zonings for risk and irrigation, whenever possible, are appropriate strategies in the case of droughts. For the climatic variability associated with El Niño and La Niña, the seasonal climate forecasts currently available, become invaluable information in the decision-making process regards the management of crops, soil and water.

3. Climate forecasts applications in agriculture

According to data shown in the previous items, El Niño, which produces above normal rainfall in spring-summer, is favorable to soybean and maize crops, raising their mean yields, whereas the La Niña phenomenon, which produces droughts in spring-summer, is responsible for losses in the harvest of these two main grain-producing crops in the region. On the other hand, the La Niña phenomenon is favorable to the production of wheat and other winter cereals and, in several cases, it is also favorable to irrigated rice. These initial results of the relationship between indicators of climate variability, rainfall and agricultural production are encouraging. They indicate that seasonal climate forecasts may constitute invaluable information for crop management, insofar as they minimize risks under unfavorable conditions and make good use of favorable situations.

In the state of Rio Grande do Sul, forecasts and warnings of the occurrence of the latest El Niño event (1997/1998) enable several decisions to be made, such as harvesting the wheat earlier and faster and hurrying up with sowing the rice, in order to minimize risks. During the La Niña event of 1998/1999, a Work Group (WG) with representatives of several organizations, including universities, technical aid agencies and farmers organizations (cooperatives and federations) was instituted under the coordination of the Secretaria da Agricultura e Abastecimento (SAA/RS), to follow the monitoring and forcasting of the La Niña phenomenon made by national and international weather and climate

forecasting institutes, analyze this information and provide technical advice to the farmers. This WG constituted an interesting experience of regional integration to apply climate forecasts in agriculture, for the purpose of minimizing the impacts of droughts that are well-known to occur during the La Niña years. The WG produced a technical document containing information about the evolution of the phenomenon, the forecasts for the next season and the technical advice based on agricultural and agrometeorological research to reduce losses. This document was disseminated to the whole State by conventional and electronic means.

This WG is now institutionalized under the general coordination of the Secretaria da Agricultura e Abastecimento (SAA-RS) as a "Fórum Permanente de Monitoramento do Tempo e Clima para Agricultura no Rio Grande do Sul". This Forum holds monthly meetings and is already on its fifteenth edition (March 2001).

However, in order to be able to profit most from long-term forecasts (climatic forecasts), such as those based on El Niño and La Niña, it is necessary to go ahead with studying the phenomenon and its impacts on the climate and on the agriculture in the region, as well as to establish mechanisms to assess the effects of decision-making on the agricultural production process.

A permanent, possibly useful system to apply to climate forecasts based on El Niño and La Niña in agriculture should consider at least the following items:

- The existence and availability of the climatic forecasts on time and space scales appropriate to agricultural activities;
- The most detailed studies possible regarding the impacts of

El Niño and La Niña on the climate in the region;

- Studies on the impacts of El Niño and La Niña on agriculture in the region;
- Generation of "products" of climate forecasts with an added agrometeorological and agricultural value;
- Dissemination of these "products" in the form of technical recommendations;
- Use of technical recommendations by farmers;
- Assessment of the result of the decision to use or not use the technical recommendations.

The latter item is crucial, since it represents system feedback. It is necessary to know whether the technical recommendations resulted in the minimization of the negative impacts of adverse meteorological phenomena on agricultural production, and also whether favorable climate forecasts proved useful. Finally, it is necessary to know whether the "climate input" used or not used made a difference to the farmer's income. But this must be quantitatively demonstrated by follow-up and statistical evaluations.

Figure 8 shows a simplified flowchart of the proposed System of Application of Climate Forecasts to Agriculture for regions that present strong signs of the El Niño and La Niña phenomenon, as is the case in southern Brazil.

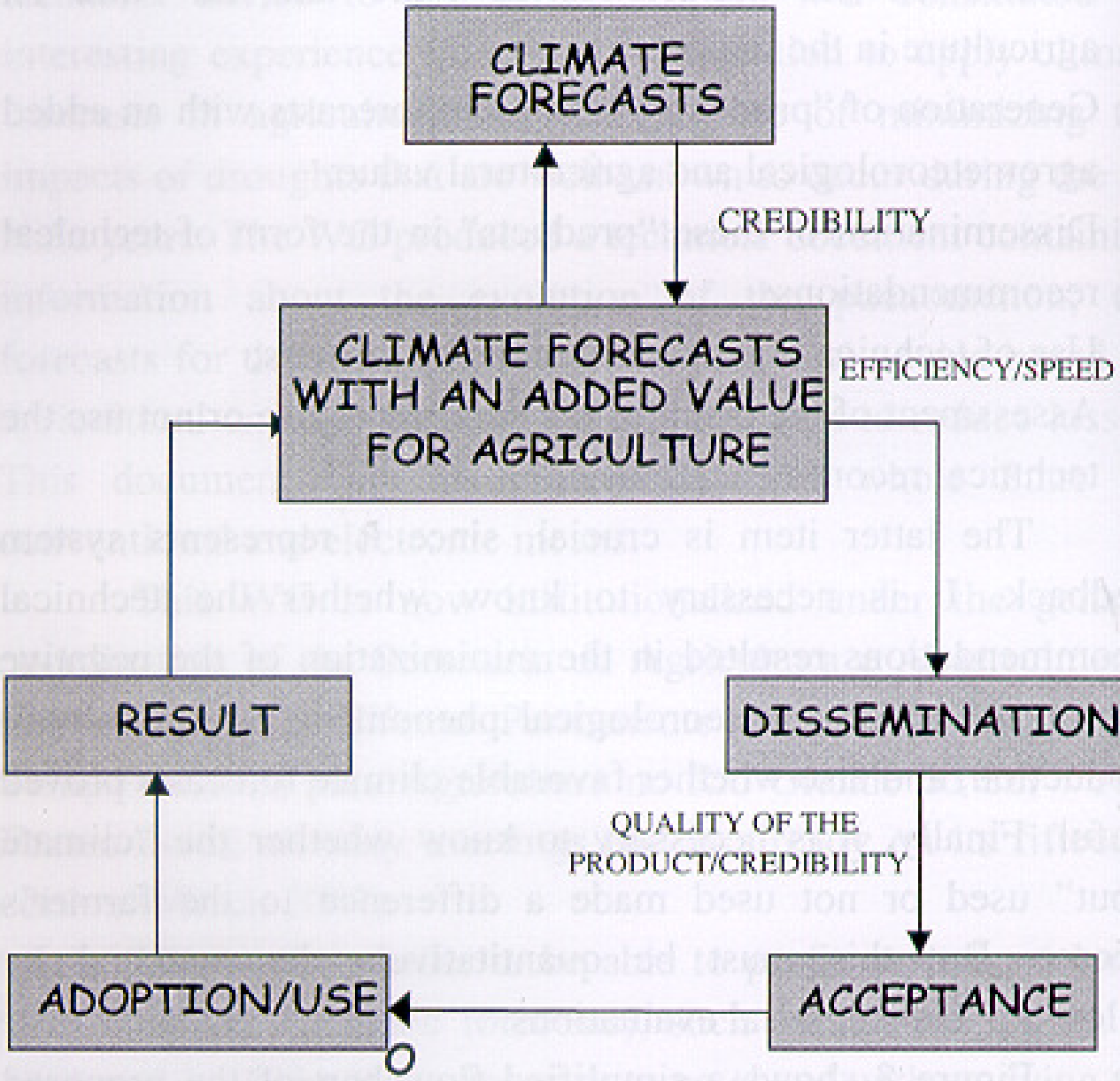

Figure 8. Flowchart of a System of Application of Climate Forecasts to Agriculture

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SUMMARY OF ACTIVITIES RELATED TO THE ASSESSMENT OF ENSO IMPACTS AND THE APPLICATION OF ENSO-BASED CLIMATE FORECASTS IN THE AGRICUTURAL SECTOR OF ARGENTINA

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Abstract

In this work we present a synthesis of the activities carried out in Argentina during the last few years related to ENSO and agriculture. The work has been focused on the end-to-end approach, looking for the feasibility of agricultural applications of ENSO-based climate forecasts. A first step was to know the impacts of ENSO on the climate of our main grain producing region. Once the signal and its intensity were quantified, the second step was to know the relations between the occurrence of ENSO phases and the production of our main crops by means of historical information. Then, the assessment of optimal crop management practices for each phase was done using crop simulation models and the selected techniques were verified with on-farm tests carried out in several farms of the main production zone. Finally the economic value of ENSO-

based climate forecasts was obtained. Results obtained indicated that ENSO affect precipitation pattern in the Argentina's Pampean region. However there is a great spatial variability in the intensity, the beginning and the persistence of the signal. During "El Niño" events in most of the region there is a high probability of having maize and soybean yields higher than normal, inversely during "La Niña" years the main maize and soybean production regions are mostly damaged. Wheat has the same behavior, but only in the southwestern portion of the region. Inversely, sunflower's yields tend to be higher during La Niña and lower during El Niño years. Differences among phases in optimal management practices were found. In general increasing the fertilizer doses and advancing planting date will be the best combination during El Niño years, while for La Niña years delaying planting dates and reducing fertilizer application will be the best. The economic value of ENSO-based climate forecast, when used to change management practices in agriculture is rather low (up to 6 %) because of high spatial and temporal variability in ENSO signal.

1. Introduction

South Eastern South America is one of the largest food producer regions of Latin America. Its economy is mainly based on agriculture and in most of the countries involved agricultural exports represent an important portion of incomes. In this region, interannual and interseasonal climatic fluctuations result in high variability in crop production with varied consequences on food supply and economy. In the

Argentina's Pampean region annual grain production was, on average, 37 Mt between 1988-1998, but it varied from 23 Mt in the worst year to 59 Mt in the best one. The uncertainty related with weather variability is a continuous challenge for the farmers in this region.

El Niño Southern Oscillation (ENSO) phenomenon is one of the principal sources of climatic variability in this region. In 1987 Ropelewski and Halpert analyzing the impact of ENSO phases on rainfall in South Eastern South America, defined a region comprising southern Brasil, Uruguay, southern Paraguay, and eastern Argentina were precipitations during November-February tended to be above normal during El Niño years. Later, they found that during La Niña years negative precipitation anomalies occurred during June-December (Ropelewski and Halpert, 1989). As in our region crop production is highly dependent on rainfall, the mentioned variability on climate patterns could severely affect crop yields, in particular in summer crops.

The influence of ENSO on agricultural production and the emerging capacity to forecast climatic anomalies at seasonal lead times suggest an unprecedented opportunity to tailor agricultural decisions to anticipated weather conditions, either to mitigate the impacts of adverse conditions or to take advantage of the favorable ones. However, effective application of climate forecasts to agriculture in a particular region depends on :a- the availability of regional forecasts of adequate lead time and accuracy, b- the vulnerability of agriculture to weather variability, c- the existence and awareness of options for using knowledge of future weather to improve agricultural decisions,

their decisions based on available information (Lamb, 1981; Sonka et al., 1986, 1987, 1992; Easterling and Mjelde, 1987; Livezey, 1990; Mjelde et al., 1993).

In this work we present a synthesis of the activities carried out in Argentina during the last few years related to ENSO and agriculture. The work has been focused on the end-to-end approach, looking for the feasibility of agricultural applications of ENSO-based climate forecasts. A first step was to know the impacts of ENSO on the climate of our main grain producing region. Once the signal and its intensity were quantified, the second step was to know the relations between the occurrence of ENSO phases and the production of our main crops by means of historical information. Then, the assessment of optimal crop management practices for each phase was done using crop simulation models and the selected techniques were verified with on-farm tests carried out in several farms of the main production zone. Finally the economic value of ENSO-based climate forecasts was obtained.

2. Methodology

ENSO phases (El Niño, La Niña, Neutral) were classified based on 5 month running means of Japan Meteorological Agency (JMA) SST anomalies, spatially averaged over the tropical Pacific from 90° to 150°W and 4°N to 4°S.

ENSO effects on precipitations, was assessed for the Pampean Region analyzing monthly values from 39 stations (1910-1995) spread over an area of 70 Mhas. These values were

grouped bimonthly from August-September of the year where the phase starts until May-June of the following year. Long term trend was removed by means of smoothing techniques, then were obtained the annual anomalies and calculated the chance of having low (lower tercile) or high (upper tercile) values for La Niña or El Niño years.

ENSO effect on crop production was analyzed at the county level using grain yields corresponding to 1923-1995 for wheat and maize, 1934-1995 for sunflower and 1969-1995 for soybean. In each county yields were corrected to eliminate the historical trend by the robust locally weighted regression proposed by Cleveland (1979). Corrected yields were classified in three categories (33 % values in each) : "low yields", "normal yields" and "high yields". Then, the percentage of "high yields" in "El Niño" years and "low yields" in "La Niña" years was performed for wheat, maize and soybean while for sunflower the opposite combination was done.

Crop models included in the decision support system DSSAT (Tsuji et al, 1994) were used to optimize management practices and net returns for wheat, maize, sunflower and soybean for each ENSO phase (El Niño, La Niña). These models had been calibrated and validated for the Pampas conditions by means of an experimental network, presenting low estimation errors. To test their performance at the field level, we used historical yield data obtained from farmers. For each crop and field, information was obtained for the last few years on: preceding crop, soil water and nitrogen contents (top 60 cm) at sowing, cultivar, planting date and density, row spacing, fertilizer doses and application dates, grain yield, soil classification and related economic information (production

cost, grain prices). As climatic inputs, we used daily precipitation recorded in each farm, and maximum and minimum temperature and solar radiation from the nearest meteorological station.

Management options to optimize crop yields and net returns for each ENSO phase included planting dates and nitrogen fertilization rates. The analysis of strategies has been done using models in DSSAT. For maize, wheat and sunflower management optimization for each ENSO phase was done considering different plantings dates and nitrogen fertilizer doses (between 0 kg/ha and 200 kg/ha). In soybean, we analyzed planting dates distributed between early November and late December in all the sites.

On-farm tests with treatments representing the best option for each ENSO phase were carried out for different crops and sites during the growing seasons 1998/99, 1999/00. The farms were located in the provinces of Buenos Aires (Juan Bautista Alberdi, Carmen de Areco, 9 de Julio), Santa Fe (Diego de Alvear) and La Pampa (Catriló, Relmo and Toay). Experimental trials representing the best options defined for each phase were installed in the selected farms. Treatments considered were those corresponding to El Niño, La Niña and the farmer's management. Experimental plots had a surface of 0.5 ha and were planted and harvested mechanically.

The economic value (EV) of climate forecasts was calculated for maize and soybean according to the decision theory (Hilton, 1981 cited by Hill et al. 2000). The sites considered were Pergamino (PE), Junín (JU), Diego de Alvear (DA) and Santa Rosa (SR). The assumption was that farmer's prior knowledge is the climatological (historical) distribution of

climate conditions represented by historical weather data. Optimal input combinations leading to maximize net returns for the climatological distribution -including planting dates and nitrogen fertilizer doses- were obtained using crop models. These results were considered as the best management options without considering climate forecasts. Then, the optimal net return for each forecasted phase (La Niña, El Niño, Neutral) was obtained, using as climatic inputs the years corresponding to each phase. To obtain expected net returns using forecasted information the net returns for a given phase were weighted by the probability of the phase occurring. Finally the economic value of climate forecasts for a given site and price was calculated as the difference between the net returns obtained using historical data and those obtained considering the three forecasted phases.

3. Results

3.1. ENSO impact on climate

At the regional scale, during El Niño years the signal (higher precipitation, chance>1.4) appear slightly during Sep-Oct and Oct-Nov in the north and southwest of the region (Fig. 1). The signal is stronger in Nov-Dec in most of the region, persisting in Dec-Jan only in the west. Then it disappears in Jan-Feb all over the region except in isolated points but restarts during Feb-Mar, Mar-Apr in some areas disappearing during the following months. In La Niña events the signal (lower precipitation, chance>1.4) starts in Sep-Oct in the north,

progressing during Oct-Nov in great part of the region, and being generalized in Nov-Dec. In Dec-Jan it persist only in some parts of the west and north, and practically disappear during Jan-Feb. In Feb-Mar the signal restart in the north and southwest progressing towards the east during Mar-Apr, Apr-May.

Important spatial and temporal differences in the occurrence of the signal and its intensity were evidenced. As an example results from two contrasting sites, one from the humid zone (site 1) and the other from the semiarid one (site 2), are presented in Figure 2. In site 1 the intensity and persistence of the signal is stronger for both phases. During El Niño events the signal (positive anomalies) is evidenced between September and June, with the exception of January and April, but the maximum response is appreciated during November and December. In site 2, the signal starts in November and continues until April but with lower intensity than in the other site. During La Niña years, negative anomalies were obtained in site 1 since October until May, except in February, with a stronger signal during November, December and March. In site 2, negative anomalies were evidenced in July-August, then since October until January and in April-May with a stronger signal in December-January.

December is a month where ENSO signal was evidenced in both sites, however looking at the distribution of precipitation anomalies (Fig. 3) is clear that for both phases the probability of having negative values is quite high. Differences between sites are better expressed during El Niño events, where the probability of having greater positive anomalies was higher in site 1.

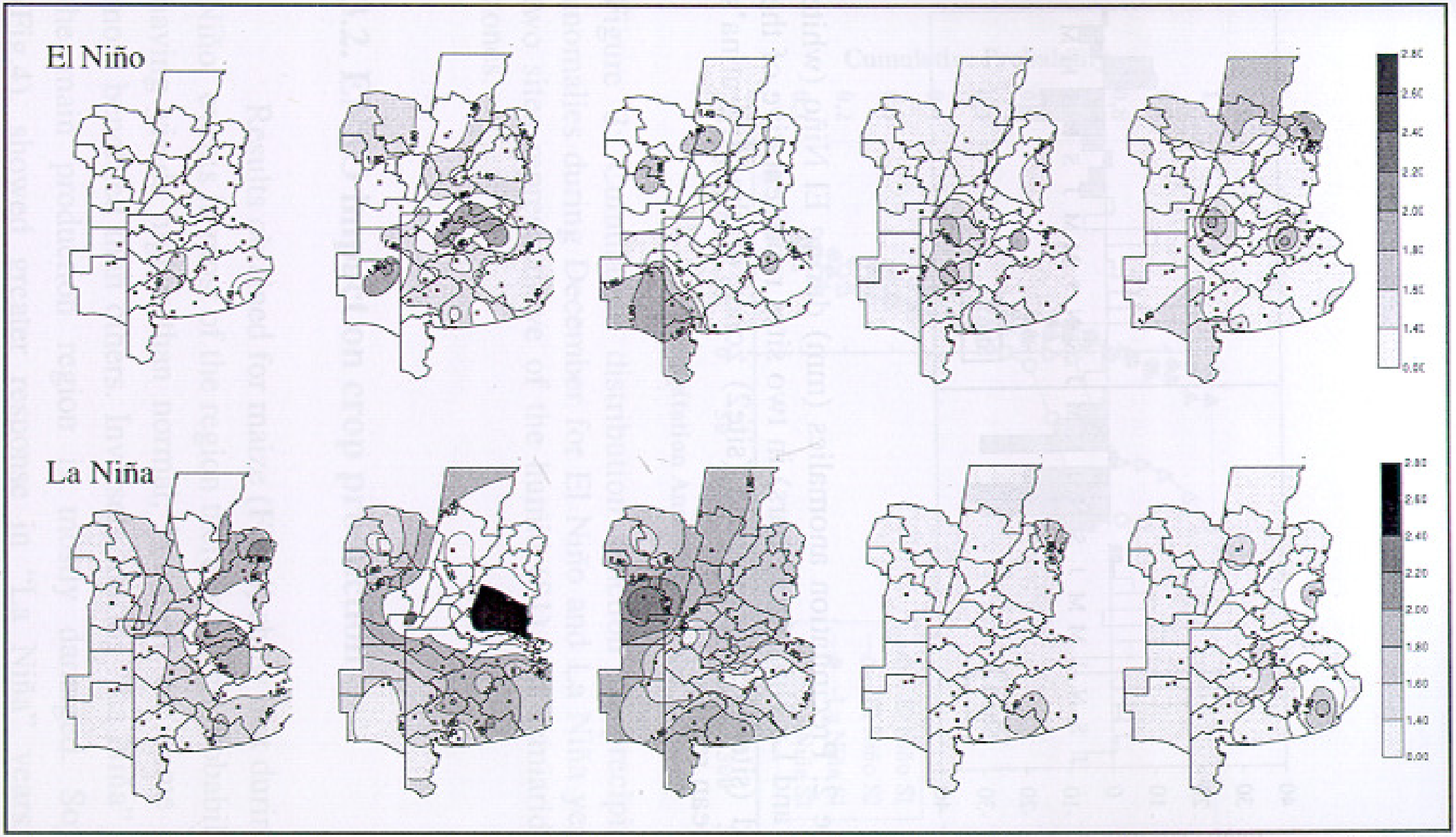

Figure 1. Chance of having precipitations higher than normal during "El Niño" years, or lower than normal during "La Niña" years in the Argentina's Pampean Region. Points indicate the meteorological stations

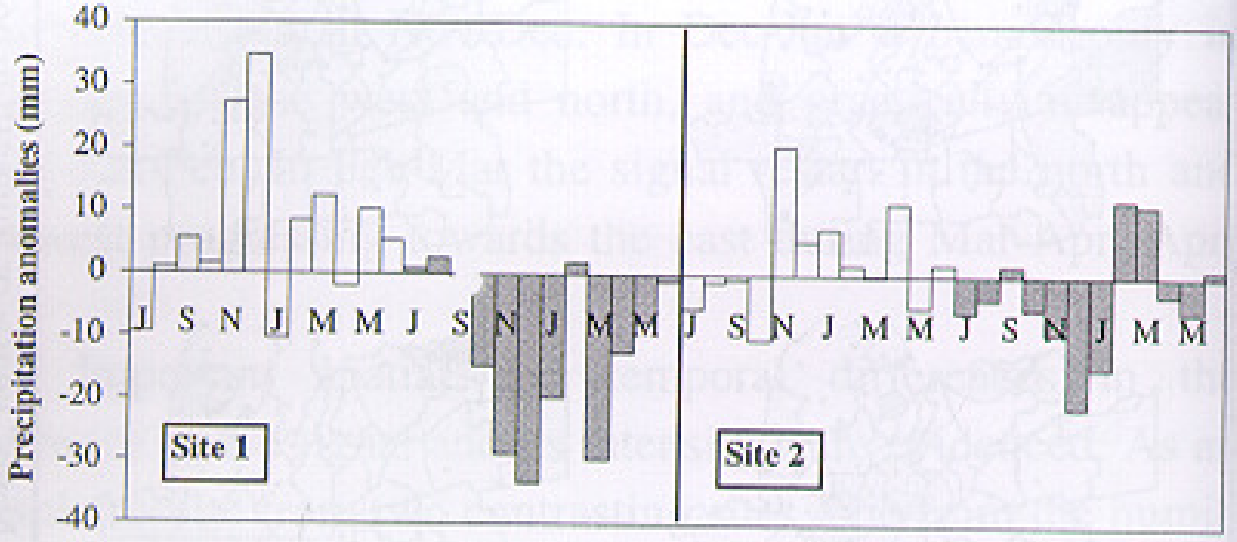

Figure 2: Precipitation anomalies (mm) during El Niño (white bars) and La Niña (gray bars) in two sites representative of the humid (site 1) and semiarid (site2) zones of the Argentina's Pampean region.

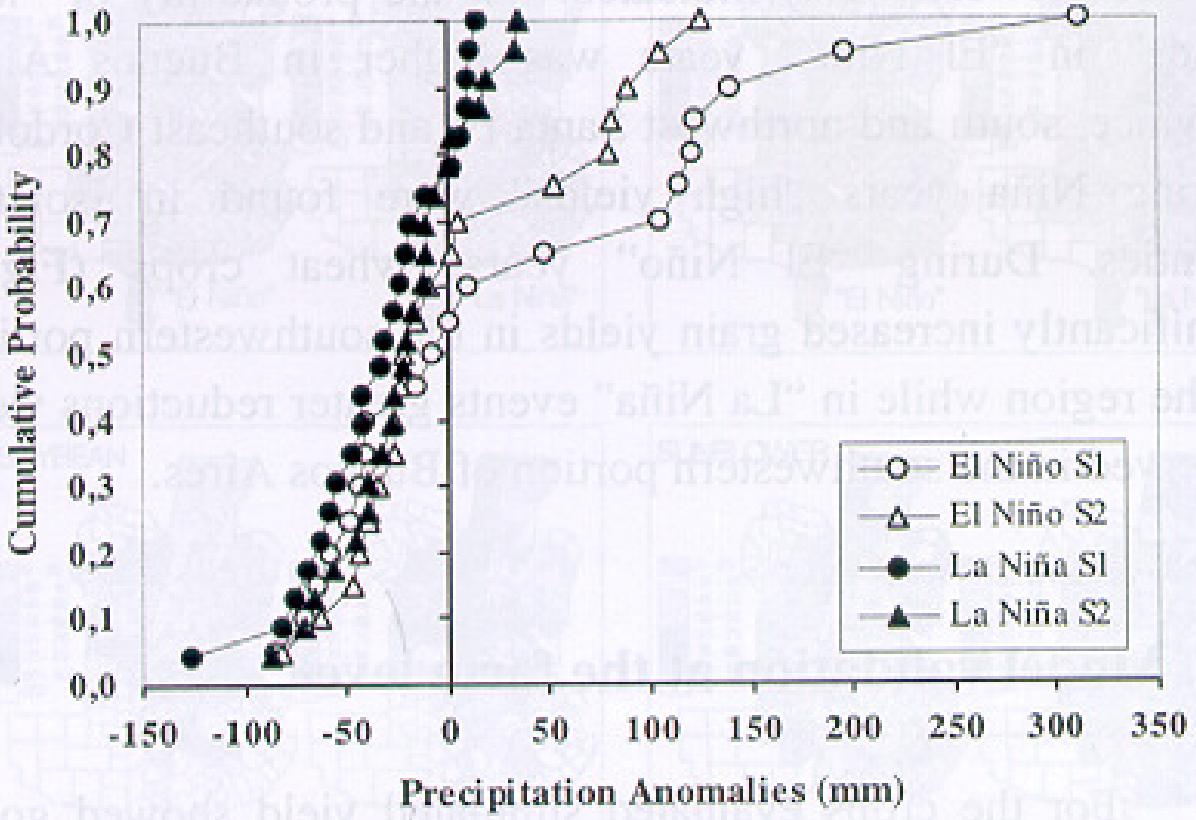

Figure 3: Cumulative distribution function of precipitation anomalies during December for El Niño and La Niña years in two sites representative of the humid (S1) and semiarid (S2) zones.

3.2. ENSO impact on crop production

Results obtained for maize (Fig. 4) show that during "El Niño" events in most of the region there is a high probability of having yields higher than normal, but there are some zones more benefited than others. Inversely, during "La Niña" years the main production region is mostly damaged. Soybean (Fig.4), showed greater response in "La Niña" years. The probability of having "low yields" is high, overriding 85-100%

in some counties. In "El Niño years, the probability of "high yields" was observed only in isolated zones. Results obtained with sunflower (Fig.4) indicated that the probability of "low yields" in "El Niño" years was higher in Buenos Aires province, south and northwest Santa Fe and southeast Cordoba. During Niña years "high yields" were found in isolated counties. During "El Niño" years, wheat crops (Fig.4) significantly increased grain yields in the southwestern portion of the region while in "La Niña" events greater reductions were observed in the southwestern portion of Buenos Aires.

3.3. Model validation at the farm level

For the crops evaluated simulated yield showed good performance (Fig.5). The root mean square errors in yield prediction were 10.9% for wheat, 7.8% for maize and 10.9 % for soybean.

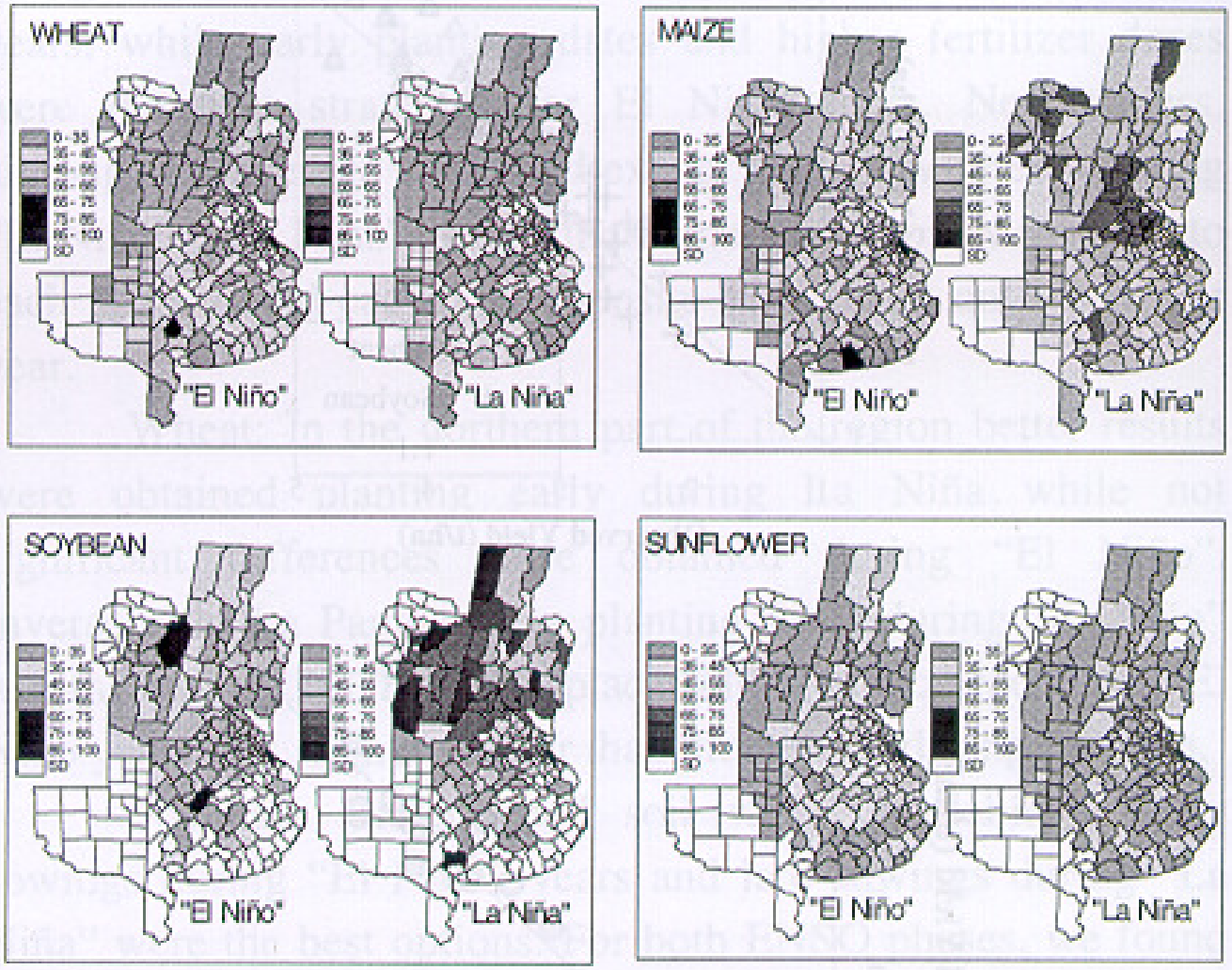

Figure 4: Probability of having high yields (upper tercile) (blue) or low yields (lower tercile) (red) during El Niño and La Niña years for wheat, maize, soybean and sunflower in the Argentina's Pampean region.

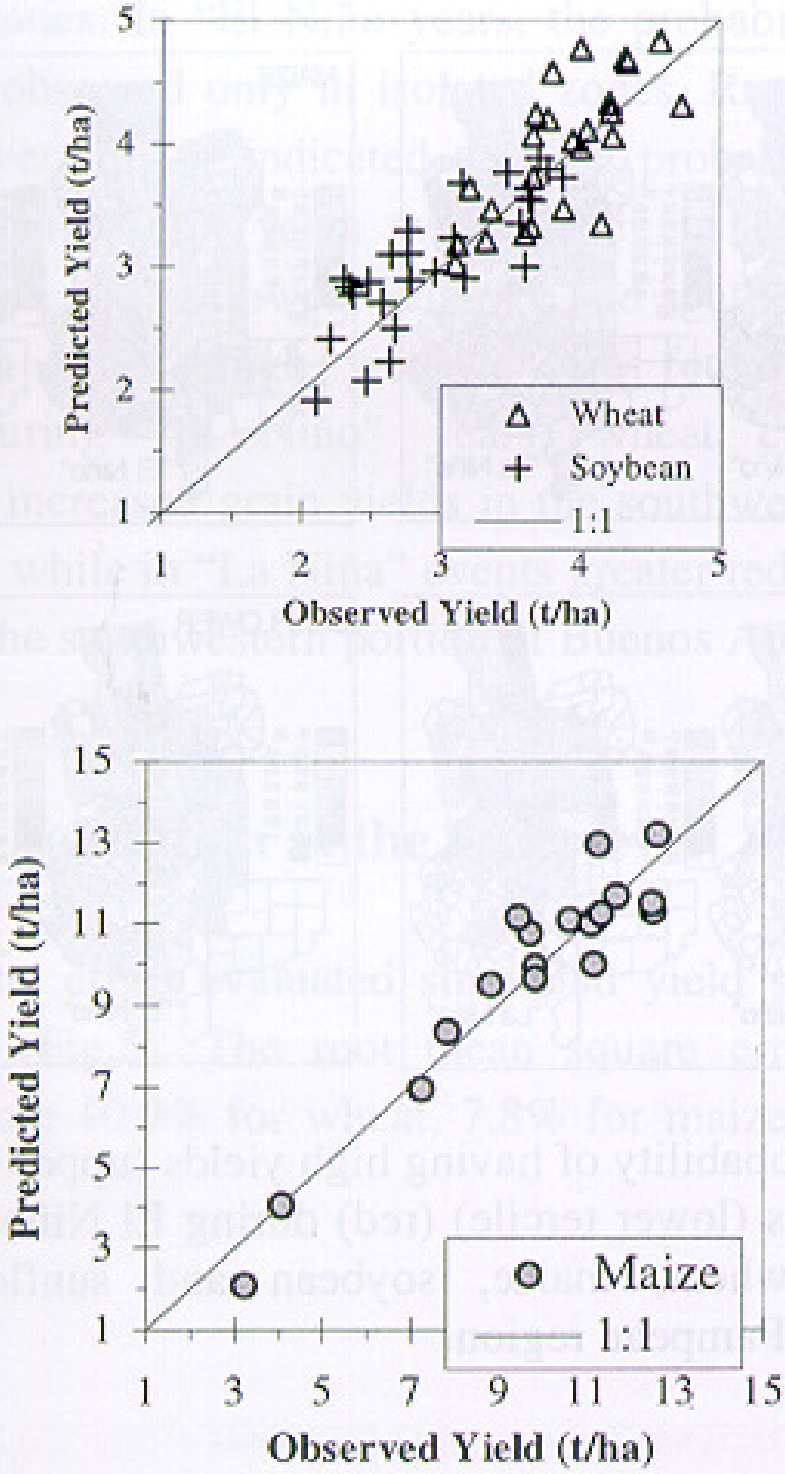

Figure 5: Observed and predicted yields at the field level for maize, wheat and soybean. 1:1 relation is also shown.

4. Optimal management options

Maize: In general, delaying planting dates and reducing

nitrogen fertilizer doses was the best option during La Niña years, while early planting dates and higher fertilizer doses were the best strategies for El Niño years. Nevertheless, although on average one could expect high (low) yields during "El Niño" ("La Niña") years, the climatic variability inherent to each phase could cause the opposite to occur in any particular year.

Wheat: In the northern part of the region better results were obtained planting early during La Niña while not significant differences were obtained during "El Niño". Inversely, in La Pampa early planting dates during "El Niño" was the best option. For most places nitrogen required during El Niño years was slightly higher than the needed during La Niña.

Soybean: Under good soil water availability, early sowings during "El Niño" years and late sowings during "La Niña" were the best options. For both ENSO phases, we found significant differences between planting dates for crop yields and gross margins.

Sunflower: The best option for El Niño conditions was to sow early, while no differences were found under La Niña conditions. As observed with the other crops, higher nitrogen doses should be applied during El Niño years.

4.1. On farm tests

Results obtained are presented in table 1. Only in 4 out of the 16 treatments tested net returns corresponding to treatments with optimal management for the forecasted phase (La Niña) were higher than those obtained under farmer's

management. Although these two years (1998, 1999) were defined as La Niña, precipitations occurred in most of the region were higher than the median values expected for this phase, in particular during November and December. For example, in Alberdi during 1998/99 growing season, precipitations occurred during November (159 mm) and December (99 mm) were higher than the median values (60 mm and 71 mm) for "La Niña" years, while in January (120 mm) and February (127 mm) rainfall was close to the median. Results obtained with maize during 1999/00 suggest that only when water was limiting the ENSO based management, in this case for La Niña, was more convenient than the farmer's option. In Figure 6 are presented cumulative precipitations for three sites during 1999/00, in the site with lower rainfall (S1) the differences in gross margin between the farmer's management and "La Niña" treatment was 12.4 US$/ha representing an increment of 41% in gross margin as compared to farmer's management. In the site with intermediate precipitations (S2) the values were 22 US$/ha and 4.5 %, while in the site with higher rainfall (S3) La Niña management lead to a loss of 140 US$/ha (-32 %). Considering all sites and crops evaluated differences in gross margin between the farmer's management and "La Niña" treatment, expressed as percentage of the gross margin obtained by the farmer, varied between -2 % and 39 % in wheat, -32 % and 41 % in maize, -45 and –23 % in soybean, and -82 and -46 % in sunflower.

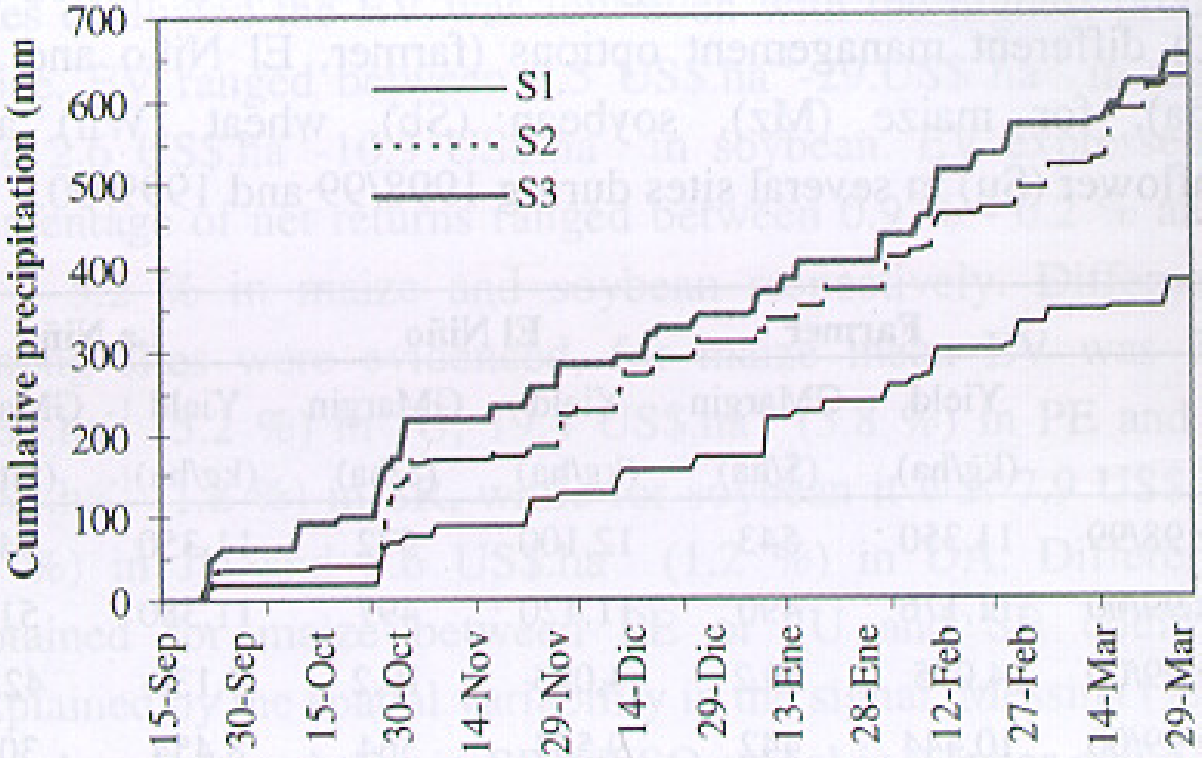

Figure 6: Cumulative precipitation during maize cycle for three sites (S1, S2 and S3) where on farm test were carried out in 1999/2000.

Table 1: Yield and Gross Margin from on-farm tests carried out with different management options (farmer, El Niño and La Niña), for maize (Mz), soybean (Sb), wheat (Wh) and sunflower (Su) in several sites during 1998/99 and 1999/00.

	Farmer		El Niño		La Niña	
	Yield (kg/ha)	GMargin ($/ha)	Yield (kg/ha)	GMargin ($/ha)	Yield (kg/ha)	GMargin ($/ha)
Mz 98/99	11,350	543	12,100	572	11,350	543
Mz 99/00	11,176	490	11,420	497	11,380	512
Mz 99/00	4,075	30.2	4,083	19.2	4,130	42.6
Mz 99/00	10,444	442	9,534	364	8,454	302
Mz 99/00	8,510	398	8,840	376	8,680	379
Sb 98/99	3,900	428	3,900	428	3,200	327
Sb 99/00	3,615	264	3,615	264	2,972	189
Sb 99/00	3,630	266	3,333	231	2,275	107
Sb 99/00	3,683	272	3,675	271	2,884	179
Sb 99/00	3,564	258	3,568	258	2,564	141
Wh 99/00	4,334	122	4,480	136	4,400	149
Wh 99/00	4,320	124	4,410	122	4,410	122
Wh 99/00	2,150	27.8	2,150	27.8	2,205	38.6
Su 99/00	1,959	179	2,002	159	1,069	32
Su 99/00	2,412	249	2,340	212	1,734	135
Su 99/00	2,090	199	1,928	174	1,240	67

5. Economic value of climate forecast

The EV (Fig.7) was different among sites and crops, and it was dependent on the product price. For both crops in all the

sites evaluated the EV was low even with the highest product price. EV ranged between 2.5 US$.ha^{-1}-29.US$ ha^{-1} in maize and 2.6 US$.ha^{-1}-10.9 US$.ha^{-1} in soybean. EV expressed as percentage of net returns ranged between 0.9 % - 6.2 % and 1 % - 5.2 % in maize and soybean respectively. Differences among sites were evidenced, for maize mean EV was 21.8 US$.ha^{-1} (5.2 %) in JU, 19.4 US$.ha^{-1} (3.8 %) in PE and 3.2 US$.ha^{-1} (1.2 %) in SR, while for soybean it was 7.9 US$.ha^{-1} (4 %) in JU and 3.6 US$.ha^{-1} (1.2 %) in DA. Differences obtained for maize between PE or JU and SR could be explained by the spatial variability in the signal. Messina (1999) had demonstrated that in SR ENSO signal is weaker and a non significant relation was found between precipitation and the occurrence of La Niña phase.

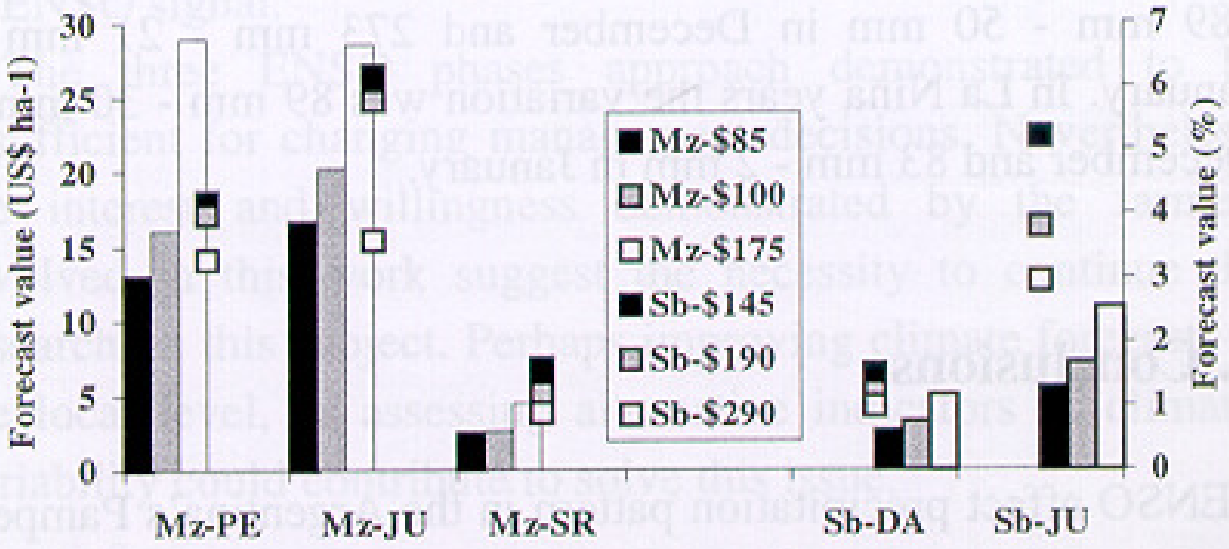

Figure 7: Absolute (US$.ha^{-1}) (bars) and relative (%) (points) economic value of ENSO-based climate forecast for maize (Mz) and soybean (Sb) in PE(Pergamino), JU (Junín), SR (Santa Rosa) and DA (Diego de Alvear), considering three product prices.

In all sites, low EV values could be explained because of the great variability encountered in crop yields for each ENSO phase. For example, in Junín considering the optimal management option maize yields variation accounted for 8,300 kg. $ha^{-1}$and 8,050 kg. ha^{-1}during El Niño and La Niña respectively, while in soybean differences between extreme values were 3,850 kg. ha^{-1} and 2,300 kg. ha^{-1} in El Niño and La Niña years respectively. The variability observed in crop yields was mainly related to precipitation occurred around the flowering period. In maize, grain yield was associated with rainfall occurred during December for El Niño years (r=0.86) and January for La Niña years (r=0.90); while Soybean yields were better correlated with precipitation occurred during December-January (r=0.78) in El Niño years and January (r=0.68) in La Niña ones. Precipitation also showed great variability in this site, ranging during El Niño years between 189 mm - 50 mm in December and 273 mm - 21 mm in January. In La Niña years the variation was 89 mm - 30 mm in December and 83 mm - 2 mm in January.

6. Conclusions

- ENSO affect precipitation pattern in the Argentina's Pampean region. During El Niño (La Niña) years precipitation are expected to be above (below) normal during spring-summer months. However there is a great spatial variability in the intensity, the beginning and the persistence of the signal. Temporal variability in monthly precipitation were also found into each phase.

- During "El Niño" events in most of the region there is a high probability of having maize and soybean yields higher than normal, inversely during "La Niña" years the main maize and soybean production regions are mostly damaged. Wheat has the same behavior, but only in the southwestern portion of the region. Inversely, sunflower's yields tend to be higher during La Niña and lower during El Niño years.
- Differences among phases in optimal management practices were found. In general increasing the fertilizer doses and advancing planting date will be the best combination during El Niño years, while for La Niña years delaying planting dates and reducing fertilizer application will be the best.
- The economic value of ENSO-based climate forecast when used to change management practices in agriculture is rather low (up to 6 %) because of high spatial and temporal variability in ENSO signal.
- The three ENSO phases approach demonstrated to be insufficient for changing management decisions. Nevertheless, the interest and willingness demonstrated by the farmers involved in this work suggest the necessity to continue the research on this subject. Perhaps improving climate forecasts at the local level, or assessing alternative indicators of climatic variability could contribute to solve this issue.

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SONKA, S.T.; CHANGNON JR., S.A.; HOFING, S.L. How

EL NIÑO, LA NIÑA, SOUTHERN OSCILLATION AND ITS IMPACTS ON WHEAT AND BARLEY CROPS IN BRAZIL

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Abstract

The El Niño - Southern Oscillation phenomenon is the best known short-term source of climatic variability in seasonal and interannual scale, acting in the entire globe. Placing emphasis on: extreme climatic anormalies related to warm phase (El Niño), and cold phase (La Niña) - of the ENSO that presents a consistent pattern of persistence (12 to 18 months). The effects ENSO in Brazil are most noticed in the Northeast Region, and in the east of Amazon (tropical zone) and in the South Region (extra-tropical zone). The possibility if quantifying the climatic variability associated to the phases of the ENSO phenomenon allows several applications in crop

management directed to reduce risks or to improve the use of favorable climatic conditions.

This study had the objective of identifying the influence of the phases of the ENSO phenomenon on wheat and barley yield in Brazil; based on the analyzes of the historical data from 1920 to 1997 for wheat and from 1938 to 1998 for barley. For wheat in Brazil, of the 23 analyzed El Niño episodes, 61 % of them showed a negative deviation in grain yield. In La Niña events the inverse was observed; in 73 % of the cases there was a positive grain yield deviation. In the neutral years, 55 % of the deviation were positive and 45 % were negative. For barley, in 19 analyzed El Niño episodes, 63 % of them were negative. In La Niña episodes, 12 events, the inverse was observed; the barley grain yield deviation in 67 % of the cases were positive. In the 30 neutral years, 50 % of the grain yield deviation were positive and 50 % were negative. Therefore the ENSO phenomenon had a positive impact in the wheat and barley crops in La Niña years and negative impact in El Niño years, particularly in the south of the country.

1. Introduction

The El Niño Southern Oscillation phenomenon is the best known short-term source of climatic variability in seasonal and inter-annual scale, acting in the entire globe. Placing emphasis on extreme climatic anormalies related to warm phase (El Niño), and cold phase (La Niña) of the ENSO that presents a consistent pattern of persistence (12 to 18 months).

The ENSO or just El Niño, as its referred in the communication media has its origin in the tropical Pacific Ocean region. It's the result of an ocean atmosphere interaction in which the behavior of the water surface temperatures in the central and west coast of South America, associated with the pressure fields (represented by the Southern Oscillation Index), changes the atmosphere general pattern and then influenciates the global climate behavior.

The ENSO (El Niño Southern Oscillation) is a two component phenomenon: one of sea nature, in the case of El Niño; and one of atmospheric nature represented by the Southern Oscillation.

The El Niño denomination goes back to the 18th century which was first used by Peruvian fishermen to designate a warm water stream that appeared from the Pacific Ocean, on the coast of South America in the late December. In reference to Christmas and baby Jesus this warm water stream was called "El Niño", a Spanish word meaning "the boy". Nowadays the expression is used to designate temperature changes on the surface of the tropical Pacific Ocean basin.

As for the atmospheric components, the works by sir Gilbert Walker in the beginning of the 20th century showed a negative correlation between the pressure at the surface of the Pacific and Indic Ocean, denominated Southern Oscillation: when high in the Pacific Ocean, pressure tends to be low in the Indic Ocean. These works tried to correlate the Southern Oscillations with the Monsoons in India.

In the 60's the Norwegian meteorologist Jacob Bjerknes living in the USA, was who idealized the link between the two

fluids - the ocean and the atmosphere - in the tropical Pacific Ocean.

The atmosphere acts mechanically over the Ocean surface, redistributing temperature anormalies. By its turn heat flow forces an abnormal atmosphere circulation, causing changes in the wind fields. The ENSO is a manifestation of instability of the coupled system, ocean - atmosphere.

Various indexes have been used for measuring the intensity of ENSO. One of them is the Southern Oscillation Index (SOI), which reflects the standardozed differences in atmospheric pressure between two key sites for the phenomenon (Darwin-AU and Tahiti) and the sea surface temperature (SST) in a region called the Niño 3 (5°N - 5°S and 90° - 150°W). The SOI measures the intensity of the Southern Oscillation (atmospheric component) and the SST from the Niño 3 region measures the El Niño (oceanic component).

In the tropical Pacific Ocean, in virtue of the tradewinds that predominantly blow southeast on the Southern hemisphere, there's a pattern in oceanic circulation in which the waters in the coast of South America, are usually cold and, in the extreme opposite, region of Indonesia and coast of Australia, the waters are usually warm.

The Pacific Ocean water surface temperature, associated to a surface atmospheric pressure fields, influenciates the zonal atmospheric circulation, in a Walker type cell, that is from East to West, where there is air ascension in the west of the tropical Pacific and dissension of air in the extreme east of this ocean. That, makes the west part of the Pacific Ocean a region of frequent rainfalls, contrasting to the east part of the coast of South America, a region of low rainfall.

In El Niño years, previously to its establishment, a reduction of the tradewinds can be detected in the Equatorial Pacific Region. This alters the pattern in oceanic circulation, reducing the upwelling of cold waters on the coast of South America and shifting the warm waters of the Pacific west to a position east of the international line of date change. With that there is a change in the ascending branch of the Walkers circulating cell to the central part of the Pacific Ocean that makes the islands of this region experience an excess of rainfalls where they are usually rare.

With the movement, more and more, towards the east, the abnormal warm waters from the tropical Pacific Ocean, reaches the coast of South America up to Peru and Equator. That ascends the air current in that region making the coast of South America experience rainfalls above normal. This ascending branch of the Walkers circulating type cell, becomes descendant in reason of the dry air over the north part of the Amazon and the northeast part of Brazil, determining accentuated dry seasons in this region.

In terms of behavior of the atmospheric fields the SOI reflects the anormalies in surface pressure by the differences in pressures between Tahiti in the central Pacific and Darwin in Australia. In the years in which the surface pressure is high in Darwin and low in Tahiti the SOI is negative (El Niño episode); inversely, when the surface pressure is low in Darwin and high in Tahiti the SOI is positive; when the SOI is strongly positive waters colder than normal appear in the central region and in the east part of the Equatorial Pacific Ocean. This cold episode is called La Niña, and implicates the climate anormalies generally inverse to the warm episode denominated El Niño.

The ENSO has a return time that can be considered irregular and involves strong, moderate, weak or even total absence of events, that is the case of neutral years. General aspects of the ENSO phenomenon, and its impacts on the global climate can be found, for example, in Philander (1990), Moura (1994), Glantz (1996), and National Research Council (1996).

Many regions of the world in which climates is affected by the ENSO phases have been identified by Ropelewsky & Halpert (1987), (1989), and (1996). Among these in the case of Brazil, in the north part of the Northeast Region and the east of Amazon (Tropical zone) and the south part (extra-tropical region) area located in a vast region localized in the Southeastern South America, involving also Uruguay, the Southeast of Paraguay and the Northeast of Argentina.

For Brazil, complementary studies as those by Alves and Repelli (1992) and by Uvo et al. (1994) for the Northeast Region and those by Grimm et al. (1996a) (1996b), Fontana and Berlato (1997), and by Diaz et al. (1998) for the South Region, looked for detailed inter-regional impacts of the ENSO phenomenon phases over the rainfall distribution.

In the South of Brazil particularly, there is an excess of rainfalls in the El Niño years and drought in the La Niña years. Eventhough the influence occurs during the whole happening of these events, there are two times of the year that are more affected by the ENSO phases. They are: spring and early summer (October, November, and December), in the initial year of the event, and late autumn and early winter (April, May, and June) in the following year of the event, as evidenciated in the papers by Grimm et al. (1996a) (1996b), and by Fontana and Berlato (1997). That raises the chances of rainfalls above

normal in El Niño years during this period and rainfalls below normal in La Niña years.

The wheat and barley producing regions of Brazil are frequently related to elements of climatic risks for production of these cereals, affecting the grain yield in quantity and in quality; excess and/or water deficiency, frosts, high temperatures, high relative humidity (favoring diseases), hail, winds causing lodging of the plants, etc.

The objective of this study was to evaluate the impacts of the phases of the ENSO phenomenon and its climatic variability associated to the grain yield of the wheat and the barley crop in Brazil.

2. Material and methods

Historical records of wheat yield from 1920 to 1997 and barley from 1938 to 1998 in Brazil were analyzed as to its variability in relation to the phases of the El Niño Southern Oscillation phenomenon (El Niño, La Niña and Neutral years). Specifically data of the annual average yield of wheat (kg/ha) aggregated by state (RS, SC, PR, SP, MS and MG) and for the country, for barley crop the average annual yield (kg/ha) was also aggregated by state (RS, SC, PR) and for the country. Statistical data are from IBGE, Banco do Brasil-CTRIN, Conab/Dipla/Depos.

The original data of the historical series of wheat grain yield (1920-1997) and barley (1938-1998) were initially submitted to a regression analyses using the year as independent variable to separate the effect of technologies

incorporated in the production system, through time, over the year of these crops, from those resulting from the interannual climate variability. By the best adjusted regression model (r^2 criteria), the technological trend associated to the data was removed using the formula:

$Yci = (Yi - (Y(Xi) - Y(Xo)))$,

Where Yci = year yield i corrected, yi = original yield from i year, Y(Xi)=i year yield estimated by the regression model, and Y(Xo)=yield of the first year of the estimated historical series by the regression model.

The annual deviation in wheat and barley grain yield in relation to the mean of the historical series was calculated from the corrected yield values. That is, after removing the technological trend present in the data being expressed in kilograms per hectare (kg/ha).

During the considered period, the years were classified according to the phase of the ENSO phenomenon (El Niño, La Niña, and Neutral years) with the base values of the Southern Oscillation Index (SOI), according to Ropelewsky and Jones (1987). As the El Niño years, were classified those, in which the values of SOI was, during five or more consecutive months, smaller or equal to -0,5; and as La Niña years when the SOI stayed with value equal or higher than 0,5, in at least five consecutive months.

The period included the following El Niño events (initial year of the phenomenon): 1923, 1925, 1930, 1932, 1939, 1940, 1941, 1946, 1951, 1957, 1963, 1965, 1969, 1972, 1976, 1977, 1982, 1986, 1991, 1992, 1993, 1994, and 1997. As La Niña years were grouped the following years (initial year of the event): 1920, 1924, 1928, 1931, 1938, 1942, 1949, 1954, 1964,

1970, 1973, 1975, 1988, 1995, 1996, and 1998. The others were classified as neutral years.

3. Results and Discussion

3.1. Impacts over the wheat crop in Brazil

In Brazil wheat has been cultivated especially in the south. In this region, Paraná and Rio Grande do Sul are the main producing states. There is also wheat in Santa Catarina although in smaller scale. In the rest of the country there is availability of statistics of wheat in Mato Grosso do Sul, São Paulo and Minas Gerais. With this, by the total expression of the brazilian wheat production and considering the sensibility of the region to the climatic variability associated to the phases of the ENSO phenomenon, it will be discussed and presented the results from the states of the Southern region (PR, RS, SC; in this order by the importance of the crop). In the sequence, the effects over the average yield in the states of MS, SP, MG and in the country will be presented.

The variability in the mean grain yield of wheat crop in Paraná, Rio Grande do Sul and Santa Catarina, from 1920 to 1997 can be seen on the Figure 1. On that parts (a), (c), and (e) includes the original historical series, showing a quadratic trend of growth in the mean yield as a function of the year. Evidently, due to the incorporation of new technologies for the production system, as cultivars with greater yield potential and the improvement of the management practices (fertilization and the

control of diseases and pest specially). From 1920 to 1940 the wheat grain yield in Brazil showed tendency to decrease due specially to the occurrence of diseases and the lack of adaptation to acid soils. In the 40's with the development of local adapted wheat cultivars as the case of Frontana, that tendency was changed. The parts (b) (d) and (f) of Figure 1 contain the same historical series of yield, after removing the technological trend associated to the data. It becomes clear in that Figure, the effect of another factor over the yield: in this case it is the climatic variability.

Figure 2, parts (a) (b) and (c) shows the deviation of the corrected yields, that is, without the technological trend related to the mean, for the states of Paraná, Rio Grande do Sul and Santa Catarina, respectively. The deviations are expressed in kg/ha - and are positive or negative according to the corrected yield in the year that stayed above or below historical mean. The bars are painted in black, white and gray, according to the classification, El Niño, La Niña and neutral years, respectively. In the period of time considered 78 years, 23 El Niño and 15 La Niña events occurred. The remaining 40 years of the period were neutral years. The analysis of Figure 2 and the data on Table 1, evidenciate that the impact of the El Niño events are most of the time negative over the wheat grain yield, in the three states of the Southern Region of Brazil. The inverse occurs in La Niña years, when the impact is predominantly positive. In the Neutral years, the impact is also predominantly positive, Figure 2 also shows that in the 60's, 70's and 80's, the deviation of the mean grain yield were bigger than in the other periods. These events not only were more frequent in this

period, but also stronger, causing greater impact over the interannual climatic variability.

The slopes of the cumulative probability for the deviation in yield expressed in percentage can be found in Figure 3. The behavior of the curves for El Niño years (bold black); La Niña years (black), neutral years (gray) and years considered without distinction between El Niño, La Niña and Neutral years (traced) reinforces the indication that the worst years for wheat (greater probability in negative yield deviation) are those classified as El Niño years. On the other hand the La Niña years are the most favorable for the wheat crop, therefore, implying greater probabilities of positive deviation on grain yield. The separation between the cumulative probability curve, as the one that represent the La Niña years dislocated to the right of the Figure, in relation to the El Niño year curve, makes possible to infer stochastically that the La Niña years are dominant in relation to the El Niño years. That is, in La Niña years the chances in having positive wheat grain deviation is higher, while in El Niño years there are greater chances of the deviation being negative.

On Figure 4, parts (a), (c) and (e) are represented as original historical series of wheat yield in the states of Mato Grosso do Sul (1971 to 1997), São Paulo (1952 to 1997) and from Minas Gerais (1976 to 1997). The data indicates a linear trend of mean yield growth of these states associated to the years. The same historical series, without technological trend can be seen on parts (b), (d) and (f) of the figure. The variability due to the nontechnological causes is evidenciated on the same series.

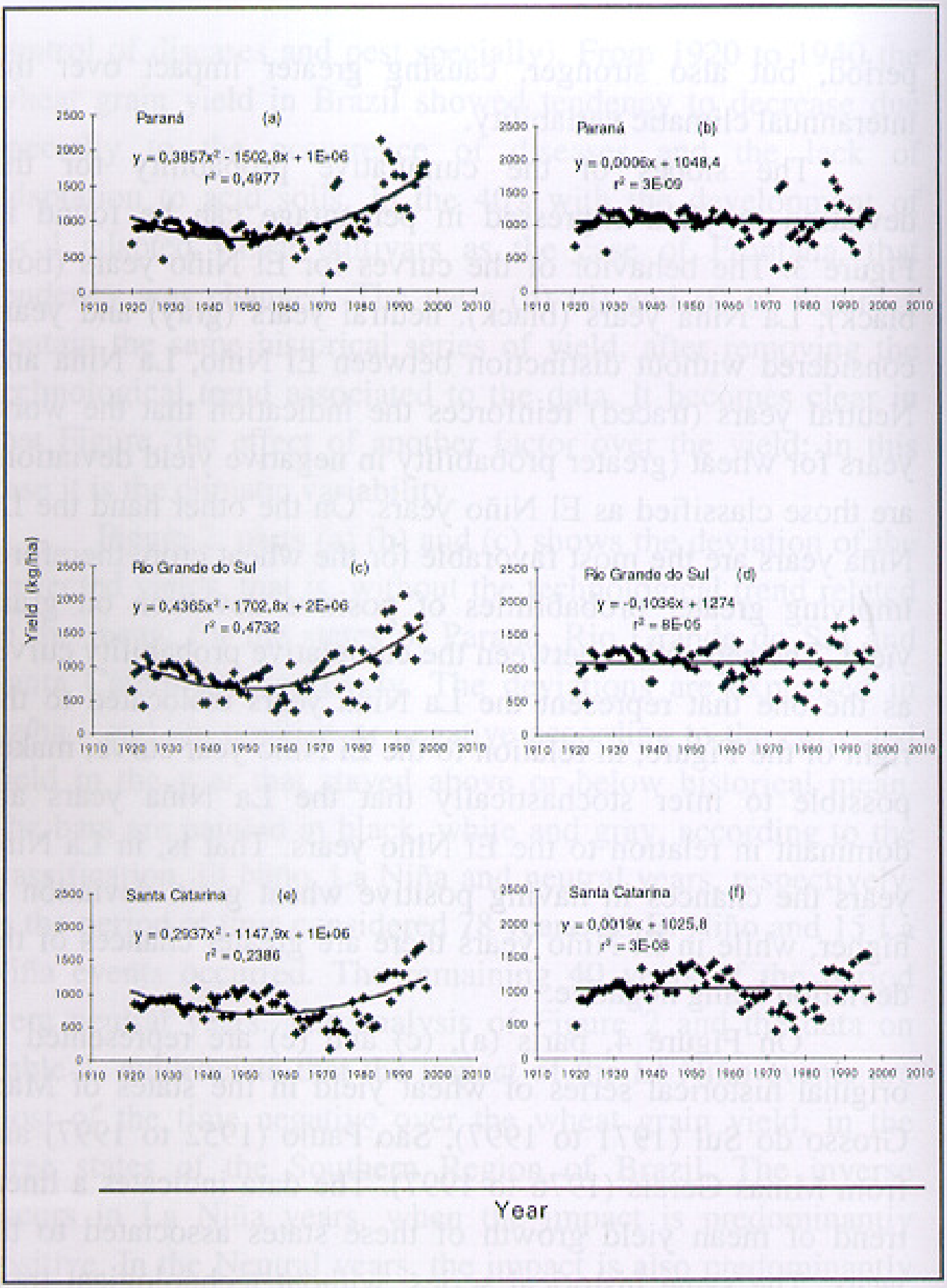

Figure 1. Wheat yield (kg/ha) time series [(a), (c), and (e)] and resulting detrend time series [(b), (d), and (f)], from 1920 to 1997, for Paraná, Rio Grande do Sul, and Santa Catarina states, respectively.

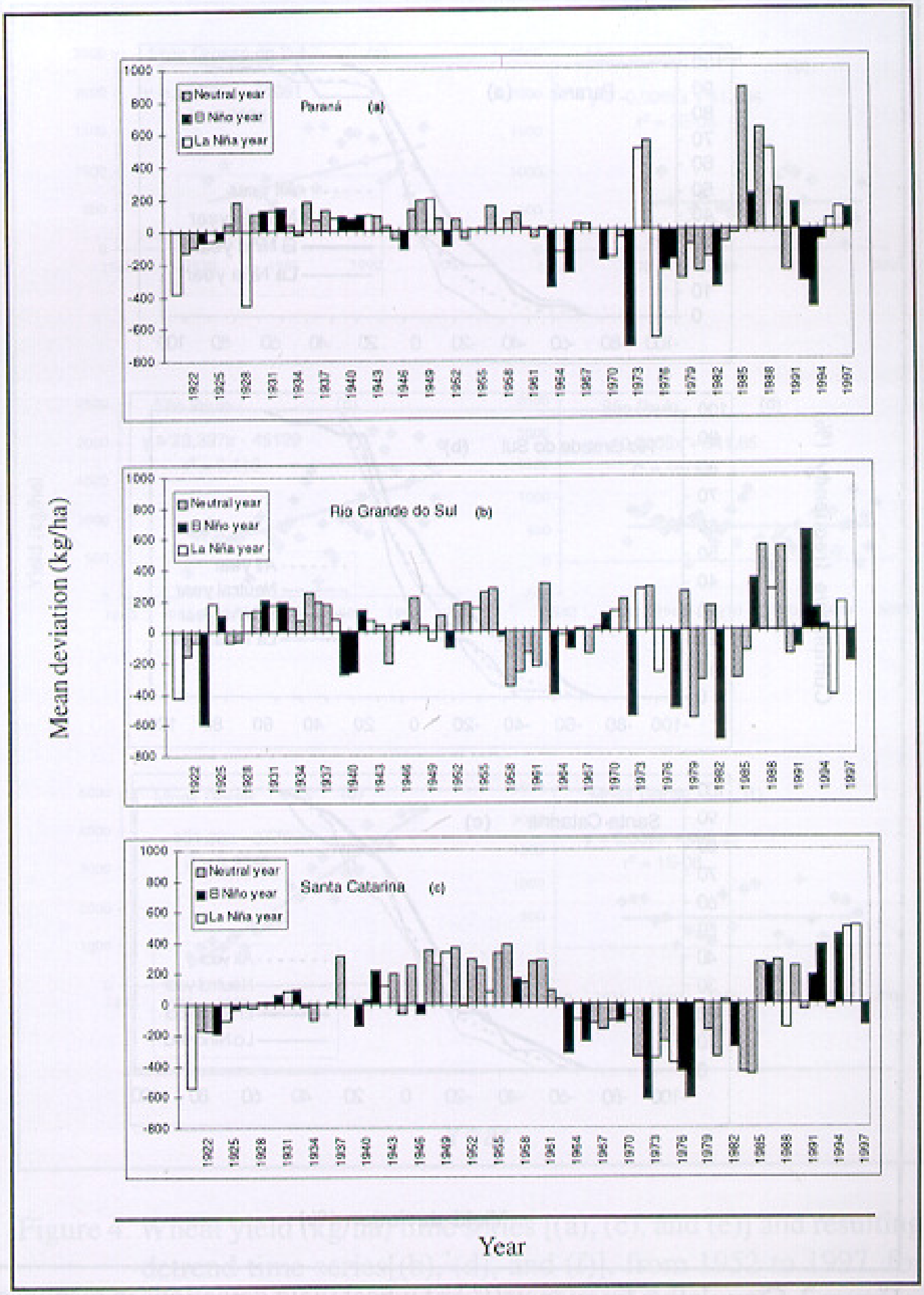

Figure 2. Wheat yield mean deviation (kg/ha) resulted to ENSO phenomenon phase for Paraná (a), Rio Grande do Sul (b), and Santa Catarina (c) states, from 1920 to 1997.

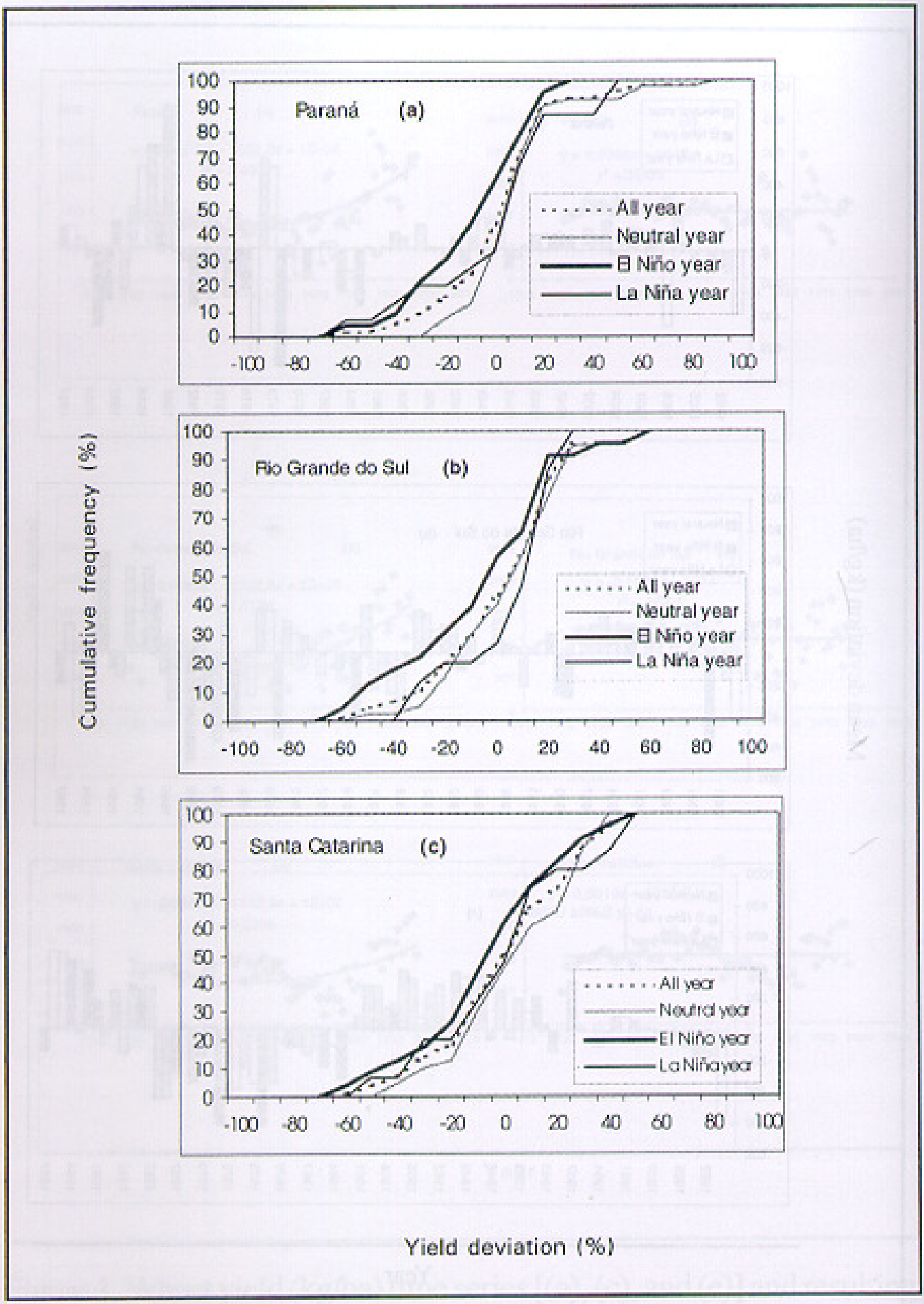

Figure 3. Cumulative frequency (%) of wheat yield deviations in response to ENSO phase for Paraná (a), Rio Grande do Sul (b), and Santa Catarina (c) states, time series from 1920 to 1997.

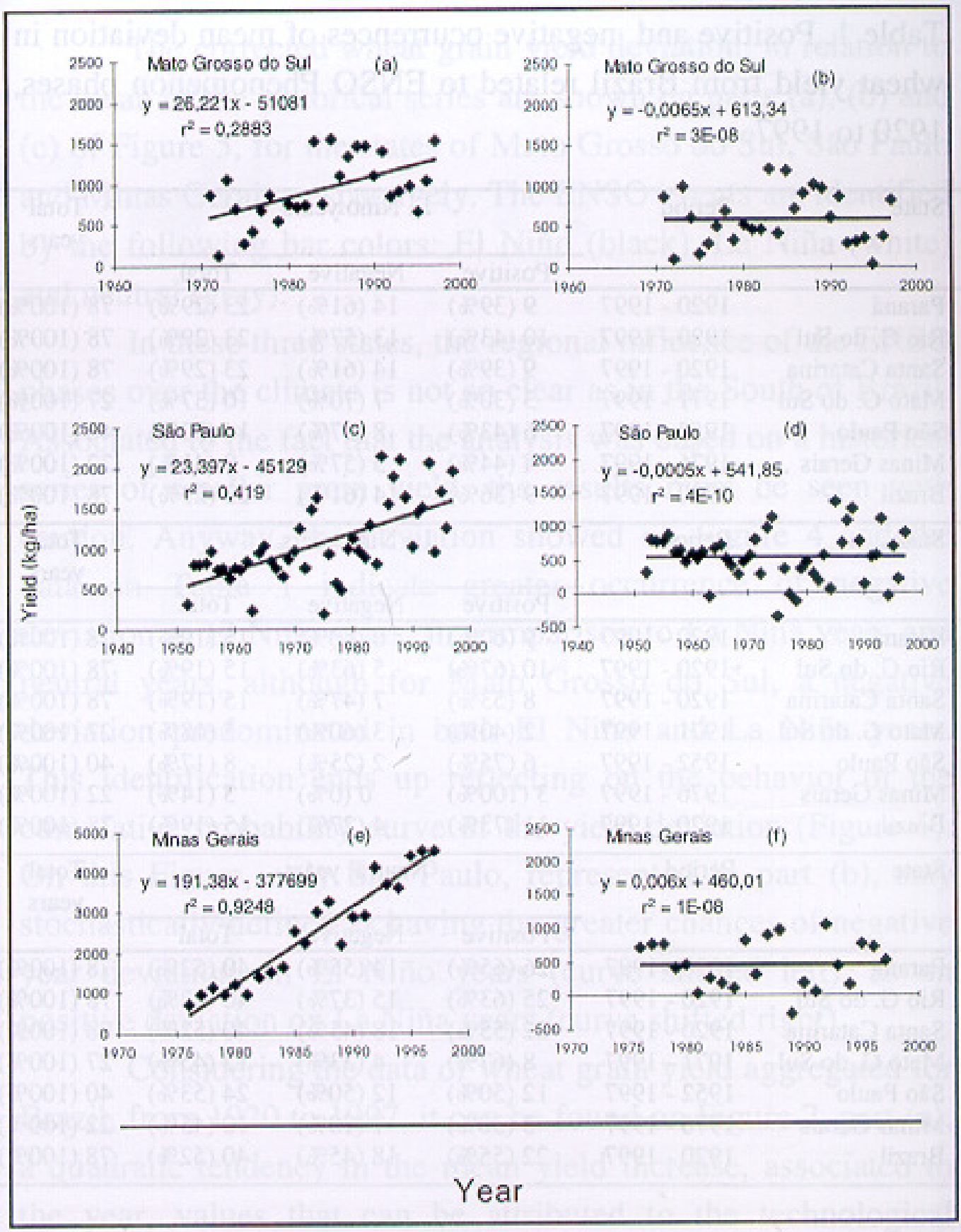

Figure 4. Wheat yield (kg/ha) time series [(a), (c), and (e)] and resulting detrend time series[(b), (d), and (f)], from 1952 to 1997, for Mato Grosso do Sul, São Paulo and Minas Gerais states, respectively.

Table 1. Positive and negative ocurrences of mean deviation in wheat yield from Brazil related to ENSO Phenomenon phases, 1920 to 1997.

State	Period	El Niño years			Total years
		Positive	Negative	Total	
Paraná	1920 - 1997	9 (39%)	14 (61%)	23 (29%)	78 (100%)
Rio G. do Sul	1920 - 1997	10 (43%)	13 (57%)	23 (29%)	78 (100%)
Santa Catarina	1920 - 1997	9 (39%)	14 (61%)	23 (29%)	78 (100%)
Mato G. do Sul	1971 - 1997	3 (30%)	7 (70%)	10 (37%)	27 (100%)
São Paulo	1952 - 1997	6 (43%)	8 (57%)	14 (30%)	40 (100%)
Minas Gerais	1976 - 1997	4 (44%)	5 (57%)	9 (41%)	22 (100%)
Brazil	1920 - 1997	9 (36%)	14 (61%)	23 (29%)	78 (100%)
State	**Period**	**La Niña years**			**Total years**
		Positive	Negative	Total	
Paraná	1920 - 1997	9 (60%)	6 (40%)	15 (19%)	78 (100%)
Rio G. do Sul	1920 - 1997	10 (67%)	5 (63%)	15 (19%)	78 (100%)
Santa Catarina	1920 - 1997	8 (53%)	7 (47%)	15 (19%)	78 (100%)
Mato G. do Sul	1971 - 1997	2 (40%)	3 (60%)	5 (18%)	27 (100%)
São Paulo	1952 - 1997	6 (75%)	2 (25%)	8 (17%)	40 (100%)
Minas Gerais	1976 - 1997	3 (100%)	0 (0%)	3 (14%)	22 (100%)
Brazil	1920 - 1997	11 (73%)	4 (27%)	15 (19%)	78 (100%)
State	**Period**	**Neutral years**			**Total years**
		Positive	Negative	Total	
Paraná	1920 - 1997	26 (65%)	14 (55%)	40 (52%)	78 (100%)
Rio G. do Sul	1920 - 1997	25 (63%)	15 (37%)	40 (52%)	78 (100%)
Santa Catarina	1920 - 1997	22 (55%)	18 (45%)	40 (52%)	78 (100%)
Mato G. do Sul	1971 - 1997	8 (67%)	4 (33%)	12 (45%)	27 (100%)
São Paulo	1952 - 1997	12 (50%)	12 (50%)	24 (53%)	40 (100%)
Minas Gerais	1976 - 1997	3 (30%)	7 (70%)	10 (45%)	22 (100%)
Brazil	1920 - 1997	22 (55%)	18 (45%)	40 (52%)	78 (100%)

The corrected wheat grain yield deviation, in relation to the mean of the historical series are shown on parts (a), (b) and (c) of Figure 5, for the states of Mato Grosso do Sul, São Paulo and Minas Gerais, respectively. The ENSO events are identified by the following bar colors: El Niño (black), La Niña (white) and neutral (gray).

In these three states, the regional influence of the ENSO phases over the climate is not so clear as in the South of Brazil. Associated to the fact that the analysis was based on a historical series of smaller grain yield, the results must be seen with caution. Anyway, the deviation showed on Figure 4 and the data on Table 1 indicate greater occurrence of negative deviation in El Niño years, in comparison to La Niña years and neutral years, although for Mato Grosso do Sul, a negative deviation predominated in both El Niño and La Niña years. This identification ends up reflecting on the behavior of the cumulative probability curve of the yield deviation (Figure 6). On this Figure, only São Paulo, represented in part (b), stay stochastically defined as having the greater chances of negative year deviation, in El Niño years (curve shifted left), as on positive deviation on La Niña years (curve shifted right).

Considering the data of wheat grain yield aggregated for Brazil, from 1920 to 1997, it can be found on Figure 7, part (a), a quadratic tendency in the mean yield increase, associated to the year, values that can be attributed to the technological increase of the wheat cropping in Brazil. Part (b) of Figure 7 shows the variability of wheat grain yield in Brazil, by natural reasons nontechnological, once the original series was removed from the detected trend.

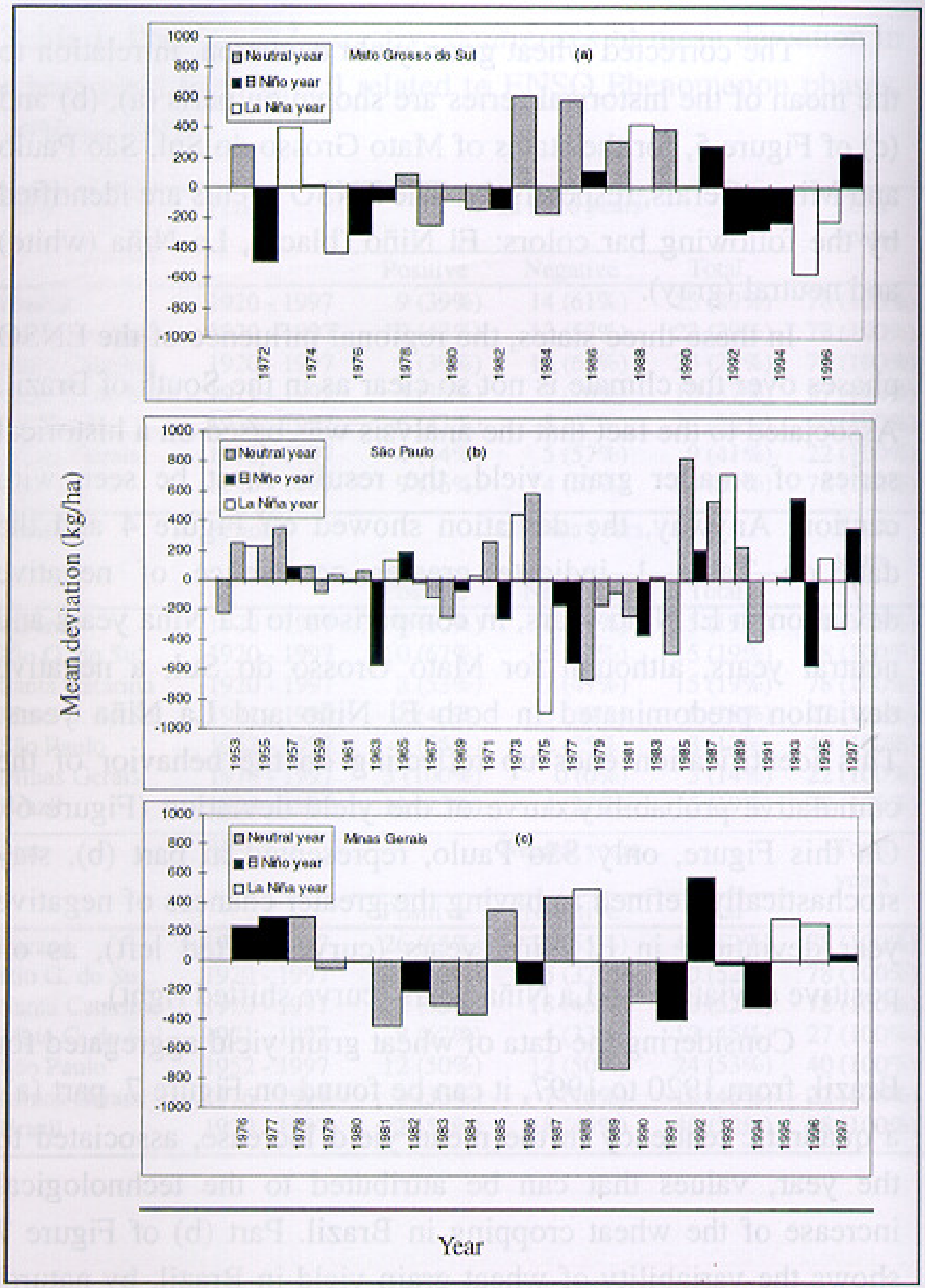

Figure 5. Wheat yield mean deviation (kg/ha) related to ENSO phenomenon phase for Mato Grosso do Sul (a), São Paulo (b), and Minas Gerais (c) states, from 1952 to 1997.

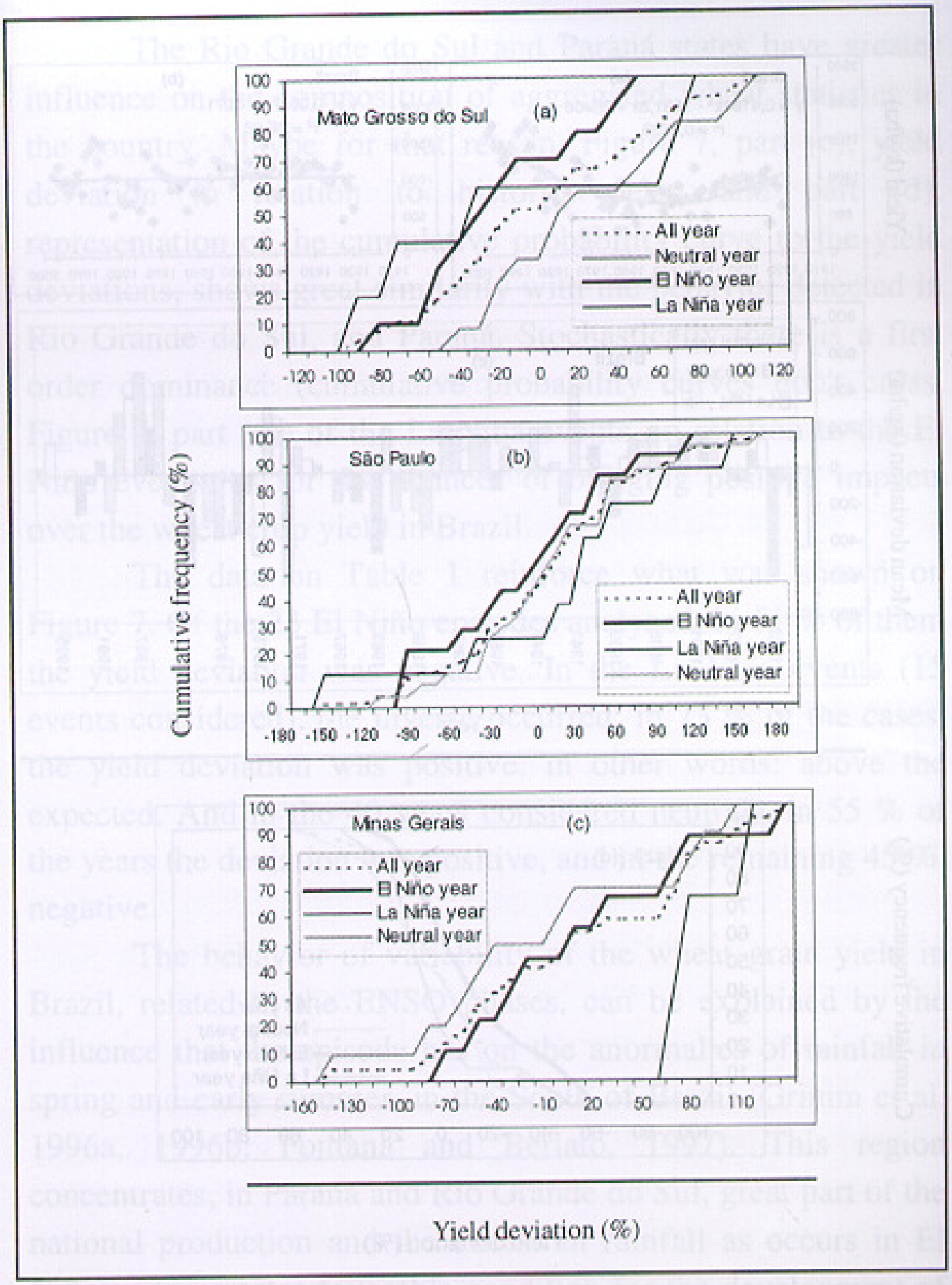

Figure 6. Cumulative frequency (%) of wheat yield deviations in reponse to ENSO phase for Mato Grosso do Sul (a), São Paulo (b), and Minas Gerais (c) states, time series from 1952 to 1997.

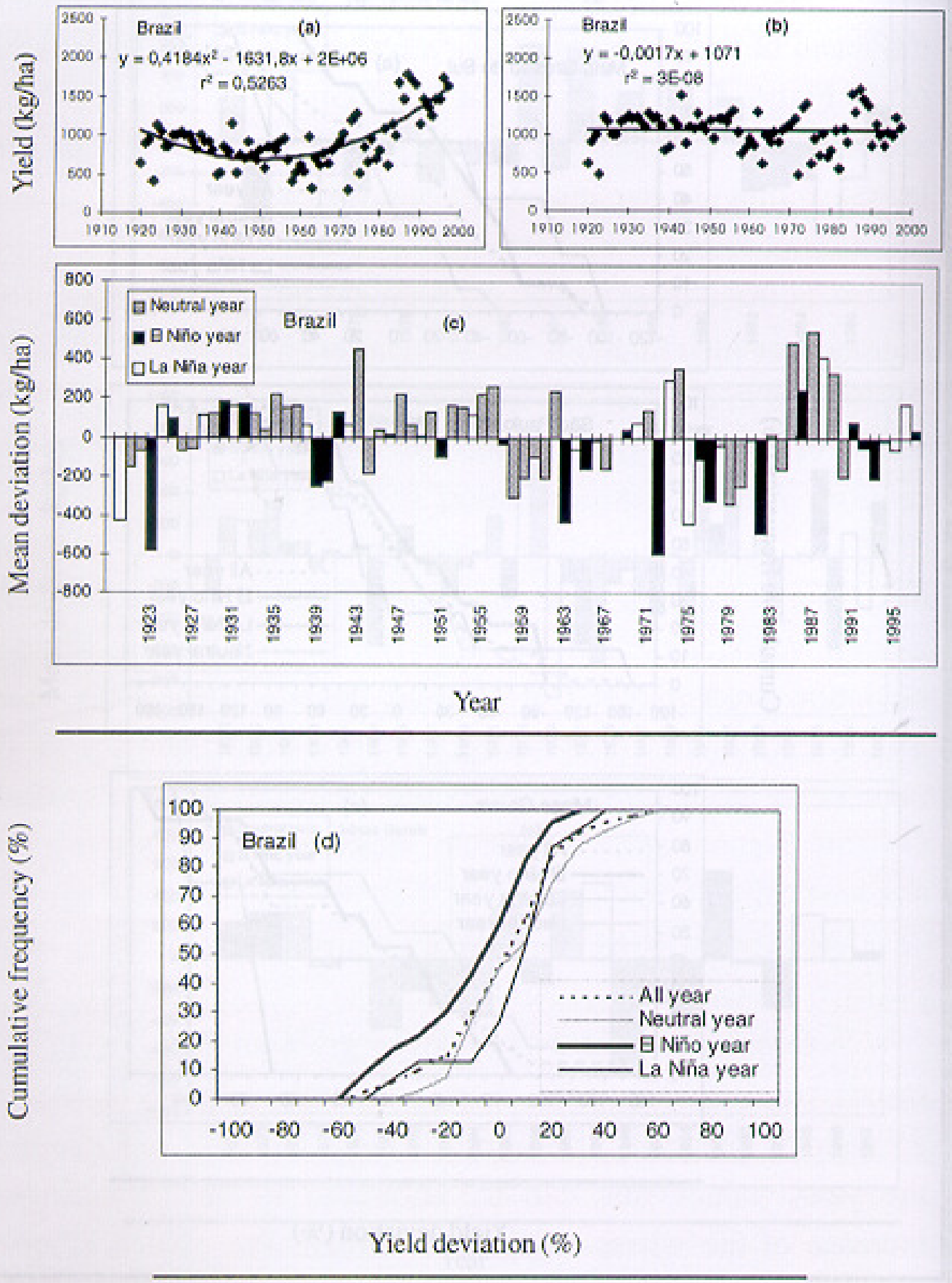

Figure 7. Wheat yield (kg/ha) original (a) and detrend (b) time serie, wheat yield mean deviation (kg/ha) (c), and cumulative frequency (%) of wheat yield in Brazil (d) related to ENSO phenomenon phase, from 1920 to 1997.

The Rio Grande do Sul and Paraná states have greater influence on the composition of aggregated wheat statistics in the country. Maybe for that reason, Figure 7, part (c), yield deviation in relation to historic mean, and part (d), representation of the cumulative probability curve to the yield deviations, shows great similarity with the behavior detected in Rio Grande do Sul, and Paraná. Stochastically there is a first order dominance (cumulative probability curves don't cross, Figure 7, part (d)) of the La Niña events, in relation to the El Niño events, as for the chances of bringing positive impacts over the wheat crop yield in Brazil.

The data on Table 1 reinforce what was shown on Figure 7. Of the 23 El Niño episodes analyzed, in 61 % of them the yield deviation was negative. In the La Niña events (15 events considered), the inverse occurred: in 73 % of the cases, the yield deviation was positive, in other words: above the expected. And in the 40 years considered neutrals, in 55 % of the years the deviation was positive, and in the remaining 45 %, negative.

The behavior of variability of the wheat grain yield in Brazil, related to the ENSO phases, can be explained by the influence that the episode has on the anormalies of rainfall in spring and early summer, in the South of Brazil (Grimm et al. 1996a, 1996b; Fontana and Berlato, 1997). This region concentrates, in Paraná and Rio Grande do Sul, great part of the national production and the excess in rainfall as occurs in El Niño years, creates favorable condition for the development of diseases. Other than that, the soaked soil and the reduction in light, verified in rainy periods; reduces the growth of the roots, and the above ground part (dry matter) having a negative

influence on the yield components, according to studies realized with wheat in the South of Brazil by Wendt and Caetano (1985) and by Sheeren et al. (1995a), (1995b). In the El Niño event of 1997, Berlato and Fontana (1997) estimated losses of 568,641 tons on the harvest for the Southern Region. Of that total 82 % was referred to wheat crop.

It was also evidenciated that not all El Niño events necessarily causes negative impact over the wheat crop in Brazil. It will depend greatly on the intensity of the phenomenon and the anormalies caused by the rainfall regime.

By the facts exposed, as a result of the represented weigh of the Southern states in the brazilian wheat production, it stays evident the greater risk for the crop, in the year which the El Niño phenomenon is acting. The chances of greater positive climatic impacts occurred in La Niña years followed by the neutral years. That is due to the behavior of the rainfall regime in the South of Brazil and its association to the phases of the ENSO phenomenon.

3.2. Impacts over the barley crop in Brazil

Malting barley has been cultivated mainly in the Southern part of Brazil. In the 1999 growing season, 123,895 hectares were cultivated, being 76.9 %, 22.3 %, 0.6 %, and 0.2 % of the area planted in the state of Rio Grande do Sul, state of Paraná, state of Santa Catarina and in the Cerrados region of central Brazil, respectively (Minella, 2000). For this reason this study was restricted to the barley crop cultivated in the three Southern states of Brazil.

The variability of the barley mean yield, in Rio Grande do Sul, in Paraná and in Santa Catarina states, from 1938 to 1998, can be seen in Figure 8. In this Figure, parts (a), (c) and (e) holds the historical original series, presenting, similar to what was verified in the wheat crop, a quadratic trend of increase in the mean grain yield in function of the year. In this case, as well, increase in grain yield can credited to the incorporation of new technologies in the production system. Parts (b), (d) and (f) in Figure 8 show the same historical series of grain yield, although after the elimination of technological trend associated with the data. And, as verified for the wheat crop, some other(s) factor(s) can be observed over grain yield, in this case it was attributed to the effect of the inter-annual climatic variability occurred in the period being analyzed.

The corrected yield deviation, that is, without the technological trend, related to the mean, for the states of Rio Grande do Sul, Paraná and Santa Catarina, are presented on Figure 9, parts (a), (b) and (c), respectively. The deviations are expressed in kilogram per hectare (kg/ha) and are positive or negative, according to, if, the corrected yield of the year stayed above or below the historical serial means. The bars where colored, according to the year classification: El Niño (black), La Niña (white), and neutral years (gray).

For the period analyzed, from 1938 to 1998, in 61 years, there were 19 El Niño and 12 La Niña events. The other 30 years were considered neutral. The data on Table 2 and analysis on Figure 9 and Figure 10 evidenciate, particularly for Rio Grande do Sul and Santa Catarina, that the impact of the El Niño events were, most of the time, negative over the barley grain yield, other than being stochastically dominated in

relation to the others. On these states, the inverse occurred in La Niña years when predominantly the impacts over yield were positive. In the Neutral years, these was a situation of equilibrium between the positive and negative impacts, in the states of Rio Grande do Sul and Santa Catarina. For Paraná, in any of the El Niño - Southern Oscillation phenomenon phases (El Niño, La Niña, Neutral condition) the impacts of the climatic variability associated to this phenomenon were predominantly positive.

Considering the aggregated barley grain yield in Brazil, from 1938 to 1998, the data on Table 2 shows, in the 19 El Niño episodes analyzed, that in 63 % of the cases there was a negative deviation. In the La Niña events, 12 episodes, the inverse occurred; in 67 % of the cases the yield deviation was positive. In the 30 years considered Neutral, in exact 50 % of the times the deviation was positive, and in the other 50 % negative. The greater influence of Rio Grande do Sul in the composition of the brazilian production of malting barley, added to the similar behavior of happenings in Santa Catarina, can explain the behavior of the data in Brazil differing from those of Paraná and being very similar to what happens in Rio Grande do Sul and Santa Catarina states. Figure 11, evidenciates this fact, showing, in the country, a similarity of the verified for Rio Grande do Sul, a quadratic tendency on the elevation of the mean yield due to the year (Figure 11 part (a)), can be attributed to the technological advances incorporate to the fields, and a variability in the brazilian barley grain yield from nontechnological reasons (Figure 11, part (b)). Also, stochastically, in terms of country a first order dominance (cumulative probability curves do not cross, Figure 11, part

(d)), of the La Niña events, in relation to the El Niño events, as for the chances of bringing positive impacts over the barley crop yield in Brazil.

The behavior of the grain yield variability of the brazilian barley, according to the phases of the El Niño - Southern Oscillation, can be explained by the influence that they have on the rainfall anormalies on the spring and early summer period on the Southern region (Grimm et al. 1996a and 1996b; Fontana and Berlato, 1997). The excess in rainfall, for barley, as occurs in El Niño years, creates favorable environmental conditions to the development of diseases, especially necrotrofics as widely discussed by Arias (1995) besides affecting negatively the malting quality (Minella, 1998 and 1999).

Also, as verified in wheat crop, it became evident that not all El Niño phenomenons necessarily cause negative impact over the barley crop yield in Brazil. The impact will depend on the intensity of it and the anomalie caused in the rainfall regime. The same is valid for La Niña episodes; not all are necessarily favorable to barley crop, although most have been.

4. Conclusion

The El Niño - Southern Oscillation phenomenon is a source of short-term climatic variability in interannual and seasonal scales that affect brazilian territory. With that, influentiates the yield of wheat and barley in the country. In general, in most of the times, the impacts are positive for La

Niña and negative for El Niño years, particularly in the Southern Region.

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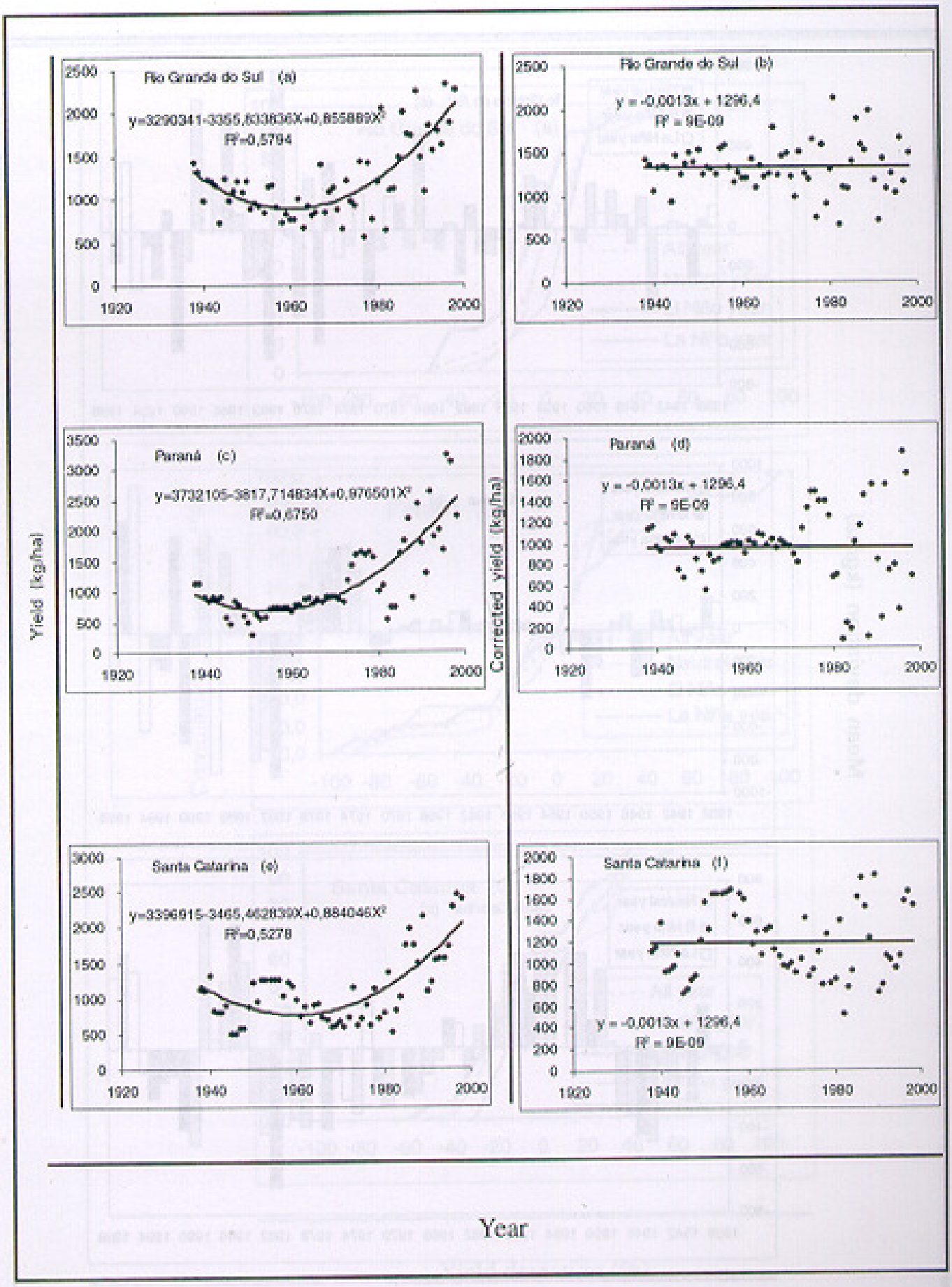

Figure 8. Barley yield (kg/ha) time series [(a), (c), and (e)] and resulting detrend time series [(b), (d), and (f)], from 1938 to 1998, for Rio Grande do Sul, Paraná and Santa Catarina states, respectively.

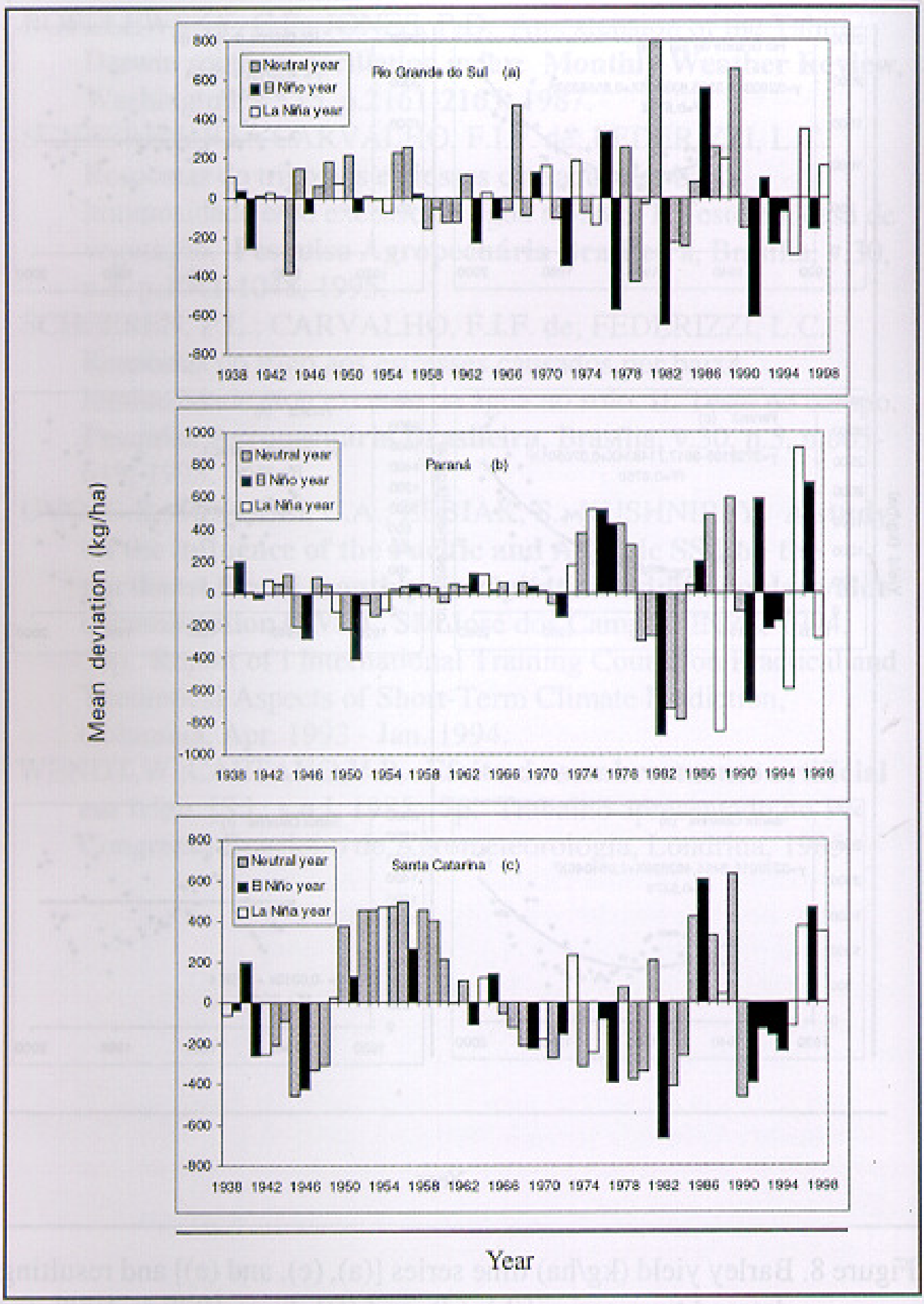

Figure 9. Barley yield mean deviation (kg/ha) resulted to ENSO phenomenon phase for Rio Grande do Sul (a), Paraná (b) and

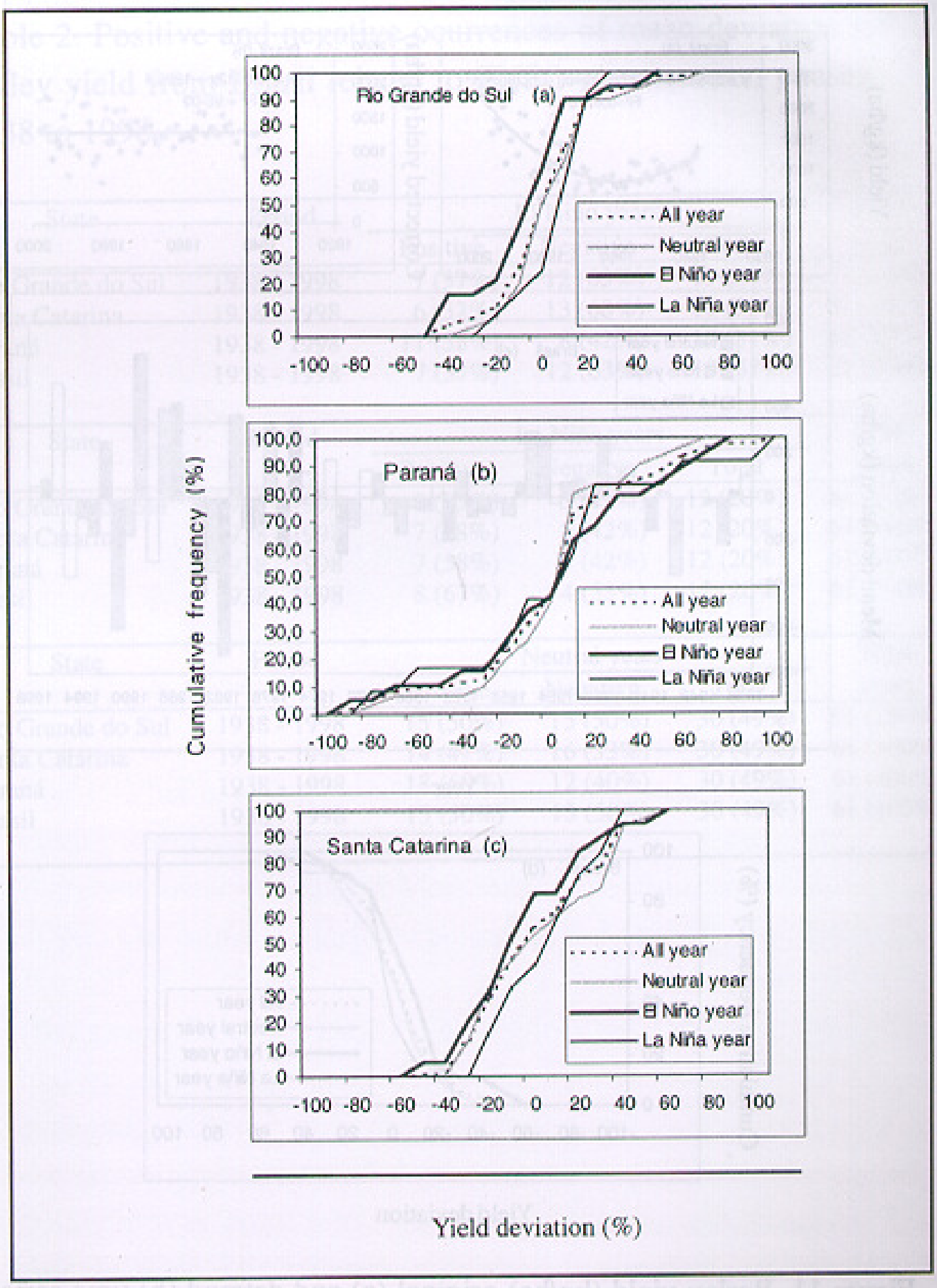

Figure 10. Cumulative frequency (%) of barley yield deviations in response to ENSO phase for Rio Grande do Sul (a), Paraná (b) and Santa Catarina (c) states, time series from 1938 to 1998

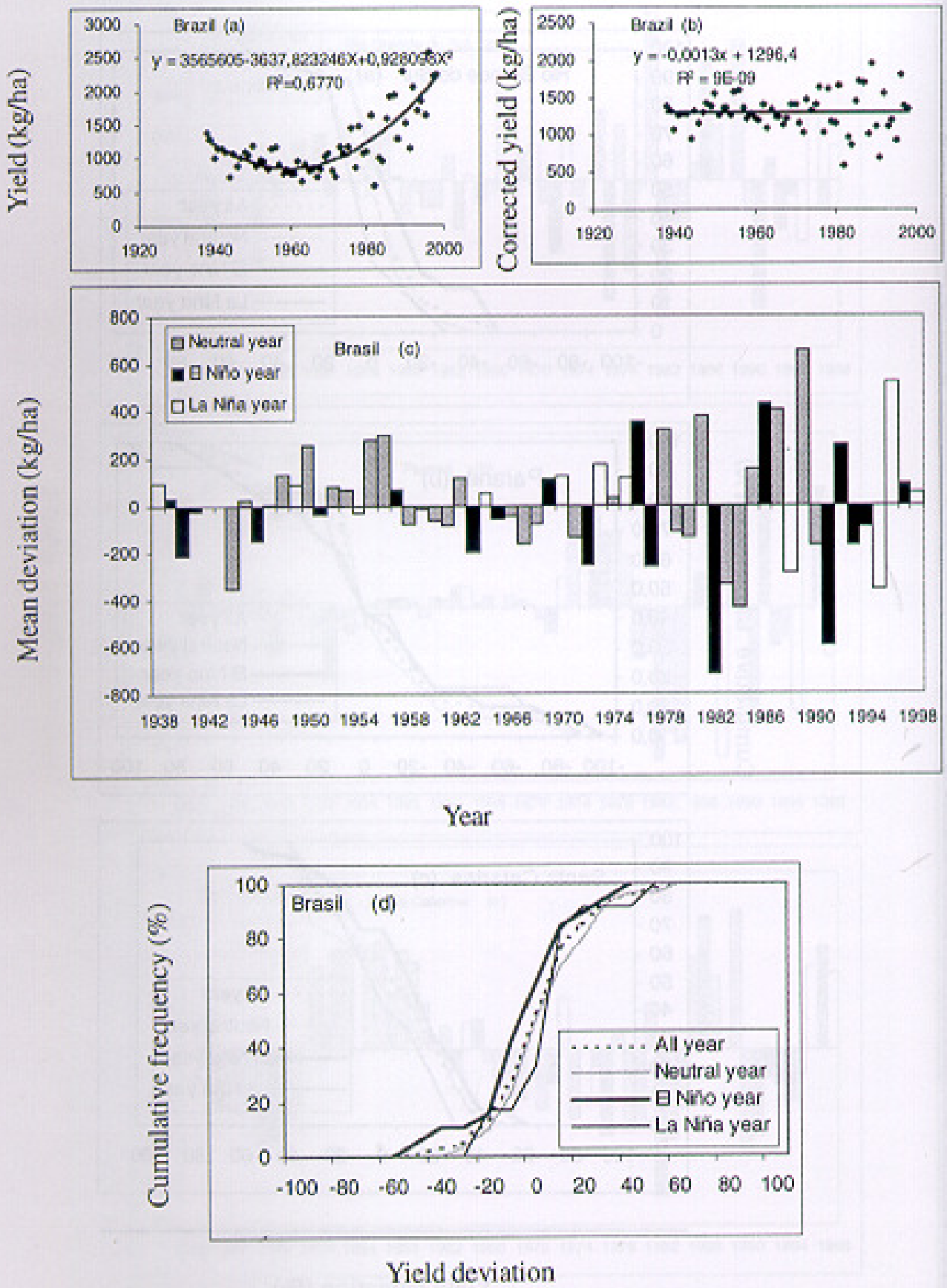

Figure 11. Barley yield (kg/ha) original (a) and detrend (b) time serie, barley yield mean deviation (kg/ha) (c), and cumulative frequency (%) of barley yield in Brazil (d) related to ENSO phenomenon phase, from 1938 to 1998.

Table 2. Positive and negative ocurrences of mean deviation in barley yield from Brazil related to ENSO phenomenon phases, 1938 to 1998.

State	Period	El Niño years			Total years
		Positive	Negative	Total	
Rio Grande do Sul	1938 - 1998	7 (37%)	12 (63%)	19 (31%)	61 (100%)
Santa Catarina	1938 - 1998	6 (32%)	13 (68%)	19 (31%)	61 (100%)
Paraná	1938 - 1998	11 (58%)	8 (42%)	19 (31%)	61 (100%)
Brasil	1938 - 1998	7 (37%)	12 (63%)	19 (31%)	61 (100%)

State	Period	La Niña years			Total years
		Positive	Negative	Total	
Rio Grande do Sul	1938 - 1998	9 (75%)	3 (25%)	12 (20%)	61 (100%)
Santa Catarina	1938 - 1998	7 (58%)	5 (42%)	12 (20%)	61 (100%)
Paraná	1938 - 1998	7 (58%)	5 (42%)	12 (20%)	61 (100%)
Brasil	1938 - 1998	8 (67%)	4 (33%)	12 (20%)	61 (100%)

State	Period	Neutral years			Total years
		Positive	Negative	Total	
Rio Grande do Sul	1938 - 1998	15 (50%)	15 (50%)	30 (49%)	61 (100%)
Santa Catarina	1938 - 1998	14 (47%)	16 (53%)	30 (49%)	61 (100%)
Paraná	1938 - 1998	18 (60%)	12 (40%)	30 (49%)	61 (100%)
Brasil	1938 - 1998	15 (50%)	15 (50%)	30 (49%)	61 (100%)

Table 2. Positive and negative occurrences of mean deviation in barley yield from Brazil related to ENSO phenomenon phases, 1938 to 1998.

State	Period	El Niño years			Total
		Positive	Neutral	Total	years
Rio Grande do Sul	1938 - 1998	7 (35%)	12 (65%)	19 (100%)	61 (100%)
Santa Catarina	1938 - 1998	6 (32%)	13 (68%)	19 (100%)	61 (100%)
Paraná	1938 - 1998	11 (58%)	8 (42%)	19 (100%)	61 (100%)
Brasil	1938 - 1998	7 (37%)	12 (63%)	19 (100%)	61 (100%)

State	Period	La Niña years			Total
		Positive	Neutral	Total	years
Rio Grande do Sul	1938 - 1998	5 (42%)	7 (58%)	12 (100%)	61 (100%)
Santa Catarina	1938 - 1998	7 (58%)	5 (42%)	12 (100%)	61 (100%)
Paraná	1938 - 1998	7 (58%)	5 (42%)	12 (100%)	61 (100%)
Brasil	1938 - 1998	8 (67%)	4 (33%)	12 (100%)	61 (100%)

State	Period	Neutral years			Total
		Positive	Negative	Total	years
Rio Grande do Sul	1938 - 1998	15 (50%)	15 (50%)	30 (100%)	61 (100%)
Santa Catarina	1938 - 1998	14 (47%)	16 (53%)	30 (100%)	61 (100%)
Paraná	1938 - 1998	18 (60%)	12 (40%)	30 (100%)	61 (100%)
Brasil	1938 - 1998	15 (50%)	15 (50%)	30 (100%)	61 (100%)

Figure 11. Barley yield (kg/ha) original (a) and detrend (b) time series, barley yield mean deviation (kg/ha) (c), and cumulative frequency (%) of barley yield in Brazil (d) related to ENSO phenomenon phase, from 1938 to 1998.

AGROMETEOROLOGY IN BRAZIL AND ITS CONTRIBUTIONS

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Abstract

This is a short report of the lecture presented by the first author during the VIII Argentinean Conference of Agrometeorology, held in Mendoza, Argentina, in September of 2000. The same material was published through the Brazilian Journal of Agrometeorology, in the second number of 2000 (Bergamaschi et al., 2000). The authors tried to detail the recent history and the current state of the agrometeorology in Brazil, especially starting from the foundation and the consolidation of the Brazilian Society of Agrometeorology (SBA). As starting point, it was considered the excellent historical made by Dr. Angelo Paes de Camargo, published in the first number of the Brazilian Journal of Agrometeorology (RBA), (Camargo, 1993), that describes the beginning of the activities and the first research groups dedicated to this important scientific area in

Brazil. The current moment of the agrometeorology in Brazil points for a necessary integration with foreign groups in the area and with correlated scientific areas, as well as for an immediate adoption of new technologies generated or adapted to the Brazilian conditions. Each day the agrometeorology science becomes more important in the scientific scenario. As an integrated area, it needs a good relationship with other basic and applied scientific areas. This will be fundamental for its own growth and, so that, the agrometeorology becomes more and more recognized among the other sciences. It seems to be opportune and indispensable for an adequate participation in the scientific scenario, as well as in technological and developmental policies.

1. Historical aspects

Studies and researches in agrometeorology in Brazil started at the beginning of the 1950´s, although many important works were made before, in some correlated areas such as meteorology, climatology, geography, ecophysiology, and ecology. Many of these studies were focused toward agricultural purposes, in spite of having a database coming from the synoptic meteorology. In several Brazilian colleges and faculties, physics and meteorology used to take part in learning programs since the first decades of the 20th Century. However, all the present research groups in agrometeorology were formed during the second half of that Century.

In 1950 the Department of Agricultural Climatology of the Agronomic Institute of Campinas (Instituto Agronômico – IAC)

was created, starting a regular acquisition of agrometeorological data, and also conducting micrometeorological experiments on coffee frost protection, studies on potential evapotranspiration and rainfall distribution, besides to begin the climatic zoning of several crops.

In 1952, the Superior School of Agriculture "Luiz de Queiroz", of the University of São Paulo (ESALQ/USP/Piracicaba), started also studies in frost protection, solar radiation and energy balances, crop evapotranspiration, and statistical climatology. During that period, the first group of specialists in agricultural meteorology area was formed. In the same year, the College of Agronomy "Eliseu Maciel" (Pelotas, Rio Grande do Sul), integrated to the Agronomic Institute of the South, started to do some works in evapotranspiration, crop water budgets, as well as in agricultural climatology studies applied to some regional crops such as wheat, rice, and soybeans.

Other important groups were formed still in the 1950´s, in many regions of the Country. In Rio Grande do Sul State, the Secretary of Agriculture of the State Government, associated to the Federal University of Rio Grande do Sul State, installed the first stations of its own agrometeorological network, besides starting some researches applied to the main regional crops. Similar activities had beginning in the same period in the States of Paraná and Pernambuco. In the 1960´s many other groups have been formed in the States of Minas Gerais, Paraíba, Pará, Bahia, and Rio de Janeiro.

Presently, at the beginning of the 21st Century, there is a significant set of professional groups in agrometeorology widespread in all over the Brazilian territory. However, the

distribution is not homogeneous, concentrating the majority or the biggest groups in the Southern and Southeastern Regions.

The main researches groups in Brazil, considering different States, are:

Santa Catarina – State Enterprise of Agronomic Research and Diffusion of Technology in Santa Catarina State (EPAGRI), and Federal University of Santa Catarina (UFSC) – Florianópolis.

Pará – Center of Agroforestry Researches in Eastern Amazon (EMBRAPA/Eastern Amazon) and College of Agronomic Sciences of Pará State (FCAP) – Belém.

Minas Gerais – Federal University of Viçosa (UFV) - Viçosa, Federal University of Lavras (UFL) - Lavras, and EMBRAPA/Maize and Sorghum – Sete Lagoas.

Paraná – Agronomic Institute of Paraná (IAPAR) and EMBRAPA/Soybeans – Londrina, Meteorological System of Paraná (SIMEPAR) – Curitiba.

Paraíba – Federal University of Paraíba (UFPB), and EMBRAPA/Cotton – Campina Grande.

São Paulo – Superior School of Agriculture "Luiz de Queiroz" (ESALQ/USP) – Piracicaba, Agronomic Institute of Campinas (IAC) – Campinas, São Paulo State University "Paulista" (UNESP) – Botucatu and Jaboticabal, National Institute of Space Research (INPE) – São José dos Campos, and Center of Learning and Research in Agriculture (CEPAGRI/UNICAMP) – Campinas.

Rio Grande do Sul – Federal University of Rio Grande do Sul (UFRGS), and State Foundation of Agronomic Research (FEPAGRO) – Porto Alegre, EMBRAPA/Wheat – Passo Fundo, Federal University of Santa Maria (UFSM) – Santa

Maria, and Federal University of Pelotas (UFPEL) and EMBRAPA/Temperate Climate – Pelotas.

Some recent or emergent groups in agrometeorological research are:

State Foundation of Meteorology and Water Resources in Ceará (FUNCEME) – Fortaleza, CE.

Federal University of Mato Grosso – Cuiabá, MT.

EMBRAPA/Cerrados – Brasília, DF.

EMBRAPA/Grape and Wine – Bento Gonçalves, RS.

EMBRAPA/Legumes – Brasília, DF.

EMBRAPA/Rice and Beans – Goiânia, GO.

EMBRAPA/Semi-arid – Petrolina, PE.

State University of Ponta Grossa – Ponta Grossa, PR.

Federal University of São Carlos – São Carlos, SP.

Federal University of Uberlândia – Uberlândia, MG.

Center of Research in Cocoa (CEPLAC) – Ilhéus-Itabuna, BA.

State Enterprise of Agronomic Research of Goiás – Goiânia, GO.

State "Paulista" University (UNESP) – Ilha Solteira, SP.

2. Brazilian Society of Agrometeorology

The Brazilian Society of Agrometeorology (SBA) was founded on March 29th of 1973, being a scientific association without financial, political or religious purposes. Nowadays, it is associated to the Federation of the Latin-American Associations of Agrometeorology (FALDA), as well as to the Brazilian Society for Progress of the Science (SPBC). Through

this two big associations, SBA is now integrated to similar scientific associations both in national and international scenarios.

Since 1999, SBA has a homepage in Internet (http://www.sbagro.org.br), containing the main information about its organization, congresses, publications, and so on. The Brazilian Journal of Agrometeorology (*Revista Brasileira de Agrometeorologia*) and the Informative Bulletins, are also two important vehicles of regular communication among the scientific community, especially to people and entities related to the area.

Since 1979 for each two years, SBA has promoted the Brazilian Congress of Agrometeorology. So that, in the period from 1979 to 1999, there were 11 national congresses, in different regions of the Country. The congresses of 1997 and 1999 were promoted together with the First and the Second Latin-American Meetings of Agrometeorology. The Table 1 presents some data related to the 11 congresses, describing the evolution of the number of presented papers and participants, during the considered period. It is important to emphasize the increasing participation of students, especially from Master and Doctoral courses.

In July of 2000, SBA had around 320 regular associated researchers, with a continuing tendency to increase, mainly during each congress.

3. Brazilian Journal of Agrometeorology (*Revista Brasileira de Agrometeorologia - RBA*)

The first number of RBA was published in 1993. This scientific journal is now internationally indexed through Agris, Agricola, and Meteorological & Geostrophycal Abstracts. It was published as one edition per year up to 1995, and since 1996 it has been edited in two volumes each year.

The number of published papers in RBA oscillates around 20. In Figure 1 it is possible to analyze the distribution of published papers for different applicated areas, in the period from 1993 to 2000, corresponding to 13 numbers of RBA. It can be observed the highest frequencies in statistical climatology, micrometeorology, cropping in protected environments (mainly in plastic greenhouses), and studies focusing water relations. The factor "water" has been intensively studied, indicating its importance to the Brazilian agricultural production. Studies related to this factor have been focused by several approaches, since the climatology of rainfall up to basic works in the ecophysiology of the water relations in the soil-plant-atmosphere system, besides studies quantifying the water requirements of different crops.

Although the series of publications is relatively short, it was observed that, in general, the areas more intensively focused used to maintain a high number of publications along the entire period. On the other hand, some subjects have shown an increasing frequency in the latest number, such as analysis of the El Niño/La Niña phenomenon and its consequences upon the rainfall distribution and production of crops. Agricultural

modeling and its applications have been also frequent in more recent publications.

It is convenient to remember a tendency observed by the Editorial Committee of RBA, regarding the decreasing of "field data" in the recent publications. Perhaps, limitations in terms of physics and financial conditions may imposed difficulties in performing new experimental works, in large scale, reducing the acquisition of new original data and the generation of new parameters. The more intensive use of electronic resources in data computing, in spite of being indispensable, may contribute for this tendency.

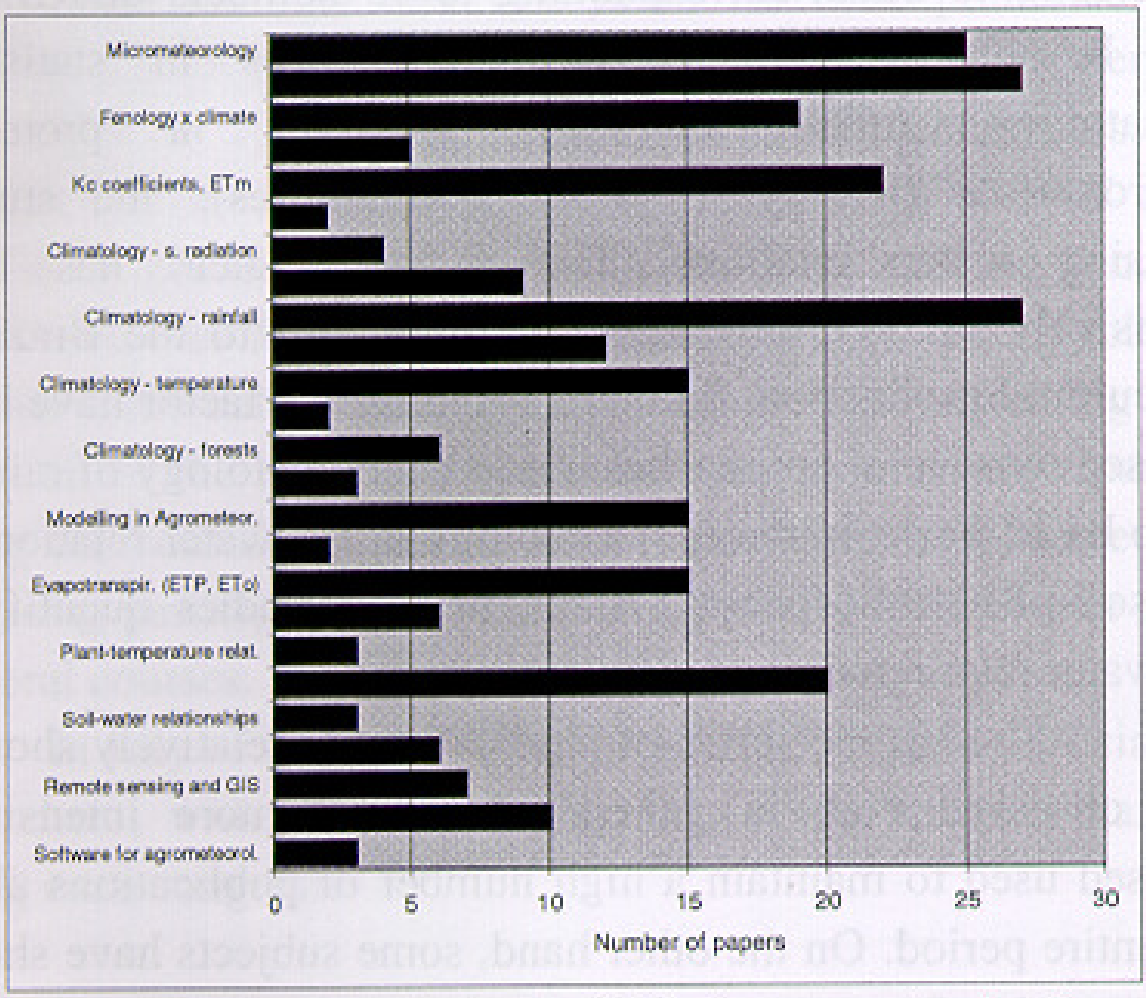

Figure 1. Distribution of the published papers in the Brazilian Journal of Agrometeorology (*Revista Brasileira de Agrometeorologia*), according to the different applications, in the period from 1973 to 2000.

Table 1. Information related to the Brazilian Congresses of Agrometeorology promoted from 1979 to 1999.

Year	Location (City, State)	Presented works	Publication (form)	Additional publication	Participants (number)
1979	Mossoró, RN	54	abstracts		220
1981	Pelotas, RS	83	abstracts		140
1983	Campinas, SP	87	abstracts	25 proceedings	200
1985	Londrina, PR	110	abstracts	24 proceedings	280
1987	Belém, PA	114	abstracts		160
1989	Maceió,AL	58	proceedings		205
1991	Viçosa, MG	126	abstracts		220
1993	Porto Alegre, RS	202	abstracts		240
1995	Campina Grande, PB	175	proceedings		250
1997	Piracicaba, SP	245	proceedings		350
1999	Florianópolis, SC	427	proceedings		510

Observation: The CBAs of 1997 and 1999 were promoted together with the I and II Latin-American Meetings of Agrometeorology.

4. Highlights

At the end the 20th Century, the teaching of the agrometeorology was disseminated in almost all the Brazilian Agronomy and Meteorology courses, besides other courses, such as Agricultural Engineering, Forest Engineering and Animal Science. The focus and the extension of the disciplines were a little different, depending on the regional emphases and the courses, as well as the academic formation of the responsible team.

The human resources formation, in Master and Doctoral level, is being done for more than three decades, through specific or related courses to the agricultural meteorology area. Standing out courses are examples, such as ESALQ/USP (University of São Paulo, Piracicaba), UFV (Federal University of Viçosa), UFPB (Federal University of Paraiba, Campina Grande), UFRGS (Federal University of Rio Grande do Sul, Porto Alegre), UFPEL (Federal University of Pelotas), UNESP (State University of São Paulo, Botucatu and Jaboticabal), UFSM (Federal University of Santa Maria), INPE (National Institute of Space Research, São José dos Campos), among others.

Several specific or related books to the agricultural meteorology area were already published in Brazil, such as: Mota (1975), Reichardt (1975, 1978), Tubelis & Nascimento (1980), Ometto (1981), Mota & Agendes (1986), Vianello & Alves (1991), Bergamaschi (1992), Mota & Zahler (1994), Libardi (1995), Assis et al. (1996), Cunha (1997), Pereira et al. (1997), Silva (2000) and some others that could be omitted. These publications were results of the high qualification of the

national authors and the wide readiness of knowledge and information existent, perfectly adapted to the Brazilian conditions. But, it is still verified a lack of specific didactic material. Considering that the climatic aspects are so variable in Brazil due to the large size of the Country and different regional emphasis, it is important to motivate new and good releases. It is necessary to organize and release to the users the great bank of technical information that came from the scientific research, disseminated through several congresses and scientific publications. On the other hand, precious results of several theses and dissertations were not still disclosed to the users, staying restricted to the authors. This represents another urgent need, to make available these important scientific research products.

The scientific research and the technical services are accomplished in several public and private institutions, as it can be checked by the mentioned research groups. Besides the universities, all the national centers of EMBRAPA and the institutes and state foundations has at least one scientific researcher working on agrometeorological area. The research activities and technical extension services have the growing participation of agrometeorologist personnel. Also, in this case, the focus and the work intensity depend on the regional characteristics and of the human capacity. There is a higher participation of agrometeorologists each time more in the institution activities, with high technologies or through revision and adjustment of traditional technologies, as are the crop zonings and planting calendars. During the last years, it can be checked a growing involvement each time more of private institutions, through the teaching and research activities in

universities, and also in technical extension companies.

Agrometeorological monitoring systems are been set up at regional level, associated with modern systems of weather and climate forecast that are improving the technical services, guiding the farmers in the crop production management, as well as the decision makers to provide early warning and the policy elaboration of regional and national development.

The Brazilian Society of Agrometeorology (SBA) published recently a paper elaborated by Steinmetz (2000), that defines the regional and national priorities of scientific research in agrometeorological areas. The Table 2 presents a summary of the areas and their respective priorities, according to the own consulted researchers. It is possible to verify the diversity of priorities, according the regional needs, due to the different climatic types and agricultural activities, as well as the differences in technical information available. In some regions of Brazil, the availability of knowledge already can be considered enough in the way to decrease the needs of new studies. This is the case of the South and Southeast regions, where the researchers teams are more numerous and where the technical information available in many areas is already enough to reduce the needs of new investments.

The work of Steinmetz (2000), that defined the research priorities should be followed by a similar study in the teaching area of the universities in the next years. It is necessary a better definition of the contents of the disciplines, according the regional needs.

The current moment of the agrometeorology in Brazil indicates to a great need each time more of internal integration (inside of its own area), with foreign groups and also with

correlate areas. It is also necessary the immediate adoption of new generated or adjusted technologies to the Country, with practical applications. As examples of ready technologies for immediate application, the crop specific water monitoring indexes, irrigation management, agrometeorological water budget, crop yield monitoring, elaboration of practices to reduce drought risks, agricultural insurance management, among other important applications.

The agrometeorology is each time more important in the technical and scientific scenario and, as an integrated area of the knowledge, needs to maintain very good relationships with other basic or applied scientific areas. This will be very important for its own development and that becomes each time more recognized among the other sciences. A strong and determined participation on the definitions of policy of science and technology, as well as in decisions related to the policy development, seems to be opportune and indispensable.

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Table 2. Priorities by research lines, for different Regions and all the Country (Steinmetz, 2000)

RESEARCH LINES	Order of Priority					
		REGIÕNS				
	BRAZIL	South	Southeast	Center-West	Northeast	North
Improvement of **Human Resources**	*1*	*3*	*2*	*1*	*2*	*1*
Definition of de **Sowing Time**	*2*	*8*	*5*	*1*	*2*	*1*
Analysis of **Climatic Risks**	*3*	*2*	*5*	*1*	*4*	*1*
Integrated Center for Agrometeorological Information	*4*	*1*	*1*	*1*	*7*	*1*
Agroclimatic Zoning	*5*	*3*	*6*	*1*	*1*	*4*
Technology in **Modified Environment**	*6*	*5*	*2*	*6*	-	*1*
Probability in **Working Days** for agricultural activities	*7*	*8*	*10*	*1*	*1*	*1*

Formation of Meteorological and Fenological **Data Banks**	*8*	*2*	*1*	*1*	*8*	*1*
Modeling for Simulation in Agrometeorology	*9*	*4*	*7*	*2*	*6*	*1*
Software applied to Agrometeorology	*10*	*2*	*5*	*1*	*8*	*1*
Plant-Environment Relations, emphasis in **Water Relations**	*11*	*7*	*4*	*4*	*5*	*2*
Water requirements of crops	*12*	*8*	*3*	*5*	*2*	*4*
Climatic **Water Budget**	*13*	*10*	*8*	*1*	*4*	*1*
Technology in **Remote Sensing** applied to Agrometeorology	*14*	*6*	*9*	*3*	*3*	*3*
Researches in **Agroforest Systems**	*15*	*9*	*11*	*6*	*1*	*1*

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AGRICULTURAL ZONING: REDUCING THE RISKS OF AGRICULTURE AND PROVIDING TRUSTWORTHY POINTERS FOR SUSTAINABLE REGIONAL DEVELOPEMENT

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Abstract

The orientation of agricultural development in Brazil used to be based, since 1965, on three Agricultural Policy Instrumental:

- The Rural Credit;
- The Minimum Prices Policy Warranty, and
- The Rural Insurance.

In 1995 a new scientifically elaborated element was introduced to improve the consistency and credibility of the agricultural development. It is the Agricultural Zoning.

With this study, farmers have indication on what crops to plant at eache county and when to plant, so that they have a way of reducing climatic risks and improving their production and income.

1. Introduction

Brazil, a tropical country, with 164,000,000 inhabitants and a continental territory of 8,548,000 km², has politically demarcated 5 regions: South, Southeast, Center-west, Northeast and North.

Looking at the brazilian map (Figure 1), we see immediately five important and great ecosystems:

1. The Brazilian Amazon, with three million km², 35 % of the Brazilian territory, embracing the North, Northeast and Center West areas. Fifty percent of the Amazon Forest are in Brazil;

2. The Brazilian Savannah, with two million km², 23 % of Brazilian territory, embracing the Center-west, Southeast, North and Northeast areas, with defined climate and rainy regime;

3. The Semibarren Northeastern: located at Brazilian Northeast Area, with dry climate and minimum rainfall;

4. The Atlantic Forest, at southeast area marine coast;

5. The South Area, with varied climate and rainfall, being, however, the largest agricultural producer of Brazil.

By the way, the Brazilian Atlantic Coast, with more than 8,000 km of extension, is going to have a fishing policy, researched scientifically and quite daring, which is now being established by the Brazilian Ministry of Agriculture.

For agricultural development, embracing agriculture, livestock, forests, environmental preservation and fishing, since 1965, Brazil has three Agricultural Policy Instruments:

1. The Rural Credit: to finance the implantation of agricultural enterprises;

2. The Minimum Prices Policy Warranty - PGPM: to assure better prices of the agricultural products at the harvest time, when the offer is larger;

3. The Rural Insurance: official (PROAGRO), as well as private, to take care to guarantee the crop losses due to climatic incidents.

Such instruments work in conformity with decisions of the Brazilian National System of Rural Credit, composed by the National Monetary Council, the Brazil Central Bank and 875 credit institutions (Official anda private banks and cooperatives), the last ones operating at more than 4,000 Brazilian counties.

The system is very fast. Having a decision from the National Monetary Council to reduce or to increase interests, to offer subsidized credit or something similar, for instance, the communication goes to the Central Bank, which, by itself, immediately transmits them to the financial institutions. So, in less than 24 hours, it goes into effect all over the Country.

However, in spite of the agility of the system, it was needed more control over it. For instance, if the National Monetary Council, suggested a R$ 300,000.00 credit for each farmer to sow cotton, the credit institutions allocated such resources where they wanted. So, cotton could be planted on the whole Brazil, and not where they should, at specific regions. Really there was not a well defined criterion, like something that could direct that credit to the farmer, and to help him reduce his risks.

Up to 1995, that was the operation of the mentioned Instruments of Agricultural Policy, culminating with a serious financial crisis that harmed the making of it. Like this, the Rural

Credit arrived at the farmers in inadequate moment, resulting that these began the planting too late and, consequently, with larger risks. The PGPM and the Rural Insurance were sensibly discredited, not doing their tasks in due time.

As such a situation, the losses in the agriculture were very big, and in the summer cultures (rice, bean, corn, soy, cotton, tapioca and others planted at rain season, from September on), the losses for drought reached up to 60 %, and for strong rains ups to 32 %. In the winter cultures (wheat, barley and another planted at Brazil south areas, starting from April), the losses for drought were 30 %, for strong rains at harvest time, 32 % and for frost 30 %. In this scenario, it could be verified that the Brazilian agriculture was an activity of high risk and even deficient.

However, from 1995 a new scientifically elaborated element was introduced to improve the consistence and credibility to the already mentioned instruments: the Agricultural Zoning.

2. Results

In the Zoning works, were computed agricultural research, meteorology programs and atuary science needed for the pertinent calculations.

We attacked the principal problems of losses in the Brazilian agriculture: draught, strong rainfall and frost. We verified that we didn't really known Brazil by its rainfall: where it rains, how it rains, how much it rains and when it rains. So, we got all data from Meteorological Stations, over 8.500 of

them, some with historical data, (about 3,000), had daily series of more than 30 years. A statistical work was done and we found, initially, six homogeneous areas of rainfall.

Refining such work, we found 25 homogeneous zones of rainfall, that made possible to know in full detail the Country in terms of rain regime. Surprisingly enough, all this was not known, or, at least, not accessible.

With such a base of data, we got to do the Brazilian Agricultural Zoning, gathering together Universities, Agricultural Research Companies, Foundations, Meteorological Institutes, renowned technicians, etc.

We collected studies of Research Companies, official as well as private owned ones, with data in excess of 20 years. Here we found another very important data related to seeds, soil types, suitability of the cultures and areas, sow time, the culture need of water at the critical phase, offer of water in all areas be cultivated, and so on.

All this data already does existed, but it was scattered apart and without any coordination.

Our task, therefore, consisted of reducing the inherent climatic risks to the agriculture that wipe out our plantations. The work of the Agricultural Zoning was to reduce the climatic risks, based in the lack or offer of rain water by nature, and it culminated in the determination of the planting time for the cultures zoned at the level of counties, correlating them with culture type and cycle of the seed.

Working with areas and homogeneous rainfall zones, by now disclosed, together with Agricultural Research Centers, more than 30 in the Country, statistics and actuary science, getting full support from Credit Institutions or Financial

Agents, we began the making of a board of agricultural risks nonexistent in Brazil and, as far as we know, in the world too.

To illustrate, let us look at a Brazilian State where the zoning was accomplished, exemplifying with Bahia, located in the Northeast Area, with 418 counties and an area of 567,000 km². By meteorological stations data we verified as it rained during one year, with daily data and yearly averages.

Knowing as it rains, how much it rains, when and where it rains, it would be still needed to qualify, within the rainfall time, when this doesn't happen.

There exists what we call "veranico", something like a "small summer", and, as generic as possible, it lasts 10 to 20 days with no rainfall. So, some statistical data was extracted over this phenomenon in that State, as well as on all others.

All this, together with the soil capacity of water storage at each county, connected with the culture and seed cycle, is quite possible to find the right planting time and where to sow with a smaller as possible risk.

At Bahia cotton was planted in the whole State and practically at any time, but, by now the period is well defined, including the proper area. Outside the time and planting place indicated by the Zoning there won't be credit and insurance, as the risk would be increased, with larger loss chances.

Such a system led in the following: the cotton losses at Bahia, that reached 60 % every year, simply disappeared.

We got from importers to exporters of cotton in less than 2 years, thanks to those hints. For counties not suitable to cotton planting, the credit was redirected for other agricultural activities, such as livestock, forest, fish farming, horticulture, etc.

The Agricultural Zoning points out the time, what and where to plant, delimiting Brazil in ecosystems, for a maintainable development.

A new refinement was made, to know where was capable or not to plant, and when and where could not plant. For this last ones, the credit would not be available in any case. Besides, the Reserves does exist, where nobody can plant in any way, in order to not change and protect the related ecosystem.

With that method, the Zoning, was good to insurance, started also beacon the Rural Credit and, consequently, the Minimum Price Policy Warranties, making possible to reduce the risks and to increase the production in the Brazilian agriculture.

We reached then the production of 29 million tons of corn, soy with 23 million, tapioca with 17 million, rice with 8 million tons. Wheat, that previously to the Zoning had only reached the productivity of 1,200 kg/ha, in less than two years passed to 2,200 kg/ha, at the capable areas of cultivation. Coffee with 2.7 million tons, bean with 2 million tons. There was, by the same way, a productivity increase with the risks decrease in the barley cultures, chestnut of the cashew, castor oil plant, apple and passion fruit. It should be pointed out that the production of sugar cane, out of the zoning, with 338 million of tons and the orange with 105 million fruits.

With the Zoning, we got to recover the Brazilian agricultural productivity, lessening the inherent risks of that activity.

As consequence, the Rural Credit is turning out quite profitable and the Private Insurances companies began to invest in Brazil.

The Brazilian areas are all delimited by culture. Rice, bean, corn and soy from Rio Grande do Sul to the south of Maranhão and Piauí and Southwest of Bahia; apple and wheat in the south of the Country; cotton from the north of Paraná to the whole northeast. Shortly we will include other cultures and horticulture, with all the data the producer should know to help him in his activity.

The Agricultural Zoning had the back-up of the National Monetary Council, having been introduced to the Rural Credit System as integral part of the Brazilian Agricultural Policy.

Their spreading is going this way: afterwards some decision of the National Monetary Council, the Brazil Central Bank, by electronic ways, quickly send the notices to the Credit Institutions and Financial Agents that operates with Rural Credit.

As we can see, the whole Country knows in a snap which counties of each State are capable for the cultures, the appropriate time for the planting, the types of appropriate soils, which areas of environmental preservation and ecosystems that should be preserved, all this accompanied by guiding Technical Notes, indicating, at the same time, the appropriated kind of seed.

The Zoning, therefore, of a technical-scientific package that the producer have access and it must use it, in order to reduce the risks of his activity, increasing, as a very important side benefit, his production and income.

This way, gone are waste and losses, production and productivity were quite increased, being preserved, very important too, the environment.

This is the Agricultural Zoning!

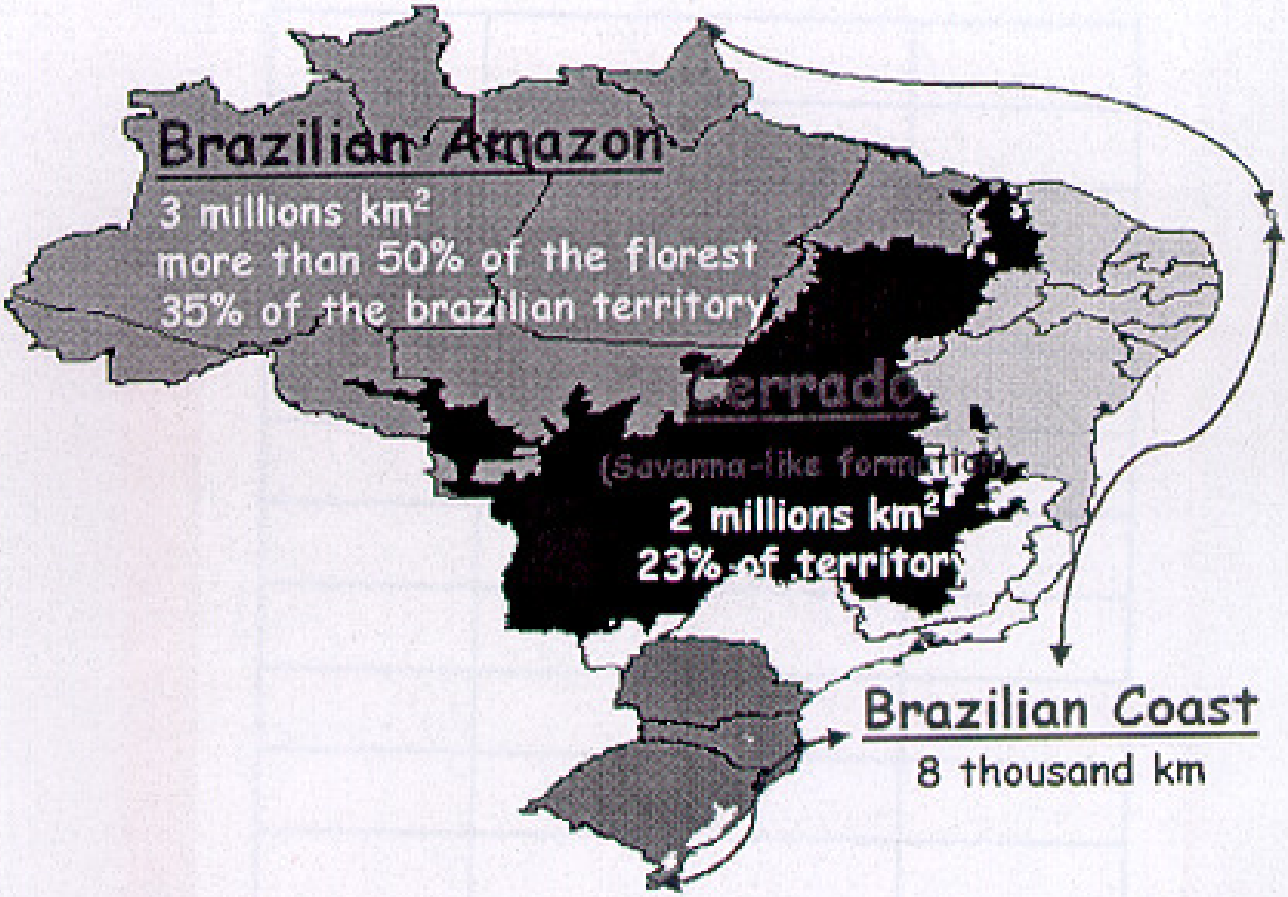

Figure 1. Brazilian ecosystems.

Embrapa

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Applications of Climate Forecasting for Better Decision-making Processes in Agriculture

The contribution from the 12th Regional Climate Outlook Forum for Southeastern South America, held in Passo Fundo, RS, Brazil, April 24-25, 2001.

Climate forecasts may constitute invaluable information for crop management, insofar as they minimize risks under unfavorable conditions and make efficient use of favorable situations.

Using the Regional Climate Outlook Fora for Southeastern South America experience as a basis, this book provides a valuable insight to the development of an efficient system to apply climate forecasts in agriculture.

Edited by

G. R. CUNHA, J. C. HAAS and M. A. BERLATO

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