MINISTÉRIO DA CIÊNCIA E TECNOLOGIA
INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

INPE-5410-PRE/1757

IAI TOPIC:
EL NIÑO - SOUTHERN OSCILLATION AND INTERANNUAL CLIMATE VARIABILITY

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A contribution presented to the Scientific Experts Meeting of the Inter-American Institute for Global Change Research, Washington, DC, 5 - 6 Mar. 1992, at NOAA/OGP

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Palavras-chave: El Niño; Oscilação sul; Variabilidade climática

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OUTLINE

A contribution presented to the Scientific Experts Meeting of the Inter-American Institute for Global Change Research, 5 and 6 March 1992, at NOAA/OGP, Washington, D.C.

(drafted by A.D. Moura and V. E. Kousky)

1. Description and Importance of ENSO

In countries with generally sparse rainfall, the rainy season is anticipated with hope and foreboding: a poor rainy season in some regions can lead to famine, migrations, abandonment of villages with its attendant social dislocations, and general disruptions in the agricultural economics on which large segments of the population depend. An excessive rainy season can lead to floods, destruction of property, and depletion of topsoil, which also may adversely affect the socio-economic systems. A normal rainy season can mean survival and perhaps even a modicum of prosperity for one more year.

The years 1982 and 1983 featured a rash of climate rainfall anomalies of severe and lasting impact. The losses in several countries have been estimated to total more than 13 billion U.S. dollars (see Table 1). Coastal Peru, a region sufficiently arid that sun-baked mud is widely used in home construction, received as much as 3 meters of rain within six months and much of the transportation infrastructure - bridges and roads - were washed away. The Peruvian and Ecuadorian fisheries, sustained by the intense oceanic upwelling that pumps nutrients to the surface , were nearly eliminated. Excessive rainfall and flooding occurred in many sections of the western and southwestern United States and in southern Brazil, northern Argentina and eastern Paraguay. In contrast, severe drought was observed during the February to May rainy season in the Nordeste region of Brazil. Mexico and many Central America countries experienced drought.

The later part of 1982 and the early parts of 1983 were also extremely unusual in the tropical Pacific Ocean. The normally cooler eastern equatorial Pacific Ocean warmed throughout the later parts of 1982. By March 1983, the water throughout the entire equatorial Pacific Ocean, from the far west to the coasts of Ecuador and Peru (an enormous distance of 15,000 kilometers), was at or near record warmth.

Observational, modeling and theoretical work by scientists all over the world, especially during the last decade, has lead to an understanding that the abnormal warming of the Pacific Ocean (Figure 1) is intimately related to a consistent pattern of climate anomalies throughout the tropics and many parts of the globe (Figure 2). The climatic disasters of 1982-83 are an extreme example of an irregular but recurring pattern known to meteorologists and oceanographers as the warm episode phase of the El Niño-Southern Oscillation (ENSO) cycle. ENSO is an irregular cycle, with extremes of variable amplitude recurring at intervals of 3 to 7 years. The period 1982-83 was an extreme example of its warm phase. The opposite extreme of the ENSO cycle, or cold phase, is also associated with a global pattern of climate anomalies, which are essentially the opposite to those observed during the warm phase. The most recent cold episode of 1988-89 featured abundant rainfall over Nordeste of Brazil and drought conditions in the southern United States and southern Brazil, Uruguay and northeastern Argentina.

Some earlier and detailed description of the phenomenon can be found in the works of Horel and Wallace (1981), Rasmusson and Carpenter (1982), Kousky et al. (1984) and Ropelewski and Halpert (1987).

Historically, El Niño was the name given to a marked warming of the coastal waters off Ecuador and Peru, observed by the local fishermen at the end of the year, around Christmas (hence the name meaning the child Jesus, in Spanish). We now know that during the ENSO warm phase the abnormal warming of the ocean covers the equatorial Pacific from South America to the date line, fully 1/4 of the Earth's circumference. This basin scale change in sea surface temperature induces changes in the tropical rainfall distribution and hence the global atmospheric circulation. At the same time, changes in the atmospheric circulation (the low-level winds) in the tropical Pacific affect the ocean currents and temperature. That two-way coupling of the tropical Pacific atmosphere and the ocean is at the heart of the ENSO cycle.

The mechanism that link ocean surface temperature changes with changes in atmospheric circulation and precipitation regimes in the tropics and extra-tropics has been and still is the focus of the worldwide scientific research community.

2. Current Understanding and Regional Impacts

The advances in understanding the ENSO phenomenon in the last decade have been remarkable. Improved monitoring techniques of the ocean and atmosphere along with advances in dynamical modeling have contributed greatly to a better understanding of how the coupled ocean-atmosphere system works in producing the ENSO cycle and has lead to skillful forecasts of warm and cold episodes up to a year or so in advance.

The rapid progress in prediction has resulted from an increased understanding of the interaction between the atmosphere and the ocean in the tropics. The key insight in understanding the phenomenon was made by a prominent Norwegian meteorologist, Jacob Bjerknes. He grasped that the ENSO is to be understood neither as an atmospheric phenomenon nor as an oceanic phenomenon, but as a phenomenon which depended intrinsically and unavoidably on the interaction between the atmosphere and the ocean, particularly at the interface of the two fluids (Bjerknes, 1966; 1967). A theory of ENSO would therefore accurately describe how the atmospheric winds change the oceanic sea surface temperature (SST) which is simultaneously producing the changes in the atmospheric winds. When a model of the ocean is coupled to a model of the atmosphere, the ENSO arises spontaneously, with the proper surface winds and the proper SST.

By 1987, this idea had been encapsulated into simplified coupled models of the Pacific Ocean and the atmosphere above it (Cane et al., 1986). The models were able to simulate correctly the major large scale features of ENSO and, more remarkably, to predict the future state of the ENSO from information about the current state of the ocean. The models proved successful in retrospective forecasts and they also successfully predicted the onset of warming in the Pacific in 1986 more than a year in advance. The 1991-92 case, predicted more than a year before, is proven to be correct, as reported by Kerr (1992).

Impacts

The agrarian societies in tropical countries are heavily dependent on the water received during the rainy season. Occurrences of floods and droughts cause large disruptions in their economies. The ENSO phenomenon is one of the major factors that causes disruptions in rainfall over many tropical and extra-tropical countries. As graphically illustrated in the National Geographic (Canby, 1984), the major ENSO warm event of 1982-83 was responsible for widespread incidence of droughts, floods and severe weather on all continents, which resulted in hundreds of deaths and losses.

Table 1 taken from The New York Times (2 August 1983), gives a summary of the human misery and damages totaling 13 U.S. billion dollars caused by the 1982-83 ENSO event.

Tropical societies are often unprepared to adjust quickly to dramatic deviations from normal climatic regimes. The persistent nature of the ENSO phenomenon together with the advances in prediction offer decision makers a unique opportunity to take into account anticipated climate variations in the planning process. Recently, scientists from several countries have begun to use the accumulated knowledge about ENSO and other tropical ocean-atmosphere phenomena, on regional basis, to predict rainfall. These predictions have proven to mitigate the socio-economic impacts of interannual climate variability.

Peru illustrates how a nation can benefit by correctly applying this knowledge (Lagos and Buizer, 1991). Peru's Gross Value for Agricultural sector dropped drastically following the 1982-83 ENSO, but interestingly did not drop following the 1986-87 event (Figure 3). In 1986, the advice given to the farmers by government officials and the head of a non-governmental agrarian organization in Peru, based on the outlook of the coming rainy season given by scientists, helped in determining the appropriate combination of crops to be sown. Two of the primary crops, rice and cotton, are very sensitive to the amount and time of rainfall. Rice needs large water volumes and relatively warmer ambient air during its growing phase and relatively drier and cooler nighttime conditions. On the other hand, cotton has deeper roots and is capable of yielding greater production during years of light precipitation. An optimum combination of rice and cotton areas sown, depending upon the projected temperature and rainfall, has helped Peru in coping with the vagaries of seasonal climate. By applying this strategy, the Peruvians were able to sustain the gross value of their agricultural sector, increasing it in 1987 in contrast to the decrease in 1983, caused by the 1982-83 ENSO.

Another example of advantageous use of inter-annual climate predictions and their anticipated impact on the population and agriculture of Northeast Brazil is reported by FUNCEME (Foundation for Meteorology and Water Resources in the State of Ceara). Slightly drier conditions were expected in 1990 and the local government guided the farmers accordingly on the timing to seed corn, rice and beans, as well as water conservation strategy. Preliminary results of FUNCEME's evaluation are very encouraging. The strategy is to combine the climate information for the rainy season with socio-economic implications to the region and bring the combined report to decision-makers and policy decision levels, including the State's Governor.

Why ENSO as an IAI research topic?

In the Americas extra-tropics, the impact of ENSO warm episodes is such that warmer than normal Winters are expected in northwestern United States and southeastern Canada, due to a jet stream split, that brings warmer tropical air to the region, while flooding are likely to occur in the Gulf Coast States. Increased frequency of forest fires has been associated with the cold phases of ENSO due to low precipitation in many areas.

A world without ENSO would have a quite different climatology. Global Circulation Models which are incapable of properly simulating interannual time scale ocean variability in the tropical Pacific are being argued as not being well suited for longer (decadal to centennial) time scale simulation of climate change. These scientific facts added to the tremendous economic value of the climate information on these time scales for socio-economic planning make this topic a natural choice to be included among those of relevance in the scientific agenda of the Inter-American Institute for Global Change Research.

3. " Pending Questions" and Research Program

Due to the persistence of oceanic and atmospheric circulation anomalies associated with extremes in the Southern Oscillation, long-range predictions can be made for certain regions with high degree of confidence. Experimental dynamical and statistical prediction techniques, developed during the last decade, have been highly successful in alerting the scientific community as to the eventual development of both warm and cold episodes. However, further work is necessary in order to be able to apply these predictions to anticipate economic and social impacts for specific regions throughout the Americas. This is an important challenge for the Inter-American Institute for Global Change Research, as the demand from diverse sectors of the economy (agriculture, energy, dam levels, forestry, industry, fisheries, etc) for advance notice of climate variations increases.

Although the global effects of Pacific warm (ENSO) and cold episodes have been discussed in the scientific literature, further work is necessary to refine the patterns on the regional scale. This effort requires enhanced regional data archives and the use of atmospheric and oceanic general circulation models to simulate precipitation, temperature and oceanic-atmospheric circulation changes. Individual countries are encouraged to collaborate in the effort to enhance regional data archives, so that better regional forecasts can be made of the climatological, social and economic impacts related to extremes in Pacific Ocean temperature anomalies.

Paleoclimate research using ice cores from the Andes Altiplano should continue to be encouraged in order to better understand the frequency of occurrence and intensity of past events. In this context, the research efforts of CRICYT in Argentina might serve as an example.

The jet stream variations and atmospheric blocking influences on the Chilean Altiplano and southeastern South America during ENSO should be further explored in order to better link the phenomenon with the climate variations in these regions.

There is an urgent need to better understand the regional and local processes, such as the sea surface temperature of the tropical Atlantic in modulating the regional climate fluctuations.

Still there should be an effort to better define the climatology at the regional scales, using most of the past data collected in the region and yet not incorporated in the previous climatologies.

Teleconnections between the tropical and the extra-tropical atmosphere have been studied, but there are still many unanswered questions that need to be addressed.

More studies need to be undertaken to provide a better description of the relative influence of the Pacific (ENSO) and Atlantic oceans on the tropical South and Central Americas, that including the Amazon, the Nordeste Brazil and the Caribbean area.

Human dimensions

The seasonal to interannual (ENSO included) climate variability forecast ability that is being developed, provides an excellent example of how a global forecast can be trimmed to a regional forecast, with some detailed precipitation and temperature distribution, combined socio-economic studies to assess impacts. This is quite useful in advising policy makers in the decision process and during the implementation of action plans. The human dimension aspects of the problem is clearly important and can be properly incorporated in the whole policy making process. This is an indispensable ingredient for the development of most countries in the region.

As an example, one may cite the study in the Sevilleta area concerning El Niño effects on habitat of the Southwestern U.S., being carried by the University of New Mexico.

4. Linkages with Ongoing International Research Programs

As a research topic, the study of ENSO-related climate variations has been undertaken by the World Climate Research Program (WCRP), under the auspices of the World Meteorological Organization (WMO), the International Council of Scientific Unions (ICSU) and the Intergovernmental Oceanographic Commission (IOC). A WCRP program called TOGA (Tropical Oceans - Global Atmosphere) is of special relevance in this context. TOGA is a decade-long (185-84) established to further explore the predictability of the coupled ocean-atmosphere system and to explore the scientific findings that sea surface temperature fluctuations at the basin-scale of the tropical oceans do indeed impact the large scale atmospheric circulation.

The IGBP regional meeting for South America (March, 1990) included ENSO as a topic of special interest for the region. As such, a close collaboration is expected with IGBP, including IGBP/START.

At the regional level, the ERFEN (Regional Group for Study of ENSO) Project would benefit from a straight link with IAI,and vice-versa, on this topic.

The Inter-American Institute for Global Change Research is expected to complement the existing international programs by dedicating itself to regional aspects of the ENSO phenomenon, as well as other seasonal to interannual climate variations in the region.

5. Institutional Arrangements and Training Program

The IAI seeks to enhance research activities in the Americas in order to improve our predictive capability of climate variations, so that anticipation for and planning for impacts on food production and human safety can appropriately and timely be made . To achieve these goals, it will be necessary to facilitate the dialogue among scientists and decision makers in the region, provide means for data exchange and efficient and timely forecast products dissemination.

A substantial amount of past climate data need to be processed and made available to the scientific community. More data will be available as a result of the implementation of new near-real time climate monitoring programs. The efficient use of these data is a crucial element for the IAI and need to be addressed in the context of data network links, integration, archiving, and interaction among the participating research groups within the region.

Exchange of knowledge on modeling, interpretation and validation of model results and on climate monitoring is a crucial element for the enhancement of the scientific capability within the region. Criterious application of climate forecasts require high level of expertise. Training on the physical aspects of the problem, as well as on the socio and economic impacts of climate anomalies is a critical issue for the success of IAI in this research topic.

IAI should strengthen the research capabilities in the participating countries by promoting joint research and advance education and training and organizing workshops, courses and symposia.

There is a sizeable scientific capacity installed in the region. Most of them in the United States. Nevertheless, institutions such as the Instituto Nacional de Pesquisas Espaciais (INPE), Brazil; the Instituto Geofisico de Peru (IGP); the Universidade de Sao Paulo (USP), Brazil; the Universidad de Chile, just to mention some, have expertise on the topic and should be encouraged to collaborate with the other research groups in the U. S. such as Columbia University (L-DGO); the University of Maryland (COLA); the National Meteorological Center (NMC); the NASA/Goddard Space Flight Center (NASA/GSFC), National Center for Atmospheric Research (NCAR), National Oceanic and Atmospheric Administration (NOAA), that including the National Meteorological Center (NMC).

6. Resources Requirements

Adequate facility for climate modeling at the regional scale, interpretation of climate model results and display of large amount of data on near real time basis need to be provided, at least with workstations class of machines and appropriate graphical software. In this respect, IAI should take advantage of new developments in computer and telecommunication technologies, with relatively inexpensive mini-supercomputers and high speed chips for worstations becoming available in the market.

There is a pending problem for climate research and applications. That is the need for an improved observational network in most of the countries in South America. The huge and almost data void area of the Amazon should have a special consideration. Oceanic data for ENSO studies are being now provided in great part by the TOGA-TAO system in the Pacific (Hayes et al., 1991) and should be maintained during the period post-TOGA.

IAI should take advantage of information provided by existing institutions in the region, many with GCM capability, and seek close collaboration with them. This does not preclude the need for enhanced local capabilities within the IAI as an institution.

Acknowledgement

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Major ENSO 1982-83 Effects

LOCATION	PHENOMENON	VICTIMS	DAMAGE
United States:			
1. Mountain and Pacific states	Storms	45 dead	$ 1.1 billion
2. Gulf states	Flooding	50 dead	$ 1.1 billion
3. Hawaii	Hurricane	1 dead	$ 230 million
4. Northeastern U.S.	Storms	66 dead	
5. Cuba	Flooding	15 dead	$ 170 million
6. Mexico - Central America	Drought	-	$ 600 million
7. Ecuador - northern Peru	Flooding	600 dead	$ 650 million
8. Southern Peru - western Bolivia	Drought	-	$ 240 million
9. Southern Brazil, northern Argentina, eastern Paraguay	Flooding	170 dead 600,000 evacuated	$ 3 billion
10. Bolivia	Flooding	50 dead, 26,000 homeless	$ 300 million
11. Tahiti	Hurricane	1 dead	$ 50 million
12. Australia	Drought, fires	71 dead, 8,000 homeless	$ 2.5 billion
13. Indonesia	Drought	340 dead	$ 500 million
14. Philippines	Drought	-	$ 450 million
15. Southern China	Wet weather	600 dead	$ 600 million
16. Southern India, Sri Lanka	Drought	-	$150 million
17. Middle East, chiefly Lebanon	Cold, snow	65 dead	$ 50 million
18. Southern Africa	Drought	Disease, starvation	$ 1 billion
19. Iberian Peninsula, northern Africa	Drought	-	$ 200 million
20. Western Europe	Flooding	25 dead	$ 200 million

Source: National Oceanic and Atmospheric Administration

Table 1 - Worldwide effects of the 1982-83 ENSO, mainly due to widespread drought and flooding. The economical losses total more than U.S. $ 13 billion (published by *The New York Times*, 2 August 1983).

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SEA SURFACE TEMPERATURE ANOMALIES FOR DECEMBER 1991

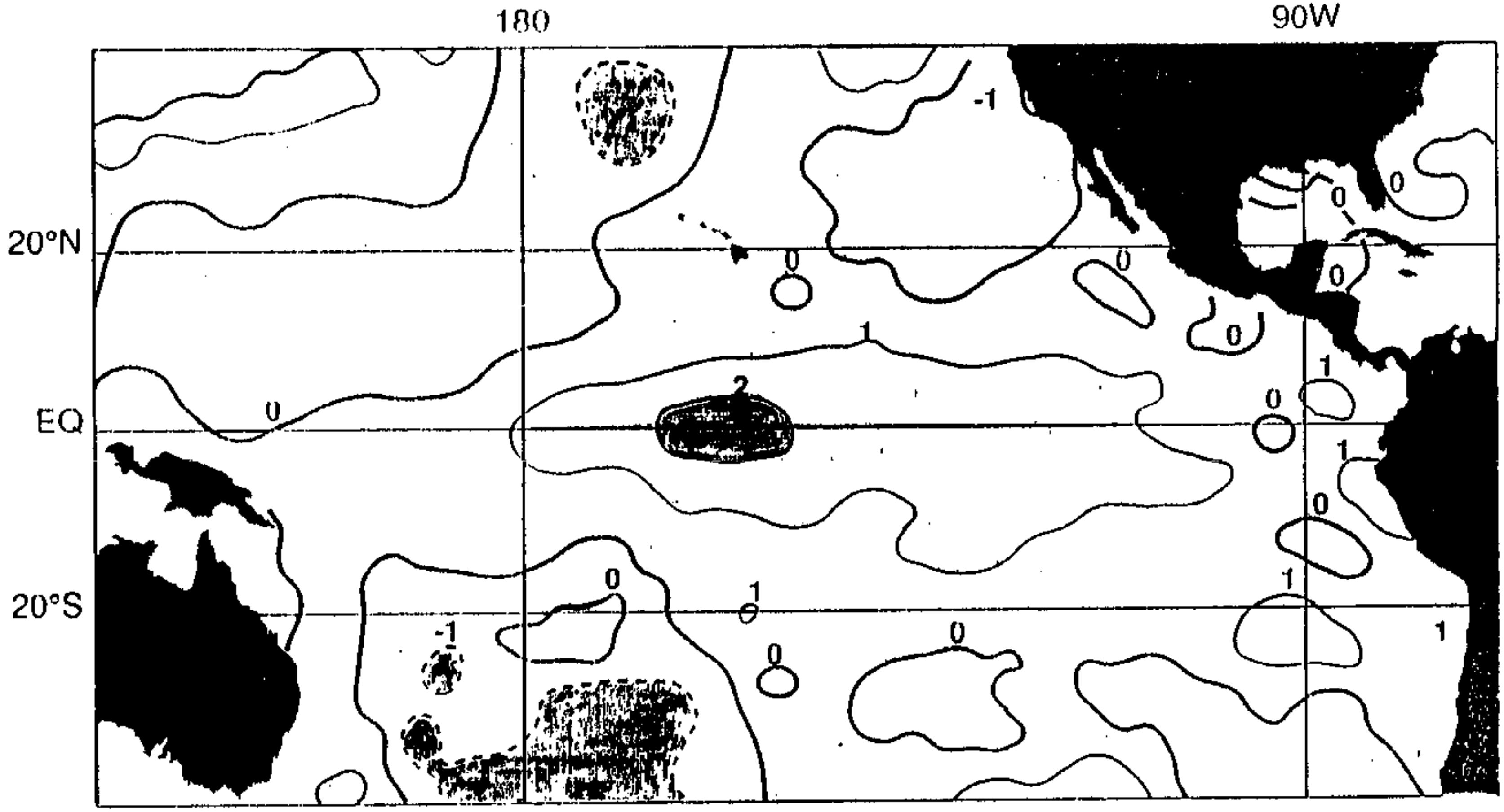

Fig. 1

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NORTHERN HEMISPHERE WINTER

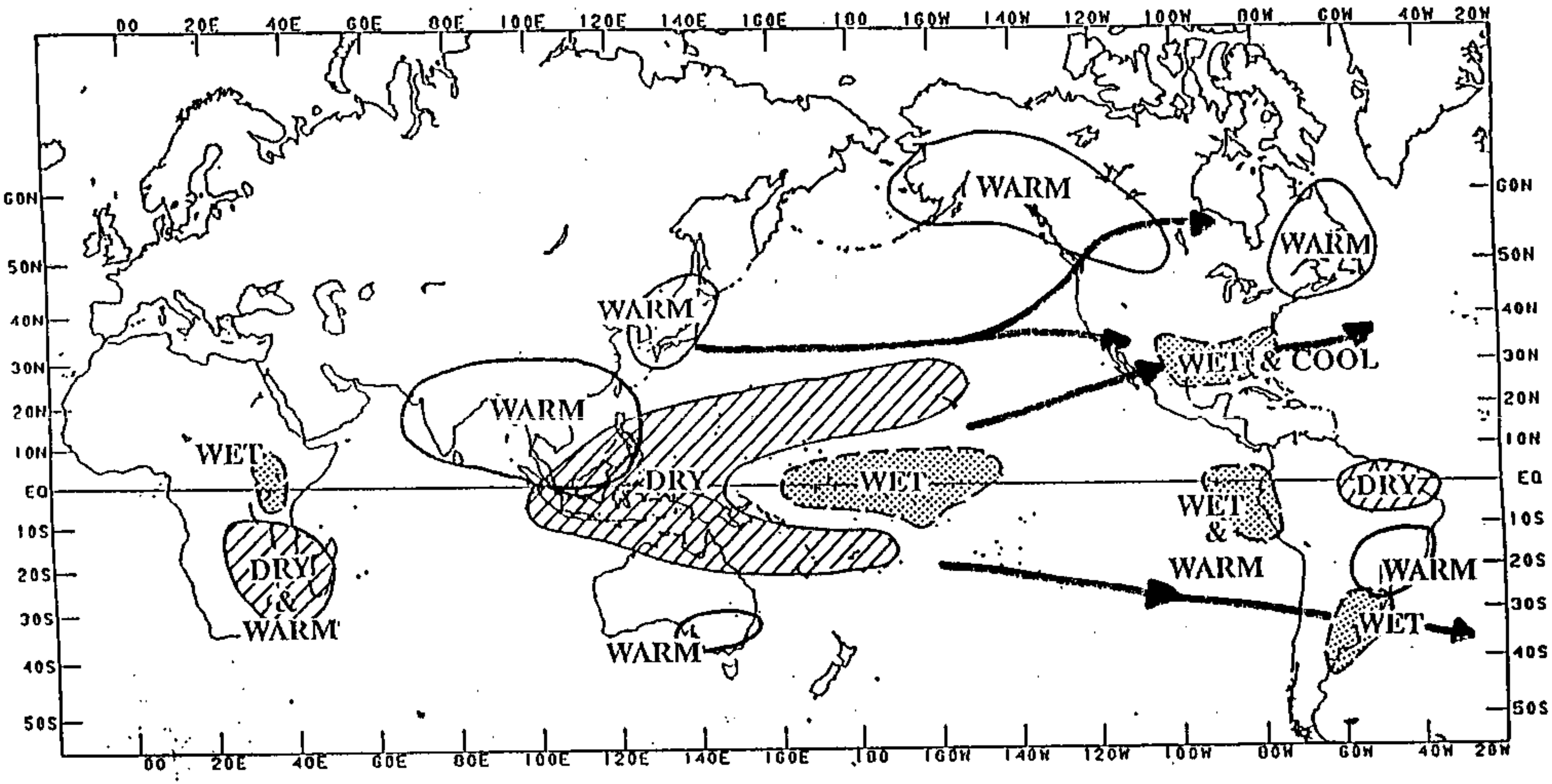

FiG. 2

Peru Gross Value of Agricultural Sector (Millions of Intis - 1979 Constant)

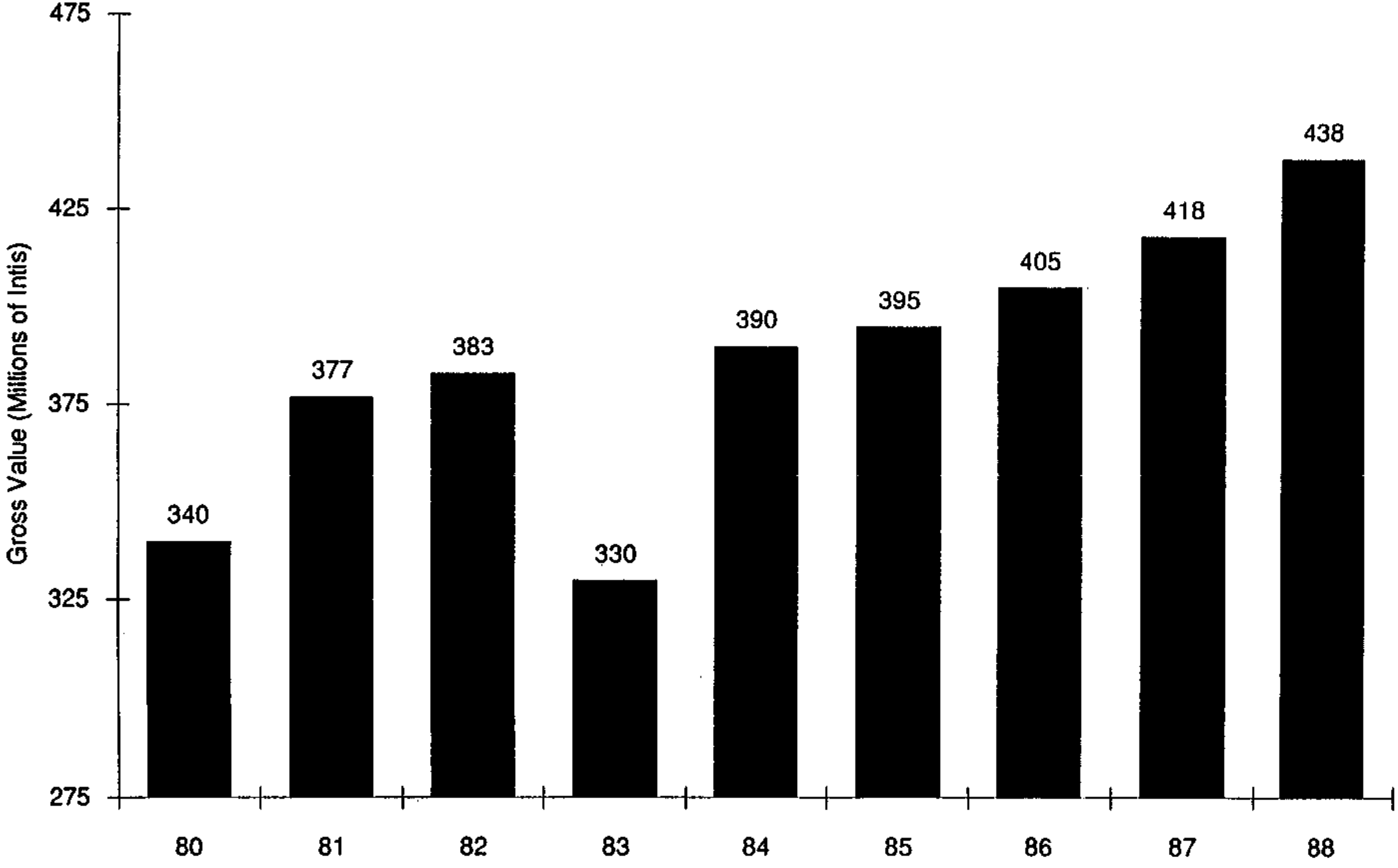

Fig. 3

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