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CLIMATE CRISIS

Michael Glantz
Richard Katz
Maria Krenz
Editors

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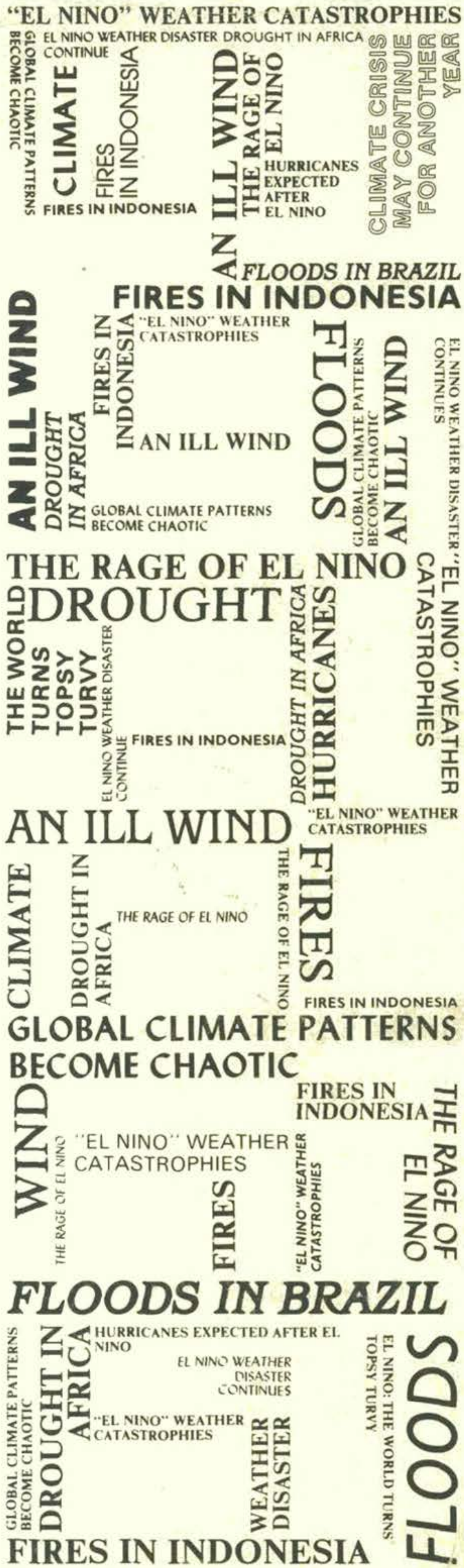

IMPACT

Climate Crisis

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CLIMATE CRISIS

The Societal Impacts Associated with the 1982-83 Worldwide Climate Anomalies

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Michael Glantz
Richard Katz
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Report based on the workshop on the *Economic and Societal Impacts Associated with the 1982-83 Worldwide Climate Anomalies,* 11-13 November 1985, Lugano, Switzerland, organized and financed by the United Nations Environment Programme and the Environmental and Societal Impacts Group of the National Center for Atmospheric Research.

1987

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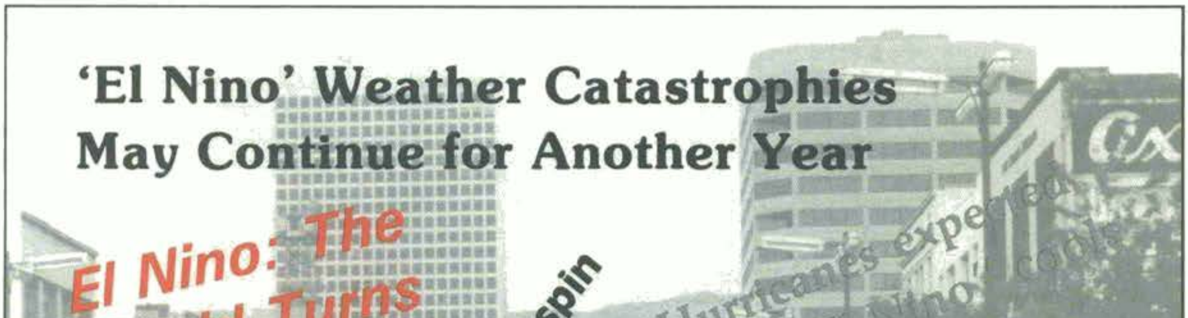

Springtime flooding in Salt Lake City, Utah (U.S.A.).
Photo credit: *Brian Heikes/NCAR*

PREFACE

The United Nations Environment Programme (UNEP) is collaborating with WMO and ICSU in the implementation of the World Climate Programme (WCP). In particular, UNEP has the responsibility to implement the World Climate Impact Studies Programme (WCIP), one of the elements within the WCP, through the Global Environment Monitoring System (GEMS). The Workshop which resulted in this publication was held as part of the activities of the WCIP.

At the invitation of UNEP, a group of scientists assembled in Lugano, Switzerland, during November 1985, to discuss the socio-economic impacts of the 1982-83 El Niño/Southern Oscillation (ENSO) event. The scientists came from several countries and represented a cross section of scientific disciplines. This volume is based on the outcome of their deliberations.

The interest shown in ENSO by scientists from different parts of the world and with different scientific backgrounds is a reflection of the growing importance that ENSO has assumed in the recent past. It is no longer of interest only to those engaged in atmospheric sciences research. This is because it has now been eatablished that ENSO events are associated with poor performance in some sectors of the economy, and resultant adverse social conditions. Secondly, such events and their impacts are on a global rather than a local scale. The 1982-83 ENSO event was, for example, associated with drought in Australia, Indonesia and Brazil; with poor fish catches in Chile and summer drought and heat waves in the USA. Clearly ENSO events have become serious environmental hazards with no respect to national boundaries, or those of scientific disciplines. The getting together by an interdisciplinary group of scientists representing many countries, in order to study this phenomenon, is most welcome.

I am aware that we still have a long way to go towards understanding fully the physical and dynamical factors leading to ENSO. Equally, we do not have the answers to the problem of mitigating its socio-economic impacts. However, I am confident that the Workshop in Lugano provided a sound contribution to our understanding of this complex phenomenon. In this connection, I extend my gratitude to all the scientists who participated in the Workshop and thereby contributed to its success. I am also grateful to Dr. Michael Glantz and his team in the Environmental and Societal Impacts Group at NCAR, who undertook all the organizational work to convene the Workshop.

Genady N. Golubev
Assistant Executive Director
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United Nations

INTRODUCTION

The Editors

In the past few years there have been many research papers as well as popular articles about El Niño events (now more broadly referred to as El Niño/Southern Oscillation or ENSO events) in the eastern equatorial Pacific Ocean. The 1982-83 El Niño has been labelled as the largest one in 100 years. Physical and social science research has recently focused on the possible relationships that might exist between El Niño events and climate anomalies worldwide. These relationships have been referred to as teleconnections by the scientific community and they hold promise for forecasting future climate anomalies some months in advance of their onset, once reliable ways to forecast El Niño events and the validity of those teleconnections can be established.

In an attempt to start the process of investigating the numerous proposed teleconnections and their potential societal impacts, the United Nations Environment Program (UNEP) and the Environmental and Societal Impacts Group (ESIG) at the National Center for Atmospheric Research (NCAR) sponsored a workshop on the *"Economic and Societal Impacts Associated with the 1982-83 Worldwide Climate Anomalies"*. The workshop was designed to bring together social and physical scientists from various parts of the world as well as from a variety of disciplines. This report is based on the papers presented at the UNEP-ESIG/NCAR meeting held in Lugano, Switzerland in November 11-14, 1985. The original papers have been revised in light of discussions at the workshop.

The climates of the countries studied at the workshop were suggested by one researcher or another to have been teleconnected to ENSO events. While many other possible teleconnections have been suggested, this particular set was chosen because research to date suggested that they were representative of various levels of strength of correlation to ENSO events. Thus, Australia, Chile, and Indonesia represent the "core" regions, whereas China, India, Brazil, and Southeast Africa represent those with somewhat weaker correlations, and the United States, Japan, Western Europe, the Soviet Union, and the West African Sahel appear (at least at this time) to have the weakest linkage to ENSO events.

These case studies briefly describe the climate situation that transpired during 1982-83. They then identify some of the societal and environmental impacts of the climate anomalies of the period. The case studies are clearly meant to be illustrative and not exhaustive. They provide a set of baseline studies against which future similar studies might be compared. Most likely, not all of these climate anomalies will prove to have been directly or indirectly related to the occurrence of ENSO events. In addition, the strength of those teleconnections that prove to be valid will have to be defined.

Chapter 1
THE EL NIÑO/SOUTHERN OSCILLATION PHENOMENON

Neville Nicholls

Bureau of Meteorology Research Centre (Australia)

Background

El Niño is the invasion from time to time of warm surface water from the western equatorial part of the Pacific Basin to the eastern equatorial region and along the coasts of Peru, Ecuador, and northern Chile. Before 1950, it was only of local interest to fishermen of those countries and especially to those involved in the mining of guano, a rich fertilizer produced by sea birds which inhabit the rocky islands along the Peruvian coast.

With the development of the Peruvian anchoveta (a variety of anchovy) fishing industry in the 1950s, interest shifted from El Niño's impacts on guano-producing birds to its impacts on the biological productivity of the waters that well upward along the Peruvian coast (referred to as coastal upwelling). By the late 1960s, Peru had become the world's number-one fishing nation (by weight of catches, not value), and this focus of interest remained until the devastating 1972-73 El Niño, during which the Peruvian anchoveta fishery collapsed.

When the anchoveta fishery failed to return to the high pre-El Niño levels of productivity by the mid-1970s, international concern about El Niño shifted once again, this time to its proposed connections to climate anomalies (deviations from the average climate) in other parts of the world occurring either before, during, or after an El Niño. Now, scientists seek to establish relationships (called teleconnections) between El Niño and, for example, specific droughts or floods that occur contemporaneously or subsequently elsewhere in the world. Figure 1.1 depicts many of the droughts that occurred in the 1982-83 period and that have been suggested as being related to El Niño.

In early 1986 El Niño once again captured headlines in newspapers and scientific magazines with reports of the probability of another El Niño event. An official scientific group involved in a major international oceanic and atmospheric experiment (TOGA, 1986) issued an El Niño Watch, which stated that

> *In light of the current trend in the sea surface temperature anomaly pattern and in view of the fact that four years have elapsed since the beginning of the last event, it seems prudent to call attention to these conditions in the form of an El Niño Watch covering the period February-April 1986. . . . It should be emphasized that this Watch does not imply a forecast that El Niño conditions will actually develop in the eastern Pacific.*

El Niño has apparently been given a place among widely acknowledged natural disasters, such as floods, severe storms, tidal surges, typhoons,

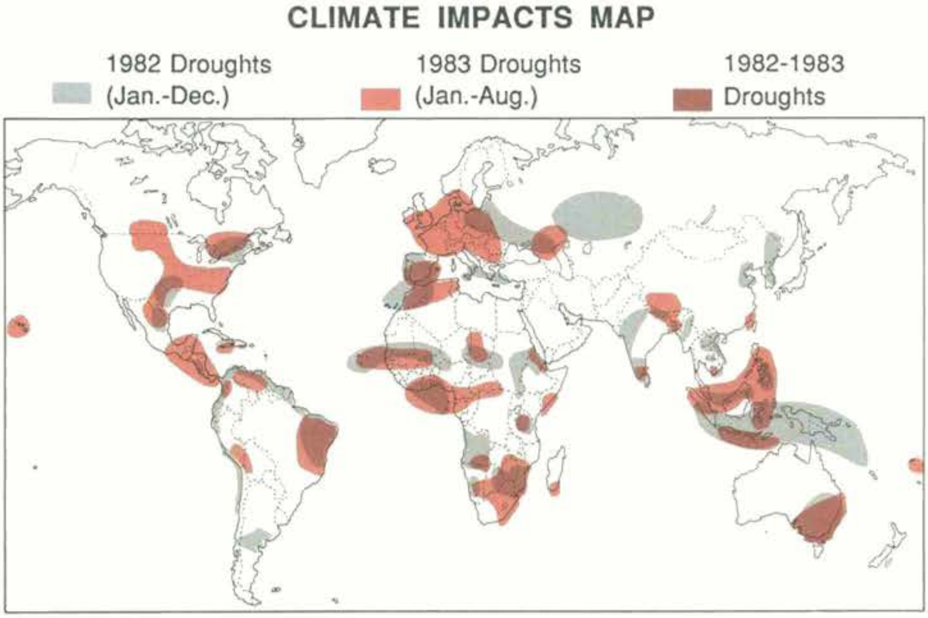


Fig. 1.1 The occurrence of drought, January, 1982 to August, 1983.

and earthquakes, that merit close scientific monitoring and investigation. Not only has awareness about it and its impacts on social and ecological systems been heightened among scientists, but also among the media, policy-making groups, and even the general public. This newfound awareness will grow as attention focuses on the impacts of this natural event on society and on the environment and as scientists continue to unravel its mysteries.

The Setting

There are five major coastal upwelling regions around the world, centered off the coasts of California, Peru, Namibia, Mauritania, and Somalia (Fig. 1.2). Peru's is biologically one of the most productive. Coastal upwelling regions are ideal breeding grounds for commercially important pelagic fish, such as sardines and anchovies, used either as food or as fish meal. Pelagic fish dwell near the surface of the ocean, have high rates of natural mortality, have a highly aggregated distribution, are shoaling forage fish, and are apparently extremely vulnerable to subtle as well as drastic variations in their atmospheric and marine environments. Shoaling pelagic fish are relatively easy to capture with efficient gear, and large quantities can be taken in a short period of time.

Along the Pacific coast of South America, and stretching westward along the equator, the sea-surface temperature (SST) is remarkably cool for an equatorial region. At 5°S, off the Peruvian coast near Paita, for example, the SST is usually only 17°C in August. On the other side of the Pacific, at the same latitude, the sea may be 10°C warmer. The cool eastern Pacific waters are caused by the currents flowing northward along the coast bringing cool water from the higher latitudes and by the welling to the surface of cool subsurface water (Fig. 1.3).

The prevailing southeast trade winds produce a surface current flowing toward the equator along the western South American coast. The earth's rotation adds an offshore component to the current's movement.

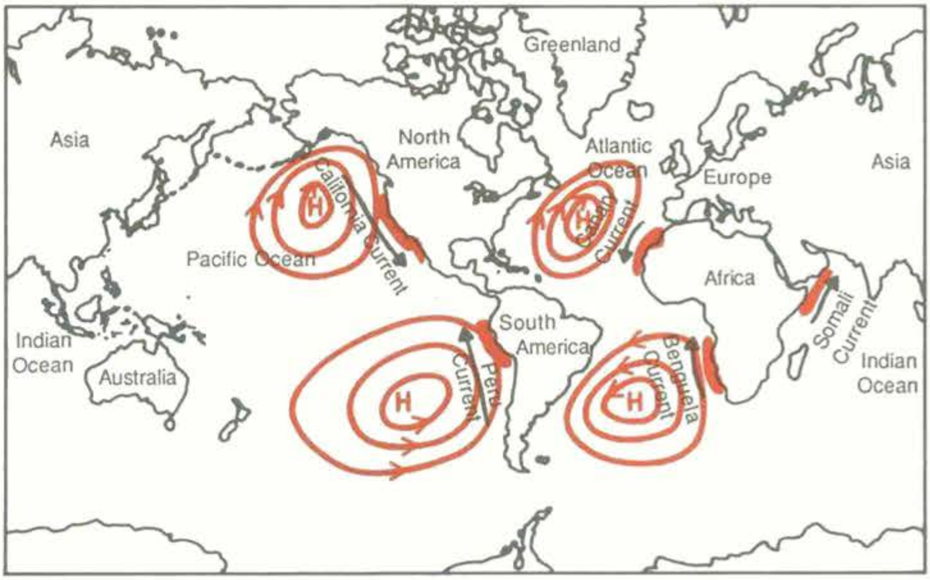
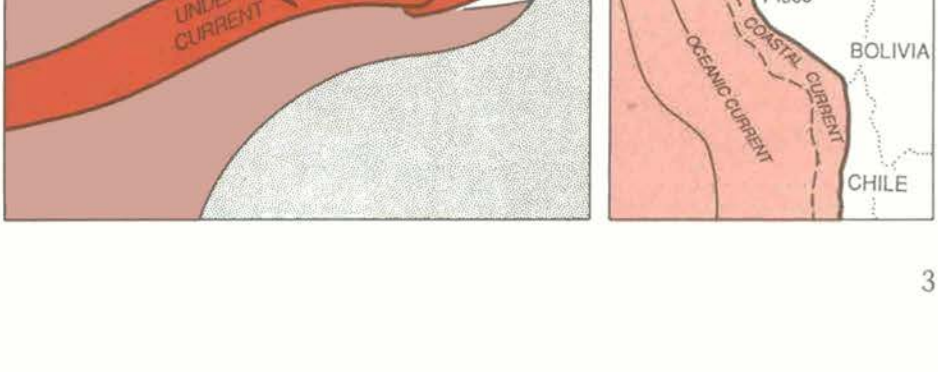


Fig. 1.2 Major coastal upwelling regions of the world and the sea-level atmospheric pressure systems that influence them.

Fig. 1.3 Peruvian current system. a) Two south-flowing elements of the Peru current are seen schematically in relation to the two north-flowing components in this figure. The countercurrent, a surface or near-surface stream of water, intrudes between the north-flowing cold coastal and oceanic currents. Normally the countercurrent does not extend much south of the equator, but when the wind that moves the north-flowing currents along falters or changes direction, its warm water pushes far to the south with disastrous biological consequences. Deep below all three currents is the second, far larger south-flowing component, the undercurrent. (From C.P. Idyll, "The anchovy crisis," copyright 1973 by Scientific American, *Inc., all rights reserved.) (b) Two north-flowing elements of the Peru current are the deep, narrow coastal current that hugs the land from Valparaiso in Chile to north of Chimbote in Peru and the deeper and wider oceanic current that reaches the latitude of the Gulf of Guayaquil. (From C.P. Idyll, "The anchovy crisis," copyright 1973 by* Scientific American, *Inc., all rights reserved.)*



The waters leaving the coast are replaced by colder water from below, a process referred to as upwelling. Similarly, the winds from the east which usually overlay the equatorial Pacific induce upwelling by pushing the waters westward and, again due to the earth's rotation, poleward. These upward motions bring the thermocline, a layer of rapid temperature decrease which separates the warm mixed surface layer from the colder stratified water below, nearer to the surface (Fig. 1.4).

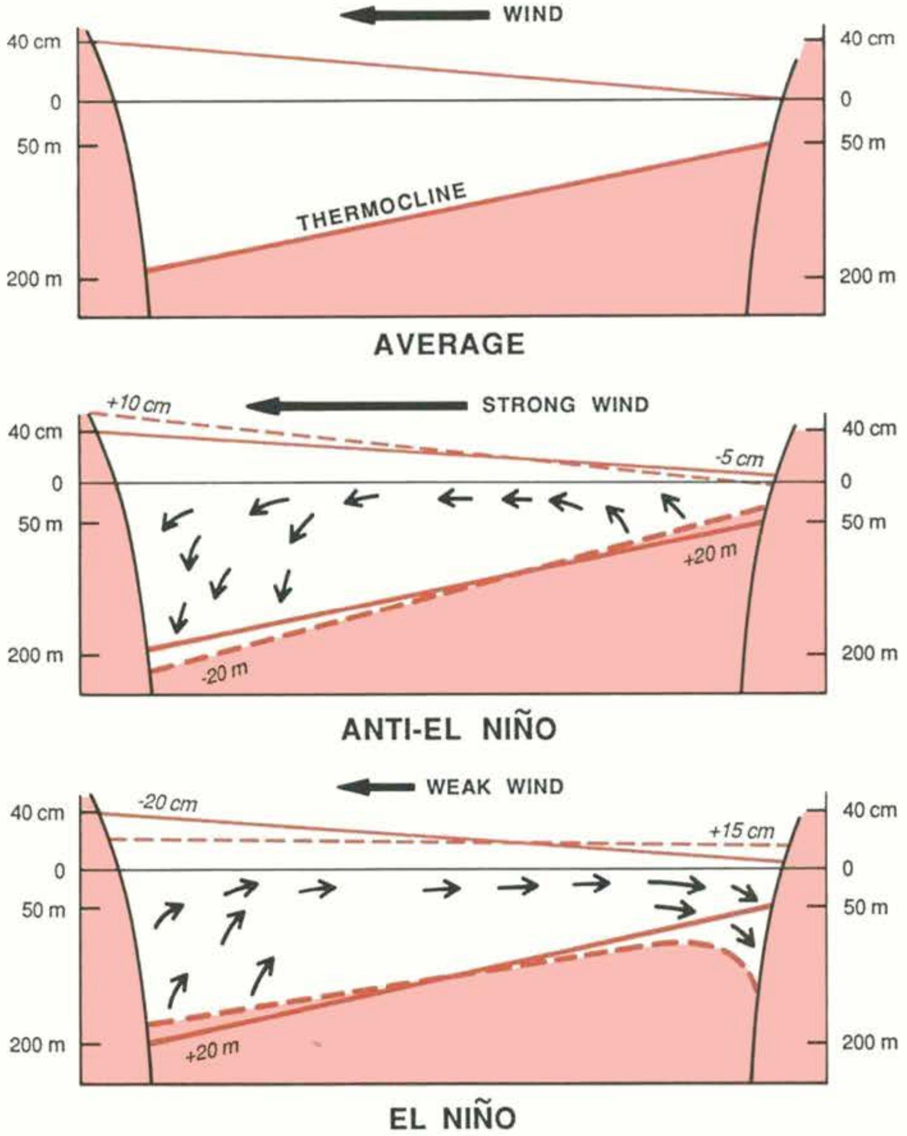
The major inorganic nutrient reservoir of the ocean is the water below the thermocline. Any process, such as upwelling, which brings the thermocline, and the nutrient-rich water below the thermocline, nearer to the surface where there is enough light for photosynthesis to take place, will increase biological productivity (Fig. 1.5).

Occasionally, warm surface water invades the eastern equatorial Pacific and disrupts the upwelling along the west coast of South America. Folklore suggests that the warming of these particular waters was named El Niño, after the Christ Child, because of a warming that takes place for a few months each year beginning in December. Although it originally referred to the local seasonal condition along Peru's northwestern coast, usage of the term "El Niño" now more frequently refers to the occasional anomalous warmings of the central and eastern equatorial Pacific.

According to existing historical records, no two El Niño events or, for that matter, their societal impacts, have been exactly alike (see climate impacts maps in Appendix). Some El Niño events prove to be local phenomena mainly affecting countries along the northwestern coast of South America.

During other major El Niño events, SSTs are exceptionally high, several degrees above normal, not only along the Peru-Ecuador coast but over much of the equatorial eastern and central Pacific. The sea level rises, and the thermocline is located much deeper than normal. Upwelling in this situation simply recycles the warmer waters near the surface, above the thermocline, instead of bringing nutrient-laden, cold subthermocline water to the surface. This reduces the nutrient content of the near-surface water and leads to widespread mortality of plankton, fish, and guano birds, disrupting the economy of Ecuador, Peru, and Chile. Heavy rain also falls along the coasts of these countries. Some warmings of exceptional magnitude, such as that of 1982–83, are especially severe and disruptive.

In the late 1960s it became apparent that the year-to-year variations in SSTs (and consequently El Niño events) were closely linked to the Southern Oscillation, an out-of-phase relationship between atmospheric pressure over the southeastern Pacific and over the Indian Ocean. The Southern Oscillation was first noticed late last century and then, in a series of papers in the 1920s and 1930s, documented by (and later named after) Sir Gilbert Walker.



Note: Vertical scale above 0 is in centimeters, scale below 0 is in meters.

Fig. 1.4 The response of the thermal structure of the equatorial Pacific to changing winds. TOP: Under normal easterly trade wind conditions sea level rises to the west and the thermocline deepens. CENTER: This situation is amplified during strong trade winds. BOTTOM: When the winds relax, water sloshes east, which leads to a rise in sea level and a deepening of the thermocline along South America. In the western Pacific, sea level drops and the thermocline rises. (Adapted from K. Wyrtki, 1982.)

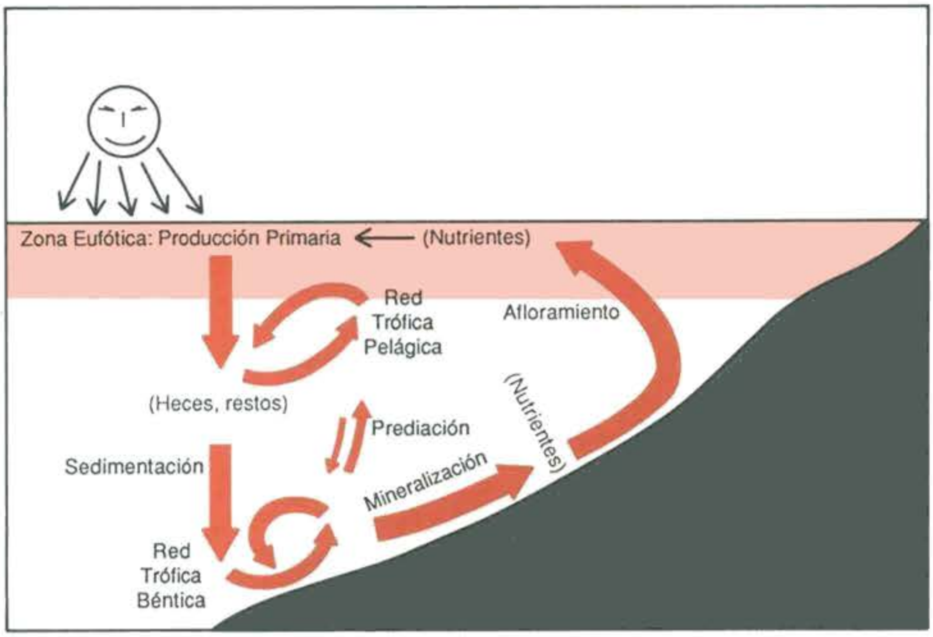
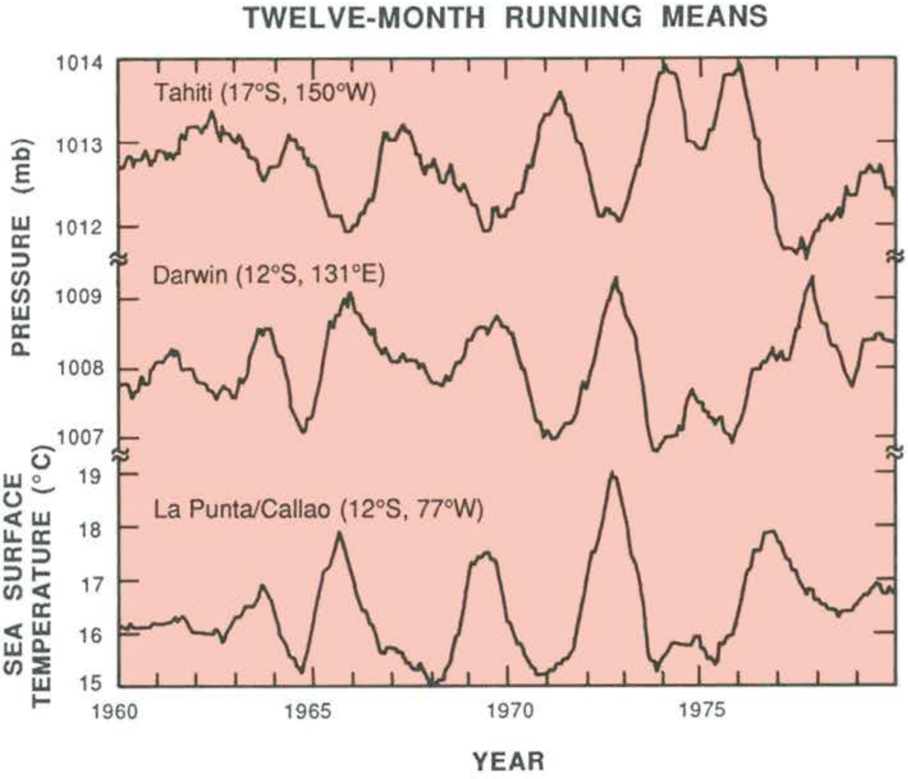


Fig. 1.5 Esquema de afloramiento, mostrando la estrecha conexion entre los subsistemas bentico y pelagico. (Schematic of upwelling showing the tight connection between the benthic and pelagic subsystems.) (Adapted from El Niño: Su Impacto en la Fauna Marina, *IMPARE, Peru, 1985)*

Fig. 1.6 Smoothed curves, with the annual cycle removed, of atmospheric pressure at Tahiti and Darwin, and the sea-surface temperature on the tropical Pacific coast of South America (La Punta/Callao). When pressure is lower than normal at Tahiti, pressure at Darwin and South American sea-surface temperature are both higher than normal.



Walker and Bliss (1932) described the Southern Oscillation as follows:

> *When pressure is high in the Pacific Ocean it tends to be low in the Indian Ocean from Africa to Australia; these conditions are associated with low temperatures in both these areas, and rainfall varies in the opposite direction to pressure.*

Figure 1.6 shows the relationship between SST on the equatorial Pacific South American coast, and atmospheric pressure at Tahiti, representing the southeastern Pacific, and at Darwin (Australia), representing the Indian Ocean and Australian region. In years such as 1972, when a major El Niño occurred, pressure at Darwin was abnormally high, while at Tahiti it was unusually low. The difference in standardized pressure anomalies, Tahiti minus Darwin, is frequently used an an index of the state of the Southern Oscillation (i.e., the Southern Oscillation Index or SOI) (Fig. 1.7).

Anomalous SST warmings (i.e., El Niño events) occur on the average about twice every 10 years although the interval between two events is irregular. The warm eastern Pacific waters and higher-than-normal Darwin pressure last for about 12 months, commencing around the start of one calendar year and collapsing just into the next year. The years before and after an El Niño episode tend to be cool SST years in the eastern equatorial Pacific. Figure 1.8 shows the SST anomaly (i.e., deviation from the normal) for the eight most significant warm episodes to have occurred between 1950 and 1983.

The Life Cycle of an ENSO

In most events, the abnormally warm waters of El Niño first appear off the coast of Ecuador and Peru in February or March. The development of ENSO can be divided into four phases: a precursory phase, an onset phase, a phase when the anomalous conditions grow and mature, and a phase during which anomalous conditions decay. The following brief description of the ENSO life cycle is

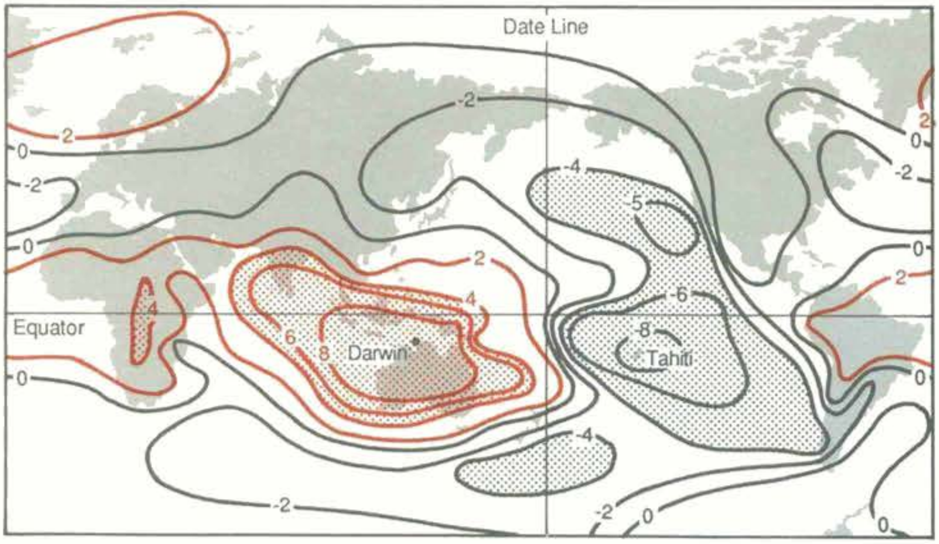
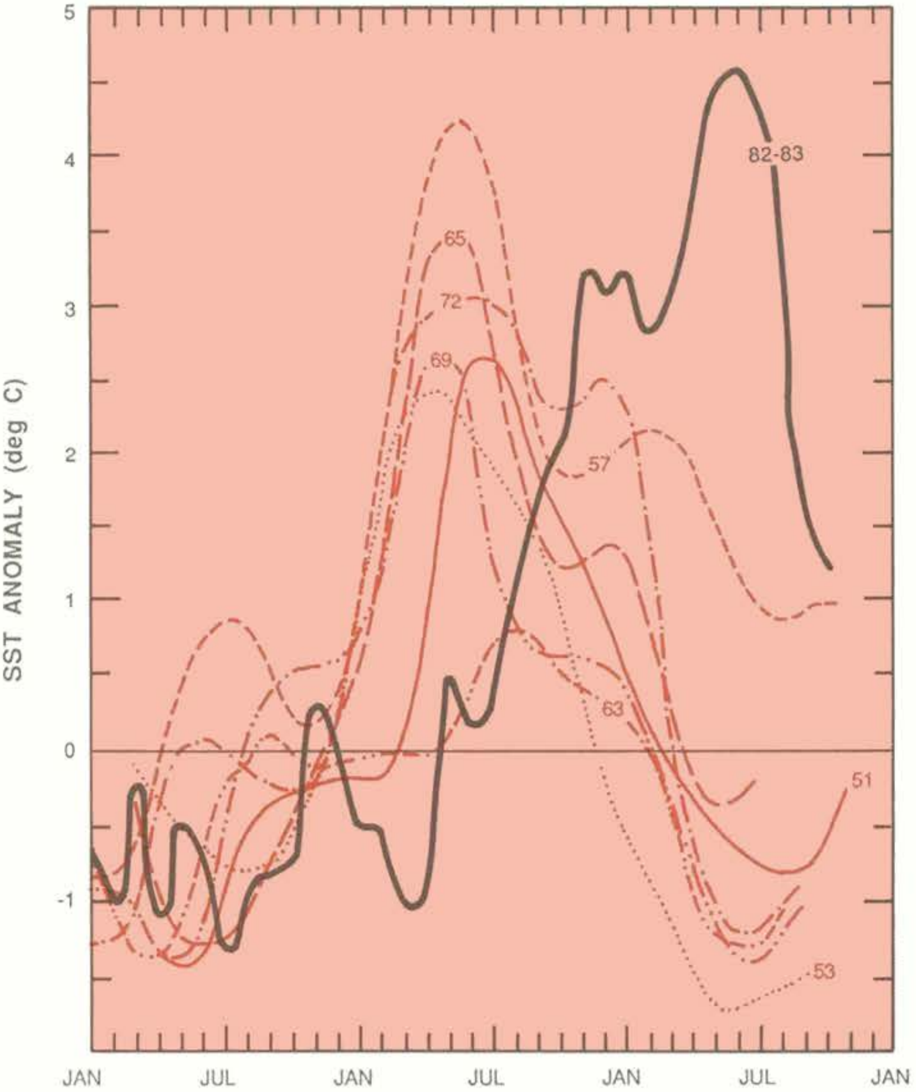


Fig. 1.7 The correlation of annual mean sea-level pressures with the pressure at Darwin, Australia, illustrates the Southern Oscillation's seesaw and demonstrates its global reach. Contour lines in color indicate positive correlation coefficients (in tenths); those in black indicate negative or no correlation. Areas in which positive correlation with Darwin is greater than 0.4 are stippled in color; areas in which negative correlation is less than − 0.4 are stippled in black. Tahiti and Darwin are at opposite ends of the seesaw, and so the difference in pressure between them is used to measure the Southern Oscillation. (After Rasmusson, 1984.)

Fig. 1.8 SST anomaly time series for the eight most significant warm episodes between 1950 and 1983. (adapted from Rasmusson and Carpenter, 1982.)



taken from Rasmusson and Carpenter (1982), Cane (1983), and Rasmusson and Wallace (1983).

The typical development in space and time of SST anomalies in the tropical Pacific during an ENSO event is illustrated in Fig. 1.9. Each El Niño event differs somewhat from this "typical" development. For instance, in the 1982-83 El Niño, warming of the SSTs along the South American coast began several months later than usual. Thus, the "typical" El Niño should be regarded as a heuristic device, rather than as an exact description of every event.

Precursors

There are stronger-than-usual surface easterly winds in the western equatorial Pacific in the months before a strong El Niño event. In fact, the entire east-west atmospheric circulation is usually stronger than normal prior to an ENSO. Associated with this are lower-than-average pressures over the Indonesian region and above-average pressures in the southeastern Pacific. The strong easterlies move water from the eastern Pacific to the west. Consequently, sea level is unusually high in the west and low in the east. The SST is slightly warmer than average in the west and colder to the east of 160°E.

Onset

Around December the warm SST anomalies disappear from the western equatorial Pacific, and the surface wind anomalies switch dramatically from easterly to westerly between Indonesia and the International Date Line. Warm SST anomalies appear in the central Pacific, and precipitation starts to increase in this usually low-rainfall area. SSTs along the northwestern part of the South American coast are about normal but rising.

Growth

Above-average SSTs off the South American coast appear in February or March, building in magnitude up to June. At the same time sea level rises, and the thermocline deepens. Warmer-than-usual temperatures now occupy the entire equatorial Pacific east of 160°E. The anomalous westerly winds have moved east to be centered on the date line. Precipitation is enhanced over much of the equatorial Pacific and is lower than normal over Indonesia. The Walker Circulation (see Fig. 1.10) weakens dramatically.

The anomalies continue to grow as the end of the calendar year approaches. Most of the anomalies, except the South American coastal SSTs, reach their peak around the end of the calendar year. By this time there is a huge area of anomalous westerly winds and warm SSTs over much of the equatorial Pacific, and Indonesia is now very dry in contrast to very heavy rainfall in the central and eastern Pacific. Pressure is much higher than average at Darwin and much lower than average at Tahiti, the opposite of anti-El Niño periods, or periods when SSTs are much colder than average.

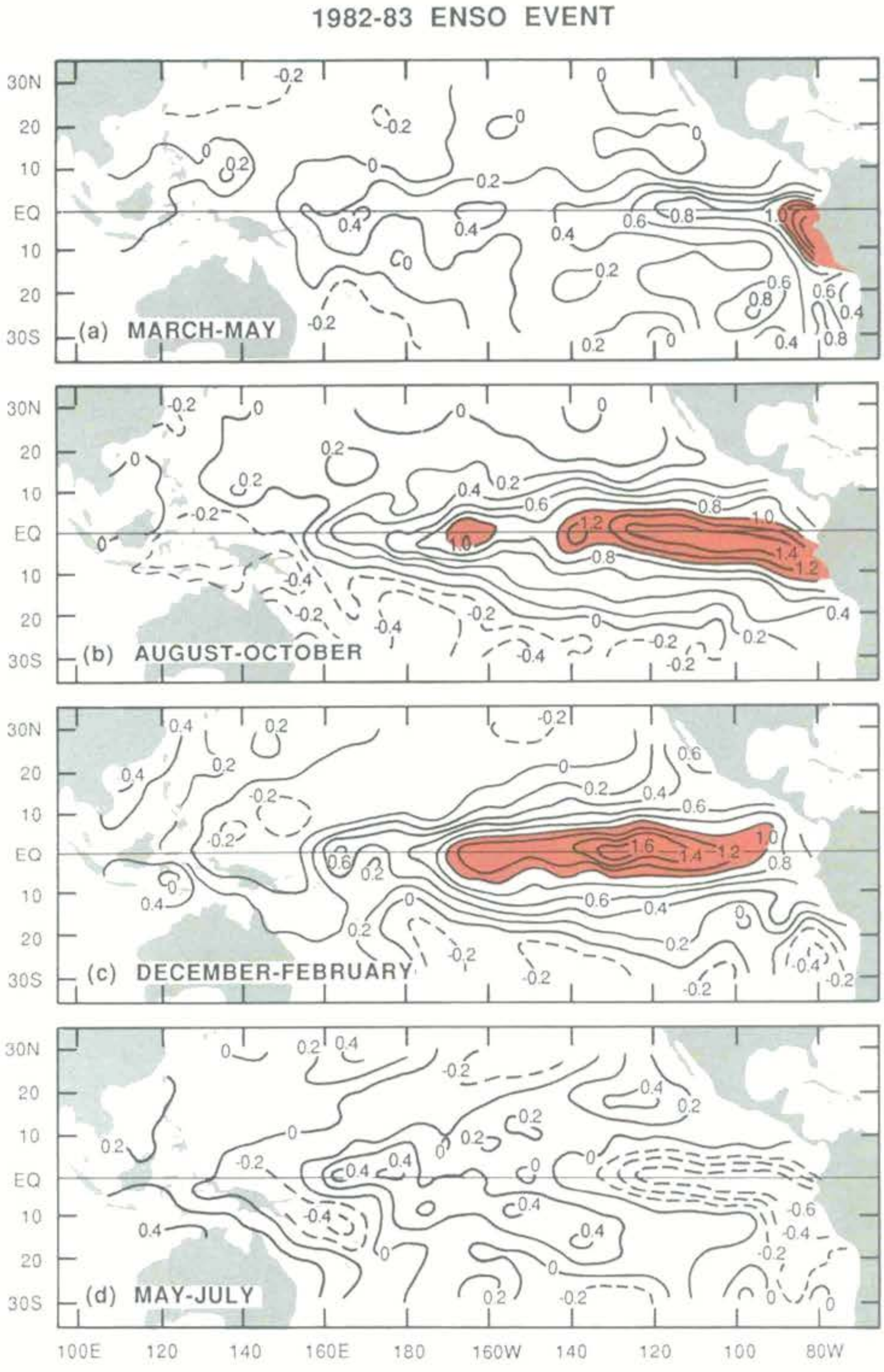


Fig. 1.9 SST anomalies during a typical ENSO event for (a) March, April, and May after onset, (b) the following August, September, and October, (c) the following December, January, and February, and (d) May, June and July, more than a year after the onset. (From Philander, 1983.)

Decay

West of the date line the westerly wind anomalies start to weaken from December and SSTs increase. There is a second warming at the South American coast peaking early in the new year, followed by a rapid decrease to colder-than-average SSTs. The thermocline returns closer to the surface. The colder waters spread westward until, about 18 months after the onset, normal conditions are re-established over the entire Pacific Ocean. Darwin and Tahiti pressures and precipitation patterns return to normal.

ENSO and the Scientific Community

The ENSO phenomenon is the result of interaction between the Pacific tropical ocean, the atmosphere, and the annual cycle of the seasons. The specific form of this interaction is not yet completely understood, and numerical models of a coupled ocean-atmosphere system need to be developed to study the complete phenomenon. Much has been learned, however, about the two sides of this interaction: the effects tropical SST anomalies have on the atmosphere, and the effects of atmospheric anomalies on tropical SSTs. Much of this understanding has been gained in the past decade through the use of numerical models, however limited these models may be.

The oceanic anomalies associated with El Niño have been explained as a response to changes in the surface wind stress over the equatorial Pacific. Westerly wind anomalies excite motions that deepen the thermocline in the east, reduce upwelling, and induce eastward movement of warm water from the western to the central and eastern Pacific. These responses to wind forcing all contribute to the rises in sea level and temperature characteristic of El Niño in the eastern equatorial Pacific. The most important wind changes featured in this process are those of the western and central Pacific, rather than those of the east.

Numerical models of the atmosphere, when driven by inputs of SSTs observed in El Niño events, have also been successful in reproducing atmospheric behavior observed in these events. When the normal SST field is replaced by, for example, that observed in the 1982–83 ENSO, ENSO-related changes in atmospheric pressure in the southeastern Pacific and in the vicinity of Indonesia, precipitation changes along the equatorial Pacific, and alterations to the wind field of the tropics have all been simulated in such models. The models correctly simulate the observed eastward shift of the region of heavy rainfall from the extreme western Pacific toward the central Pacific.

Thus it appears that the SST anomalies of ENSO arise principally from the surface wind anomalies, which in turn are caused mainly by SST anomalies. The feedback interaction between the SSTs and the surface winds produces, through some as-yet-unknown mechanism, the specific life cycle of ENSO with its tendency to commence early in the new year and to survive for about a year. It is clear that the annual cycle plays an important role in governing the behavior of the feedback processes leading to ENSO events and their life cycle.

ENSO and Climate Teleconnections

The relationship between climate fluctuations in the equatorial Pacific and ENSO is extremely strong and has been well documented over many years. During ENSO events rainfall is above average in parts of Peru and Ecuador and in the central and eastern equatorial Pacific (Rasmusson and Carpenter, 1982), with drought over New Guinea (Nicholls, 1974) and Indonesia (Quinn et al., 1978). The beginning of the wet season over tropical Australia is usually delayed during ENSO events (Nicholls, 1984a). Cloudiness over all the waters around Southeast Asia is significantly reduced during ENSO (Wright et al., 1985) (Fig. 1.10).

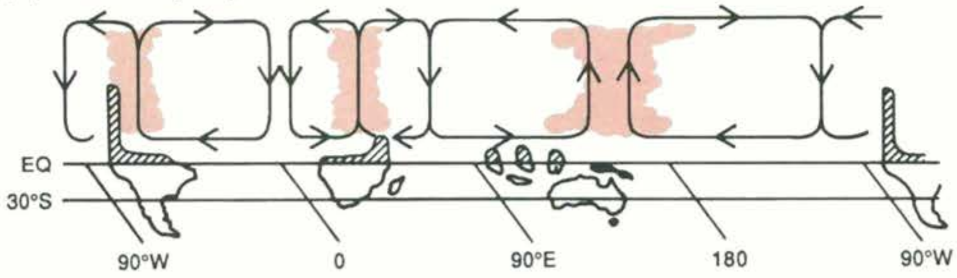
While the existence of relationships between ENSO and climate in the core region of the phenomenon, that is, in the equatorial Pacific, should not be surprising, the quite strong simultaneous and lagging correlations between ENSO and climate anomalies in some areas outside the equatorial Pacific are intriguing. As noted earlier, relationships between climate and/or oceanic anomalies in widely separated areas have been called teleconnections. Suggested teleconnections associated with ENSO are numerous.

In years when there is an ENSO event, many climate anomalies occur, but, in fact, anomalies occur somewhere on the earth every year. However, some anomalies tend to recur with most ENSO events. Anomalies during the 1982–83 ENSO event can be compared with the anomalies for two previous major ENSO events, 1957–58 and 1972–73. For example, east Australia had a drought in each event, as did southeast Africa and northeast Brazil. Other areas had different anomalies during the three events. Only those climate anomalies which tend to recur during most, if not all, ENSO events are labeled "ENSO-climate teleconnections." Charts of climate anomalies during all three recent ENSO events are shown in the Appendix.

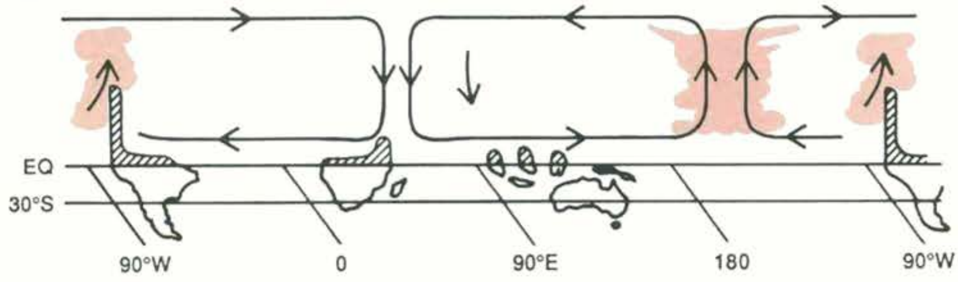
The strength of teleconnections between ENSO events and climate outside the equatorial Pacific varies from area to area and season to season,

Fig. 1.10 Schematic of the Walker Circulation based on computations of upper and lower tropospheric divergent winds by Y. Tourre (Tourre and Rasmusson, 1984). (a) Winter (DJF) mean east-west overturning Walker circulation. (b) ENSO Winter 1982–83 pattern. Note the shift of the Pacific ascending branch to the east of the date line and suppressed convection (subsidence) over the rest of the tropics. (From Global Climate Systems Review 1982-1984, *WMO.)*

(a) WINTER (DJF) MEAN



(b) WINTER (DJF) 1982 - 83



with the tropics and subtropics generally showing the strongest relationships. The timing of the occurrence of some teleconnections is illustrated in Fig. 1.11 (Rasmusson, 1985).

Tropical cyclone behavior

One example of a suggested ENSO-climate teleconnection is the pattern of tropical cyclone occurrence. The global distribution of tropical cyclone occurrence is apparently markedly affected by ENSO. For example, based on observations of hurricanes throughout this century, Gray (1984) has suggested that "tropical eastern and central Pacific SST warming events associated with the El Niño reduce hurricane activity in the western Atlantic during the season following the onset of the El Niño event." He also noted that "SST and hurricane activity usually return to normal in the second summer following such an event." Figure 1.12 depicts the observed number of hurricane days in El Niño and non–El Niño years.

Fig. 1.11 An occurrence of the ENSO phenomenon involves large-scale changes in climate such as drought in normally productive agricultural regions and heavy rains in normally dry regions. Areas where cold and dry climatic anomalies typically appear are enclosed in colored lines; areas of wet and warm anomalies are enclosed in black lines. Duration of the anomalies is expressed in months; roman type indicates a month during the year of the major warming of the waters along the coasts of Ecuador and Peru; italics indicate a month during the following year. (After Rasmusson, 1984.)

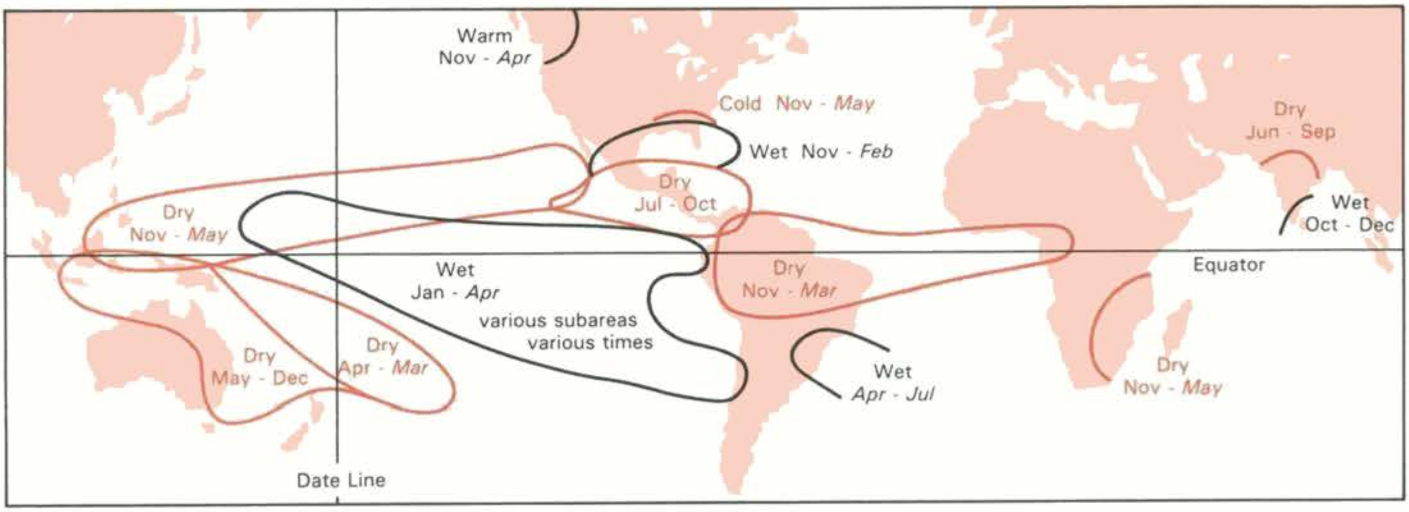
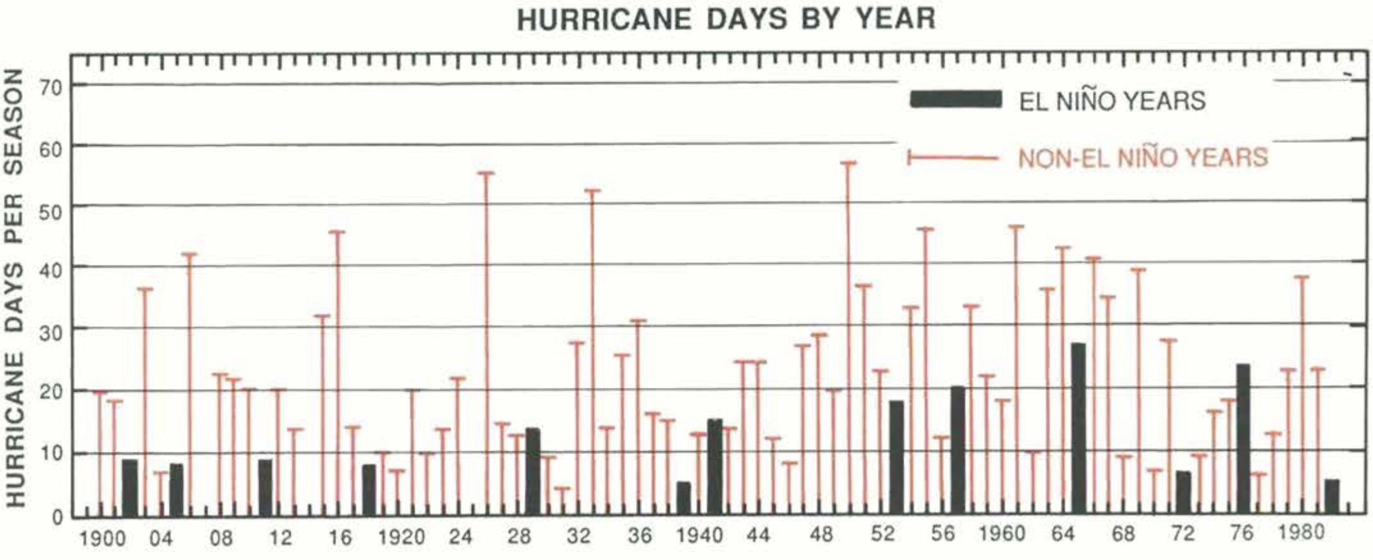


Fig. 1.12 Number of hurricane days in El Niño and non–El Niño years from 1900 to 1982. (From Gray, 1984.)



Using teleconnections for prediction

The existence of so many rather strong teleconnections between ENSO and climate anomalies and the relatively long-term memory characteristic of oceanic variables suggest that the long-range prediction of some of these anomalies may be feasible. The most obvious possibility would be to find an accurate method for predicting, say, six months in advance, the occurrence of an ENSO event. Then the likely occurrence of the climate anomalies generally associated with ENSO, e.g., a dry Indian summer monsoon and drought over eastern Australia, could also be predicted. Several empirical studies have identified what appear to be precursors of ENSO events, but their use in prediction has yet to be satisfactorily demonstrated. Some work is under way examining early warning signatures of ENSO, as distinct from methods for predicting ENSO (e.g., Shukla and Paolino, 1983; Nicholls, 1983, 1985).

Meanwhile, the fairly well-defined life cycle of ENSO provides other methods for the long-range prediction of some climate anomalies connected to it. As discussed earlier, the onset of ENSO usually occurs early in the calendar year. By about August it is generally possible to determine whether an event is under way. Climate anomalies that are related to ENSO but occur later in the ENSO life cycle (e.g., during the Southern Hemisphere summer, December-February) may, therefore, be predictable simply through monitoring ENSO.

One example is tropical cyclone activity in the Australian region. Tropical cyclones occur here during the Southern Hemisphere summer and the number occurring each year appears to be related to ENSO (Nicholls, 1984b). Chan (1985) found a similar tendency for tropical cyclone activity in the North Pacific to be displaced eastward during ENSO. If, say by October, monitoring of an index of ENSO (such as Darwin pressure or SST along the western South American coast) indicates that an ENSO event is under way, then a prediction of less-than-average tropical cyclone activity could be made well in advance of the tropical cyclone season.

Other climate anomalies which occur during the Southern Hemisphere spring and summer, and are related to ENSO, may also be predictable. Australian spring rainfall, the onset of the wet season in Indonesia and northern Australia, and rainfall in southeastern Africa are just a few forecasts that appear to be possible because of their relationships to ENSO and their relatively late occurrence in the ENSO life cycle.

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Chapter 2

THE 1982-83 DROUGHT IN INDONESIA: ASSESSMENT AND MONITORING

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Introduction

The weather of the Indonesian archipelago, which is closely related to the Southern Oscillation (Berlage, 1957), has not received much attention internationally, even though the 1982–83 period was characterized by the *Economist* as "the worst drought in a decade" (*Economist,* 1983). This section concentrates on two aspects of Indonesian drought: an assessment of the consequences of the 1982–83 weather anomalies for Indonesian rice production, and an examination of the connection between the 1983 drought and the forest fires that took a heavy toll on the tropical rain forest of East Kalimantan and North Borneo.

The 1982–83 ENSO and Drought in Indonesia

Preceding the onset of El Niño, the eastward displacement of the Walker circulation cell (see Fig. 1.10), generally located over the Indonesian-Australasian convergence region, causes the development of a high-pressure zone over eastern Indonesia. The weakening of the vertical convergence itself leads to the suppression of rainfall-producing mechanisms over the region (Philander, 1983). While such precursors over the western Pacific region appear as necessary conditions for El Niño/Southern Oscillation (ENSO) events, they are not sufficient to trigger anomalies over the central and eastern Pacific Basin. Every low rainfall over the Indonesian archipelago is thus not necessarily associated with an ENSO (Philander, 1983). Nevertheless, an association is strongly suggested by Berlage (1957), who, using time series of sea-salt production data in Madura (a parameter intimately linked to weather conditions), calculated that 93% of the drought periods occurred during years when El Niño events were under way and that 78% of El Niño events can be associated with east monsoon (April-October) droughts (Quinn et al., 1978).

The rainfall data for selected stations in rice-producing areas of Java and Sulawesi illustrate the overall situation in 1982 - early 1983; the record shows (Table 2.1) no delay in the onset of the dry season but very little to no rainfall starting in May 1982. (In this context an agricultural drought can be considered to occur when precipitation is less than 100 millimeters per month; the requirement for wetland rice is 200 mm/month; Oldeman, 1975; Wilhite and Glantz, 1985). The end of the dry season – normally October – was clearly delayed by at least a month for Java and Bali.

In a more detailed analysis, Soerjadi (1984) calculated that the end of the 1982 dry season occurred almost 20 days earlier than normal and that the start of the wet season was 30 to 40 days late for central and eastern Indonesia. He reported that 1982 rainfall was below normal throughout most of the archipelago, especially over southern Sumatra, Java, Nusa Tenggara Timur, Nusa Tenggara Barat, Sulawesi, and the Moluccas. Ten-day interval rainfall data indicate that at the delayed end of the 1982 dry season (this could be considered as the beginning of the El Niño proper), rainfall was very erratic and that several regions experienced a "false start" of the western monsoon.

Two salient characteristics of the 1982–83 weather were important for plant production: reduced rainfall in the 1982 dry season with no significant rainfall for four to five months in the main rice-producing regions of the country, and the delayed/erratic onset of the rainy season. The first characteristic may be considered a precursor of ENSO, while the latter belongs to the series of phenomena directly associated with it.

The 1982–83 Drought and Rice Production

The impact of weather on agricultural production is often perceived in varying ways, and assessments very much depend upon the indicators adopted for the evaluation. Rice production in Indonesia has consistently increased since the early 1970s. As a result of a series of measures aimed at improving production factors such as irrigation, new seed varieties, fertilizers and pesticides, credit availability, and marketing, Indonesia has progressed from being the largest importer of rice at the end of the 1970s to being self-sufficient in this basic commodity. The impact of the 1982-83 drought must be examined in this perspective.

Global production statistics for lowland rice (greater than 94% of total production) show the development that took place during the last decade or so (Fig. 2.1). From 1968 to 1979, the progression averaged 3.3% a year; between 1979 and 1981, the growth was 10.7% annually. In 1982 this annual increase fell to 2.5%, the smallest increase since 1977; in 1983, the increase was 4.8%. Clearly, the drought occurred at a time when, for various reasons (intensification of inputs and favorable weather in the recent past being the main ones), rice production in Indonesia was in its most productive phase ever. A continuation of this trend would have placed the 1982 production at 34.3 million metric tons instead of the 31.7 million metric tons actually realized. For the first time since 1974, the per capita index of food production declined in 1982 (1981: 136, 1982: 131, 1983: 134 on base 100 in 1969-71, USDA, 1984). Yet, despite this brief setback, production did not decrease from its 1981 level and was still much higher than one could have expected on the basis of the 1968-79 trend (see Fig. 2.1). Good weather and improved technical inputs were responsible for the dramatic increase of 1979-81; the 1982 and 1983 production data show that even under adverse weather conditions, the contribution of technology remained positive; irrigation in this instance may have effectively provided drought insurance.

These aggregate data do not, however, provide the best perspective on the impact of weather on rice production in Indonesia in 1982-83. First of all, since the drought covered the May 1982 to May 1983 period, adding dry-season (May to October) and wet-season (November to April) crop production in annual aggregates obscures the real impact of drought on the relevant season. This is especially true in this case since the wet 1982 and dry 1983 seasons appear to have been "normal." Annual data, therefore, are not very good estimators of the impact of ENSO. Second, the persisting Indonesia-Australasian high-pressure system associated with

Table 2.1: Rainfall at Selected Stations in Rice Producing Areas of Indonesia (in millimeters)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
WEST JAVA												
Jatiwangi												
30 yr. average	(461)	(405)	(264)	(264)	(159)	(83)	(59)	(30)	(43)	(109)	(259)	(417)
1982	538	612	245	310	90	20	2	1	0	55	40	379
1983	360											
CENTRAL JAVA												
Tegal												
30 yr. average	(369)	(307)	(243)	(129)	(117)	(84)	(62)	(39)	(46)	(52)	(120)	(253)
1982	403	346	274	236	12	55	2	6	0	21	14	62
1983	472											
EAST JAVA												
Madiun												
30 yr. average	(273)	(271)	(264)	(232)	(156)	(78)	(43)	(25)	(27)	(79)	(191)	(243)
1982	118	183	330	259	0	0	3	0	0	0	NA	196
1983	284											
BALI												
Denpasar												
30 yr. average	(334)	(276)	(221)	(88)	(75)	(70)	(55)	(43)	(42)	(106)	(168)	(298)
1982	334	267	145	53	2	1	0	3	0	1	79	35
1983	146											
SOUTH SULAWESI												
Ujung Pandang												
30 yr. average	(714)	(515)	(423)	(154)	(95)	(65)	(32)	(14)	(11)	(45)	(183)	(581)
1982	648	482	434	109	77	6	0	0	0	0	30	323
1983	348											

Source: USDA, 1983

├─┤ Denotes Dry Season

ENSO has been shown to exert its influence in the eastern-southern part of the archipelago more than in the western and northern parts (Soerjadi, 1984). Weather variability within a region is therefore an important factor to take into account in a country that spans more than 5,000 kilometers from west to east. Third, some cultivation systems are more sensitive to meteorological drought than others (i.e., irrigation alleviates water shortages, with more or less efficiency). Finally, rainfall and solar radiation affect the two production components – harvested area and yield – in different ways; these must be identified in order to detail the impact of weather upon production. Some of these factors are now discussed with reference to the 1982–83 drought.

Provincial rice production data can be divided into three categories: provinces where production increased between 1981 and 1982, those where it decreased less than 10% between 1981 and 1982, and those where it decreased more than 10% in that period. Not surprisingly, considering the annual aggregation of data referred to earlier, only three provinces showed a decrease in wetland rice production in 1982 (see Fig. 2.2). When the growth rate is plotted, a different picture emerges. The provinces that suffered most from reduced growth are the main rice-producing provinces of Java and Bali, as seen in Fig. 2.3. In absolute terms, the 3% growth of production in East Java represents a gain of only 173,000 metric tons between 1981 and 1982, as compared to 800,000 tons between 1980 and 1981. In central Java the 1982 production remained essentially unchanged. One must remember that even if the provincial production data allow an assessment of the spatial aspects of the drought, they are still inadequate to represent the realities of the prolonged drought as experienced in the traditional agricultural systems of some regions. Information on local food shortages, lack of drinking water, cholera outbreaks, loss of cattle, and so forth, all common features of drought, is often episodic and can be collected only through an exhaustive review of local reports or newspapers.

Fig. 2.1 Rice production in Indonesia, 1969–83. Solid line, standardized production; dashed line, continuation of 1969–79 trend; dotted line, continuation of 1979–81 trend.

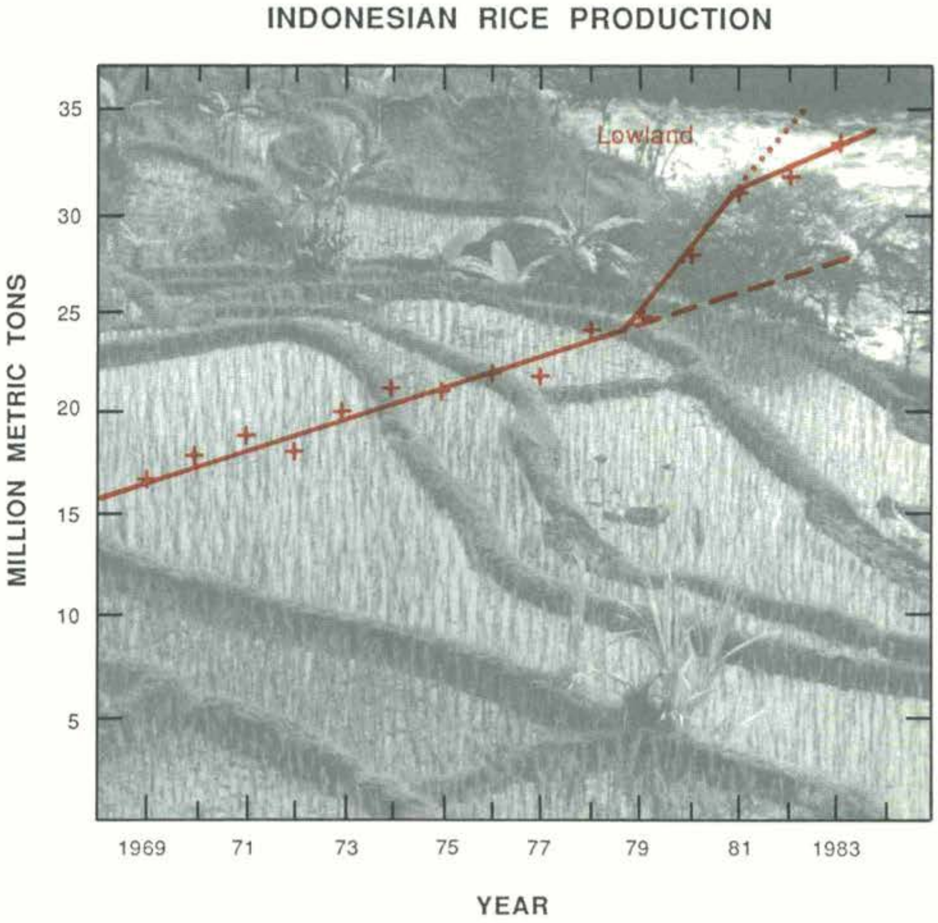
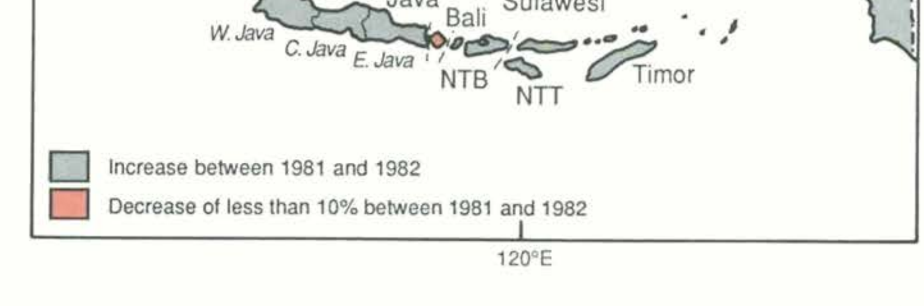


Fig. 2.2 Changes in rice production between 1981 and 1982 for the provinces of Indonesia.



The breakdown of the annual production data into seasonal figures gives some additional information on the mechanics of the drought in the intensive rice cultivation system of Indonesia. (In the present case, such information is only available for the so-called intensification program, which covers the paddy area where government programs have been organized, i.e., more than 75% of the total lowland rice production.) The wet- and dry-season rice crops are usually affected differently (Fig. 2.4). In the main producing areas of Java, the 1982 dry-season crop was planted in April-May, more or less on schedule, but started to suffer from water shortage as the season progressed. Depending upon the availability of water in storage or upon the magnitude of the river's base flow, this period of stress can occur at different periods and last for different lengths of time. Losses in planted areas are common in the dry season (Malingreau, 1980), and the 1982 data show a reduction of the harvested area of more than 10% for East, Central, and West Java, as compared to previous dry seasons. Because of the late arrival of the monsoon at the end of 1982, delays in planting occurred for the wet-season rice which was in the ground by the end of December instead of the normal early November (about a month of sufficient rainfall is necessary for field preparation). The compression of the 1983 wet-season harvest (April) put extensive pressure on the overall harvest, milling, and storage system (USDA, unpublished reports, 1983). Crop losses that resulted from water shortages at critical development stages may also have been important in the provinces affected by the erratic western monsoon at the end of 1982 (see Fig. 2.5).

In addition, weather conditions at the end of 1982 led many farmers to divert their land from paddy to corn production (USDA, unpublished reports, 1983), as corn is a crop that requires less water. This explains the reduction in rice production in East Java for the 1983 wet season (Fig. 2.4) and the striking 56% increase in corn production for that province in 1983. The 1982-83 sugar cane production also increased (2%); this increase could be explained by the fact that the cane usually occupies well-irrigated areas and performs especially well in conditions of high solar radiation (which tend to occur in dry years).

The impact of the 1982-83 drought on rice production in Indonesia can be summarized as follows:

- The overall effect was not a

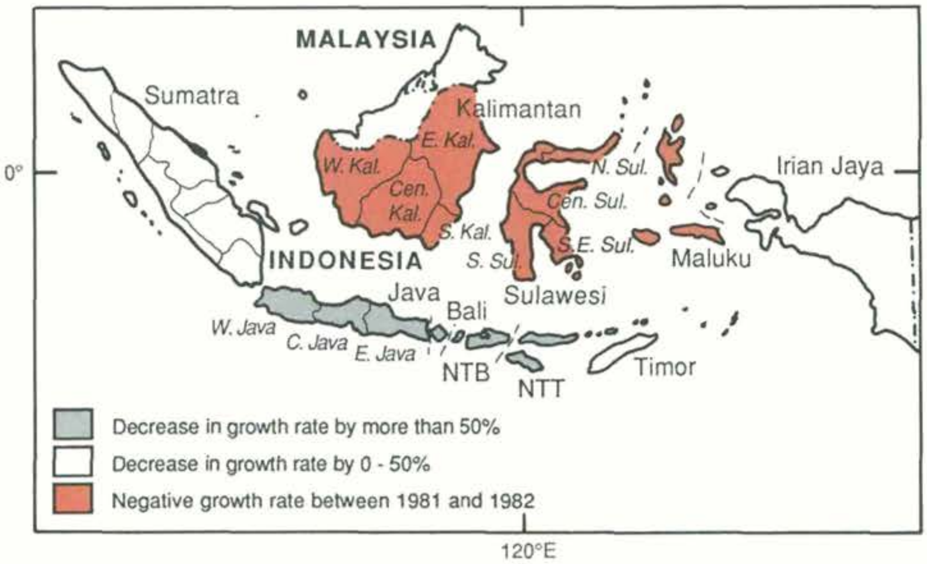
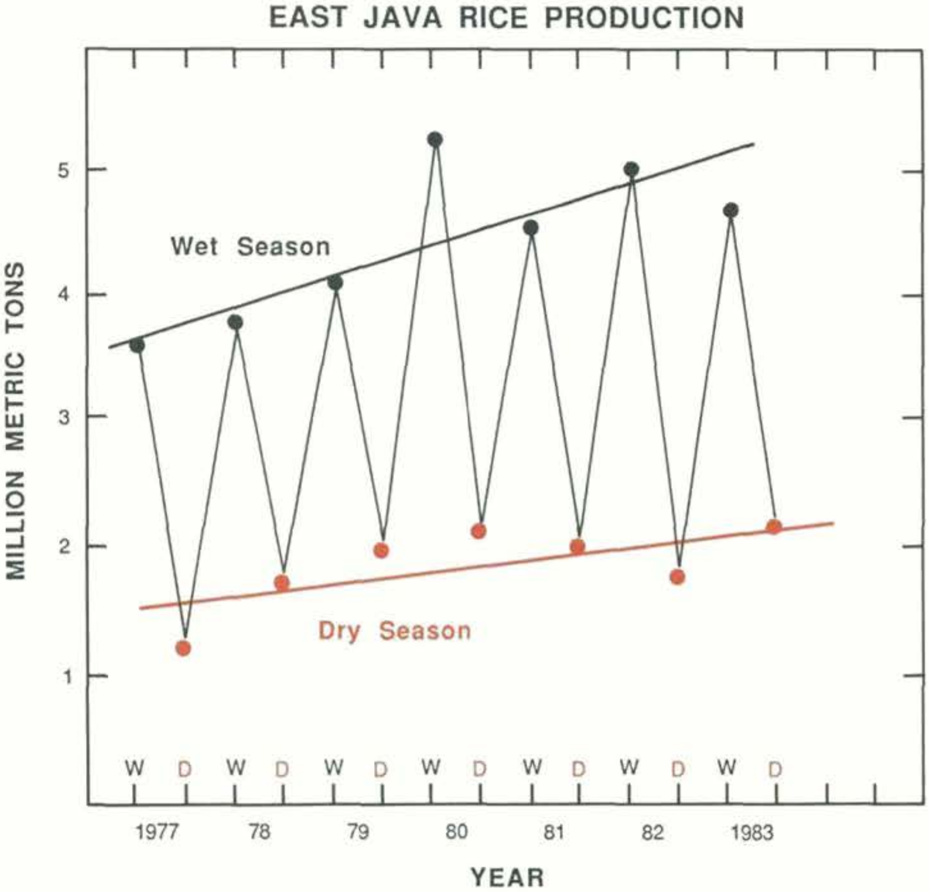


Fig. 2.3 Rice production for Indonesian islands. Changes in growth rate from 1981 to 1982 as compared to 1980 to 1981 rate.

Fig. 2.4 Wet-season and dry-season rice production in East Java.



decrease in production but a drastic reduction in the growth rate (which remained positive).

- The drought effects were concentrated in the eastern part of the archipelago.
- The drought affected the dry-season crop of 1982 and delayed the planting of the 1982-83 wet-season crop.
- Production of secondary crops that were much affected in 1982 rebounded in 1983. Crop substitution mitigated the impact of the drought.
- At the national level, the main consequence of the drought was that it postponed the realization of self-sufficiency objectives until 1984, and the 1982-83 production represents a major setback in this respect.
- Despite the intensity of the drought, the rice production system of Indonesia appears to have shown good resilience inasmuch as no province returned to the pre-1980 production levels and, by 1984, the situation appeared to have returned to normal. Current views that intensive agriculture systems are increasingly susceptible to climatic variations may have to be revised in light of these observations.

Drought and the Forest Fires of Kalimantan

The most dramatic and disastrous effects of the 1982-83 drought in Indonesia were felt in the tropical forest of East Kalimantan. While receiving more than 2,500 mm of rainfall as an annual average, this area, with parts of Sabah (Malaysia), is one of the driest of the island of Borneo. The drought in this region started with an unusually low rainfall during the drier months of June to October 1982 and persisted until May 1983. Diagrams for two East Kalimantan stations (Fig. 2.6) illustrate this pattern of low rainfall in 1982, some recovery in the November-to-January period, and then almost no rainfall in February, March, and April 1983 (rainfall data are from TAD, 1984, and Leighton and Wirawan, 1985).

In a thorough analysis of the rainfall record for East Kalimantan, Leighton and Wirawan (1984) showed that "in 44 years of records (1940-83), ten drought years have occurred of which nine are matched by one of the ten ENSO that have occurred during this period." In an attempt to rate the severity of the 1982-83 drought, Leighton and Wirawan also found that the cumulative rainfall for various periods between June 1982 and May 1983 was generally lower than the mean of corresponding periods representing the previous years on record. Without drawing definitive conclusions, they estimate that a drought as bad as the 1982-83

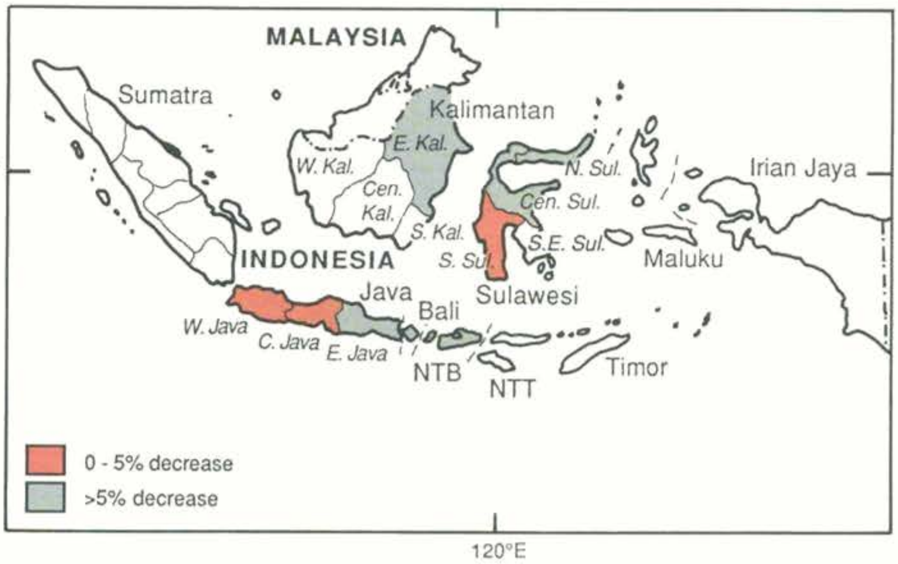
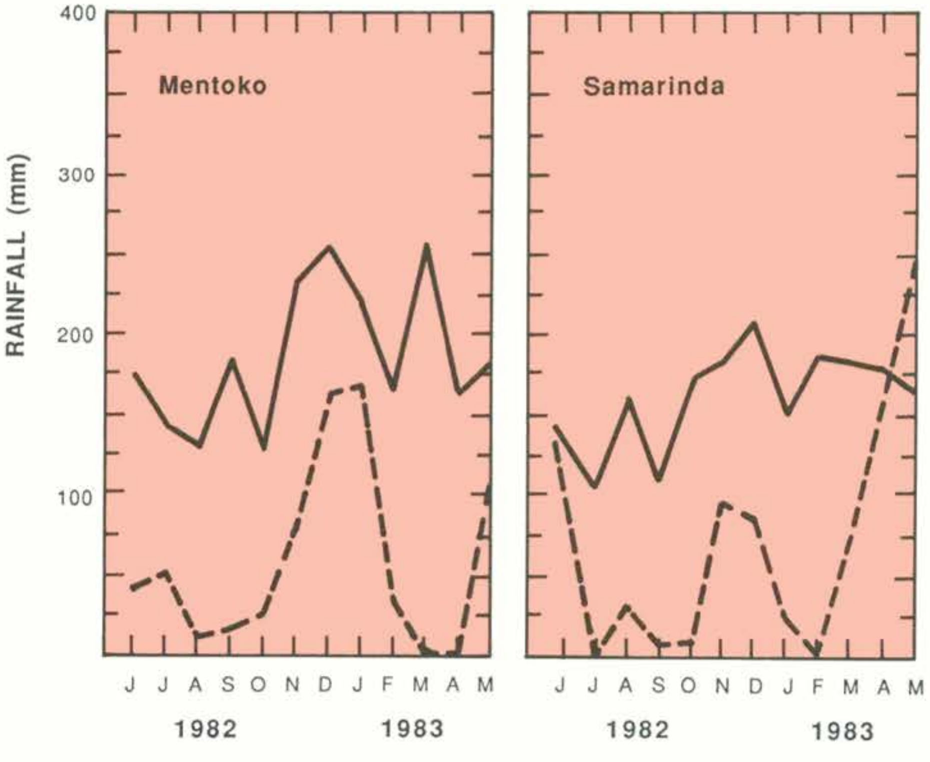


Fig. 2.5 Decrease in provincial rice production for the 1982-83 wet season (intensification program only).

Fig. 2.6 Mean monthly rainfall (solid line) and monthly rainfall from June 1982 to May 1983 for two localities in East Kalimantan (Leighton and Wirawan, 1985).

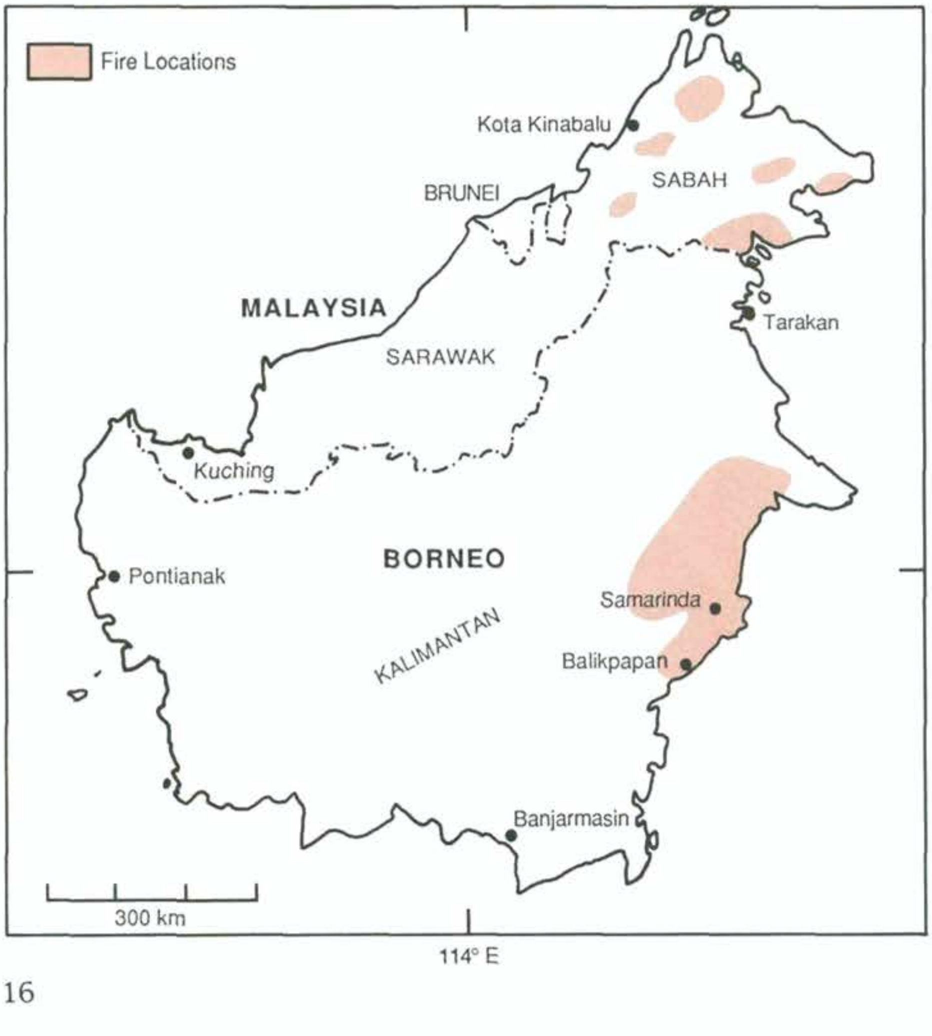


one "perhaps occurs on the order of once every hundred to several hundred years."

The drought in East Kalimantan was so pronounced in 1982 and early 1983 that it led to serious damages to the tropical evergreen forest, which was hitherto believed to be protected from climatic events. Drought and fire have damaged an estimated 3.5 million hectares in East Kalimantan alone (Lennertz and Panzer, 1984; Leighton and Wirawan, 1984; Malingreau et al., 1985); recent information indicates that close to one million hectares of tropical vegetation could have been damaged in the Malaysian state of Sabah (Beaman et al., in press), as shown in Fig. 2.7. The magnitude of these events was such that it prompted the International Union for the Conservation of Nature to call it "one of the worst environmental disasters of the last century" (Earthscan, 1984). The loss in revenue for the Indonesian forestry sector has been estimated at more than $6 billion (in terms of damaged logs and reduced growth). Patterns of employment in the local lumber and plywood industry were disrupted. Internal navigation, the only means of transport of people and goods to the interior, was interrupted for several months because of low river flow. Damage to rattan plants, a major source of income in some districts, has been especially critical for the local economy.

Drought in 1982 led to the shedding by evergreen species and to the accumulation of dry litter on the forest floor. With the low atmospheric moisture and the dry winds that prevailed during early 1983, the accumulated organic material provided abundant kindling and fuel for the fires to spread. The most extensive of those fires took place from August to October 1982 and especially from March to May 1983. Smoke from the East Kalimantan fires lingered over the island for more than four weeks in early 1983 and reached Java, Singapore, and peninsular Malaysia (more than 1,500 km to the west), where it interfered with air navigation. Airports in East Kalimantan were closed for many weeks in March-April 1983. The busy seaport of Balikpapan was brought to a virtual standstill for prolonged periods with vessels standing offshore, waiting for a sea breeze to improve visibility (Johnson, 1984).

Fig. 2.7 Map of Borneo and general location of the 1982-83 fires.



The fires appeared to have been triggered by agricultural practices, which include burning as a land-clearing procedure. In the hinterland, the population density is still very low (four people per square kilometer), but accelerated settlement programs as well as spontaneous migration are rapidly changing the landscape of East Kalimantan; large tracts of land along the coast and main rivers are being deforested for agricultural uses. Large sections of the tropical forest are also covered by forestry concessions (more than 100 with sizes ranging from 2,000 to 10,000 ha). There are indications that the logged forest suffered more, comparatively, from the 1983 fires than did the untouched primary forest. Selective cutting, as practiced in Indonesia, removes only a few trees per hectare, but the resulting accumulation of organic debris provided unique material and pathways for the fires to spread. Thus, there is strong evidence that, the extreme climatic conditions of 1982-83 notwithstanding, the extent and severity of the fires in East Kalimantan were closely related to human activities.

Site and soil factors have also influenced the impact of climate and have, to a large extent, determined the susceptibility of vegetation to drought and fire. Paradoxically, the peat swamp forest suffered the most damaging burns; the lowering of the water table in the freshwater swamps of the hinterland Kutai District exposed the top peat layers to desiccation and caused the death and toppling of strongly buttressed but shallow-rooted trees. Dry peat and dead woody material allowed underground and surface fires to spread unabated over large portions of the swamp forest (0.5 million ha in a first estimate). In the dryland areas, topographic features also influenced the susceptibility of the vegetation to drought and fire.

Climate, site, vegetation, and human factors thus created a mosaic of patches affected to varying degrees by drought and single or repeated fires. By all accounts, however, the "Borneo fires," as they have come to be known, were ecological events of major proportions that have profoundly affected the human, plant, and animal communities of tropical ecosystems already subjected to numerous pressures. Apart from drawing our attention, once more, to the fact that tropical ecosystems can be very vulnerable, the 1982-83 events in East Kalimantan lead to important observations, not unrelated to current ENSO analysis efforts.

Fires raged unmonitored and unabated for close to three months in early 1983. Outside of a small group of forestry officials and scientists working in the region, the extent and severity of the damage were virtually unnoticed until the end of 1983, more than nine months after the last fires had been extinguished by the May storms. The significance of the drought and its implications for the tropical forest were thus never recognized during the period of occurrence. A lack of appreciation for the severity of the 1982-83 weather anomalies and a certain lack of awareness of the evolutionary role of droughts and fires in shaping tropical ecosystems partially explain that situation. Early warning systems of the kind established for arid and semiarid areas generally find less justification in tropical regions. Yet, despite an annual rainfall of more than 2,000 mm, such regions can be seriously affected by drought. If, as suggested by the East Kalimantan events, intensified land use increases the risk of fire in tropical ecosystems, the impact of future droughts is likely to be even worse than that of 1982-83. In addition, repeated drought and fires in the degraded forest can prevent the return of the original forest vegetation. Thus, a better understanding of the ENSO phenomenon and its precursors could help in designing appropriate management approaches for the tropical forest ecosystems. New approaches should include adjustments of burning season and "cleaner" forest logging practices. An improved understanding of the possible impact of such climatic events is all the more urgent because large sections of tropical forests of Southeast Asia are being logged and converted into agricultural land.

The Borneo fires also point to the need for better use of the techniques currently available for monitoring environmental changes. Global observation tools carried on board earth-orbiting satellites could have provided better information on the state of the tropical forest of Borneo before and during the various phases of ENSO. For example, changes in vegetation indexes measured by the National Oceanic and Atmospheric Administration's AVHRR instrument (see appendix to this chapter) were noticed in mid-1982. The appearance of fires in early 1983 could have been monitored by the same instrument (Malingreau et al., 1985). In short, when combined with weather observations and an appropriate understanding of the possible phenomena at play, such remote sensing data could be used to alert authorities about impending disasters.

Conclusions

The two very different ecosystems of Indonesia analyzed in this chapter show contrasting responses to the 1982-83 drought. Both have been affected, but to varying degrees. Through various measures, the intensively managed wetland rice production system was somewhat protected from disastrous consequences that had affected it in previous dry years (e.g., 1972, 1976). No decrease in production was recorded at the national level, and the temporary reduction in the production growth rate was quickly reestablished, thereby reducing possible long-term consequences of the drought. However, the tropical forest of Kalimantan suffered one of its worst disasters in recorded history, due to a combination of an unusually prolonged drought and the outbreak of fires exacerbated by land-use practices.

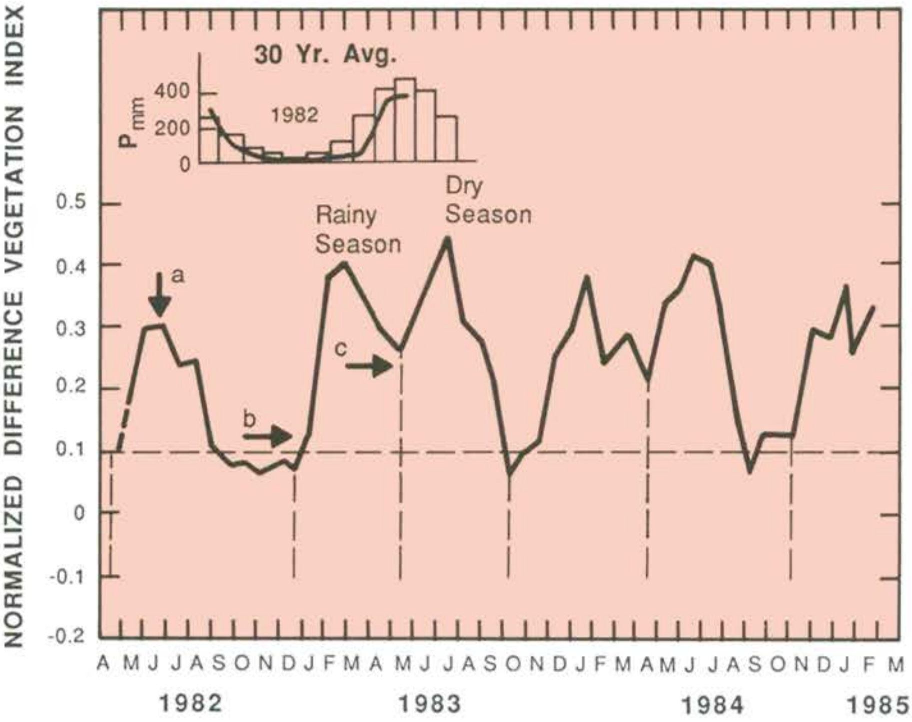


Fig. 2.8 Vegetation index development curve for wetland rice in West Java from 1982 to 1985. Data are from the NOAA AVHRR GVI set. The 1982-83 drought-related features are (a) lower maximum vegetation index for 1982 dry season, (b) longer fallow period and delay in wet-season planting for 1983, and (c) delay in 1983 wet-season harvest.

APPENDIX

Drought Monitoring Using Satellite Data

Daily observations of the earth's surface by the NOAA meteorological satellites can be used to monitor the dynamics of vegetation. Data collected by the Advanced Very High Resolution Radiometer carried on board those satellites allow the calculation of vegetation indexes related to conditions in the plant canopy. Such data are available at 1-, 4-, and 15-km resolution levels. For global observations, even the low-resolution data can often give adequate information on changes and anomalies in the vegetation canopy. Daily satellite data can be assembled in weekly or biweekly vegetation indexes that represent the best sample in the set.

A series of weekly vegetation index data at 15-km resolution were analyzed for the April 1982–March 1985 period over Southeast Asia. The analysis was geared toward detecting anomalies in the "normal" vegetation dynamics in areas affected by the 1982–83 drought. The satellite-derived vegetation index development curve for a major rice-growing area of West Java best illustrates the value of this approach (Fig. 2.8). The impact of the 1982–83 drought is clearly visible through a reduction in the vegetation index from April to August 1982, as compared to the 1983 and 1984 cases. The peak value in July 1982 reaches only 60–70% of the values observed in the other dry seasons on record. This may reflect two distinctly different factors: stress in the plant canopy because of water shortages in the fields, or reduction of the relative planted area within the instrument's elementary field of view because of water shortages in the irrigation system. Both phenomena are normal responses to adverse weather. The other important information that can be derived from this vegetation development curve is the late planting of the 1983 wet-season crop; this crop emerged at the end of December 1982, compared to the normal planting time of early November (see 1983) or even mid-October (1984). This in turn delayed the 1983 harvest. Anomalies of this kind have been observed in satellite-derived vegetation index data for various regions of Asia in 1982; the result of that analysis is given in Malingreau (in press).

The 1982–83 forest fires of East Kalimantan and North Borneo represent another case in which satellite data could have provided a better understanding of the unfolding events. Drought in the tropical forest, an unusual event, was marked by a gradual decrease of the vegetation index for several parts of East Kalimantan as early as April 1982. Smoke was readily apparent on the daily NOAA visible images, and its travel could be monitored. Thermal sensors on board the same satellite provided early indications of the appearance of fires in February 1983; periodic measurements showed that the density of fires in the tropical forest of East Kalimantan peaked in mid-April and that most of them were extinguished by 19 May 1983. By that time, however, numerous fires began to appear in Sabah. Unfortunately, all those data received daily in the local satellite stations were little used in 1983.

The examples given above are but a few of the applications of satellite observations that are currently being developed around the world. They illustrate that technological developments have made it possible to use a number of types of measurements from orbiting platforms to address important issues related to the impact of climatic anomalies upon terrestrial ecosystems. Perspectives upon such measurements are twofold: first, satellite observations can contribute fundamental improvements in our understanding of the dynamics of the processes at play in large-scale systems. Second, by providing repetitive and reliable observations, earth-orbiting sensors can be useful in averting some of the most adverse effects of climate anomalies.

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Chapter 3

THE 1982-83 DROUGHT IN AUSTRALIA

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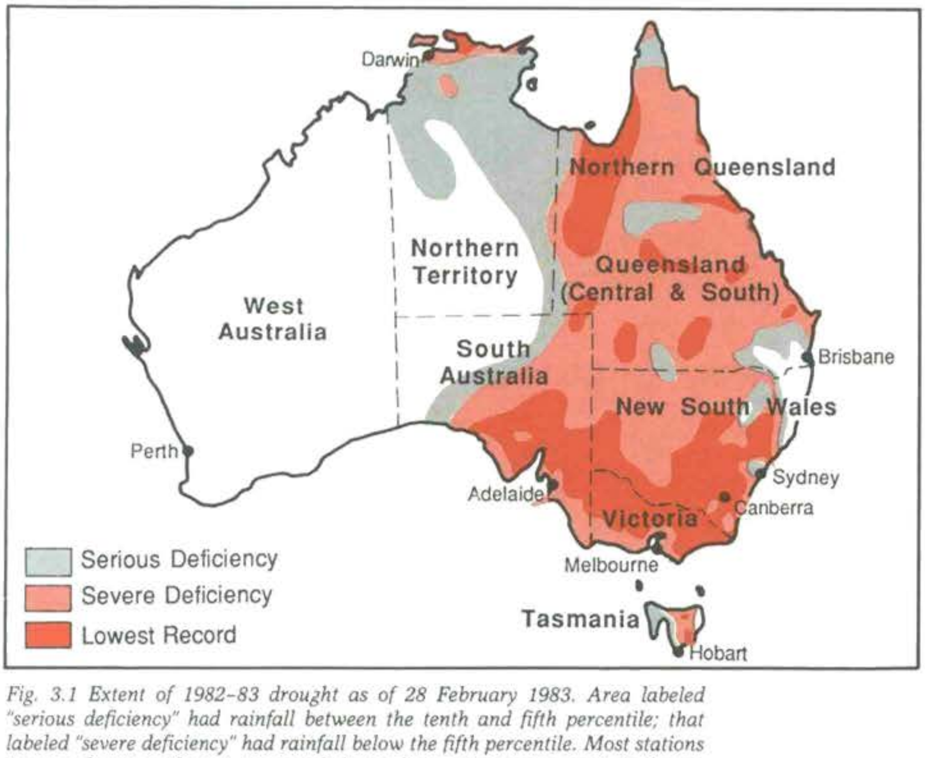
There has been a long history of drought in Australia, and the literature demonstrates that the environmental and societal impacts have usually been economic hardship in the rural community along with significant national economic recessions (Campbell, 1968; Chapman, 1976; Coughlan et al., 1979; Heathcote, 1967; Lovett, 1973). The major features of these droughts have been reduced yields, reduced harvests and excessive livestock losses, while local urban water supplies have often been affected. In times of drought, soil erosion has also accelerated and the incidence of destructive bush fires has increased.



▨ Serious Deficiency
🟥 Severe Deficiency
🟥 Lowest Record

Fig. 3.1 Extent of 1982-83 drought as of 28 February 1983. Area labeled "serious deficiency" had rainfall between the tenth and fifth percentile; that labeled "severe deficiency" had rainfall below the fifth percentile. Most stations in area shown as "lowest on record" have observations over a period of more than 80 years. The durations of the drought to 28 February were seven months in the Northern Territory, ten months in northern Queensland, 11 months in central and southern Queensland, New South Wales, Victoria, 10 months in South Australia, and nine months in Tasmania (Gibbs, 1984).

In many respects the drought of 1982-83 was regarded as a major national disaster, with some observers calling it the worst in the southern and eastern parts of the country in more than a hundred years (Martin, 1983). Its impacts in the rural areas had secondary effects on various sectors of the national economy and were associated with a significant amount of land degradation and disastrous bush fires.

The Meteorology of the Drought and the ENSO Connection

The drought of 1982-83 (Fig. 3.1) was triggered by the failure of the winter rains of June-September 1982 over the southeastern grain and pasture areas of Australia and the subsequent failure of the summer rains of December 1982-February 1983 over the grain and pasture lands of northern New South Wales and southern Queensland. The lowest rainfalls on record were observed over parts of southern Queensland, central New South Wales, much of Victoria, and the southern half of South Australia. The onset of "normal" autumn-winter rains in southeastern Australia (March-May 1983) brought an end to the meteorological drought.

Meteorologically, this period was marked by atmospheric circulation anomalies in Australasia. The 1982 winter circulation showed a persistent "blocking" of west-to-east wind flow by an expanded high-pressure cell centered over Australia. As a result, winter cyclone tracks and frontal passages were displaced to the south, removing the major source of winter rainfall.

During March to August 1982, colder SST anomalies were observed along the east coast of Australia (Wyrtki, 1984; Wyrtki and Nakahara, 1984). The exact relationship of such observations to Australian rainfall is difficult to deduce, although some suggest that rainfall-producing mechanisms may be suppressed, partly because evaporation from the ocean surface is reduced or because the atmosphere is cooler. The following Southern Hemisphere summer (1982–83) was notable for its weak monsoonal conditions (i.e., poor rainfall) over northern Australia and Indonesia (Nicholls, 1983a; Soerjadi, 1984).

The relationship of Australasian circulation anomalies to the ENSO phenomenon is still not clearly understood. However, anomalous strong subsidence (a descending motion of air that inhibits the formation of rain-producing clouds) over eastern and central Australia, and thus a suppression of major rain-producing mechanisms, seem to be inherent in ENSO teleconnection events (van Dijk et al., 1983). This type of atmospheric anomaly was inherent in the blocking anticyclones over the continent during the 1982–83 ENSO and could explain much of the apparent relation of Australian droughts to ENSO episodes (Allan, 1984, 1985).

Recent research indicates that the climate anomalies in the Australasian region may not be simply a weaker and passive extension of the more spectacular Pacific Ocean manifestations of ENSO. Tropical cyclones in the Australian region (Keen, 1982) and changes in the southeast tradewinds off eastern Australia (Harrison, 1984a,b) may have been possible triggers for the onset of the 1982–83 drought and other ENSO events. These phenomena are closely linked to changes in the South Pacific Convergence Zone (e.g., van Loon and Shea, 1985). Further, scientific research on changes in oceanic circulations, sea levels (Pariwono, 1984a,b), and SSTs (Streten, 1981, 1983) in the Australian region has lent increasing support to indications that the ENSO phenomenon plays a more active role in ocean-atmosphere events in Australia.

The relationship between droughts in eastern Australia and ENSO is one of the best-documented teleconnections. For example, discharge in the Darling River, part of the major river system of eastern Australia, is low during ENSO events (Williams et al., in press). Pittock (1975, 1984) has demonstrated the relationship between ENSO and rainfall (which results in the relationship with river discharge), as shown in the accompanying time series (Fig. 3.2) of Darwin, Australia, pressure (an index of the Southern Oscillation) and an index of rainfall in winter and spring over the eastern half of Australia. The close relationship is clear. When Darwin pressure is high (i.e., during ENSO), the rainfall index is low (i.e., there is drought).

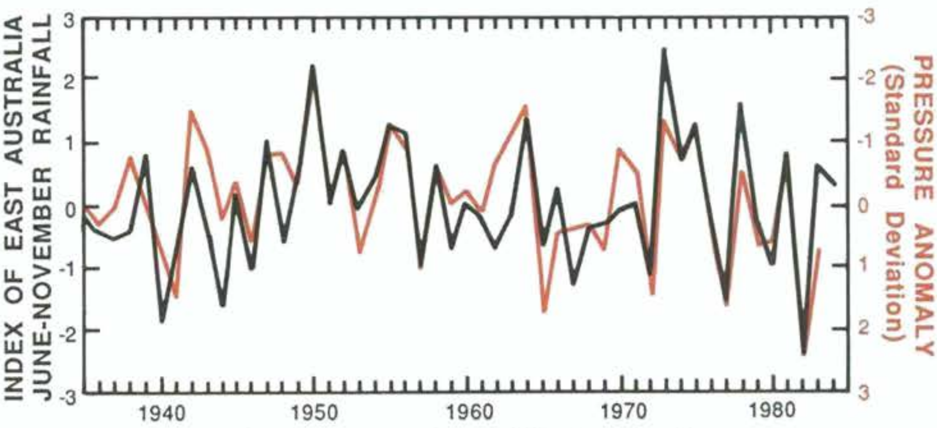


Fig. 3.2 Time series of index of eastern Australian rainfall in June-November (black line) and pressure at Darwin (colored line). The Darwin pressures have been standardized by subtracting the 1935–84 mean and dividing by the standard deviation. The pressure scale is reversed (Nicholls, 1985).

If these "predictable" climate anomalies have impacts on the agriculture, ecology, or economy, then these impacts may also be predictable. For example, interannual variations in spring rainfall in eastern Australia affect yields of sorghum. As was noted above, eastern Australian spring rainfall is related to, and predictable from, indexes of ENSO. Therefore, Australian sorghum yields may be predicted by monitoring ENSO. In fact, reasonably accurate predictions of yield can be made several months before the crop is planted, in late spring (Nicholls, 1986), simply by noting, around August, whether an ENSO event is under way. There is no need to actually predict the occurence of ENSO. Of course, if a method were found to predict ENSO, then even earlier (and thus more useful) predictions could be made.

Other climate impacts, even if related to ENSO, might be more difficult to predict. If the impact occurs early in the ENSO life cycle, say, around April-June, a very early indicator of an ENSO event will be needed. For instance, the planting of wheat in eastern Australia starts about April-May. Wheat yields are closely related to winter and spring rainfall, which in turn are related to ENSO. For a useful prediction of wheat yield, however, a very early indicator, available about February, would be necessary.

Recent papers by Coughlan (1983) and Nicholls (1983a,b) have suggested that the ENSO linkages offer hope for the prediction of rainfall or drought over at least southern and eastern Australia. The 1982–83 drought thus appears to have been significant, not only as a phenomenon linked to ENSO but also as, perhaps, the first drought which might have been predicted from those linkages.

The Economic Impacts of the Drought[1]

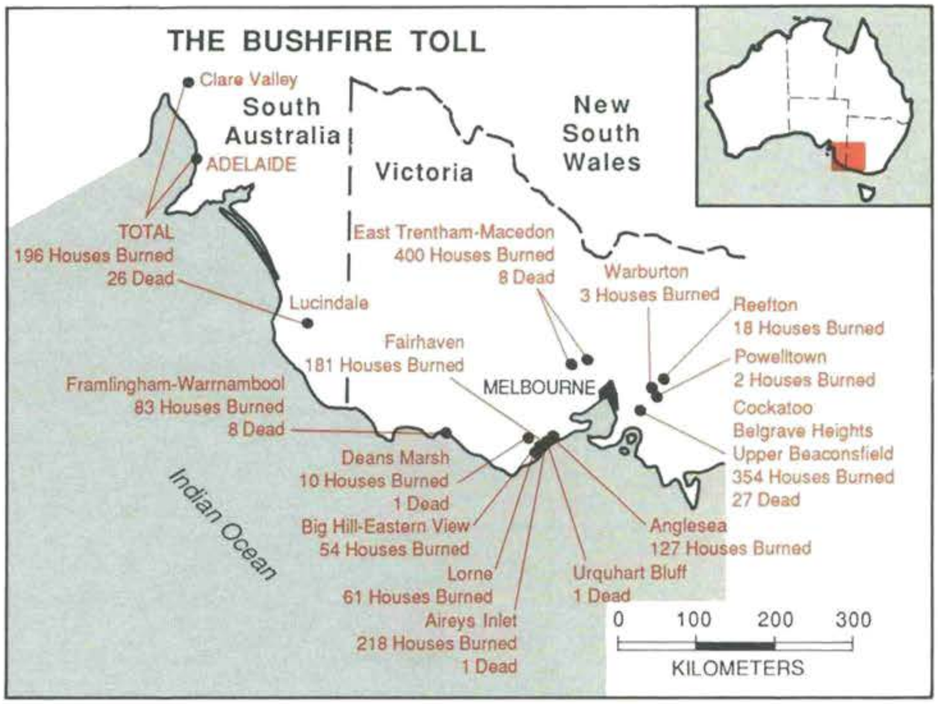
The immediate impacts of the drought took the form of reduced harvests of crops and livestock products. Approximately 60% of the nation's grazing and agricultural farms were affected (i.e., some 67,000 farms). The national wheat harvest was halved (from 15.5 to 7.8 million metric tons from 1981-82 to 1982-83), and the average yield dropped similarly (from 1.38 to 0.76 metric tons per hectare from 1981-82 to 1982-83). There was an average decrease of 45% in the quantity of wheat sold per farm and wheat receipts declined by 58%. The oat crop (1.6 to 0.8 million metric tons) and barley crop (3.5 to 1.7 million metric tons) were similarly affected. Overall crop production fell by 31%.

Even the irrigated farms, with water allocations from the shrunken reservoirs (reduced to 10% of normal in some extreme cases), were seriously affected in, for example, the northwestern part of New South Wales (van Dijk et al., 1983). Rice crops were down by 39% from 1981-82 production figures, and cotton was down by 25%. In this instance of severe drought, even irrigation was ineffective as a "drought-proofing" mechanism.

The picture for livestock production was less spectacular since retention of unsalable stock on farms boosted the official counts. Sheep numbers fell by six million from 138 million, while cattle numbers fell by almost two million from 25 million. The drop in the number of cattle, however, reflected an acceleration of a longer-term overall decline. Livestock production, in fact, fell by only 1%, the slaughter of stock increased, and the national wool clip fell by only 3%.

Farm incomes were reduced by 24% (mainly as a result of the poor wheat harvests) and farmers responded by cutting their costs. But even so the cash surplus per farm was reduced by 45-50% – a national reduction that amounts to about 1.1 billion Australian dollars. National employment fell by 2% (representing a loss of about 100,000 jobs), and rural exports fell by approximately $500 million (3% of total exports).

Fig. 3.3 The Bushfire toll for the Ash Wednesday fire, 16 February 1983. (Modified from Bardsley et al., 1983, p. 134.)



Specific industries were particularly hard-hit. Chemical fertilizer manufacturers and flour and cereal processors lost 10-11% of their normal production, while the state-run railways registered a 6% decline in business.

Other Impacts

Apart from the obvious short-term economic impacts just cited, the drought had significant effects upon the Australian environment and its wildlife. The process of land degradation, which is currently being documented in Australia (Woods, 1983), was considerably accelerated by wind erosion from drought-blasted grain fields and pastures. A dust storm on 8-9 February 1983 brought an estimated 150,000 metric tons of soil from farms in the northwest of Victoria to the capital of Melbourne and on out to sea (Anon, 1983). A week later a series of massive bush fires covering some 500,000 hectares in southeast South Australia and Victoria, led to the death of 72 people and more than 300,000 animals and caused approximately $400 million in property damage (Fig. 3.3) (Bardsley et al., 1983; Oliver et al., 1984). The causal link with the drought was quite clear. Less clear was the link between the drought and erosion losses (up to 48 metric tons of soil lost per hectare) from some of the burned areas in the drought-breaking rains of March 1983 (Atkinson, 1984).

Wildlife losses from the drought must have been considerable, although documentation is sparse. Estimates of kangaroo populations within the commercial shooting zones over the period November 1982 to June 1983 suggested that the drought had caused the deaths of up to 70% of mobs (herds), quite apart from the commercial culling (ACF, 1983).

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[1] The following summary is based upon the findings of Campbell et al., 1983; Gibbs, 1984; Martin, 1983; and Purtill et al., 1983.

Official Responses

Official reactions to the drought were generally along traditional lines. Disaster relief was essentially economic, since there was no direct threat to life. But the indirect effects of the drought – especially the bush fires – required the declaration of a State of Emergency and the mobilization of the State Emergency Services in South Australia and Victoria.

Drought relief was provided to farmers and pastoralists in the form of concessional low-interest loans with repayments deferred for two years, subsidies on interest over 12% on existing farm loans, and subsidies to evacuate starving livestock or to move stock feed and restock after the drought. A recent study by the Commonwealth Bureau of Agricultural Economics has been highly critical of several of these measures on the grounds that they did not encourage rural producers to protect themselves against future recurrences of drought (BAE, 1984). This echoes earlier criticism of traditional drought-relief schemes in Australia's pastoral industry (Robinson, 1982).

Conclusion

The 1982–83 drought in Australia caused significant national economic hardship in the short term and accelerated land degradation, with all the long-term problems which that implies. It is likely, however, that it will be more memorable within the scientific community as the drought which demonstrated the linkage with ENSO and encouraged meteorologists to dream of successfully forecasting future droughts through those linkages (AMSTAC, 1983).

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Chapter 4

IMPACT OF THE 1982-83 ENSO ON THE SOUTHEASTERN PACIFIC FISHERIES, WITH AN EMPHASIS ON CHILEAN FISHERIES

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Introduction

The consequences of the El Niño phenomenon along the Chilean coast are less well known than in other areas along the western coast of South America, perhaps because the climate effects appear less spectacular or dramatic to those outside the region. The diversity of climatic regions in Chile ensures that El Niño events will have disparate impacts throughout the country at the same time. It can be shown that the ocean-atmosphere interaction through El Niño events represents an important climate control for the central part of Chile (Romero and Garrido, 1985). As an example, in central Chile the 1982-83 ENSO produced 623 millimeters of rainfall at Santiago, comparable only to the 1926 record rainfall level of 700 mm, the annual average rainfall being about 300 mm. One of the consequences of the 1982 rainfall was the biggest flood recorded in Santiago. The high intensity of this El Niño exacerbated drought problems in the agricultural areas in the northern part of Chile (CPPS, 1985).

Colder-than-usual ocean temperatures (referred to by some scientists as anti-El Niño events), on the other hand, are associated with strong droughts in central Chile, which adversely affect agricultural production in that region. El Niño events also have an important effect on the anchoveta fishery of northern Chile. The 1957-58, 1965, and 1972-73 El Niño events strongly modified the availability and abundance of this biological resource.

The 1982-83 El Niño/Southern Oscillation (ENSO) has been recognized as the largest of the century, and it demonstrated that not all events are the same. The impacts of the 1982-83 ENSO appeared off the

Fig. 4.1 Southeast Pacific area.

coast of northern Chile in October 1982 (Blanco and Diaz, 1985). Symptoms of this warm sea-surface temperature (SST) anomaly could be found as far south as Talcahuano (36°S), with the highest temperature at this latitude occurring in February 1983. The most outstanding features were its very large temperature anomalies, reaching a maximum of 6°C off Arica in June 1983 (Blanco and Diaz, 1985), and the depression of the thermocline and the 15°C isotherm, which reached its maximum depth of 150 meters in May 1983. The sea-surface salinity reached values never before registered (35.8‰), and salinity levels of more than 35.3‰ were dominant off the northern Chilean coast between 1982 and October 1983. Some changes in the surface circulation were also identified.

Table 4.1: Annual Catches by Species Obtained by the Industrial Fleet (tons per thousand)

		1970	1971	1972	1973	1974	1975	1976	1977
Northern zone (Arica-Antofagasta)	Jack mackerel	175,003	184,993	62,886	71,392	163,392	186,890	237,876	225,907
	Sardine	13,891	24,820	10,831	50,894	169,270	134,278	280,287	551,680
	Mackerel		8,466	1,017	3,808	215	15,235	52,712	138,215
	Anchoveta	624,444	790,579	283,770	142,543	328,715	197,360	389,356	10,168
	Total	813,338	1,008,858	358,504	268,997	661,600	533,763	960,231	925,970
Coquimbo	Jack mackerel	3,222	5,296	5,736	3,874	5,222	7,302	10,606	2,850
	Sardine		31	1,422	6,572	15,179	22,471	31,268	34,845
	Mackerel			9	12	5	23	47	222
	Total	3,222	5,327	7,167	10,458	20,408	29,796	41,921	37,917
Talcahuano	Jack mackerel	8,143	1,779	1,364	5,030	7,456	27,649	54,964	72,735
	Sardine					1,670			386
	Mackerel								332
	Anchoveta	76,255	197,411	141,575	144,077	164,127	47,214	6,592	12,867
	Common sardine								
	Total	84,398	199,190	142,939	149,107	173,259	74,863	61,556	86,420
Total		900,958	1,213,375	508,610	428,562	855,265	638,422	1,063,708	1,050,307

		1978	1979	1980	1981	1982	1983	1984
Northern zone (Arica-Antofagasta)	Jack mackerel	365,265	331,265	284,272	435,061	756,484	282,226	655,530
	Sardine	687,815	1,429,924	1,592,395	1,425,499	1,663,254	2,394,630	2,276,229
	Mackerel	171,238	39,574	101,967	98,964	14,527	7,043	101,518
	Anchoveta	191,981	45,377	99,332	199,817	71,978		195
	Total	1,416,299	1,846,064	2,078,016	2,159,341	2,506,243	2,683,899	3,038,595
Coquimbo	Jack mackerel	4,798	20,030	23,876	24,739	48,986	28,093	37,111
	Sardine	36,303	51,499	38,986	25,601	49,211	105,734	52,456
	Mackerel	1,700	748	2,341	380	984	1,249	222
	Total	42,801	72,277	65,303	50,720	99,190	135,076	97,950
Talcahuano	Jack mackerel	144,539	183,008	191,422	406,212	579,722	500,759	600,684
	Sardine	1,570	37,068	72,325	86,226	7,698	16,260	66,381
	Mackerel							215
	Anchoveta	5,915	14,810	3,600			5,244	37,332
	Common sardine							478
	Total	182,024	234,986	277,841	492,438	587,420	522,263	716,690
Total		1,641,124	2,153,327	2,421,160	2,702,499	3,192,853	3,341,238	3,853,235

Source: IFOP, 1985. Note: Table does not include catches by small-scale fishermen.

Table 4.2: Landings for Ecuador (A) and Peru (B) (metric tons)

	1975	1976	1977	1978	1979	1980	1981	1982	1983
A. ECUADOR									
Anchoveta									
Sardine (*)						250,000	285,000	185,000	48,000
Jack mackerel						–	–	–	24,937
Mackerel						570,617	656,753	248,000	96,527
B. PERU									
Anchoveta	3,078,810	3,863,050	792,106	1,187,041	1,362,763	720,124	1,225,168	1,720,437	118,160
Sardine	62,851	174,701	870,903	1,257,948	1,727,201	1,480,396	1,182,947	1,491,068	1,064,448
Jack mackerel	37,899	54,155	504,992	386,793	151,599	123,380	37,875	45,023	67,904
Mackerel	23,588	40,172	46,071	101,505	117,953	59,062	32,803	18,895	21,015

Source: FAO (*) from Grupo Técnico Científico, 1984

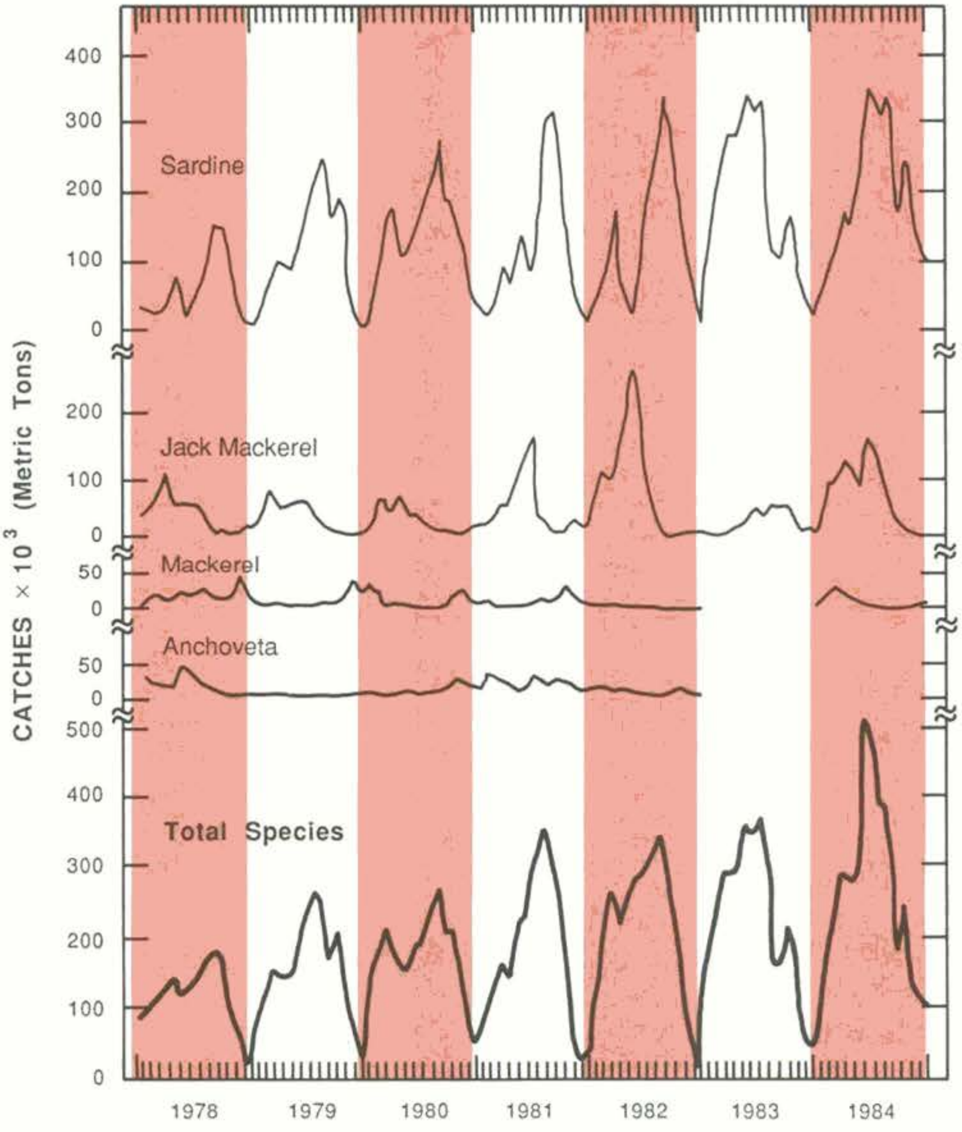

Fig. 4.2 Seasonal pattern of catches of the sardine, jackmackerel, mackerel, anchoveta, and total for the pelagic fishery of Northern Chile. From Martinez et al., 1984, IFOP. Chile.

Impact of the 1982-83 El Niño on Marine Living Resources

The impacts of El Niño can be classified in two categories. The first, short-term effects, includes changes in behavior that affect the availability, accessibility, and vulnerability of fish populations. The second category is long-term effects revealed by an overall change in the population dynamics that represents a greater, structural instability.

Generally, the most important fisheries along the Chilean coast and the Southeast Pacific are based on the pelagic fish populations, dominated by the anchoveta (*Engraulis ringens*), sardine (*Sardinops sagax*), jack mackerel (*Trachurus murphyi*), and mackerel (*Scomber japonicus peruanus*) (Tables 4.1 and 4.2). Among these species, the sardine and jack mackerel show the largest changes in behavior, strongly affecting the fisheries of the region.

In northern Chile, where the main fishery is located (Fig. 4.1), the ENSO event increased the vulnerability of the sardine population by concentrating the school aggregations near the coast, mainly during the first half of the year. This was shown by a hydroacoustic survey (Lillo et al., 1983) and by the behavior of the fishing fleet (Subsecretaría de Pesca, 1983; Martinez et al., 1984). This greater vulnerability produced an increase in sardine catches and a change in the seasonal pattern of those catches (Fig. 4.2). At the same time, the sardine population in northern Peru moved to greater depths and migrated southward from its normal distribution (6-14°S), thereby becoming less accessible to the fishing fleet (Santander and Zuzunaga, 1984) (Fig. 4.3). This change in distribution significantly decreased catches (Table 4.2).

El Niño affected the seasonal pattern in the availability of jack mackerel (Fig. 4.2) by causing the fish population not to enter the fishing areas along the Chilean coast, with the effect being stronger in the northern part of the country. These changes were not evident in Peru; but in 1983, for the first time, catches of this species were registered in Ecuador, suggesting that the jack mackerel had extended its distribution toward the north.

These facts show that El Niño in the short term can produce opposite effects in different localities. The overall catches in Chile increased, mainly because sardine compensated for the decreases in jack mackerel catches. However, in Peru, overall landings decreased because of the decline in both sardine and anchoveta, with the latter becoming very scarce (Table 4.2).

The second category referred to earlier is long-term effects, as shown by overall changes in the population dynamics. The low levels of primary production that took place during 1983 strongly affected the biological condition of the fish (Ramirez, in press; Barber et al., 1985; Avaria, 1985). Sardines in northern Chile, for example, lost about 20% in weight (Subsecretaría de Pesca, 1983; Martinez et al., 1984). In Peru sardines 16 centimeters in length lost about 12% of their weight while those of 30 cm lost about 24% (Grupo Técnico Científico, 1984).

The diminished condition of the sardines had significant consequences for its reproduction. The gonadic index (Fig. 4.4) shows that they did not spawn in the summer of 1983, and their low level of reproduction during the main spawning season (July-August) clearly shows a diminished fecundity (Subsecretaría de Pesca, 1983; Retamales and Gonzalez, 1985). This conclusion is also supported by the very low fat content of the sardine, hence, scarce fat for gonad development and, consequently, for egg production.

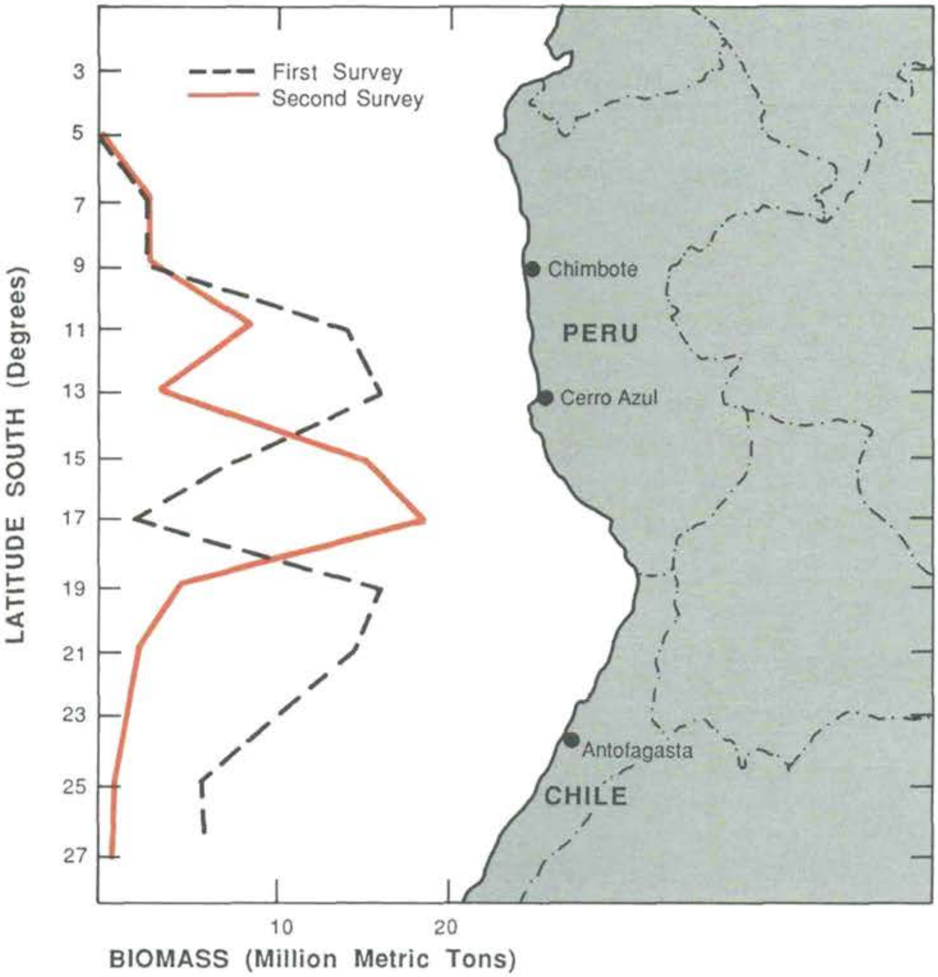

Fig. 4.3 Latitudinal distribution of sardine biomass estimated through hydroacoustic surveys. From Grupo Técnico Cientifico, 1984.

The intensity of the oceanographic perturbation makes the survival of embryos, larvae, and postlarvae very uncertain, resulting in poor recruitment (i.e., addition to the usable stock of fish that have reached a certain age) to the fishery. This finding is confirmed by Santander and Zuzunaga (1984) for central and northern Peru.

The response of the sardine to an El Niño reproduces the pattern described elsewhere for the anchoveta, with certain important differences. The sardine has a greater longevity than the anchoveta (11 years compared to four or five), and it enters the fishery later (not before four or five years). The anchoveta enters the fishery at less than one year old, which explains the immediate drop in its abundance in connection with ENSO events. The sardine's longevity, late recruitment, and greater number of age classes can act as a buffer against reproduction failures that would affect the fishery in the short term. If proper management occurs in time, for example, reducing fish catches, the recruitment failure could be controlled to avoid a much bigger decline in sardine abundance and therefore even worse consequences for the fishery.

Aguayo et al. (1985) conclude that sardines grew less during 1983 than in previous years. Yet another important consequence of the diminished condition of sardines was the change in composition of fish meal and a decrease of fish oil production by about 60% (Romo, 1985). These changes included a decrease in fat content and an increase in ash content.

The 1982-83 ENSO also strongly affected the littoral ecosystem. Soto (1985) described the massive mortality of sea urchins (*Loxechinu salbus*) and of false abalones (*Concholepas concholepas*). Both species support an important small-scale artisanal fishery in northern Chile, which at present is under a moratorium so that the resource can recover. Significant detachment of brown algae (or kelp), *Lessonia nigriscens,* and *Macrocystis integrifolia,* was also observed, affecting the entire kelp community, which will take some years for complete recovery. Brown algae landings decreased by 60% in 1983 and 70% in 1984 compared with 1982, with adverse economic and social consequences.

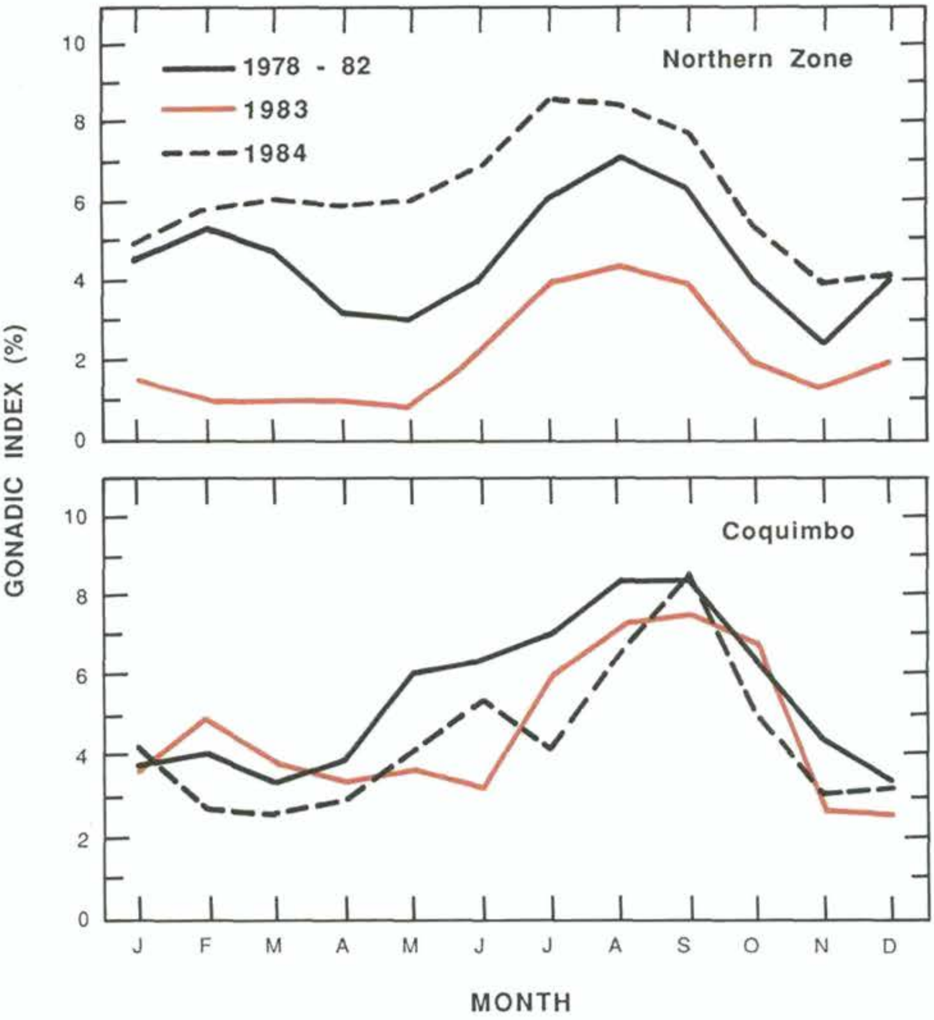

Fig. 4.4 Sardine gonadic index for the northern zone and Coquimbo, Chile. From Martinez et al., 1984.

Summary

- The 1982-83 ENSO had a major effect on the fisheries resources in the Southeast Pacific. The catches decreased significantly in Ecuador and Peru but increased in northern Chile. These effects are explained by opposite reactions of fish populations. Fish were less accessible off Ecuador and Peru, whereas in northern Chile the larger vulnerability of the sardine produced an important increase in catches that compensated for the observed decrease in jack mackerel catches.
- This change of catches caused significant economic losses for the ocean fisheries of Ecuador and Peru, but was extremely profitable for the fisheries of northern Chile, at least for the short term.
- A short-lived impact is expected on the sardine fishery of the whole region, because some weak year-classes, probably produced during the ENSO event, will enter the fishery, thereby affecting its productivity.
- The ENSO event also had a serious adverse effect on the abundance of anchoveta, false abalone, sea urchins, and brown algae, which in turn had important economic and social consequences, especially for the small-scale fisheries of northern Chile.

- As noted in the report of Chile's National Workshop on the 1982-83 El Niño Phenomenon,

> *[T]he great amount of information available today about the El Niño phenomenon indicates that this natural event had affected, and will do it in the future, in an intense manner the Chilean coast, especially the northern and central parts. Thus, the event must be considered as one more variable in the planning of national productive activities and of infrastructure development (IFOP, 1985, p. 252).*

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Chapter 5
CLIMATE ANOMALIES AND THEIR IMPACTS IN BRAZIL DURING THE 1982-83 ENSO EVENT

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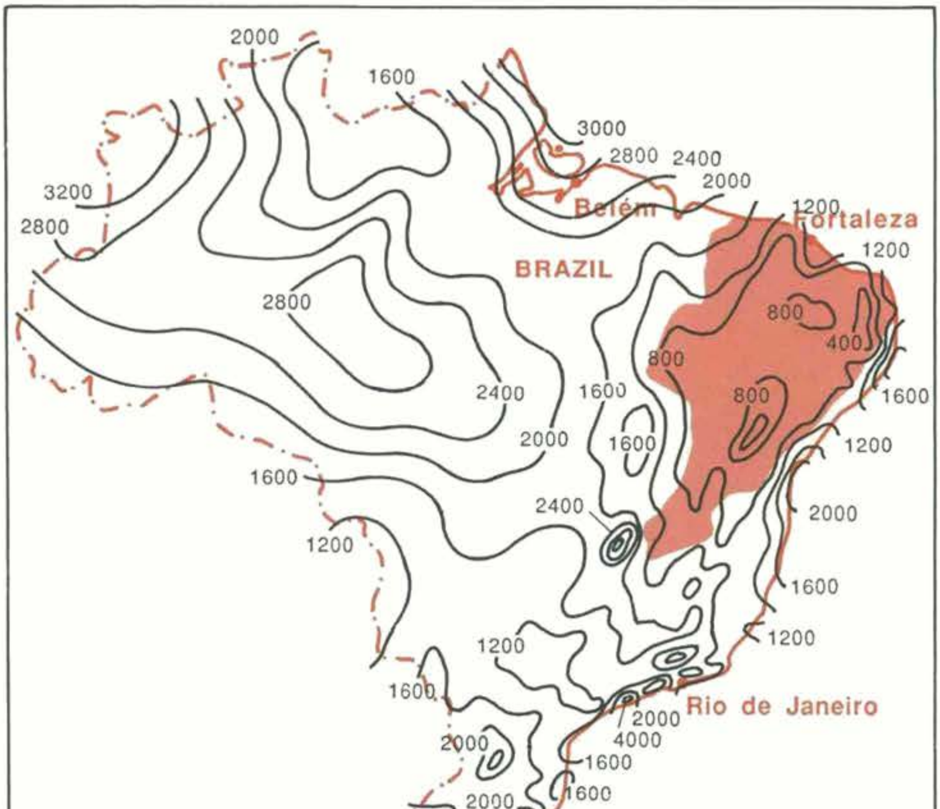
Between 1979 and 1983 the Brazilian Northeast (called Nordeste) was adversely affected by drought (*seca*) with 1983 being an extreme drought year. In the 1982-83 period, floods plagued Brazil's southern region. There has been much speculation about the possible linkage between El Niño events and Brazilian regional droughts and floods (e.g., Caviedes, 1973; Hastenrath, 1985), since regional droughts and floods often follow the onset of El Niño. These linkages, however, are still unclear. This chapter focuses on these climate anomalies and their impacts on Brazil's society and economy.

It is easy to see from Fig. 5.1 that the climatic characteristics of these two regions of Brazil, the Nordeste and the south, are very different. The semiarid Brazilian Nordeste is considered a drought-prone region, exhibiting a high degree of rainfall variability in both space and time. Along the coast the mean annual rainfall exceeds 1600 mm, yet inland this figure decreases rapidly to only 300-800 mm per year. Toward the equatorial forests of Amazonia there is again a mean annual rainfall increase, to over 2,000 mm. Within this region it is possible to define a "drought polygon," an area where the rainfall is between 300 and 800 mm per year and the mean evaporation rate is about 2,000 mm per year (DNOCS, 1985). In case of a drought in the Nordeste, there is a high probability that it will be in "the heart of the semiarid," that is, in the interior of the states of Ceará, Pernambuco, Paraiba, and Rio Grande do Norte. Much has been written about the societal impacts of these droughts within the region referred to as the drought polygon (e.g., de Queiroz, 1930; da Cunha, 1944).

Rainfall in Ceará is representative of precipitation conditions in the drought polygon (Table 5.1). In such semiarid regions, however, mean annual rainfall statistics are not necessarily descriptive of the regional rainfall characteristics, because of the

Fig. 5.1 Rainfall map of Brazil (isohyets).



high degree of variability from year to year as well as within the growing seasons. For several locations in Ceará, precipitation in 1983 was below the lower limit of the *existing* range of precipitation. The monthly average rainfall data shows that in some municipalities there was hardly any precipitation for several months in 1983 (Fig. 5.2).

By contrast, the rainfall regimes of southern Brazil are very different from those of the Nordeste. Rainfall is generally higher and displays relatively less interannual variability. In 1982 and 1983 precipitation was considerably above average. For example, in different municipalities of the state of Parana the rainfall levels surpassed the long-term averages by 70 to 100% (Table 5.2; Fig. 5.3). A similar situation occurred in the southern state of Santa Catarina. Figure 5.4 shows the area affected by droughts in 1983 in the Nordeste, as well as the municipalities affected by floods in the southern region in the same year.

Brazil's climates are determined by the atmospheric circulation systems of both the tropical and the temperate latitudes. As Hastenrath (1985, 293–94) has noted,

> *At least three factors in the surface circulation are conducive to rainfall [in the drought-prone Nordeste] at this time of year [March-May]: (i) the convergence band [ITCZ] over the Atlantic is closest to the Nordeste; (ii) the surface waters of the Equatorial South Atlantic upstream from the Nordeste are least cold, which serves to enhance the moisture content and instability of the boundary layer flow; (iii) the perennial contrast between warm north equatorial waters and cold waters to the south of the equator is weakest.*

Drought in the northeast is associated with the failure of one or more of these conditions to occur. Thus, if the near-equatorial zone of convergence (associated with maximum cloudiness and rainfall) remains north of its customary March-May position, or if sea-surface temperatures (SSTs) in the southern equatorial Atlantic become colder than average, or if the north/south SST contrast remains great, a drought may then ensue. Along the coast where these influences are mitigated by land/sea-breeze circulations and orographic rainfall, annual precipitation amounts are considerably higher than in the semiarid interior of the Nordeste.

In addition to the three factors discussed above, a number of authors have suggested the possibility of a relationship between ENSO and rainfall in the Northeast (Walker, 1928; Hastenrath and Heller, 1977; Caviedes, 1973). Using 23 years of data, Rao et al. (1986) have correlated the Southern Oscillation Index (SOI), as given by the Easter Island-minus-Darwin sea-level-pressure difference, with a monthly rainfall index for the Northeast. They found that the highest correlations occurred with a two-month lag: January SOI index with March rainfall, February SOI with April rainfall, and March SOI with May rainfall. The relationship was a positive one, indicating that high rainfall is associated with a high SOI, and vice versa. While this analysis strongly suggests that ENSO years may be associated, at least to

Table 5.1: Annual Precipitation (mm) in the Municipalities of Ceará

Municipalities	1979	1980	1981	1982	1983
Acarau	491.9	343.9	630.8	970.2	462.9
Aracati	433.8	526.6	687.6	842.4	325.6
Iguatu	594.0	856.0	712.0	688.0	398.6
Morada Nova	419.0	780.6	630.0	369.5	351.0
Monsenhor Tabosa	503.0	477.8	465.8	431.6	166.2
Mulungu	631.0	787.7	804.3	941.0	604.2
Nova Russas	635.0	757.6	414.8	436.7	357.8
Quixada	437.0	633.0	553.0	778.0	217.0
Quixeramobim	422.7	949.3	597.7	631.2	277.9
Russas	592.6	697.5	481.1	709.1	459.6
Averages	516.0	681.0	597.7	679.8	362.0

Source: FUNCEME (Fundação Cearense de Meteorologia e Chuvas Artificiais).

Fig. 5.2 Precipitation in 1983 in the municipalities of Quixeramobim and Acarau, state of Ceará.

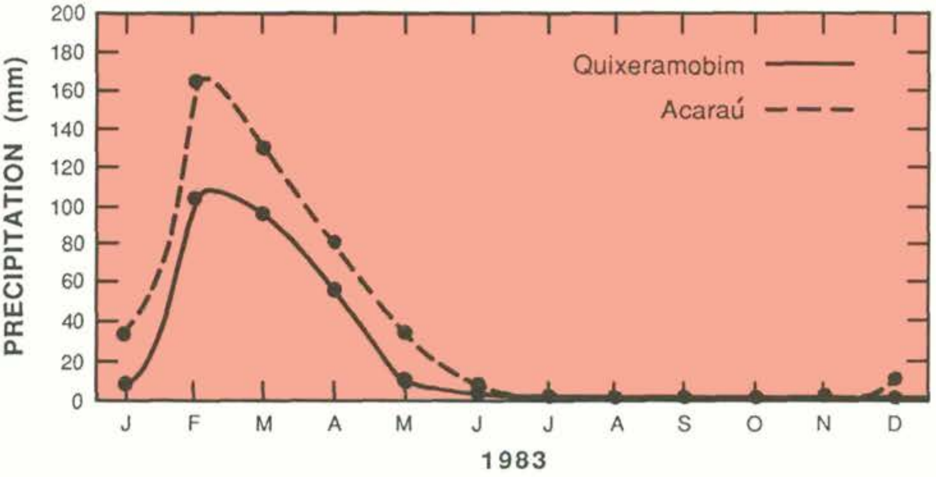


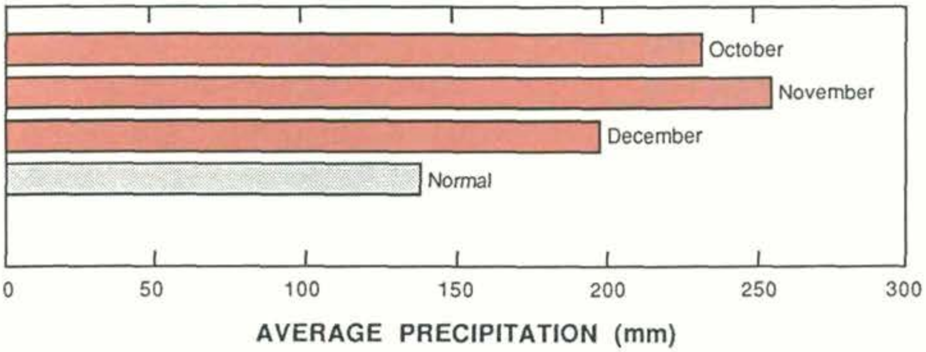
Table 5.2: Precipitation in the State of Paraná January-July, 1983

MUNICIPALITIES	ACCUMULATED TOTALS (mm)		VARIATION (%)
	Normal	Observed	
1	1,525	2,117	38.8
2	1,500	2,259	50.6
3	1,475	1,833	24.3
4	1,575	2,092	32.8
5	1,650	2,340	41.8
6	1,500	2,043	36.2
7	1,500	2,174	44.9
8	1,600	2,259	41.2
9	1,350	3,117	130.9
10	1,675	2,379	42.0
11	2,150	3,215	49.5
12	2,000	2,897	44.8
13	2,025	2,225	9.9
14	1,700	2,920	71.8
15	2,125	3,320	56.2

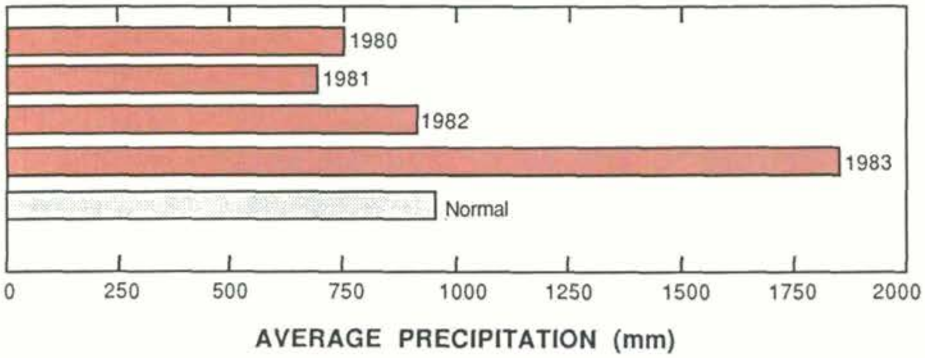
Source: SEAG (Secretaria da Agricultura do Paraná), July 15, 1983

Fig. 5.3 Average precipitation in Paraná and Santa Catarina.

State of Paraná (Curitiba) - October to December 1982



State of Santa Catarina - 1980 to 1983



some extent, with droughts in the Brazilian Nordeste, Molion and Nobre (in press) have noted that

> *Care should be taken when relating ENSO episodes to NEB [Northeast Brazil] precipitation anomalies because one also finds years with strong El Niño which were not reported as severe drought years in NEB. The droughts in NEB do not depend on the occurrence of El Niño only, they depend also on its phase, that is, if eastern Pacific warm SST anomalies [occur] before the beginning of the NEB rainy season (i.e., December) it may not be affected.*

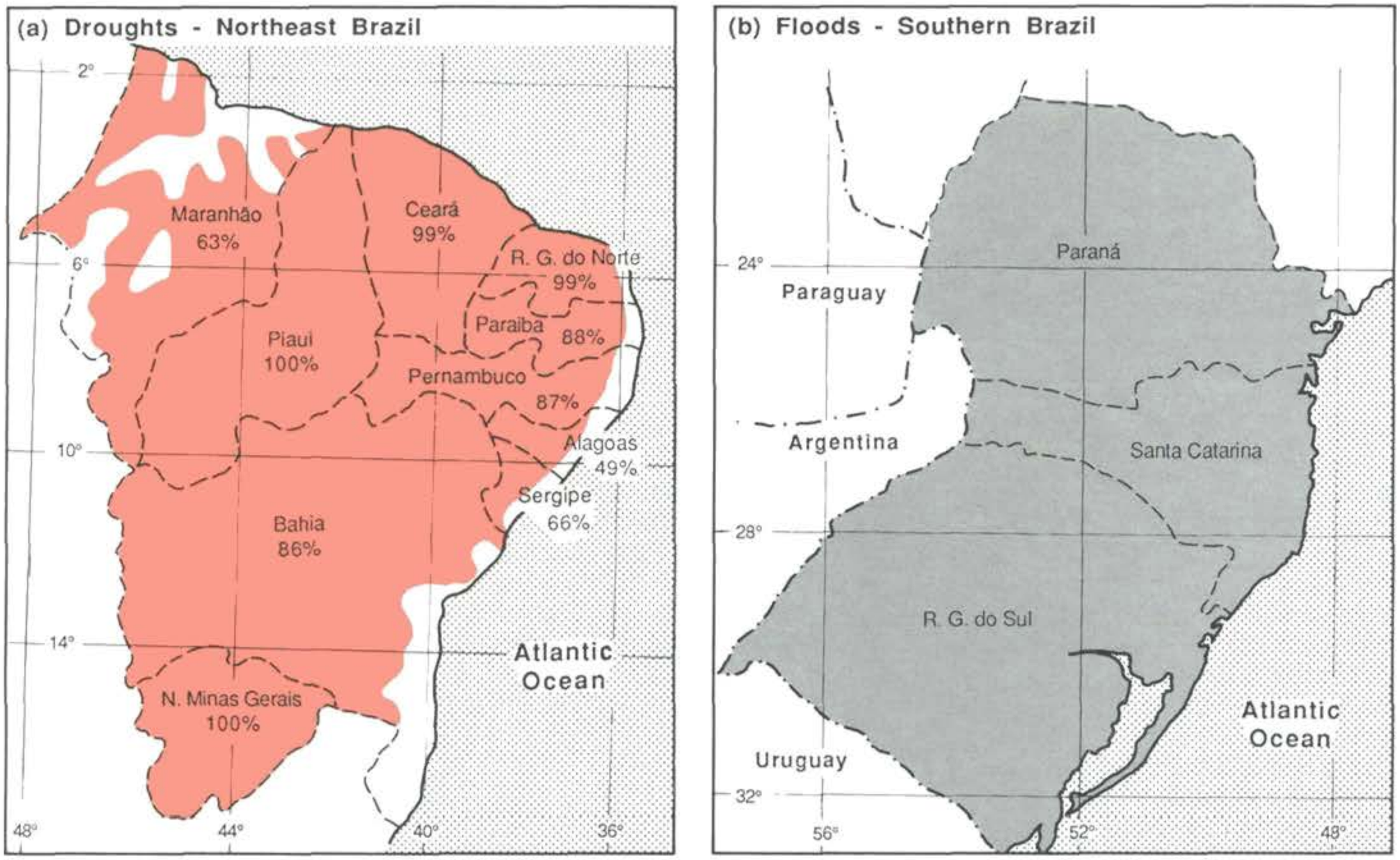
Over southern Brazil, on the other hand, the dominant atmospheric influences are those associated with temperate latitude frontal systems in the southern hemisphere. Annual precipitation totals are high, with the mean seldom falling below 1,500 mm per year. Although some rainfall occurs every month of the year, the maximum amounts generally occur in November and December. There is evidence that, during El Niño years, strong activity in these regional frontal systems leads to floods.

Impacts of the 1982-83 Drought and Floods

Nordeste

In 1983 approximately 88% of the area of the Brazilian Nordeste was adversely affected by meteorological drought (i.e., a major decrease in precipitation), resulting in a 16% decline in the region's agricultural production. In addition, a relatively large segment of the regional population was affected by drought. Although the population receiving drought assistance in 1983 amounted to 2.8 million, the actual number of people affected was more than 14 million. In 1980, for example, while the population receiving assistance totaled just over 700,000, the total number of adversely affected individuals amounted to about 13 million, seven million of whom were from rural areas (MINTER, 1981). Clearly, agriculture is the sector of the economy most affected, especially subsistence farming. A study by

*Fig. 5.4 a. Areas of the Nordeste under drought emergency in March of 1983 (*Folha de São Paulo, *18 March 1983). b. Southern provinces affected by the 1983 floods.*



the Joaquim Nabuco Foundation (FJN, 1983) concluded that subsistence crops were more affected by drought than were livestock. The industrial sector was less affected by drought in 1983 than the agricultural sector, partly because that sector depends on raw materials from other parts of Brazil. Although the impacts of drought can affect everyone in a region, those effects are different among different classes. Indeed, for those with medium and large landholdings the dry season is mainly a production problem. For farmers with small landholdings, however, drought challenges their ability to subsist. It was shown, for example, in the sample of small farmers who suffered from the drought that there was practically no distinction with regard to losses among the various subcategories of small farmers, suggesting a similar degree of vulnerability among them. Virtually all lost most, if not all, of their entire production during the dry periods.

Other effects of the drought included increases in the prices of products and in indebtedness. Regarding the latter, it has been noted that, during the drought period, 35% of a family's expenditures was required for debt repayment. This percentage of indebtedness was abnormally high. With regard to the prices of subsistence products, increases in food prices by as much as 300% have been reported during drought years.

Many books, reports, newspaper articles, government documents, and even novels on droughts in the Nordeste have been published in the past 100 years. The examples here are only illustrative and are by no means exhaustive.

South

Heavy rains in southern Brazil caused widespread flooding, and destruction of houses, buildings, transportation and communication networks. This was considered to be the worst flooding in the region in this century. The floods adversely affected commercial and industrial activities. In addition to the scores of people who perished, several hundreds of thousands of inhabitants in the three most affected Brazilian states of Paraná, Santa Catarina, and Rio Grande do Sul became homeless (*desabrigados*) from the floods and their impacts. Floods affected 270 municipalities in Paraná, 199 in Santa Catarina, and 191 in Rio Grande do Sul (*Jornal do Brasil,* Retrospectiva 83, 31 December 1983). In addition to government emergency relief activities, the Brazilian public became involved in relief operations by sending hundreds of tons of food, clothing, and medical supplies into the region.

The 1982-83 rainfall had a major adverse impact on various stages of crop growth and development in southern Brazil. In addition, different agricultural operations, from preparation of the soil to harvesting, were adversely affected. The crops most damaged were corn, soybeans, cotton, coffee, and potatoes in Paraná; corn, soybeans, beans, and rice in Santa Catarina; and rice, potatoes, beans, corn, and soybeans in Rio Grande do Sul (MINTER, 1983).[1] The impacts of the excessive rainfall in Paraná in 1982-83 are shown in Table 5.3. The decline in the 1982-83 harvest in the state of Santa Catarina is shown in Table 5.4.

The rainfall in Santa Catarina in 1983 became more intense from May onward, although abnormal rainfall had occurred since the previous September. Of the state's 199 municipalities, 124 declared a state of public emergency during the floods. Total crop losses for the 1982-83 agricultural year were estimated in U.S. dollars at $924 million. Losses in the Goods Circulation Tax for agricultural and livestock products were estimated at about US$95 million. Livestock losses were estimated at about 800,000 poultry, 6,500 swine, and 43,000 cattle. Also, water erosion was responsible for the loss of an estimated 25 million tons of fertile topsoil.

Indirect effects of the anomalously heavy rains included, but were not limited to, reduction in the quality of the various crops, reduction in industrial output, loss of fertilizers, constraints on the marketing of agricultural production, increases in the costs of production, increases in prices, and unemployment of seasonal laborers. Excessive rains during harvest, reduced credit availability, and increased input costs combined in 1983 to reduce the production of most crops in the major commerical producing areas of southern Brazil (USDA, 1984). Disappointing harvests of export crops such as coffee and soya as a result of flooding also exacerbated Brazil's external trade deficit.

Table 5.3: Losses Caused by Excessive Rainfall in the State of Paraná, for 1982-83 Crops

	LOSS	
Crop	**Tonnage**	**Cost (in million US $)**
Corn	750,000	156.1
Beans	260,000	135.5
Soybeans	185,000	78.0
Cotton	154,000	128.2
Potatoes	145,000	75.7
Coffee	23,000	66.9
Sunflowers	18,700	61.3
Rice	17,000	72.5
Sorghum	10,000	1.7
Peanuts	6,000	1.7
Total	**1,568,700**	**777.6**

Source: SEAG (Secretaria da Agricultura do Paraná), 1983

Table 5.4: Losses Caused by Excessive Rainfall in the State of Santa Catarina for 1982-83 Crops

	CROP PRODUCTION (Tons)		AMOUNT OF LOSS	
Crop	**Estimated Yield**	**Harvested Yield**	**(Tons)**	**(%)**
Rice	431,100	395,000	36,100	8.4
Potatoes	163,230	118,494	44,736	27.4
Beans	324,000	162,428	161,500	49.8
Apples	74,000	57,338	16,662	22.5
Corn	2,860,000	1,687,300	1,172,700	41.0
Soybeans	600,000	405,400	194,600	32.4
Total	**4,452,330**	**2,825,960**	**1,626,298**	**36.5**

Source: CEPA (Comissão Estadual de Planejamento Agrícola), 1983

The decline in area planted, production, and yield between the 1981-82 season and the 1982-83 season, a decline that was largely attributed to the impacts of climate, is shown in Table 5.5. Indeed, all regions, except the semiarid Nordeste, suffered from floods in 1982, while the Nordeste suffered from drought. During the first half of 1983, the south and the Nordeste together lost US$875 million in agricultural production, or approximately 10% of the total volume of expected production in that year (*Folha de São Paulo,* 14 July 1983).

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[1] Southern Brazil is an important agricultural region and contributes the following percentages of crops to national production: 78% of soybeans, 87% of wheat, 34% of rice, 57% of corn, 34% of beans, 50% of potatoes, 44% of onions, and 79% of tobacco.

Conclusion

Different climatic anomalies affect a nation's economy and society in different ways. The southern and northeastern regions of Brazil are different not only from a climatic point of view, but also with regard to levels of development. Southern Brazil is economically more developed, with a modern agricultural base, a higher degree of industrialization, and a higher and more evenly distributed income. The impact of floods on agricultural production in this region was extensive and caused a decrease in per capita income, but it did not affect the ability of that population to subsist. In fact, the resilience of that population to recover from climate-related shocks has proven to be very high.

Because northeastern Brazil is relatively less developed, however, and because the average income is considerably lower and its distribution among segments of the population is more uneven, a substantial percentage of the region's population is vulnerable to drought episodes. Therefore, the impacts of the recent (as well as earlier) droughts were considerably more pronounced. A primary impact of drought on agricultural production activities is the elimination of employment opportunities and, as a result, millions of workers become jobless. During the 1983 drought year the government had to employ directly more than 2.8 million people.

Many researchers and policymakers have suggested that societal impacts in Brazil could be reduced, if the occurrence of a flood or a drought could be forecast with some degree of reliability. While the research of meteorologists and climatologists offers much promise, government planners and policy makers must become involved in the application of the findings of that research. Since the climatic anomalies in Brazil discussed in this chapter are recurrent, aperiodic phenomena, society must prepare to deal with them on an ongoing basis.

Table 5.5: Beans—Harvested Area, Crop Production and Yield in Selected States and Regions 1981-82 to 1982-83

REGIONS/STATES	AREA (1000 ha)		PRODUCTION (1000 t)		YIELD (kg/ha)	
	1981-82	1982-83	1981-82	1982-83	1981-82	1982-83
South						
Paraná	880.0	746.0	666.8	365.0	758	489
Santa Catarina	373.0	421.0	318.0	165.0	853	392
Rio G. Sul	213.4	187.4	146.7	92.4	687	493
Southeast						
Sao Paulo	617.8	510.7	470.2	315.1	761	617
Espirito Santo	110.0	62.5	55.4	26.6	504	426
Minas Gerais	750.7	545.4	349.3	243.8	465	447
Rio de Janeiro	26.0	23.4	16.7	14.3	642	611
Central-West						
Mato G. Sul	50.7	39.5	26.6	19.7	525	499
Mato Grosso	66.2	80.7	33.6	23.7	508	294
Distrito Federal	1.5	0.9	0.9	0.6	600	667
Goias	232.0	206.9	95.7	85.7	413	414
Central-South*	3,321.3	2,824.4	2,179.9	1,351.9	656	479
North-Northeast	2,966.1	1,443.3	961.6	345.0	324	239
Brazil	6,287.4	4,267.7	3,141.5	1,696.9	500	398

(*Central-South = South + Southeast + Central-West)

Source: IEA (Instituto da Economia Agrícola), Prognóstico da Ragião Centro-Sul, 1983-84, p. 92

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Chapter 6

THE 1982-83 DROUGHT IN INDIA: MAGNITUDE AND IMPACT

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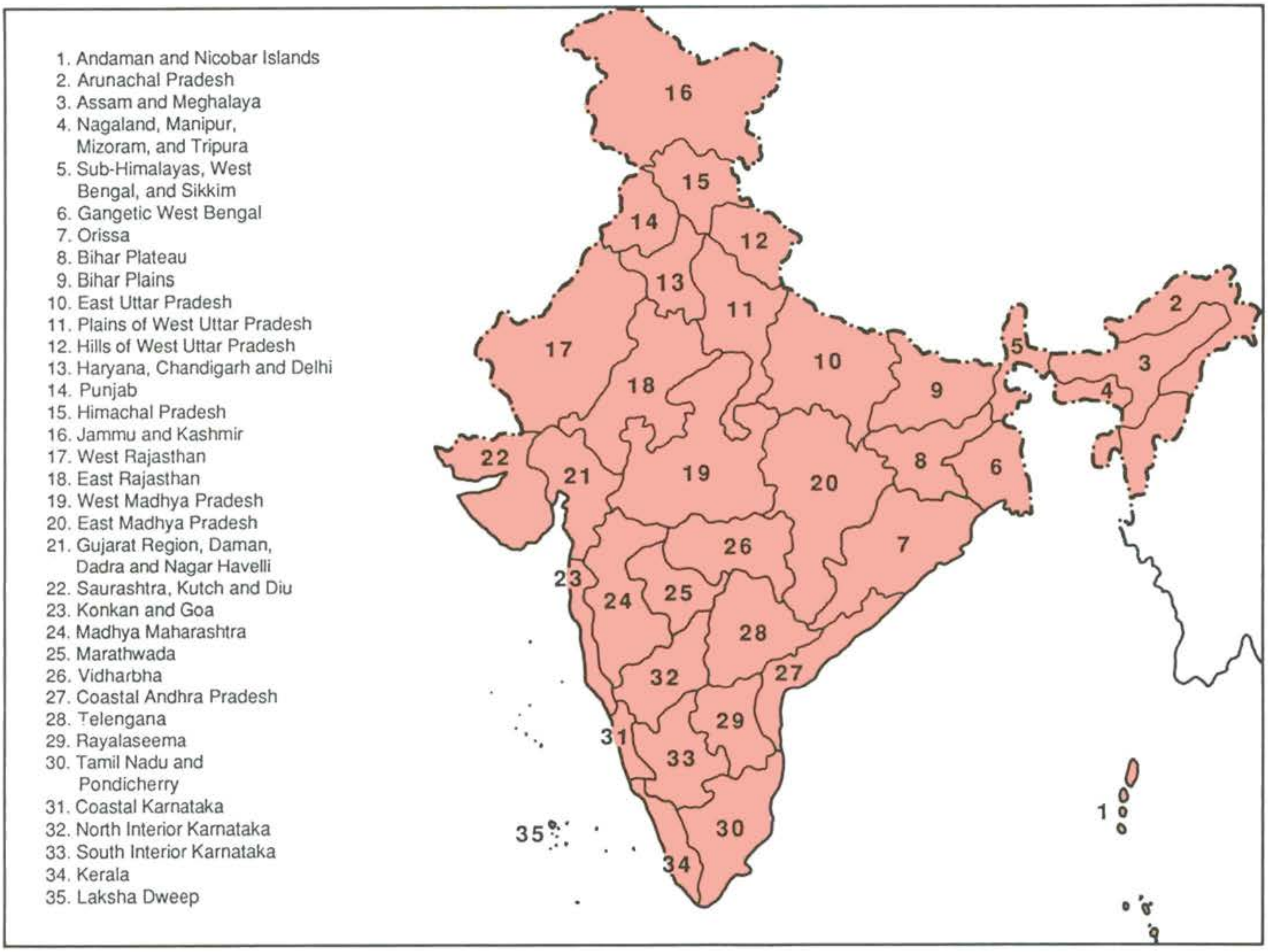


Fig. 6.1 Meteorological zones of India

Drought in India

Growth slowed in all South Asian economies during 1982/83 mainly because of a poor monsoon in 1982 that damaged fall harvests. India, Sri Lanka, and Nepal were most severely affected.

For ages monsoon-related weather changes have influenced the life of people on the Indian subcontinent. The monsoon is a major source of water in India. In a large and topographically diverse country like India, an erratic or abnormal monsoon causes both droughts and floods simultaneously in different parts of the country. For almost a century, scientists have attempted to study the causes of anomalies in the monsoon to enable prediction of rainfall quantities and patterns (e.g., Das, 1984; Walker, 1924). It is now recognized that the surroundings of the Indian subcontinent alone do not determine the monsoon. Events in the Southern Hemisphere could have a profound effect on monsoon activity over the Indian subcontinent.

One of the major effects of the failure of monsoons is drought. There are good records of droughts in India for the past hundred years, though references to droughts and famines can also be found in the ancient history of India, extending back several thousand years. One of the worst droughts in recorded history occurred in 1899, when about three-fourths of the country's area experienced a rainfall deficit. Droughts in 1918 and 1972 affected more than 73% and 43% of the area of the country, respectively (Sinha et al., 1986).

Among more recent droughts, the 1982-83 drought was "one of the worst in recent memory" in, for example, Gujarat (Randhawa, 1984). Throughout the country, it affected 11 out of 35 meteorological divisions, the important ones being Bihar

Table 6.1: Rainfall During Southwest Monsoon Period (June-September)

Subdivision	Normal (mm)	1982 Actual (mm)	Departure (%)	1979 Actual (mm)	Departure (%)
1. Andaman and Nicobar Islands	1,586	-	-	1,123	-29
2. Arunachal Pradesh	1,907	-	-	1,609	-16
3. Assam and Meghalaya	1,415	1,427	1		
4. Nagaland, Manipur, Mizoram, and Tripura	1,218	1,080	-11	1,281	2
5. Sub-Himalayan, West Bengal, and Sikkim	2,226	1,940	-13	1,778	-21
6. Gangetic West Bengal	1,046	900	-14	991	-9
7. Orissa	1,121	1,013	-10	902	-19
8. Bihar Plateau	1,087	735	-32	736	-33
9. Bihar Plains	1,032	692	-32	854	-19
10. East U.P.	897	948	6	435	-51
11. Plains of West U.P.	756	696	-8	399	-49
12. Hills of West U.P.	1,622	1,164	-28	953	-38
13. Haryana, Chandigarh, and Delhi	509	460	-10	331	-35
14. Punjab	441	361	-18	285	-38
15. Himachal Pradesh	1,313	771	-41	578	-56
16. Jammu and Kashmir	373	287	-23	257	-32
17. West Rajasthan	291	191	-35	282	-3
18. East Rajasthan	624	523	-16	476	-26
19. West M.P.	933	964	3	616	-34
20. East M.P.	1,190	1,107	-7	687	-42
21. Gujarat Region, etc.	767	558	-27	618	-20
22. Saurastra, Kutch	551	277	-50	904	64
23. Konkan and Goa	2,536	2,292	-10	1,913	-25
24. Madhya Maharashtra	508	438	-14	574	12
25. Marathwada	642	528	-18	685	6
26. Vidarbha	983	718	-27	956	0
27. Coastal A.P.	545	458	-16	400	-29
28. Telangana	765	818	6	618	-20
29. Rayalseema	417	296	-29	351	-17
30. Tamil Nadu and Pondicherry	282	355	26	175	-37
31. Coastal Karnataka	2,931	2,594	-11	3,518	14
32. North Interior Karnataka	575	628	9	536	-6
33. South Interior Karnataka	404	540	34	328	-12
34. Kerala	1,735	1,750	1	1,528	-11
35. Laksha Dweep	992	1,147	16	992	0

Plateau, Bihar Plains, West Rajasthan, Saurashtra, Vidharba, and Rayalseema, in addition to some smaller divisions (Fig. 6.1). The India Meteorological Department uses the following definition of drought (relative to mean rainfall):

+20% or more	Excessive rainfall
+19% to −19%	Normal rainfall
−20% to 59%	Deficient rainfall (drought)
−60% or more	Scanty rainfall (severe drought)

The total area affected by drought was approximately 37% of the country. This drought is now being associated with the 1982-83 El Niño/Southern Oscillation (ENSO) event. Apparently, several earlier droughts also coincided with ENSO events, though they were of lesser magnitude (Shukla and Paolino, 1983).

In recent times, however, the widespread drought of 1979-80 was the most severe, accounting for a 20-54% water deficit in about 41% of the country's area. It affected 11 out of 35 meteorological divisions which included the country's most productive agricultural areas. This drought received little attention around the world because there was neither famine nor the need to import food grains. Interestingly, there has been no apparent linkage between this drought and an ENSO event. It is also interesting that most of the divisions (except Bihar Plateau) that experienced drought in 1979-80, escaped drought in 1982-83; the divisions that had normal rainfall in 1979-80 were drought-affected in 1982-83 (i.e., Bihar Plateau, the hills of West Uttar Pradesh, and Himachal Pradesh) (Table 6.1).

Despite extensive studies, Indian scientists have not yet found definite cycles of abnormal monsoon. They have also not been able to predict the pattern of rainfall, particularly its onset, withdrawal, and intensity. For example, it was predicted that the 1985 monsoon would be normal. It began late and was followed by a long break of 21 to 28 days in different parts of the country. The normal withdrawal time is early September from north India, but the late monsoon was vigorous and rains continued until early October. Thus, sometimes a year might end as "normal" from the point of view of total rainfall, but because of its distribution during the year it could have caused drought and failure of crops. This was the case in 1982-83. The monsoon began late, but at many places 150 to 250 mm of rain was recorded within 24-hour periods. Such events cause serious difficulties for agricultural operations. Nonetheless, through experience and extensive available data for the past 100 years, some general conclusions about the recurrence of drought have been made (Table 6.2).

Table 6.2: Recurrence of Drought

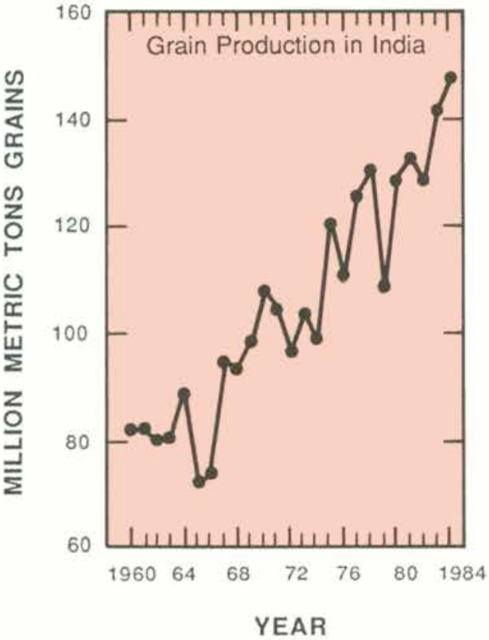
Meteorological Subdivision	Recurrence of Severe Drought
Assam	Very rare, once in 15 years
West Bengal, Madhya Pradesh, Konkan, Coastal Andhra Pradesh, Maharashtra, Kerala, Bihar, Orissa	Once in 5 years
Southern Interior Karnatka, Eastern Uttar Pradesh, Vidarbha	Once in 4 years
Gujarat, Eastern Rajasthan, Western Uttar Pradesh, Tamil Nadu, Kashmir, Rayalseema, Telengana	Once in 3 years
Western Rajasthan	Twice in 5 years

In spite of what is known about monsoons, it has not been possible to predict a bad monsoon year. Sometimes, two or three consecutive years can be bad ones. Over the years, however, people and the Government have prepared themselves to face an abnormal monsoon that can cause both floods and droughts.

General Impacts of Droughts

Despite heavy industrialization, 50% of India's gross national income is derived from agriculture. Any adverse climatic factor that influences agriculture thus influences not only individual farmers but the national economy as well. Indian droughts result in crop losses of different magnitudes, depending on their geographic scope, intensity, and duration. In 1982-83 there was a 3.7% decline in agricultural production because of drought.

Fig. 6.2 Grain production in India



1960 refers to 1960 - 1961 and so on.

National production figures may sometimes hide the serious and disastrous effects in a particular region. However, the national production data are important for governmental planning and action. Total food grain production in India has shown a continuous upward trend, although it is characterized by peaks and troughs (Fig. 6.2). For example, a peak of

131.4 million tons of food grain production was reached in 1978-79. It was followed by a low production of 109 million tons in 1979-80, which happened to be one of the worst agricultural droughts in this century. Thus, within a year the production dropped by 22.4 million tons. It rose again to 129.5 and 133.3 million tons in 1980-81 and 1981-82, respectively.

Though the 1982-83 drought affected 11 of 35 divisions, the reduction in total grain production was only five million tons, a remarkable achievement for Indian agriculture.

Food for work program

In times of drought there is a shortage of food, fodder, and drinking water in particular regions. The food is available, but the people do not have the purchasing power because there is hardly any work. Therefore, the government introduced a program called "Food for Work" for all able-bodied persons. People are paid primarily in the form of grains for the work that is mostly directed toward the conservation of land and water. This helps to reduce hardships in subsequent years. The Food for Work program has been reasonably successful and has sparked proposals to develop new programs such as "Food for Aforestation" or "Food for Soil Protection."

Distribution of Production in India

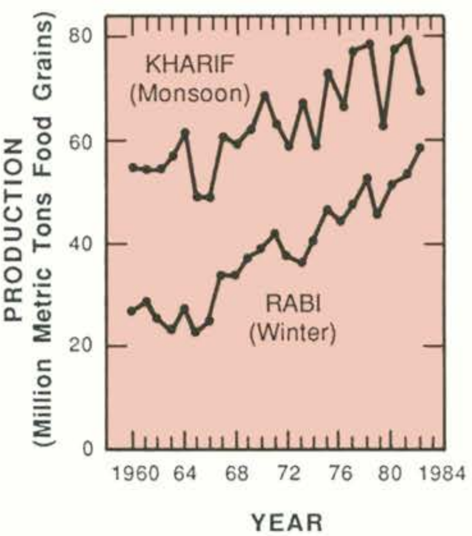
As noted earlier, India is divided into 35 meteorological subdivisions, about ten of which make major contributions to grain production. These divisions include Punjab, Haryana, West Uttar Pradesh, Coastal Andhra Pradesh, Tamil Nadu, Bihar Plains, and West Bengal. Most of the other divisions essentially have self-provisioning farming. Consequently, marketable surpluses of food grains are obtained from a few divisions, such as Punjab, Haryana, West Uttar Pradesh, Coastal Andhra Pradesh, and Tamil Nadu, and reduced crop production in these divisions can cause serious adverse effects on the national agricultural economy.

The food grain production occurs in two main seasons, *kharif* (monsoon) and *rabi* (winter). Food production during the former is almost completely dependent on rainfall obtained during this season. The *kharif* season is characterized by relatively high temperatures and high evapotranspiration. In contrast, the winter crop production is dependent on stored soil moisture and winter rains that result from storms that originate to the west and are not associated with monsoon. This crop season has relatively lower temperatures and lower evapotranspiration rates. Even the response of crops to fertilizers is more assured as a result of the availability of irrigation. When there is failure or abnormality of monsoonal rainfall, efforts are made to increase production during the winter season. The main crops of this season are wheat, barley, gram (chick-pea), and rice in the coastal areas. Over the years, winter production has kept increasing, and the difference between the two seasons has narrowed (see Fig. 6.3). Oilseeds are the second most important farm commodity produced in India, after food grains (USDA, 1984, p. 20).

Effect of 1982-83 Drought on Production

In 1982 the Indian monsoon arrived late, was erratic, and withdrew early from key agricultural production areas. This led to a sharp decline in 1982-83 fall harvests of rice, coarse grains, and oilseeds. This "abnormal" monsoon season (*kharif*) resulted in reduced food grain production by ten million tons, from 79 million tons in 1981-82 to 69 million tons in 1982-83. However, the winter production increased from about 54 million tons in 1981-82 to about 59 million tons in 1982-83, a net gain of five million tons. Thus, despite a drought, the year ended with a loss of only 5 million tons. The winter season cultivation provides a buffering action to the vagaries of climate and receives considerable attention by farmers as well as by the government.

Fig. 6.3 Food grain production in the kharif *and* rabi *season.*



1960 refers to 1960 - 1961 and so on.

The weak 1982 monsoon reduced plantings and yields in the major producing areas during the *kharif* season, resulting in more than a 10% decline in total 1982-83 oilseed production. Production in the winter was more secure, primarily because of irrigation.

Tables 6.3 and 6.4 show rice and wheat production in some states. Rice production was badly affected in Madhaya Pradesh, Orissa, and Uttar Pradesh in 1979-80, but was reduced by 25% in Orissa in 1982-83. In other states the effect was marginal. In Punjab, where rice is a completely irrigated crop, there was no reduction of production in 1979-80 and there was an actual increase in 1982-83. Wheat production is much more stable. Despite drought, there was increased production in all the five major wheat-producing states (Table 6.4), partly as a result of the availability of irrigation, and partly as a result of favorable winter rains from January to March 1983.

The effect of the 1982-83 drought could also be seen in the levels of procurement of rice and wheat. There was no increase in the marketable surplus of rice over 1981-82 deliveries, but wheat purchases by the government increased in 1982-83 approximately 15% over 1981-82. This shows, once again, that rainfall in 1982 had some effect on the monsoon season production but had little or no effect on winter season production.

Research stations of the All-India Coordinated Project on Dryland Agriculture are distributed around the country. One of these centers in Gujarat (Dantiwada) received somewhat below "normal" rainfall. In addition to starting late, most of the rains came on only two occasions, resulting in a sharp reduction in the yield of pearl millet (Table 6.5), but only 30-40% reduction in cowpea and castor bean. Low-yielding species of green gram (mung bean) were hardly affected, nor were local low-yielding variety of pearl millet, suggesting that a low-yielding technology is less sensitive to drought. However, such technology has little chance to take full advantage of favorable conditions in other years.

In Punjab the yield of *kharif* crops such as maize was affected, but with improved technology was maintained around 30 q/ha. However, in *rabi,* the winter rains helped to produce 35 q/ha of wheat in drylands.

Since droughts have been a common feature on the Indian subcontinent and have often been followed by famines, the governments at the time have pursued food-related policies that depended upon their attitude towards the people. The earliest writings in *Arthashastra* (Economics) by Chanakya in 321 B.C. said, "Famine relief was a special care of the state, and half the stores in all the state warehouses were always kept in reserve for times of scarcity and famines." Thus, the concept of buffer stocks maintained by the government is very ancient in India, and most rulers followed it until the beginning of the colonial era.

Following the severe droughts of 1966-67, the idea was again revived but at that time no surplus harvest was available. Nevertheless, in the 1970s buffer stocks were established through market purchases by the government. In 1982-83, the government had a buffer stock of 18 million tons; thus, it was somewhat less difficult to compensate for a five-million-ton shortage in food grain production. Had the government not intervened and supplied food to the needy at a reasonable price, the situation could have become difficult for the landless laborer and for nonagricultural communities. The All-India Index of Wholesale Price of all cereals increased by 2% between January 1982 and August 1982. By this time, the impact of the poor monsoon was apparent. The wholesale price index increased by almost 12% between August 1982 and 1983. The maximum increase occurred in the price of rice, followed by pulses and wheat (Fig. 6.4). Thus, relatively speaking, wheat served as a price-stabilizing factor for food grains. A survey of prices in different Indian states showed that, in fact, they had varied considerably from one location to the next. Food price increases were mainly the result of shortages associated with the 1982-83 drought, and with the 1983 favorable monsoon and record setting crop production, wheat prices, for example, declined.

Table 6.3: Variability in Rice Production in Four States in India (production in million metric tons)

State	1978-79	1979-80	1980-81	1981-82	1982-83
Madhya Pradesh	3.56	1.83	4.00	3.83	3.40
Orissa	4.40	2.92	4.32	3.85	2.90
Punjab	3.09	3.04	3.22	3.75	4.15
Uttar Pradesh	5.96	2.55	5.44	5.90	5.53

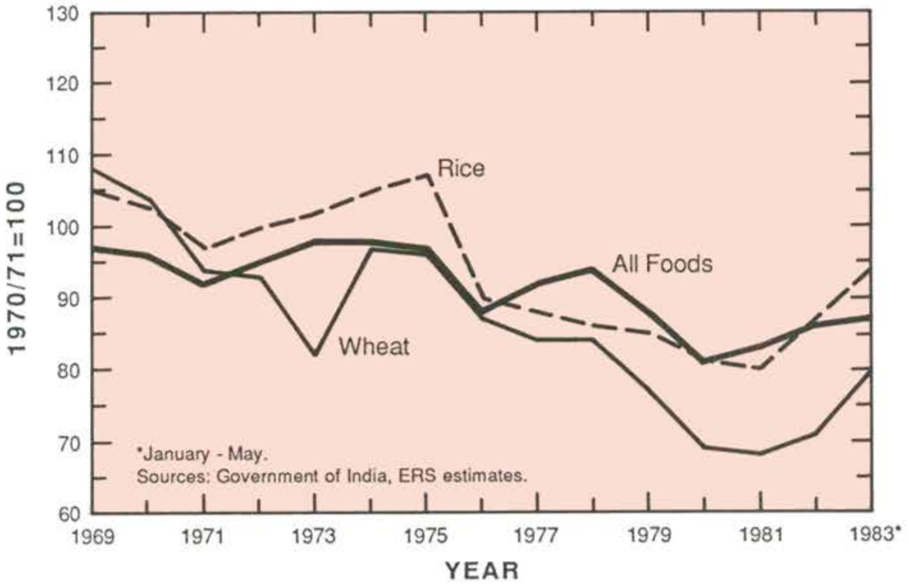
Table 6.4: Variability in Wheat Production in Five States in India (production in million metric tons)

State	1979-80	1980-81	1981-82	1982-83
Madhya Pradesh	2.15	3.06	3.31	3.68
Haryana	3.28	3.60	3.68	4.35
Punjab	7.89	7.70	8.55	9.18
Rajasthan	2.70	2.39	2.93	3.78
Uttar Pradesh	9.89	13.13	12.75	15.29

Table 6.5: Experimental Yields at Dryland Agriculture Research Centre, Dantiwada, Gujarat (yields in quintals/ha)

	1979	1980	1981	1982	1983	1984
Rainfall (mm)	287.3	475.1	467.7	489.4	445.4	525.5
Green gram (mung bean) T 44	3.32	4.52	8.60	8.28	7.90	10.03
Pearl millet, B.J. 104	3.90	19.80	18.43	6.51	29.66	18.72
Cowpea, Chharodi-1	-	9.83	13.06	7.63	12.21	10.87
Castor, Gauch-1	17.97	11.57	14.29	7.67	13.30	-
Clusterbean, FS-277	2.68	1.93	7.12	2.92	-	-

Fig. 6.4 Deflated wholesale price indexes for wheat, rice, and all foods in India.



*January - May.
Sources: Government of India, ERS estimates.

Concluding Remarks

Weak monsoons and consequent water deficit resulting in drought in some parts of the country are a normal feature of Indian climate. What we call "normal" monsoon or rainfall is, in fact, only an average and is rarely experienced in quantity and distribution. What can safely be predicted is that no year will be a normal monsoon year based on the average. Therefore, the government must remain vigilant and prepared to meet any eventuality. Buffer stocks built up in good monsoon years, government price supports for food grains, public distribution systems, and making winter season agriculture more productive are some of the appropriate measures that have been taken.

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Chapter 7

THE IMPACT OF THE 1982-83 EL NIÑO EVENT ON CROP YIELDS IN CHINA

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Introduction

This chapter summarizes the 1982-83 El Niño as it relates to China and analyzes the impacts of El Niño-related climatic anomalies on crop yields in China on a regional basis over the two-year period. Although the connections between these El Niño-related events and crop yield fluctuations in China tend to be less dramatic and less obvious than those in other countries, significant connections at a regional level can be detected. The problem of separating the effects on crop yields caused by fluctuations in climate from changes in relevant policy or technology is discussed, since this traditional problem in crop-climate analysis is particularly acute in longitudinal studies of Chinese agricultural production (Hsu, 1982). A map of Chinese provinces (Fig. 7.1) provides a reference to regions and provinces discussed in this chapter.

Crop Yield Data in China

It is well known that crop yields are significantly affected by social policy and technological factors. Recent studies by Tang (1980) and Kueh (1984) have demonstrated significant correlations between policy-cycle fluctuations and grain yield fluctuations since the time of the establishment of the People's Republic of China.

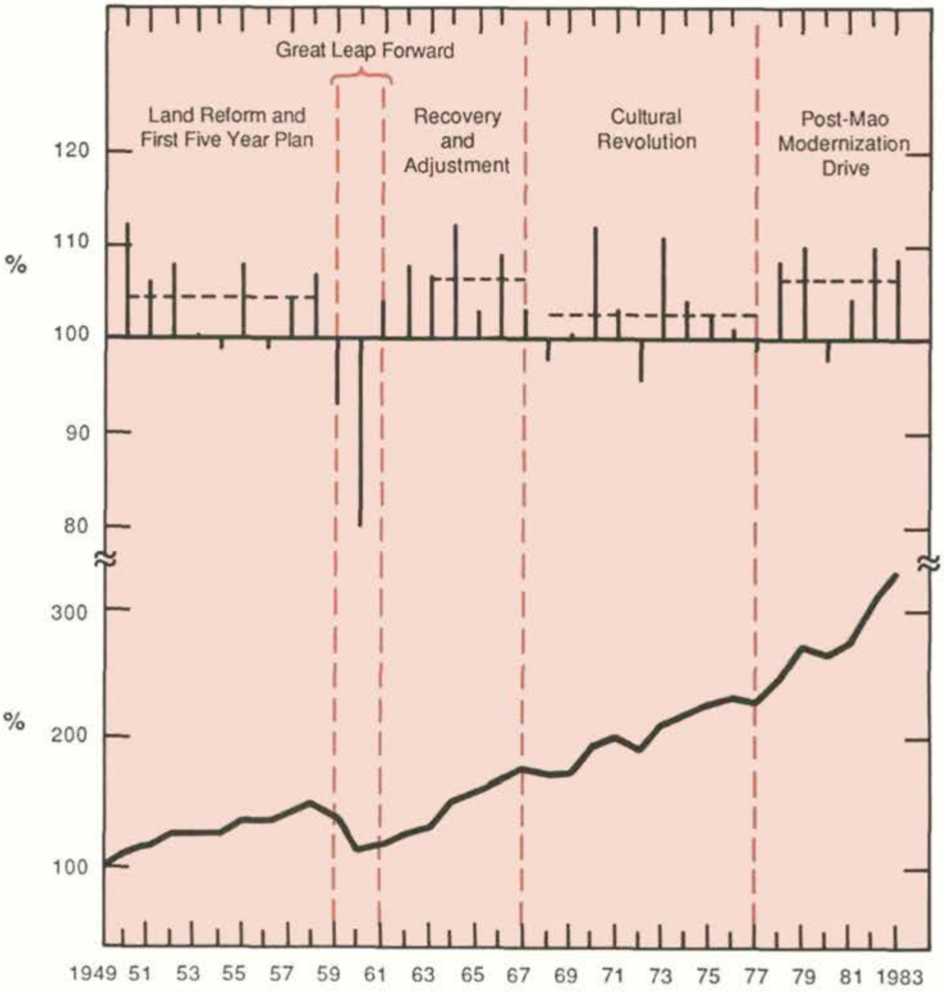
Political policy cycles in China can be categorized in several ways. Approximately five periods are generally recognized (Tang, 1980; Hsu, 1982), although the specific years included in each period vary. According to Hsu (1982), these periods include Land Reform and the first Five-Year Plan (1949-1957), the Great Leap Forward (1958-1960), the Recovery and Adjustment period (1961-1965), the Cultural Revolution (1966-1976), and the post-Mao Modernization Drive (1977 or 1978 to at least 1984). When researching the influence of factors such as climate on crop yields, it is important to account for the effects of social policy as much as possible. In a previous study of El Niño events and harvests in China (Wang, in press), a linear trend representing technological

Fig. 7.1 Provinces of China.

change was removed from the original yield series reported by the Agricultural Ministry of China. Yield anomalies attributed to climatic fluctuations (assumed to be the residuals around the linear trend), were obtained and expressed in percentage deviation from the trend. In the 1980s crop yields increased significantly compared to earlier periods, but the time interval has been too short to allow for a separate linear trend; instead, only the rate of yield increase is examined.

The curve in the lower part of Fig. 7.2 shows the grain yield for China, expressed as a percentage of the yield in 1949.[1] In Chinese agricultural statistics, the grain category includes the following crops: wheat, rice, coarse grains (corn, sorghum, millet, barley, and oats), soybeans, pulses, and the grain-equivalent-weight of tubers (USDA, 1982). In the upper part of Fig. 7.2 the ratios of yield (in percentage of the yield from the previous year) are given. The five broken lines represent the average for the period covered. It is quite clear that these ratios are connected to social factors. During the early years of the People's Republic the grain yield increased steadily except in 1954 and 1956, when China suffered from the most serious floods observed in 100 years. The 1959-61 period was characterized in the north by severe drought, under the influence of which grain yields decreased sharply. Flooding was also prominent in the south during the same period.

Fig. 7.2 Top: *each year's yield as a percentage of the previous year's yield. Dashed lines represent mean values for the years indicated.* Bottom: *grain yields as percentages of the yield in 1949. Approximate time periods of political cycles are indicated by vertical dashed lines.*



The social and political factors in this period were also significant, for this period immediately followed the initiation of the Great Leap Forward (1958). The political objectives of the Great Leap were to mobilize rural resources to accelerate the development of agriculture and light industry. Unfortunately, some of the structural changes instituted in the transformation from collectives to communes were deleterious to efficient agricultural management (Hsu, 1982). For example, decision-making power in agricultural management was given to individuals who lacked farming experience. Hence, inappropriate technical considerations, such as deep plowing and poorly designed irrigation systems interacted with the less-than-optimal weather to seriously reduce yields. The rate of increase in 1961 and 1962 does not indicate an absolute increase of yield, since the 1962 yield was still lower than that in 1958. Therefore, the period 1959-62 can be regarded as a special period of lower yield.

From 1963 to 1967, the grain yield increased steadily once again, exhibiting the highest rate of increase of the preceding 30 years. This period is generally referred to as Recovery and Adjustment from the approaches of the preceding period.

During the so-called Cultural Revolution (1966-76), grain yield either decreased or increased insignificantly. The higher rates of increase in 1970 and 1973 are linked with lower yields in the previous years. The Cultural Revolution is the period of the second lowest rate of yield increase since 1949.

After 1976 (post-Cultural Revolution), the social and political factors became more favorable for maintaining high rates of increase in yield,

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[1] Yield data were provided by the Agricultural Ministry of China.

Table 7.1 Ratio (%) of Grain and Other Crop Yields in Pairs of Successive Years*

	1978/77	1979/78	1980/79	1981/80	1982/81	1983/82	Mean
Grain	108	110	98	104	110	109	106.5
Rice	110	107	97	105	113	105	106.2
Wheat	126	116	88	112	116	115	112.2
Cotton	105	110	112	104	108	124	110.5
Rapeseed	137	121	97	128	128	85	116.0
Sugar Cane	110	109	113	113	105	84	105.7
Peanuts	115	101	113	100	105	111	107.5
Soybeans	100	97	107	106	92	120	103.7
Potatoes	102	96	109	96	106	109	103.0
Beets	117	117	149	102	99	116	116.7

*The ratios of the yields in two successive years are given in percentages. If 100% is subtracted from the ratios, the rate of change can be seen. The mean rate of change for the time period is given in the last column (if 100% is again subtracted).

although 1980 was one of the years in which a series of climatic events considerably diminished yield. Preliminary information suggests that the grain yields in 1984 and 1985 have increased successively. It is believed that the interval of time beginning in 1978 will become the period with the highest rates of increase, although the mean rate of increase for 1963-67 and for 1978-83 is approximately the same.

The 1982-83 El Niño occurred in the last political/policy cycle (the post-Mao Modernization Drive), so the mean rate of increase in yields during 1978-83 is used as the norm to investigate the effects of meteorological factors, including El Niño. Later, this base period is used not only for grain yield but also for individual crop yields because the social and political factors of this period that affected agriculture were relatively uniform for all crops. Although this approach might not be the best one, it does provide a reasonable base for investigating the impact of the 1982-83 El Niño on crop yields.

Climate and Crop Yields in 1982

In general, climatic conditions for the 1982 crop seasons were favorable for increased grain yield. Dry conditions, however, prevailed from fall 1981 through spring 1982 in parts of the North China Plain, a highly productive grain area. Summer dryness predominated in the northeast provinces, whereas in central China the summer was distinctly cold and wet. Climatic conditions in the south, where rice production dominates, were primarily very favorable. Average precipitation and normal temperatures were present throughout the growing season.

The ratios of grain yield and the yields of other crops are given in Table 7.1. It shows that, for China as a whole, the yield increase in 1982 was not lower than normal (represented by the mean increase) for grain in general, nor for rice, wheat, rapeseed, or potatoes. However, the increases for cotton, and peanut were lower than normal. The yields even decreased absolutely (indicated by ratios of less than 100) for soybeans and beets.

As stated earlier, the summer of 1982 was very cold in central China, and was accompanied by severe flooding in the area between the Huangho (Yellow) and Changjiang (Yangtze) rivers. It is easy to see that the reductions in absolute yield of soybeans, beets, and peanuts, as well as the smaller rates of increase in the yields of sugar cane and cotton, are associated with the lower temperature; but the drought in the north, especially in Nei Monggol and northeast China, undoubtedly also had a part in reducing the yields.

The influence of the drought in northeast China is demonstrated in Fig. 7.3. The increase in grain yield in that region was 10% below normal in 1982 (Fig. 7.3, upper map), despite the fact that the grain yield average for all of China was 3.5% greater than normal (Table 7.1). The lower grain yield in northeast China cannot be attributed solely to reduced wheat yields, especially in Jilin and Heilongjiang provinces. Reduction in soybean and coarse grain output (corn, sorghum, and millet) also contributed to the aggregate decrease. Figure 7.4 shows that in 1982 the wheat yield in Jilin increased by 6% over that of 1981, and in Heilongjiang it decreased by only 7%. Both figures are less than the 8% and 12% decrease in total grain yield in the respective provinces.

In southern China the 1982 climatic conditions were favorable to grain yield. Good harvests of wheat and rice (Figs. 7.4 and 7.5) contributed to a 10% increase in grain yield over 1981.

A determination of climatic effects on rice yield is particularly complicated since there are five different rice crops: early (harvested in early summer), intermediate, single crop late, double crop late, and northern (the last four harvested in autumn). Hence, the effect of weather on these crops is partially dependent on the varying sowing and harvesting dates. In 1982 weather was generally good for both early and late harvests. Excellent fall weather in particular boosted yields of the higher-yielding intermediate and single late crops.

The expanded use of higher yielding varieties was also a factor in the 12% increase over 1981 yields (based on USDA calculations, 1983). The sown area of hybrid rice (which makes up 21% of rice planted) increased by 5.6 million hectares, and posted a 10.3% increase in yield (5.7 tons/ha) in 1982 (USDA, 1983).

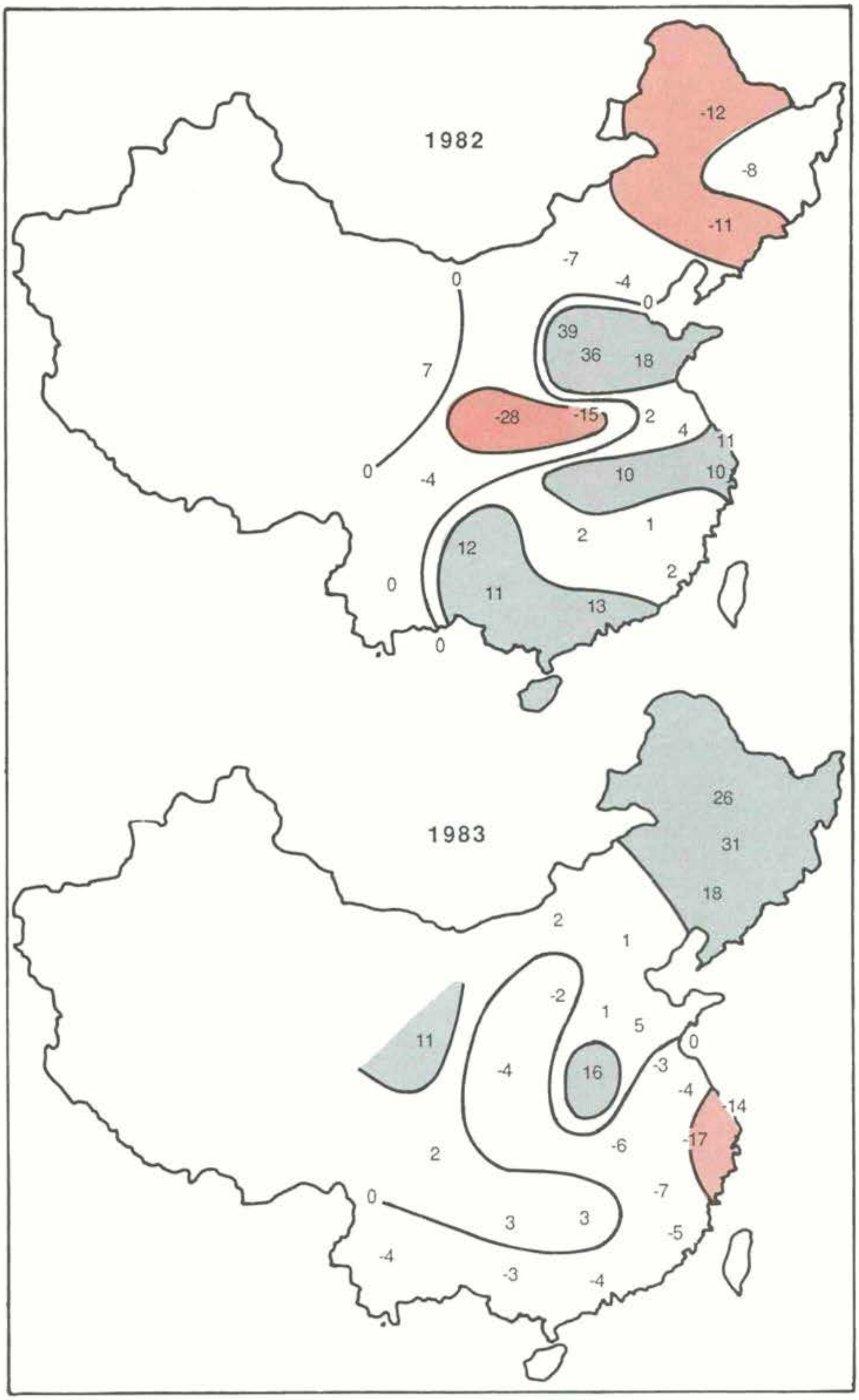

Fig. 7.3 Grain yield anomalies in 1982 and 1983 (percentage of deviation from 1977-1983 mean value).

As mentioned above, the 1982-83 El Niño was delayed relative to previous events, in that the temperature increase in the eastern equatorial Pacific did not exceed 1°C until August. Therefore, it is hard to link the changes in climate and crop yields in China during the summer of 1982 directly to El Niño. The main crop damage resulted from the cool summer in central China and the summer drought in the north, which occurred before the El Niño really matured. However, the climate and the harvest in China during the summer of an El Niño year may be linked to the high sea-surface temperature (SST) in the eastern equatorial Pacific in an indirect way (Wang, in press). It has been demonstrated that most of the cool summers in China and in Japan were observed to have occurred in or near El Niño years (Wang, 1984). Of the 30 cool summers identified in northeast China for the period 1860-1980, 16 were concurrent with El Niño events and 12 occurred either 12 months preceding or following an El Niño year. Wang (1984) has suggested that the cool summers in China and Japan, or in East Asia in general, are linked to the lower SST from the northwest to the central part of the northern Pacific, which is an important concomitant of a high SST in the eastern equatorial Pacific (Reynolds, 1983). The SST was lower than normal during the summer of 1982 in the northwest and central northern Pacific, despite the fact that in the eastern equatorial Pacific the SST did not exceed 1°C warmer than normal until August (see Wang, 1984). Japan suffered from prolonged summer monsoon rain (Mayui) and cold weather in the 1982 summer. The low summertime temperatures in East Asia were similar to that occurring during other El Niño events. Thus, one can suggest that the cool summer, which contributed to reduced yields, is associated with the 1982-83 El Niño.

The Impact of El Niño on Yields in 1983

The climate and the yields in China in 1983 were quite different from those of 1982. The most unusual climate anomaly in 1983 was the winter flood in south China. A flood in the winter in this area had not been previously observed, at least not in the present century for which instrumental observations are available. The anomalous precipitation pattern is shown in Fig. 7.6. The maximum winter precipitation (December 1982 to February 1983) is found in Guangdong province, near Guangzhou, more than 700 mm, exceeding the average by 300%. Precipitation increases of 50% or more predominated in most of south China. Precipitation in the first ten-day period of January 1983, and in the first and third ten-day periods of February 1983 was five to nine times the average. The wet trend persisted to some extent into spring (at least in March and April), which aggravated the damage to wheat and early rice yields, as illustrated in Figs. 7.5 and 7.6. The wheat yield even diminished by 60% from the 1982 yield in Fujian and Guangdong provinces. These extreme reductions in yield were unique to this crop in these provinces, which are not major wheat-producing areas. At the same time, increased precipitation in the North China Plain increased yields in that important wheat-producing region (USDA, 1984).

The unusual winter floods were caused by the unusual intensifying of the subtropical high in the Western Pacific (Wang, in press). The location of the subtropical high, which was west of its normal location (40° longitude), was also unusual. Wang et al. (1984) indicated that the subtropical high in the western Pacific closely correlates with the SST in the eastern equatorial Pacific. Among the indices of the subtropical high, the intensity index has the strongest relation to SST. The subtropical high is intensified when the SST is high and vice versa. The record-breaking intensity of the subtropical high observed in the 1982-83 winter is in good accordance with the unusually strong El Niño event of 1982-83. It is easy to see that the 1982-83 El Niño is the most important link between winter flooding in south China and bad harvests in that region. Yet the precipitation anomalies in other El Niño years are not consistent. Indeed, sometimes there were floods, although of lesser intensity than in 1982-83; at other times there were even droughts. This discrepancy can be explained by the seasonal diminishing of the intensity of the subtropical high, the ridge of which is usually located far from the south coast of the Asian continent, and thus rarely affects the winter precipitation there. But, in an extreme circumstance, as was the case in 1982-83

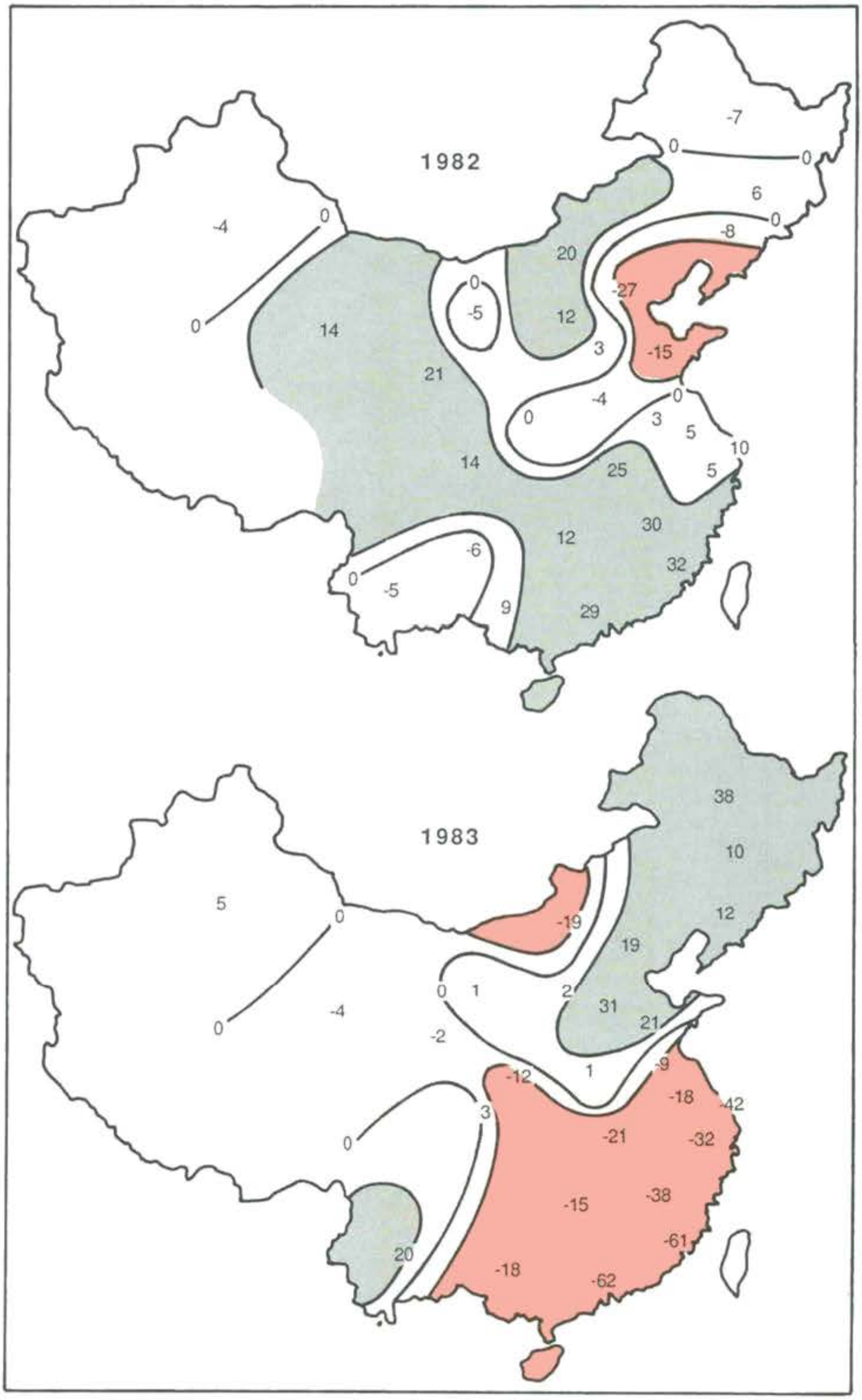

Fig. 7.4 Wheat yield anomalies in 1982 and 1983 (percentages).

when the subtropical high was abnormally intensified and extended toward the continent, it can exert considerable influence on winter precipitation in south China.

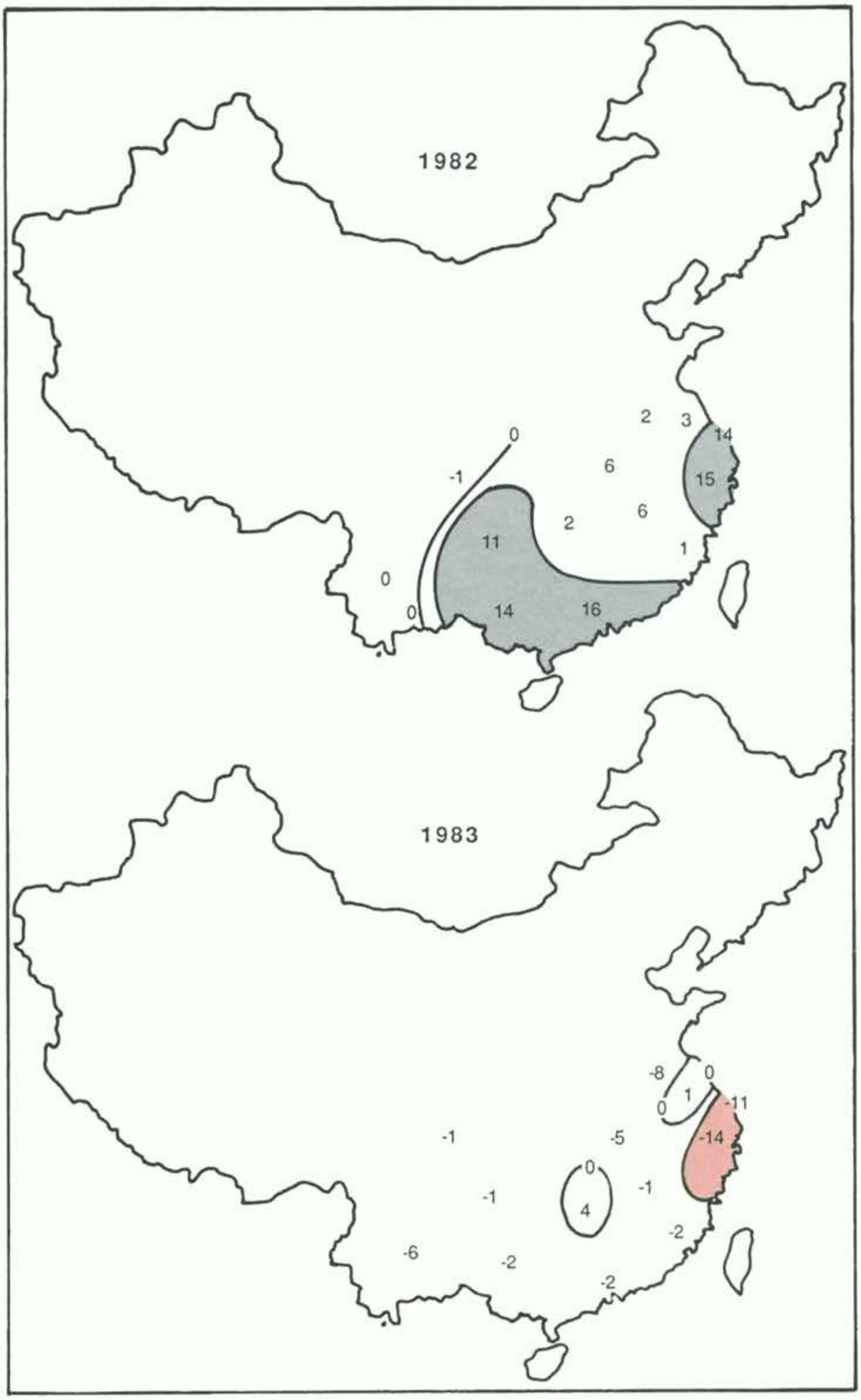

Fig. 7.5 Rice yield anomalies in 1982 and 1983 (percentages).

Climatic conditions were favorable in general for the harvest in the summer of 1983, except that there was drought in the North China Plain and cold weather prevailed in northeast China. Despite these unfavorable conditions, there were record-breaking wheat yields in Helongjiang and Jilin, and the rates of increase were the highest recorded. Of course, wheat is less influenced by the summer climate, but the temperature, at least in early summer, plays some role in wheat yield, especially in northeast China where spring wheat is grown. However, the wheat yield was still good in 1983, mainly because of the favorable climate in winter and spring. The rate of increase in the wheat yield was still higher than normal for the whole of China, although it had decreased significantly in south China. Grain yield increased by 9% compared to 1982, higher than the 6.5% average (Table 7.1).

The effect of the 1983 climate anomalies on rice yields is somewhat complex. The aforementioned heavy spring rains, especially in the Yangtze River Valley, resulted in reduced production of the early rice crop, which obtained yields about equal to those of 1982. The heavy spring and summer rains also delayed planting of the fall-harvested rice crops, which make up 66% of the rice output. Fortunately, warm weather in the fall allowed for the maturing of these late-planted crops, which obtained record high yields and compensated for the relatively low early rice yields. Hybrid rice yield increased 18% over 1982 (USDA, 1984).

The 1982–83 El Niño apparently exerted an influence on the wheat and rice yields in south China. In addition, rapeseed and sugar cane yields both decreased considerably in 1983 (Table 7.1), a situation linked partly to the cold and wet climate in south China in the winter and spring. However, climatic conditions were favorable in general, especially in the north, and 1983 became one of the good harvest years. Of course, favorable political and social conditions were also a factor in increasing yields (for example, the use of increased incentives). It must be remembered that nonclimatic factors contributing to yield increases are not necessarily eliminated by calculating rates of yield increase. Although it is difficult to separate totally the contribution of either climatic or policy factors, the impact of the 1982-83 El Niño on crop yields on a regional basis is difficult to deny.

In summary, the anomalously heavy winter and spring precipitation, the major climatic event associated with the 1982-83 El Niño, affected crops differently in different regions. Whereas the effect was negative on southern wheat yields, it was positive on North China Plain wheat yields. Moreover, other climatic conditions not associated with the El Niño event (e.g., the warm 1983 fall) exerted a countervailing influence on the negative effects of flooding in the south.

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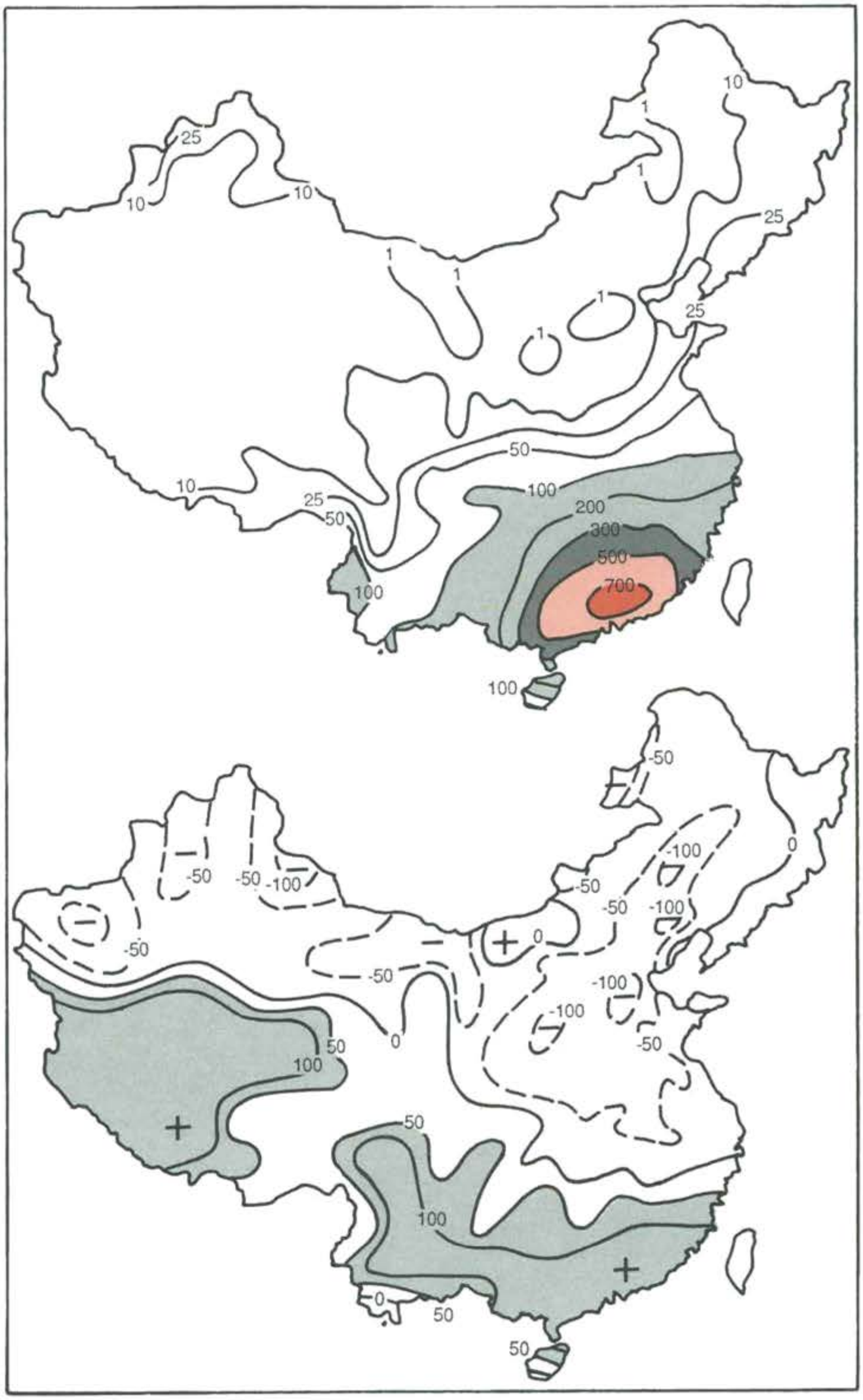

Fig. 7.6 Top: *seasonal precipitation for December 1982 to February 1983 (mm).* Bottom: *seasonal precipitation anomalies for December 1982 to February 1983 (%).*

CHAPTER 8

CLIMATIC ANOMALIES OF EL NIÑO AND ANTI-EL NIÑO YEARS AND THEIR SOCIOECONOMIC IMPACTS IN JAPAN

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Japanese Weather and the 1982-83 ENSO Event

There is strong evidence to suggest that climate anomalies in Japan are affected by the variability in sea-surface temperatures (SSTs) in the western and eastern equatorial Pacific Ocean. This chapter presents a brief review of summer and winter climate anomalies that have occurred in the past few decades and discusses their possible linkages with El Niño/Southern Oscillation (ENSO) events. Some possible ENSO-related impacts on agricultural production in Japan are also examined.

ENSO and Summer Climate Anomalies

Japan's rainy season (called *Baiu*) normally starts around mid-June and ceases around mid-July. In the summer of 1982, the *Baiu* was unusually long-lasting because of a stationary polar front over eastern Asia. This active persistent monsoonal front was accompanied by a cooler-than-normal air mass to the north. As a result, wetter and cooler conditions prevailed over many parts of Japan, especially the western and central regions.

A wet, cool summer was not a feature unique to 1982 but, in fact, appears to be an occurrence that accompanies longer-than-usual monsoons which tend to take place in El Niño years. Table 8.1 illustrates that in typical El Niño years with warm SSTs over the eastern equatorial Pacific, rainfall during the *Baiu* is greater than during years with cool SSTs in that region (referred to by some scientists as anti-El Niños). It is also apparent (see Table 8.2) that the dates of withdrawal of the monsoon in the region are considerably later during El Niño years than in other years.

Table 8.1 Mean *Baiu* Rainfall Amounts

	Fukuoka (mm)	Osaka (mm)	Tokyo (mm)	Niigata (mm)	Sendai (mm)
El Niño	700	457	322	262	248
Anti-El Niño	329	288	173	247	171
Normal	509	377	255	270	246

Source: Asakura, 1985

Table 8.2 Mean Date of Withdrawal of *Baiu*

	July		
	Fukuoka	Osaka	Tokyo
El Niño	21.4	22.3	25.0
Anti-El Niño	13.0	12.1	12.6
Normal	18.0	17.0	18.0

Source: Asakura, 1985

Table 8.3 Departures from Mean Temperatures for El Niño Years

	Summer Departures (July, August) (°C)			Winter Departures (Dec., Jan., Feb.) (°C)		
	West	Central	North	West	Central	North
1951*	−0.6	−0.2	1.1	−0.7	−0.4	−0.3
1953*	0.0	−0.9	−0.5	1.3	0.7	0.4
1957	−0.3	−0.4	−0.3	0.3	0.7	1.1
1963*	0.2	0.2	0.0	0.2	0.3	0.7
1965	0.2	−0.6	−0.8	0.2	0.2	0.2
1969*	−0.1	−0.3	−0.5	−0.4	−0.5	−0.9
1972	−0.7	−0.3	0.6	0.9	0.9	1.6
1976*	−0.9	−1.5	−0.8	−1.5	−1.2	−1.8
1982	−1.2	−1.0	0.4	0.3	0.7	0.8
Mean	−0.4	−0.6	−0.1	0.1	0.2	0.2

*Minor El Niño year

Source: Kurihara, 1985.

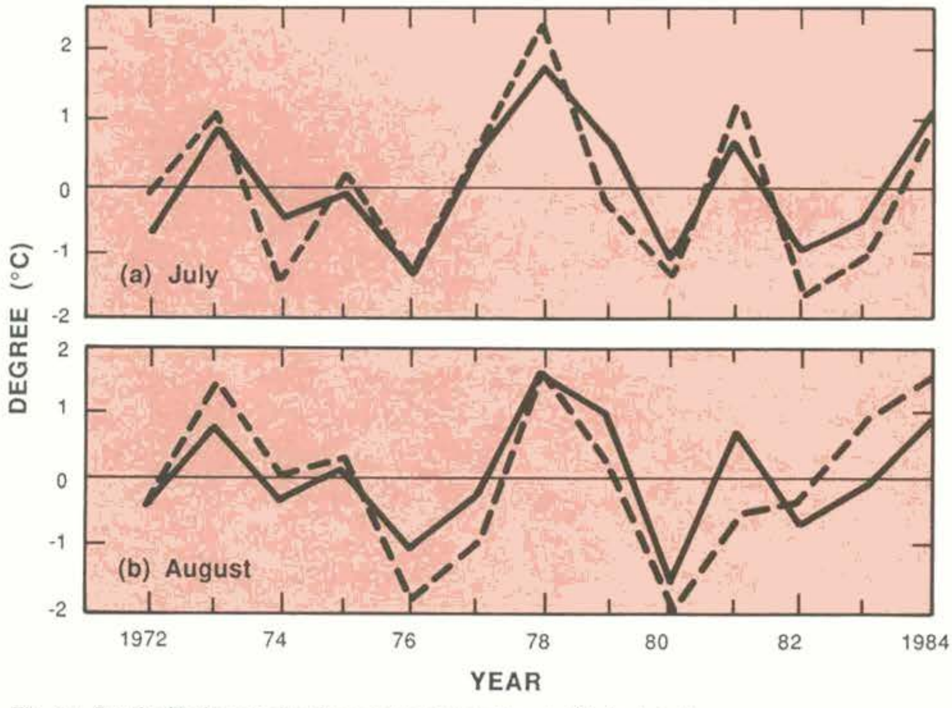

Fig. 8.1 Standardized anomaly of sea-water temperature (solid line) in the equatorial western Pacific (at 20 m and over 3° to 6°N) and mean air temperature over central Japan (dashed line) for (a) July and (b) August (Kurihara, 1985).

Air temperature anomalies for the summer and winter over western, central, and northern Japan during the past several El Niño events are identified in Table 8.3. Temperatures for July and August are significantly below normal in western and central Japan. It is important to note, however, that the air temperature and SST anomalies over the eastern equatorial Pacific do not consistently show the same correlations. Some of the largest summer anomalies occurred in 1976, a year with a relatively mild El Niño event.

Kurihara (1985) addressed this apparent discrepancy by comparing the Japanese air temperature anomalies with upper-ocean temperature anomalies in the *western* equatorial Pacific (see Fig. 8.1). He found a high correlation between these two factors. In fact, the air temperatures over most of Japan appear to be highly correlated with SST anomalies over the western Pacific, as shown in Fig. 8.2. This significant correlation might be interpreted meteorologically as a strong coupling, by way of the Hadley cell, between the convective activity over the Indonesian archipelago and the western part of the subtropical high-pressure system over the northern Pacific (Kurihara, 1984).

ENSO and Winter Climate Anomalies

The 1982–83 winter in Japan was a relatively warm one. This is generally the case during El Niño years, as shown in Table 8.3. El Niño winters are apparently associated with higher-than-normal zonal indexes (that is, a well-developed westerly flow in the upper atmosphere) over East Asia.

The 1983–84 winter was the coldest in the past 40 years, in contrast to the winter of 1982–83. Tokyo, for example, experienced a 22-cm snowfall and ten snowfall days in February, or three times the long-term average. Kurihara and Kawahara (1985) suggested that this severe cold winter may have been directly related to intensified convection over the western Pacific, coupled through the Hadley cell circulation. The severe cold winter corresponds well with typical anti-El Niño conditions (that is, correspondingly large negative SST anomalies in the eastern equatorial Pacific and large positive anomalies in the western Pacific) and with a well-developed Hadley cell circulation.

ENSO and Societal Impacts

The wet summer that accompanied the prolonged monsoon season was associated with severe rainstorms that led to flooding, mudslides, and property damage. More specifically, heavy rains, strong winds, and typhoons in the summer and autumn (1982) brought about the death of more than 400 people in addition to crop losses and damage to roads and property (Farmer, 1983). Flooding in the Nagasaki area was considered the worst in 25 years.

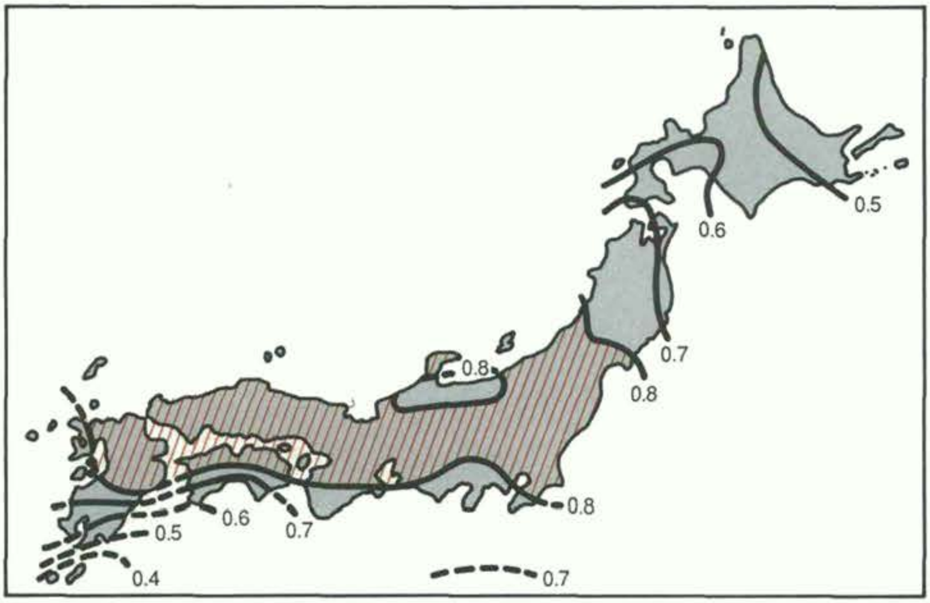

Fig. 8.2 Distribution of correlation coefficients (r) between mean July sea-water temperature averaged over 4 points from 4°N to 7°N (depth = 20 m) and monthly mean July air temperatures at various stations in Japan for 1972–1982. Area with r greater than 0.8 is hatched.

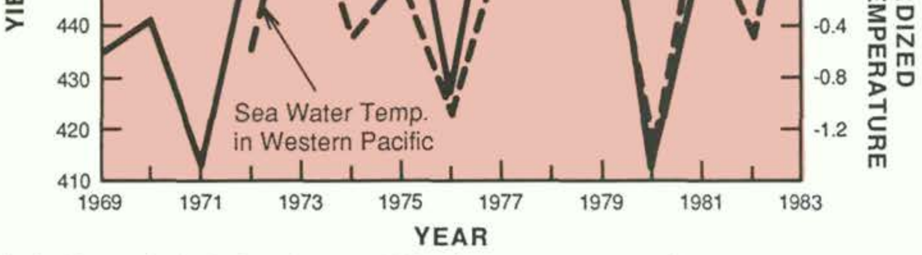

Fig. 8.3 Rice production in Japan (1969 to 1983) and sea-water temperature in the western Pacific (1972 to 1983).

With respect to the number of typhoons occurring in the Northwest Pacific region, it appears that there is little relationship with ENSO. Gray (1984) has shown that the average number of typhoons in the area in an ENSO year is 26.6, in the year preceding is 25.8, and in the year following is 26.8. In other years the average number of typhoons in the Northwest Pacific region is 25.7. Gray's analysis was based on 15 ENSO episodes between 1900 and 1982. This result is quite different from the situation in the Atlantic basin, where ENSO years are linked to a marked decline in the number of tropical storms.

Agricultural production in 1982 and 1983

Rice is by far the most important crop in Japanese agriculture, contributing about one-third of the gross agricultural output. (Agriculture in turn contributed 4.3% of the gross national product in 1982-83). At the end of 1979 Japan had 5.9 million tons of rice in store. This surplus was removed by the introduction of rice disposal programs giving subsidies for exports, animal feeding, and industrial use. However, from 1980 through 1983 rice yields were consistently below average, bringing stocks to a dangerously low 90,000 metric tons in October 1983. This caused the government to introduce a rice-production plan, running from 1984 to 1986, to rebuild stocks (USDA, 1983, 1984). To what extent can ENSO-related weather anomalies be linked to these yield shortfalls?

Table 8.4 shows rice-production figures for 1969 to 1983. The salient features of this table are illustrated in Fig. 8.3. Over the 15 years, 1980 had the second-worst yield. As far as the ratio of damaged crops to normal production is concerned, 1980 was the worst harvest; it also had the greatest quantity of rice damaged or lost due to abnormal weather. Although 1980 was not an ENSO year, its growing season was marked by low temperatures and heavy rainfall. This was linked to anomalously low sea temperatures in the equatorial western Pacific, although an El Niño failed to develop.

From 1969 to 1983 there was a gradual upward trend in rice yields, interrupted in 1971, 1974, 1976, and from 1980 onward. Of the six harvests that fail to match the upward trend, only three occurred in ENSO years: 1976, 1982, and 1983. But it is worthwhile to note that both the ratio of damage and the area damaged due to abnormal weather show a sharp increase during the last four years. As is indicated in the "Note" column in Table 8.4, a cool summer prevailed in these four years. This cooling was particularly prevalent in northern Japan. According to the USDA (1983, p. 13), although "Japan's total agricultural output grew 4% in 1982 . . . cold weather and storms during summer caused considerable damage, mostly to the rice crop." Rice production in 1982 was affected not only by bad weather, but by reduced area planted as well.

In 1983, while crops in northern Japan suffered damage from the cool summer, southwest Japan was warm. As a result, total agricultural production improved slightly as compared to 1982. The USDA report (1984) noted that "cold weather hindered production of wheat, rice, pulses, forages, onions, and potatoes" in 1983, while fruit production increased. Because of weather-related low yields, 1983 rice production increased only slightly from that in 1982. This was the fourth year in a row of below-normal harvests.

Table 8.4 Paddy Field Rice Yield and Damages, 1969-1983

			Damages by Abnormal Weather		
	Yield (kg/ha)	Ratio of Damage* (%)	Area (x 10^3 ha)	Quantity (x 10^3 t)	Note
1969	4,350	10.2	1,201.0	709.3	
1970	4,420	9.2	1,173.0	375.9	
1971	4,110	15.2	2,032.0	1,090.0	Bad harvest (cool summer) in northern Japan
1972	4,560	7.3	722.9	358.5	
1973	4,700	6.6	544.2	275.3	Good harvest (warm summer)
1974	4,550	9.3	736.6	308.6	
1975	4,810	6.4	898.5	298.0	Good harvest (warm late-summer)
1976	4,270	16.6	1,963.0	1,321.0	Bad harvest in northern and central Japan
1977	4,780	5.9	517.2	213.9	
1978	4,990	5.6	664.2	294.6	Best harvest (warm summer) in northern Japan
1979	4,120	7.1	976.8	420.4	
1980	4,120	22.0	1,992.0	1,603.0	Bad harvest (cool summer) in northern Japan
1981	4,530	13.0	1,504.0	956.3	Cool summer
1982	4,580	13.5	1,792.0	896.9	Cool summer
1983	4,590	12.3	1,646.0	711.5	Cool summer in northern Japan, but warm summer in SW Japan
AVG.	4,590	10.9	1,229.2	855.6	

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*Ratio of total quantity damaged by abnormal weather, diseases, and insects to normal production.

According to a study by T. Uchijima (unpublished), variation of rice yield is closely related to the variation of air temperature in the summer. Growth of paddy field rice is particularly sensitive to air temperature during the heading phase, and damage resulting from cool summers is a recurrent phenomenon in northern Japan.

Wheat production also declined in 1983 as unusually cold weather reduced yields and production in Hokkaido where one-third of Japan's wheat is grown (USDA, 1985, p. 11).

Overall, it appears that the 1982-83 El Niño was associated with lower crop yields in Japan, because of the related cool summer temperatures. However, it must be observed that non-El Niño years have been associated with low rice yields as, for example, in 1980. Further, some El Niño years such as 1972 had no discernible climate-related yield reductions.

Conclusion

Wet, cool summers with marked *Baiu* frontal activity are closely related to El Niño over the equatorial Pacific. Temperature anomalies over western and central Japan are highly positively correlated with upper-ocean temperature anomalies in the western Pacific.

It is also suggested that cold winters are associated with anti-El Niño events over the equatorial Pacific, whereas warm winters are associated with El Niño occurrences. The severely cold winter of 1983-84 was directly connected with the enhanced anti-El Niño condition in the western Pacific.

Damage resulting from climate-related natural disasters seems to increase in El Niño years, mostly because of severe rainstorms associated with the active *Baiu* front. Cool summer temperatures over Japan in El Niño years are linked to lower crop yields. However, this does not occur in every El Niño event, nor are the shortfalls any greater than have occurred in years with no El Niño.

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CHAPTER 9

IMPACTS OF THE 1982-83 ENSO EVENT ON EASTERN AND SOUTHERN AFRICA

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Introduction

The term "eastern Africa" here refers to Kenya, Uganda, and Tanzania, and "southern Africa" to Malawi, Zambia, Zimbabwe, and Botswana (Fig. 9.1). Some economic data have also been drawn from Ethiopia and Mozambique.

The region has large spatial variations in climate as a result of the influence of local and regional factors, which include several large inland lakes and other complex topographical features. Rainfall amounts vary from around 200 mm mean annual in the desert areas of southeastern Botswana and northeastern Kenya to over 2,000 mm in highland areas and around the large inland lakes. Variation over time is also a marked feature of the area's climate.

The countries of eastern and southern Africa generally receive their rainfall at the time of "high sun." The northeastern trades of the Northern Hemisphere and the southeastern trades of the Southern Hemisphere flow equatorward from the subtropical high-pressure belts (located at about latitudes 18°N and S). The region where the trades meet is termed the Intertropical Convergence Zone (ITCZ) and is associated with rainfall (Fig. 9.2). The passage of the sun is accompanied by the north-south-north movement of these major weather systems of the region. Thus, close to the equator there are two distinct rainy seasons centered on March to May (long or main rainy season) and October-November (short rainy season) as the ITCZ passes over the region. Farther from the equator, beginning with southern Tanzania, most of the rainfall is concentrated within a single rainy season, centered on the Southern Hemisphere summer period. Double rainfall peaks within a single rainy season are, however, observed at

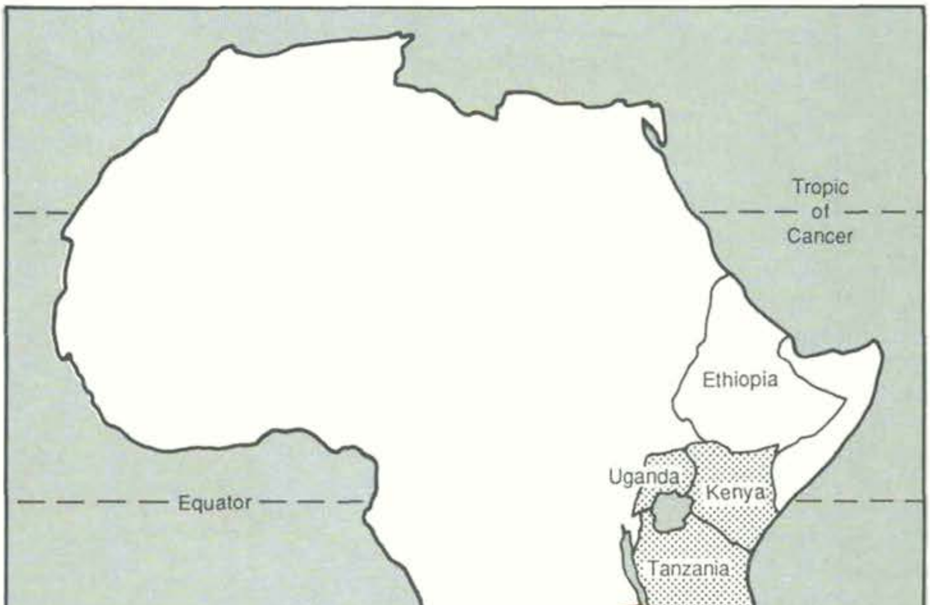
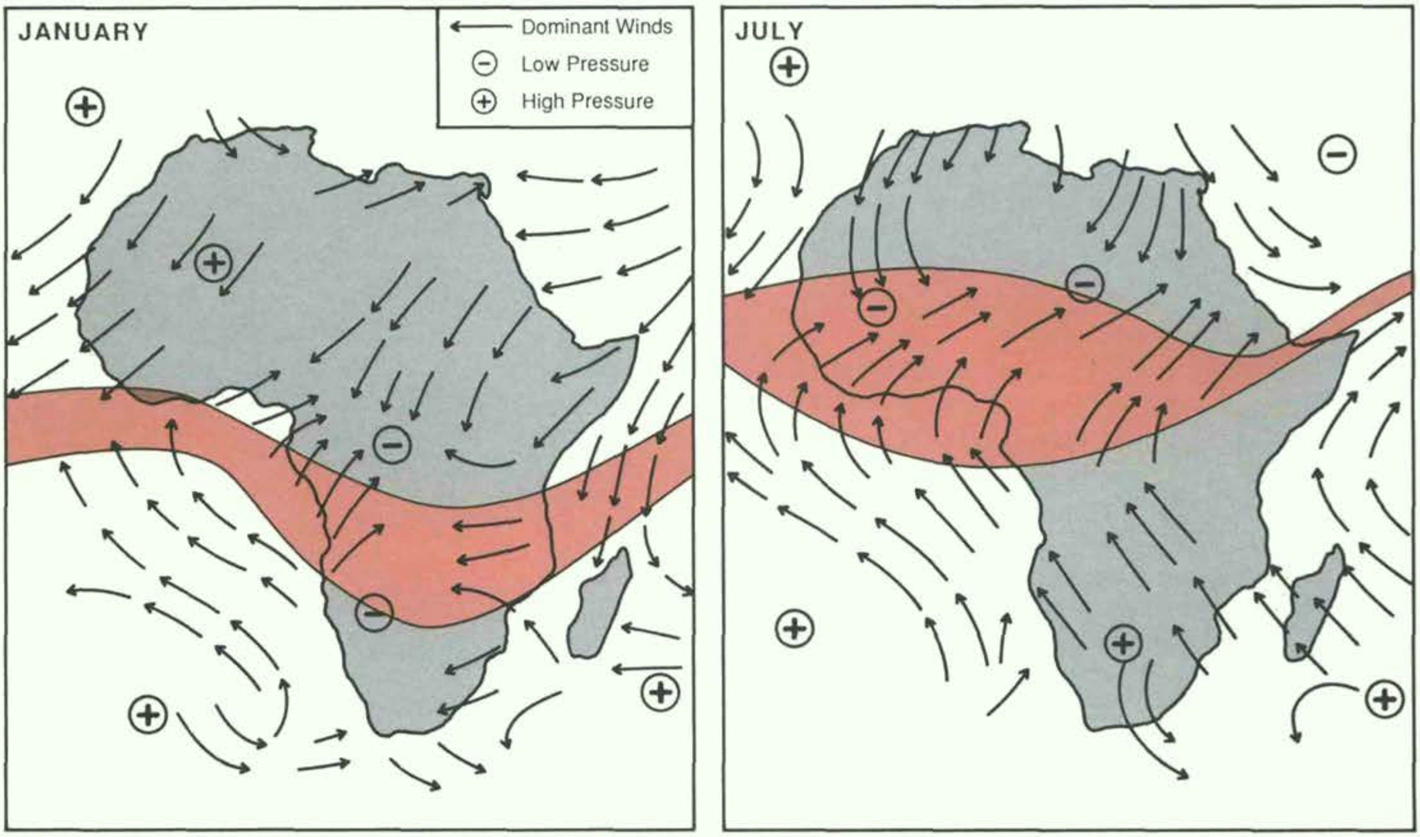


Fig. 9.1 Eastern and southern Africa.

Fig. 9.2 Movement of the Intertropical Convergence Zone (ITCZ). (Red areas)



some locations in the north of Zambia and Malawi. In parts of East Africa, trimodal seasonal rainfall patterns are found, especially in the western regions, which are often under the influence of moist westerly winds flowing from the Atlantic Ocean and the equatorial forests of the Zaire/Congo Basin. The third rainfall peak is centered around July-August.

The occurrence of extreme weather, particularly droughts, has significant impact on seasonal agricultural production. The primary limiting factor on agriculture over much of the study region is soil moisture availability, as determined by the balance between rainfall and evapotranspiration. The rate of evapotranspiration is related in part to radiation. Thus in tropical and equatorial areas of intense sunshine a rainfall total of, say, 750 mm, which would be regarded as entirely adequate for agriculture in most temperate latitudes, becomes marginal. Furthermore, the rainfall of eastern and southern Africa displays relatively high interannual variability (Farmer and Wigley, 1985). The combination of marginal mean annual rainfall and high variability renders agriculture and pastoralism in much of the study area highly vulnerable to meteorological drought. Such extreme weather events also affect other economic activities, such as water supply for domestic and industrial use.

The climate history of the region indicates that extreme weather anomalies such as droughts and floods have been recurrent. The observed patterns, however, show that the spatial and temporal characteristics of these extreme climatic episodes have varied from one season or year to another as well as from one region to another (Palutikof et al., 1982). The causes of these anomalous climatic events have been linked to the anomalies in the structure, intensity, and location of the ITCZ, subtropical anticyclones, tropical cyclones, the jet stream, and other local and regional factors (Ogallo and Anyamba, 1986.) Possible connections to climate anomalies in different parts of the globe (i.e., teleconnections) have also been investigated (Sansom, 1955; Okoola, 1986; Ogallo and Okoola, 1986; Wright, 1985).

Weather Anomalies and ENSO Events

Drought is a familiar event in southern and eastern Africa. Where communities are not constrained by factors such as population pressure or the needs of their central government for cash crops, they are usually well adapted to the recurrence of drought years on a somewhat regular basis. However, rainfall data suggest that there is a clear tendency for droughts to occur in spells of two to three years or even longer. It is particularly difficult to cope with these longer runs.

Tyson (1980), working on a rainfall series from southern Africa, found that there was a quasi-20-year oscillation, such that, for example, the periods 1944–53 and 1963–72 were drier than normal with an intervening wet phase. Nicholson and

Entekhabi (1986) presented rainfall series for East Africa and for the north and south Kalahari. There is little evidence for "clustering" of spells of wet and dry years in the two southern series. However, in the East Africa series there is a very marked dry spell during 1940-59 when 14 of the twenty years were below average. This was followed by a spell of unusually wet conditions in the 1960s (Rodhe and Virji, 1976). It has been suggested (Palutikof et al., 1982) that one reason that conditions in the study area have been perceived as particularly severe in recent years is that people grew to accept the wetter conditions of the 1960s as normal.

Localized droughts occur in almost every year. Such spatially restricted droughts sometimes have severe agricultural and economic impacts, especially when they affect the major agricultural zones.

Evidence for a significant correlation between El Niño/Southern Oscillation (ENSO) events and weather anomalies over the region is conflicting. However, some of the excessively dry and wet years appear to correspond to the periods of strong ENSO events and to periods of colder-than-usual sea-surface temperatures (termed anti-El Niño events), respectively. An index of southeastern African rainfall for 1875-1978 showed that of 27 ENSO events over this period, 21 were associated with deficient rainfall years for this area (World Climate Data Program, 1985). This was also the case during the 1982-83 ENSO event. More rigorous attempts at quantification, however, have proved less successful. Dyer (1979), for example, in a study of coastal rainfall series from southern Africa, was unable to relate the interannual rainfall variability to an index of the Southern Oscillation, although he found good agreement between interannual rainfall variability and a measure of the latitude of the subtropical high-pressure belts. For East Africa, Sansom (1955) attempted to use an indicator of the Southern Oscillation to forecast seasonal rains. Forecasts based on the surface pressure changes at Cape Town were, however, not very accurate. Okoola (1986) and Ogallo and Okoola (1986) observed that, although monthly and daily rainfall patterns over many parts of East Africa display some unique regional characteristics, significant teleconnections were evident with anomalies over some parts of the Indian Ocean regions.

In a recent study, Nicholson and Entekhabi (1986) have investigated possible relationships between African rainfall and the Southern Oscillation. They note that strong quasi-periodic variations exist in both South African rainfall (Tyson et al., 1975) and East African rainfall (Rodhe and Virji, 1976). In the Rodhe and Virji paper, a spectral analysis of rainfall series produced peaks at 2-2.5, 3.5, and 5-5.5 years, a result largely confirmed by Nicholson and Entekhabi. Furthermore, these peaks coincide closely with the results from spectral analysis of the Southern Oscillation Index (SOI). Nicholson and Entekhabi find a strong relationship in the range of 2.2-2.4 years between rainfall in eastern and southern Africa and the SOI. The relationship is a positive one (high rainfall/high SOI) in southern Africa and inverse in eastern Africa. Since El Niño years are related to a low SOI and vice versa, the Nicholson and Entekhabi results may loosely be interpreted as suggesting that El Niño is linked to drought in southern Africa, and high rainfall in eastern Africa. However, this interpretation is complicated by the fact that the relationship is restricted to the range of 2.2-2.4 years. Other relationships, although weaker, hold at other time bands.

The rainfall anomalies over the region during the strong ENSO event of 1982-83 are presented in Figs. 9.3a-e. Figures 9.3a-d show rainfall anomalies for the two wet seasons of eastern Africa, in 1982 and 1983. Anomalies for the March-May "long rains" are given in Figs. 9.3a and b. Figure 9.3a indicates that during March-May 1982, normal rainfall was recorded over most parts of eastern Africa. Dry conditions, however, continued to prevail over many parts of southern Africa. Similar patterns were discernible during 1983 (Fig. 9.3b).

Anomalous patterns over the region for the September-November "short rains" of 1982 and 1983 are shown in Figs. 9.3c and 9.3d. Figure 9.3c indicates that most of the region reported near-normal or above-normal rainfall conditions. Very wet conditions were reported over the coastal regions of eastern Africa and parts of the inland. Many stations in these regions recorded more than twice the normally expected precipitation for the September-November season. In 1983, however, conditions were markedly below average in much of southern Africa and Tanzania. On the other hand, the major crop-growing regions of Uganda and Kenya received satisfactory rainfall.

Figure 9.3e shows rainfall anomalies over the region during the northern winter (southern summer) months of 1982-83. December-February is usually a dry period over many parts of eastern Africa, other than southern Tanzania and near the large bodies of water. This is, however, the peak rainfall season for most of southern Africa. The figure shows that below-normal rainfall was recorded over most of southern Africa, apart from northern parts of Zambia and Malawi. These findings agree broadly with the results of Nicholson and Entekhabi (1986) outlined above. While rainfall/ENSO relationships were negative over many parts of eastern Africa, positive relationships were evident over much of southern Africa.

Drought Impacts in Eastern and Southern Africa

With respect to human activities, the most important climatic events in 1982-83 in this region were the widespread and persistent droughts that adversely affected southern Africa. From the above discussion, it appears that these may in part be ENSO-related. Conversely, in East Africa conditions were generally wetter than average, particularly in 1982. This phenomenon too may be related to ENSO; however, not all extreme weather anomalies observed over the region are necessarily connected to ENSO.

Before moving to any detailed consideration of the climate impacts of this period, it is as well to review the background against which the events occurred. The economies of the study area are primarily agricultural, and with the exceptions of such nations as Zambia and Botswana, where mining is important, there are no other significant natural resources. Generally, some 70–90% of the population are employed in agriculture or pastoralism, which in turn contribute to the principal exports. Thus in Kenya the largest foreign exchange earners are, in near-equal proportions, coffee, tea, and tourism. Population growth rates are high, 3.5–4% per annum, and in many nations there is already excessive pressure on high-potential land (Palutikof et al., 1982). Foreign trade terms are unfavorable: prices for tropical commodities are low and subject to intense fluctuations, whereas prices for oil and agricultural inputs such as fertilizer and pesticides are relatively high. Thus recent years have seen a stagnation or even a decline in agricultural productivity that, although it may be in part climate-related, is also a result of decreased applications of fertilizer and other inputs, and a move back to a more subsistence-oriented economy. Although this is perhaps more a characteristic of countries in Sahelian areas or Central Africa, and may be less obvious in the more cash-crop-oriented economies of eastern and southern Africa, it must be borne in mind when intepreting the material that follows (see Glantz, in press).

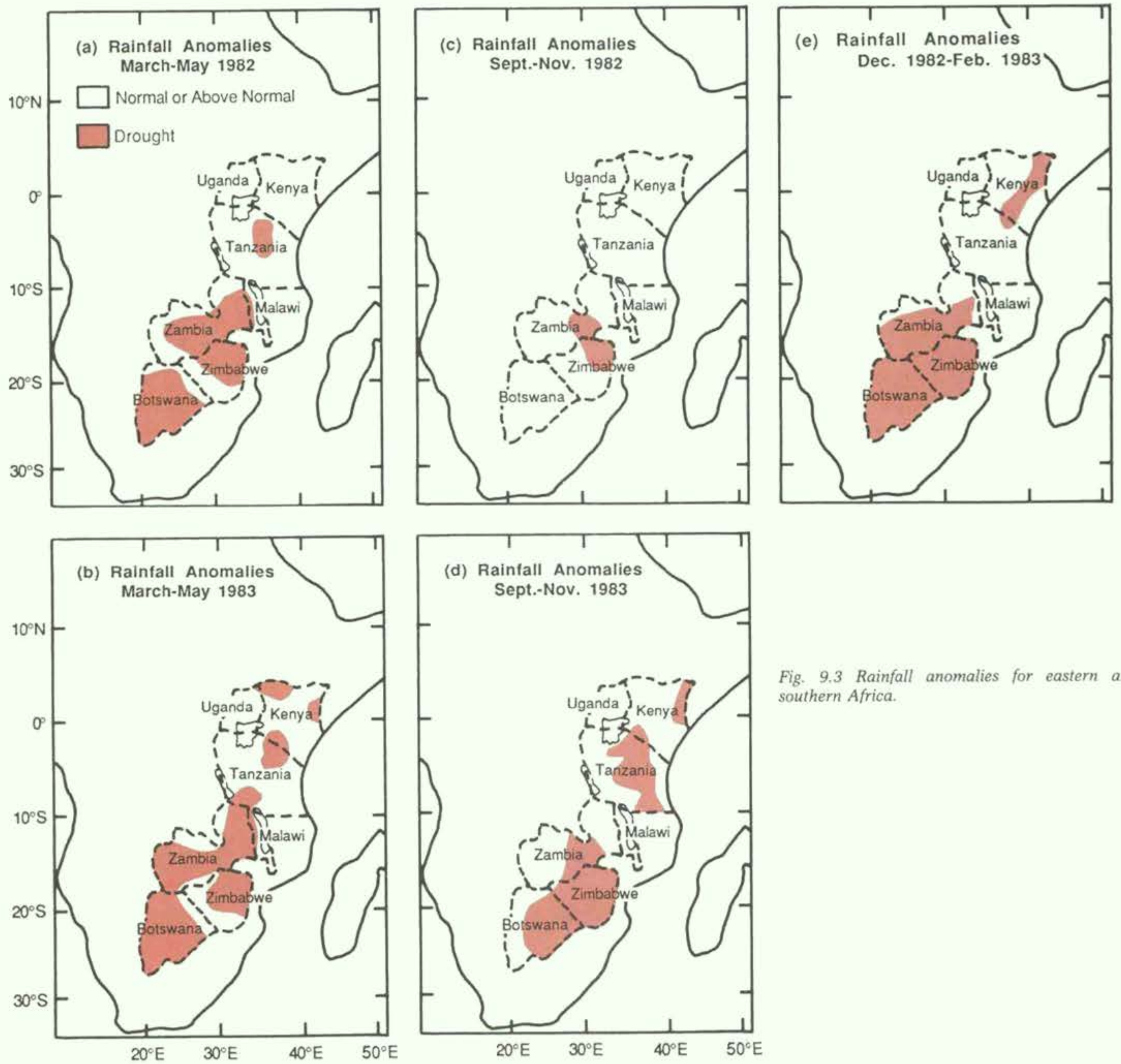


Fig. 9.3 Rainfall anomalies for eastern and southern Africa.

Figure 9.4 shows indexes of total agricultural production from the study area for the period 1980-84. In southern Africa, Zimbabwe and Mozambique show the clearest link between drought and production. In 1982 production declined slightly or stagnated, followed by a severe drop in 1983. Malawi showed a small decline in 1983, but clearly is well-cushioned against drought because of the favorable climate prevailing over much of the country. Zambia showed a decline in production in 1982 but recovered well in 1983. In eastern Africa, the production trends in Ethiopia and Tanzania were not well-defined during the five-year period. Kenya and Uganda showed steady growth of total agricultural production throughout. It is of interest that the 1984 drought failed to produce any marked decline: its impact was mainly in the subsistence medium-potential areas, which would fail to show in these production series. Table 9.1 shows the losses from the 1982-83 drought for some of the countries of the region.

In the following sections the climate impacts on three countries in the study region over the period 1982-83 are examined in more detail. This discussion draws heavily on publications of the U.S. Department of Agriculture (1983, 1984, 1985).

Kenya

Agricultural output in Kenya in 1982 increased 2.4% over the preceding year in part as a response to good weather and in part as a response to an increase in the prices paid to producers. Two consecutive good corn and wheat crops enabled Kenya not only to reduce food imports but also to resume food exports in 1983. The total area planted in Kenya in 1983 was down from 1982, as was the total production for corn, wheat, and rice. Grain production declined about 15% from 1982. This decline was partly a result of weather factors such as erratic rainfall and the late start of the rainy season, and partly the result of internal financial problems. There was also a reduction in the output of some crops such as coffee and sugar, but this has generally been attributed to a shift by farmers to food crops. The Kenyan tea crop, on the other hand, was excellent in 1983, due to good temporal distribution of rainfall and relatively warm temperatures.

Zimbabwe

Although many people thought the 1981-82 crop season in Zimbabwe (October to April is the maize crop-year) was the beginning of the multi-year drought, conditions then were relatively mild compared to the 1982-83 and 1983-84 droughts. In 1982 and 1983 drought adversely affected agricultural production to varying degrees in different parts of the country (Bratton, in press). A major problem was the occurrence of

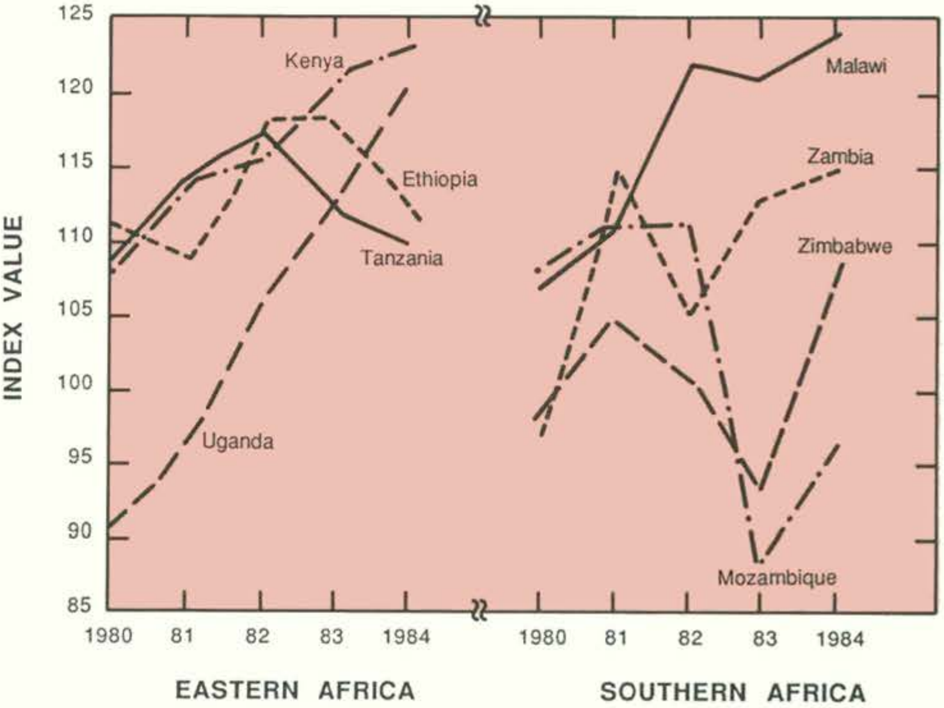


Fig. 9.4 Indexes of total agricultural production in eastern and southern Africa, 1980-84 (1976-78 = 100). (U.S. Department of Agriculture, 1985, p. 45.)

Table 9.1: Financial Cost and Losses from the 1982/83 Drought (US$ million)

Country	Direct Agricultural Losses	Drought Relief Costs	Total
Botswana	68.9	51.9	120.8
Lesotho	45.0	78.7	123.7
Malawi	-	13.4	13.4
Mozambique	75.1	79.0	154.1
Swaziland	26.4	2.9	29.3
Zimbabwe	360.0	119.6	479.6
Total	575.4	345.5	920.9

Source: SADCC Drought Report, January 1984 as reported in Mupawose (1985, p.32).

heavy rains early in the season followed by untimely (for agriculture) dry episodes thereafter. Reduced rainfall was accompanied by high temperatures. It led to relatively large expenditures for drought relief and diverted funds away from development projects and toward emergency relief efforts. The drought that occurred in the 1982–83 crop-year was the worst for the last half century and it affected the entire country.

The record wheat crop of 1982 in Zimbabwe was followed by a sharp reduction in wheat production in 1983 because of the lack of water for irrigation. After the 1982 bumper maize crop, a 65% drought-related reduction in production occurred in 1983. Industries related to agriculture such as the agroindustrial and transportation sectors were, in turn, adversely affected. Severe water shortages in the traditionally drier southern and western parts of the country were critical not only to agriculture but to livestock maintenance. These shortages led to water rationing in both urban and rural areas.

Mozambique

The drought in 1982 and 1983 was considered to have been the worst in Mozambique in the past 50 years. Internal unrest, combined with drought, had a disastrous impact on food production in the southern half of the country and led to many human deaths. In addition, tens of thousands of Mozambicans sought refuge in neighboring Zimbabwe, further straining that country's food situation. Not only did agricultural production decline, but rangeland conditions also deteriorated significantly, leading to both human and livestock deaths. Irrigated agriculture was also adversely affected by drought as a direct result of reduced stream flow in various rivers.

Conclusion

The 1982–83 period was marked by a severe and persistent drought over much of southern Africa. There is some evidence that this drought was ENSO-related (Nicholson and Entekhabi, 1986). The drought led to a marked decline in agricultural production.

Decreases in agricultural production and their associated emergency food imports have severe impacts on the scarce foreign reserves of many African states. Often these impacts force governments to cut their expenditures, suspend many ongoing or planned development projects, and borrow additional foreign funds. In some cases no funds are available for importing major agricultural inputs (such as fertilizers and herbicides) once the drought episode has passed.

These drought-related impacts, together with other factors, impose severe constraints on many societies. It should, however, be noted that the international market prices of agricultural products, together with the high cost of imported agricultural inputs (fertilizer, tools, agricultural chemicals, oil, etc.), sometimes impose constraints more severe than those imposed by weather anomalies. A good example occurred in 1984 when the main (March-May) rains totally failed in many parts of eastern Africa, resulting in a severe drop in agricultural production. Favorable international market prices for agricultural products for export, especially tea and coffee, however, resulted in a significant increase in foreign exchange earnings, instead of the expected severe drop. International market prices for tea, for example, rose from 2,184 Kenya shillings in 1983 to 5,184 Kenya shillings per 100 kilograms in 1984. In some years of bumper harvest lower foreign exchange earnings have been obtained than in years of poorer harvest, because the former often results in lower international market prices.

With the help of the World Meteorological Organization and Food and Agriculture Organization, some pilot projects to monitor the impacts of weather on agriculture are now operational within the region. Furthermore, governments are beginning to create planning and management structures to minimize the impacts of severe drought (Cohen and Lewis, in press). As an example, following the severe drought of 1980, the Kenyan government set up guidelines for national food production and distribution. The national food policy is outlined in Government Sessional Paper No. 4 of 1981, which reviewed the various causes of food shortage in Kenya and the plans for self-sufficiency in food production. The outcome of this planned approach to climate anomalies was that during the 1984 drought the government was able, aided by good foreign exchange earnings, to import and distribute food in advance of anticipated shortages. In southern and eastern Africa adverse weather conditions will always be a threat to rainfed agricultural production, and it is only through setting up early warning systems and management strategies that governments can avert the threat of a drought situation developing into a famine.

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CHAPTER 10
IMPACTS OF THE 1982-83 CLIMATE ANOMALIES IN THE WEST AFRICAN SAHEL

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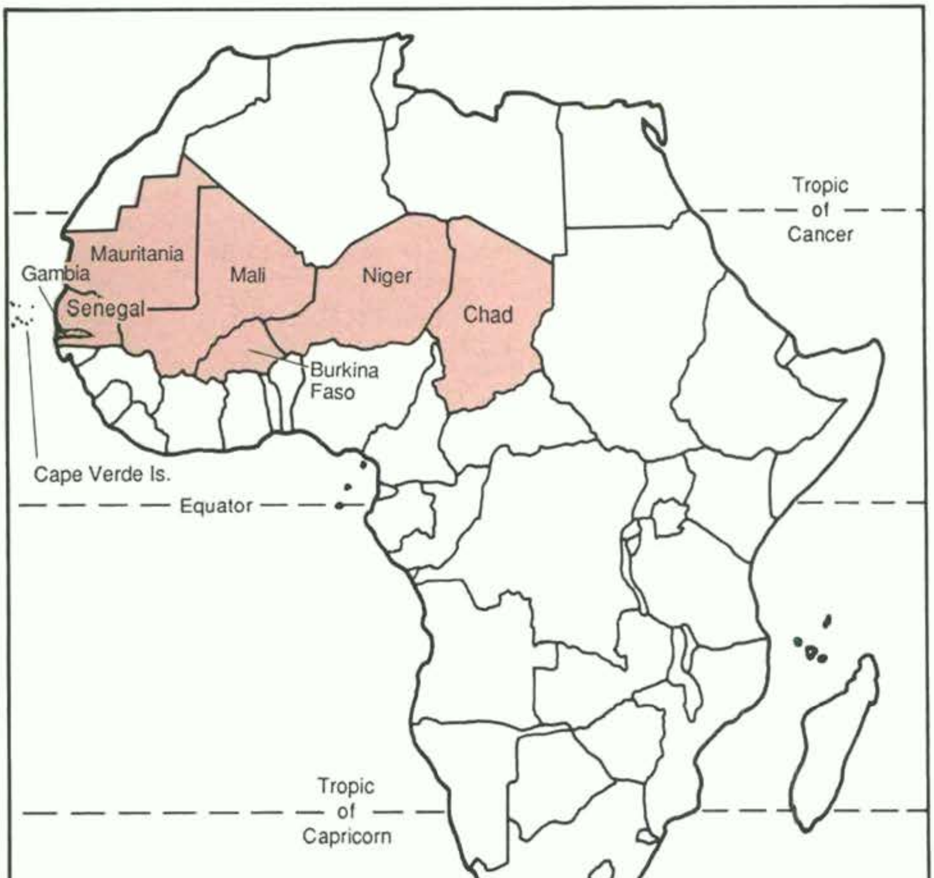
Fig. 10.1 West African Sahel.



Drought in the West African Sahel (Cape Verde, Chad, Gambia, Mali, Mauritania, Niger, Senegal, and Burkina Faso; see Fig. 10.1) has persisted more or less since 1968 (Nicholson, 1985). Scores of books and thousands of articles have been written on this drought. Some scientists have associated the prolonged drought's increased intensity during 1982-83 with the El Niño/Southern Oscillation (ENSO) event of that period. Other scientists argue that this intensification of drought appears to be more strongly linked to sea-surface-temperature (SST) anomalies in the Atlantic Ocean. Such scientific views draw attention to the climatological aspect of Sahelian drought and the possibilities for eventually forecasting it. In fact, this drought has spanned two of the most intense ENSO events this century as well as a minor one. The 1982-83 drought in the region cannot easily be attributed directly to the ENSO event of that year.

The drought in the 1982-83 period was as intense as it had been during 1972-73, when world attention focused on the region. At that time, more than 100,000 deaths were reported, millions of livestock perished, and hidden processes leading to desertification of large segments of the Sahelian landscape were exposed (Glantz, 1977). The most recent drought years, however, did not manifest the same level of destruction on populations and the environment as the earlier years, although their impact on food production and

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*The National Center for Atmospheric Research is sponsored by the National Science Foundation.

food imports was considerable (Lofchie, in press).

While the Sahelian drought had shared the headlines on and off for about 17 years with devastating droughts in Ethiopia, in 1982-83 these two regional droughts were accompanied by droughts throughout sub-Saharan Africa, including the unusual occurrence of drought in Zimbabwe, normally a regional exporter of foods. Over 30 countries in Africa, including all of the Sahelian countries, requested and received emergency food relief and assistance through the UN Food and Agriculture Organization and other international and national governmental and nongovernmental organizations.

Considerable research in both the social and natural sciences has been carried out on numerous aspects of the prolonged droughts in the West African Sahel and in Ethiopia since 1972-73, and on droughts in other parts of the African continent since 1982-83 (Glantz, in press). In this chapter attention is focused on the West African Sahel.

ENSO and the Sahelian Drought

There is no general agreement about the cause of the recent prolonged drought in the Sahel. Scientific investigations show that climate varies on millenial, decadal, and interannual time scales. On the millenial scale, changes in the orbit of the earth could affect the amplitude of the monsoon circulation and hence the rainy season in the subtropics. On the interannual and decadal scales, speculation about the causes of drought in Africa centers on both natural and anthropogenic causes. Natural causes include random interannual climate fluctuations, long-term climatic change, and links between ENSO events and climate anomalies in separate parts of the globe (teleconnections). Suggested anthropogenic causes include increases in atmospheric carbon dioxide and other radiatively active trace gases and the modification of land surfaces.

The 1982-83 ENSO event, which was the largest of the century, and the previous major ENSO event (1972-73) coincided with a spate of major droughts worldwide, including drought in the West African Sahel and in the Horn of Africa. Rasmusson (in press) has suggested that a strong correlation exists between ENSO events and rainfall in southeastern Africa. However, he finds much weaker correlations between ENSO and rainfall in the Sahel, Ethiopia, and East Africa. It has been suggested by Rasmusson and others (e.g., Folland et al., 1986) that Sahelian droughts may be better explained by warmer-than-normal SSTs in the Atlantic, which cause changes in the atmospheric circulation and moisture transport in the tropics.

Social and Economic Impacts of the 1982-83 Drought

Figure 10.2 depicts the declining per capita food production in sub-Saharan Africa. The per capita food production situation in the West African Sahel reflects a similar trend. It is important to remember that many factors affect food production, of which climate variability is just one. Drought in some instances is the primary factor in declining agricultural production. In other instances, national and international policies and commodity prices determine the levels of food production in these countries.

Agricultural activities dominate the economies of the countries of the Sahel. Therefore those economies are extremely vulnerable to interannual and intraseasonal variations in rainfall, even in what might be considered good rainfall years by meteorological standards. Yet, the value of their agricultural production is dependent on government policy within the country and on the international marketplace outside.

In 1982 localized drought and insect damage lowered coarse grain output in several Sahelian countries. For example, Senegal's millet and sorghum output dropped by over 20% from 1981 levels, due mainly to insufficient rains in the northern part of the country (USDA, 1983). In Mauritania grain production in 1982 declined by more than 75% from

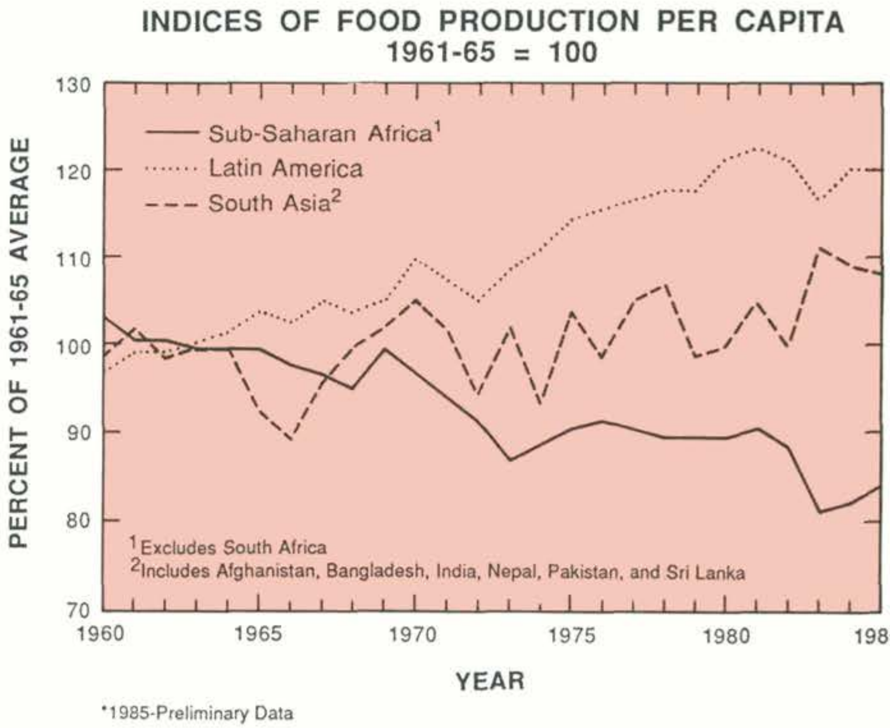

Fig. 10.2 Per capita food production indexes. (Chart provided by the Economic Research Service of the U.S. Department of Agriculture.)

1981 because of insufficient rains and lack of flooding in the Senegal River basin. As a result of drought in eastern and central Mali, coarse grain production in Mali also declined. Chad's 1982 food crop was affected by drought in the north as well as by transportation problems in southern crop-growing regions resulting from civil disturbances and by the delay of the rains. Late rains delayed the harvest in most areas. Cash crop production of peanuts and cotton increased in 1982 in Senegal and Gambia, but declined in Mali and Niger as a result of lower prices and because more acreage was put into cereal production (USDA, 1983).

Food production in the Sahel was adversely affected again in 1983, as late and insufficient rains reduced yields, degraded pastures, and lowered agricultural production. Drought in northern Senegal was reportedly the worst since 1972–73, with cereal production declining by one-third (USDA, 1984). Lack of pasturage led to heavy livestock losses in Mauritania. Drought also adversely affected grain production in Gambia and Cape Verde. It had only limited impact on agricultural production in Mali as drought affected primarily the marginal agricultural areas. Adequate rainfall in Niger led to slightly higher production of cereals when compared to the previous crop year. Normal rainfall in Chad's main agricultural areas in the south, along with a lull in the civil war and higher prices for cotton, increased cereal and cotton production in that country (USDA, 1984).

Summary

Drought in the West African Sahel has continued at varying levels of intensity since 1968. One rainfall index for this region (Lamb, 1985) depicting this situation is shown in Fig. 10.3. The droughts of 1982–83 and their impacts must be considered in this historical light. Clearly, drought has been only one of the factors that has adversely affected agricultural production in the West African Sahel, but it has been an important factor. Although the drought conditions in 1982 and 1983 have been likened to the devastating early 1970s, the worst years of this continuous drought, the recent impacts have been of a different nature. Human and livestock deaths as well as environmental degradation were considerably reduced in West Africa, in part because of the involvement of international governmental and non-governmental organizations in providing food assistance. While on the surface it may appear that the region has become relatively less affected by drought (as suggested by fewer deaths), vulnerability still remains high.

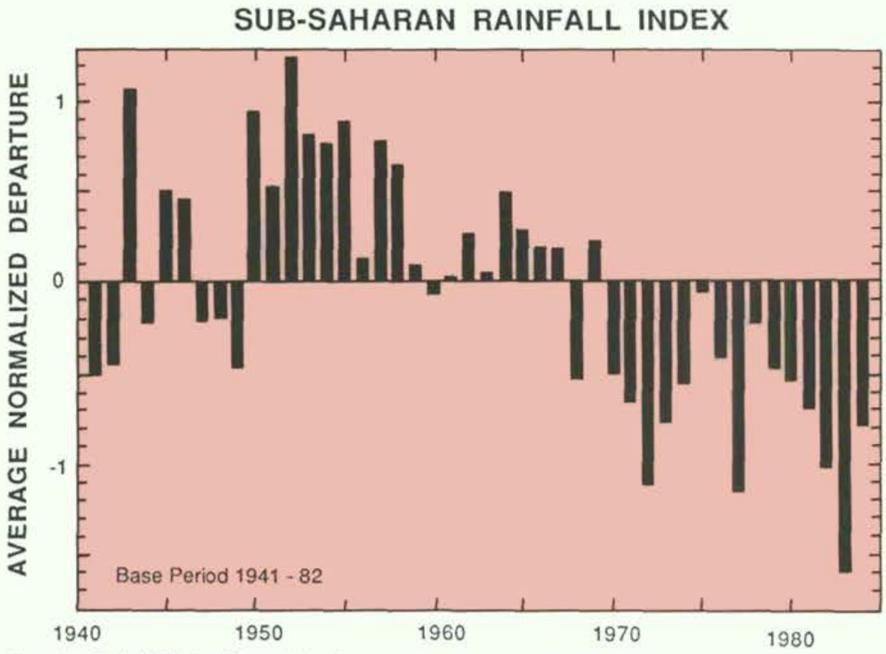

Fig. 10.3 Rainfall index for 20 Subsaharan stations in West Africa west of the 10°E between 1°N-19°N (developed by Lamb, 1985).

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CHAPTER 11

The IMPACT OF 1982-83 WEATHER ANOMALIES ON SOME BRANCHES OF THE ECONOMY OF THE USSR

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Introduction

Some of the most remarkable weather anomalies of 1982-83 in the Northern Hemisphere were the abnormal conditions that occurred over much of Eurasia. These coincided with the strongest El Niño/Southern Oscillation (ENSO) events of this century over the tropical Pacific Ocean. This possible connection is particularly interesting from a climatological point of view because, according to Rasmusson and Wallace (1983), there is no evidence of systematic patterns of anomalies over high- and middle-latitude Eurasia during previous ENSO events.

Weather Anomalies in the USSR during the 1982-83 ENSO Event

The following is a brief inventory of weather anomalies during the 1982-83 period over the USSR (Fig. 11.1). From April to August 1982 there was severe drought in

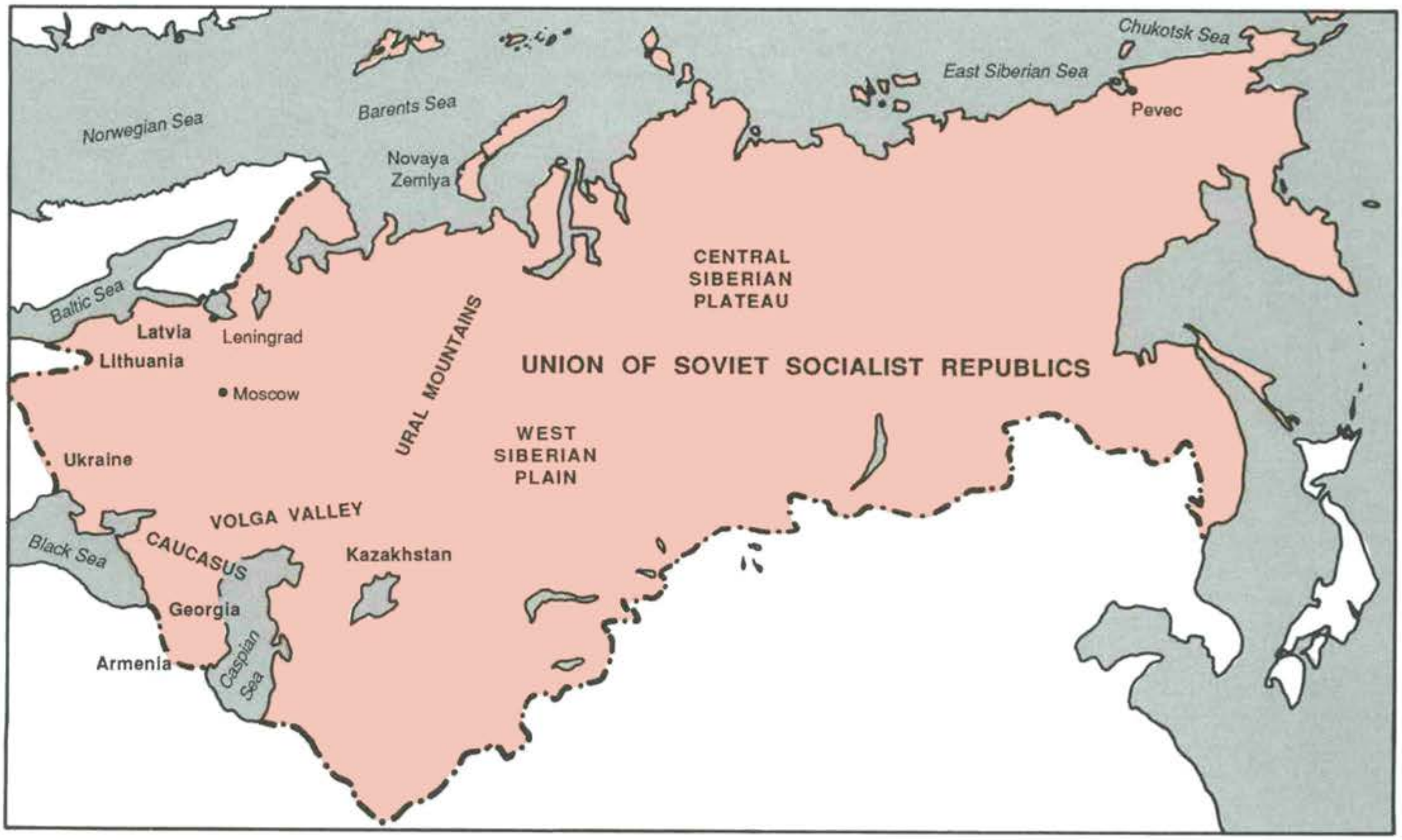

Fig. 11.1 The USSR.

Kazakhstan, the southern Urals, the lower Volga valley, and western Siberia. At some stations, the total amount of precipitation recorded for this period was more than two standard deviations (in absolute value) below the 1951–80 average. An anomaly of this magnitude can be expected only about one year in 20.[1] In contrast, from April until the middle of June torrential rains and hailstorms resulted in rapid snow melt and flooding in the western regions of the Georgian Republic.

In the autumn of 1982, unusually dry conditions spread into the northern Caucasus, the Ukraine, Latvia, and Lithuania. For example, during September-November, only 12–40% of normal precipitation was recorded in the Krasnodar region (north of the Caucasus). In early October in the Azerbaijan Republic (south of the Caucasus between the Black Sea and Caspian Sea), the anomalies were of a different kind, with extraordinarily heavy rains accompanied by flooding.

As a whole, the autumn of 1982 was characterized by positive anomalies of surface temperature over the European territory of the USSR (ETS). The temperatures recorded that autumn were as high as 9°C above normal in some places in December. The chronological development of the temperature anomalies is given in Fig. 11.2 (Quiroz, 1983). Higher-than-normal surface temperatures continued into the winter of 1982–83 in the region north of 45°N.

The total snow-cover area was near normal for the USSR, but the snow depth ranged from one-half to one standard deviation below normal in the central and southern ETS. Above-normal precipitation in the form of heavy rain and snow was observed in the northern and northwestern regions of the ETS. A series of severe storms in the Baltic region during the winter brought flooding to many areas.

The greatest weather anomalies of the spring of 1983 occurred in the southern regions of the ETS. In March, heavy snow fell in Georgia, and severe frost occurred in Armenia with the minimum air temperature falling to −25°C at some locations (at approximately latitude 40°N). Such extremes had never before been observed during the period of instrumental records. Unusual frosts in March were also observed in the lower and middle reaches of the Volga valley and in the northern Caucasus. In the northwestern republics of Latvia and Lithuania, the spring was characterized by heavy rain, with positive anomalies of monthly precipitation at some stations in May of between one-and-one-half and two standard deviations.

The summer of 1983 was cold and wet in the ETS as a whole. The anomalies were similar in July, but by August a persistent blocking system dominated the ETS, with high pressure affecting much of the central and western part of the area, and cyclonic activity prevalent in the southern part of the ETS. As a result, during that summer there were contrasting temperature conditions in some regions of the country. For example, in June and July there were negative surface temperature anomalies in the central ETS region (one to two standard deviations), but in August positive ones (approximately one standard deviation). Heavy rains were recorded in Armenia and Azerbaijan in June, and in Georgia in July. Dry conditions prevailed in the lower Volga valley and the northeast Caucasus (one to one-and-one-half standard deviations below normal at most stations). During October-November, precipitation totals were approximately two standard deviations above the 30-year normal in the northwestern and central parts of the ETS. There were positive temperature anomalies (up to two standard deviations at some locations) in western and central Siberia, whereas anomalies were negative again in eastern Siberia over the same period.

The following winter, 1983–84, was characterized by large positive surface temperature anomalies over the north central USSR, with an extreme positive average departure of 7°C for the winter months (about two-and-one-half standard deviations) just east of the Northern Urals (Fig. 11.3). This system was reminiscent of the persistent, large-scale anomaly observed the previous winter. The 1983–84 pressure anomaly developed in October. By late January the pattern of anomalies had become modified due to circulation

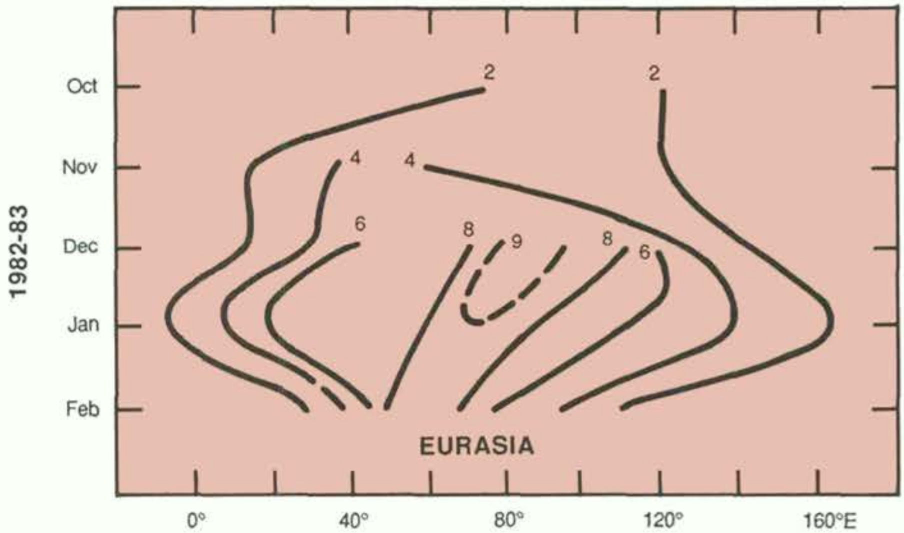

Fig. 11.2 Longitude-time diagram of western and eastern limits of regions with positive surface temperature anomaly, °C (Quiroz, 1983).

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[1] One can expect an anomaly larger than one standard deviation (in absolute value) roughly one year in three.

changes related to the development of blocking over the Asian territory in January, and a major blocking in the Atlantic-West European sector in February (Quiroz, 1984). By late winter the center of the warm anomaly had shifted far to the northwest over the Arctic regions around Novaya Zemlya. Records of snow cover indicate a trend in the USSR from above-normal snow cover (one standard deviation) in December to below-average (0.8 standard deviation) snow cover in February (Quiroz, 1984).

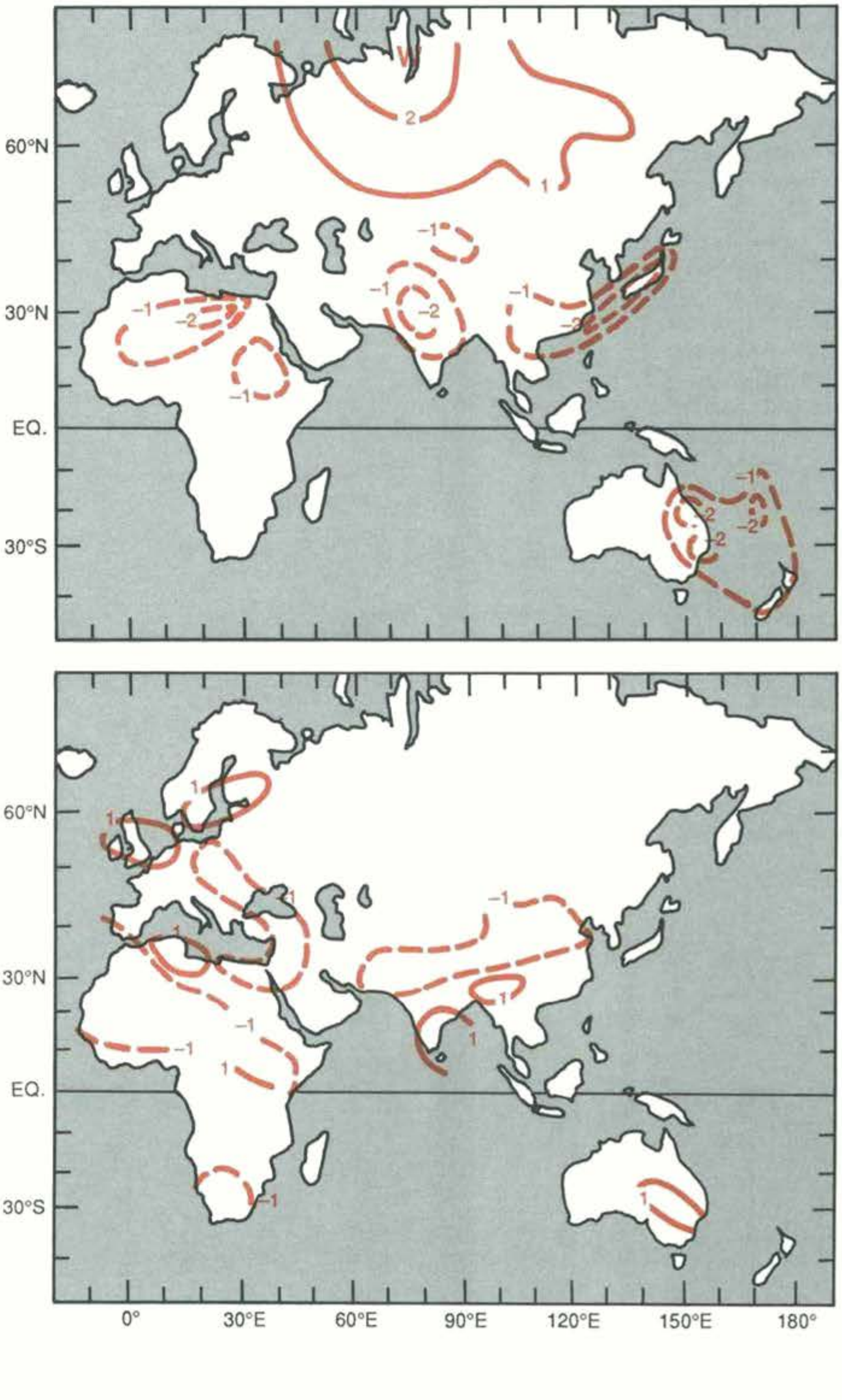
The Impact on Agriculture

The gross agricultural output (by value) in all categories of agricultural enterprises in 1982 and 1983 was 127.4 and 133.8 billion rubles, respectively (compared with 122.0 billion for the 1976–80 average) (*Yearbook of Statistics of the USSR in 1983,* 1984). The total cereal production in the USSR in both 1982 and 1983 was close to average levels (based on recent trends). According to an assessment by Tarrant (in press), total cereal production in 1982 was approximately 195 million metric tons and in 1983 about 205 million metric tons. Such a level of production is much less than in a particularly favorable year such as 1978, when it was 237.4 million metric tons (Ulanova, 1984), but greater than in years of widespread droughts like 1975 and 1979 (140 and 179.8 million metric tons, respectively).

As already indicated, the major limiting factor for agriculture in the most important agricultural regions of the USSR is water deficiency. The severe droughts of 1982 affected a huge territory, including four of the most important agricultural regions of the country: Kazakhstan, the southern Urals, the lower Volga valley, and western Siberia. However, reduced production in these regions was partly compensated for by high crop yields in the ETS. Heavy rain and hail in June 1982 also damaged crops and fruit in some Georgian regions.

The weather conditions during the following growing season (1982–83)

Fig. 11.3 Temperature and precipitation anomalies of the winter of 1983–84. Top: standardized departures from normal temperature of at least one standard deviation (below normal, dashed lines; above normal, solid lines). Only absolute departures of at least 2°C are shown. Bottom: regions in which precipitation fell in the upper 10% (solid lines) and lower 10% (dashed lines) of long-term distribution (Quiroz, 1984).



were especially unfavorable for winter crops. A dry autumn in the northern Caucasus, the Ukraine, and northwest of the ETS resulted in damage to winter crops in these areas. Fluctuations of snow cover were also unfavorable for the crops. Some winter crops were damaged by waterlogging. The thin snow cover and frosts in March resulted in crop damage from low temperatures in the northern Caucasus, Volga valley, and central regions of the ETS.

There was drought in the summer of 1983 in the northern Caucasus and the lower Volga valley. In other regions of the country, there was sufficient precipitation, and precipitation was excessive in some central regions of the ETS. However, the late-maturing, heat-loving crops grown in the central regions were exposed to reduced temperatures. Thus, yields were below average, as is shown in Table 11.1.

Finally, July frosts were responsible for considerable damage to crops and vegetables in the Baltic republics, and fruits, especially grapes, were severely affected by unusual spring snowfalls and frosts in Georgia and Armenia.

The Impact on Water Resources

The unusual weather of 1982–83 also had an impact on water resources. The average inflow into the reservoirs of the Volga River system in the spring months is 158 cubic kilometers. If the inflow is lower than 150 km³, unfavorable impacts on hydroelectric power generation, agriculture, and fisheries can result. The water inflow in 1983 was only 144 km³ (Komarov and Dementyev, 1985). The decreased inflow to the Volga and Siberian river systems resulted in a decrease of hydroelectric power production as can be seen in Table 11.2.

Table 11.1 1983 Yields of Heat-Loving Crops in Two Regions of the European USSR Compared with Expected Yields (based on recent trends)

	1983 Yield (t/ha)	Expected (t/ha)
Central non-chernozem region:		
Millet	0.63	1.2
Buckwheat	0.27	0.6
Central chernozem region:		
Millet	0.82	1.3
Buckwheat	0.43	0.8

Source: *Yearbook of Statistics of Russian Soviet Federal Socialist Republic in 1983* (1984).

Table 11.2 Total Hydroelectric Power Production in the USSR (in billion kilowatt hours)

Year	1980	1981	1982	1983
Power	183	187	175	180

Source: *Yearbook of Statistics of the USSR in 1983* (1984).

The Impact on Sea Navigation in the East Arctic Region in 1983

The seaway that connects the European, Siberian, and Far Eastern regions of the USSR along the Arctic coast plays a very important role in the economy of the country. During the summer and autumn of 1983, there were extraordinarily unfavorable conditions for navigation in these waters. The ice thickness in the East Siberian and Chukotsk seas was below average up to the period of normal ice melting. However, lower-than-normal temperatures were recorded in June, varying from 0.8°C to 2.8°C below average in these areas. In the eastern part of the East Siberian Sea, even in June the mean monthly surface temperature was below 0°C. This resulted in a very slow sea-ice melting, and the ice thickness in July was 35–50 centimeters above average. Only in the second half of July was it possible for ships to reach the port of Pevec in the east of the Chukotsk Sea without ice-breakers.

However, this short-term improvement in ice conditions occurred simultaneously with a deterioration of the overall weather situation. In late August, cyclonic activity increased over the eastern Arctic region. Atmospheric pressure dropped to a 40-year record low by September. The ice drift caused by these atmospheric processes led to drastic changes in the ice field. The area of continuous ice usually decreases in September, but in that year the area increased on an unprecedented scale (by about 34%), and the resulting ice field blocked the Chukotsk Sea almost completely (Kovalyov et al., 1985). As a result, the last convoy of ships bound for Pevec encountered severe problems that were catastrophic for some ships.

Floods, Storms, and Mud Slides

There were episodes of floods, storms, and mud slides in several regions of the country during 1982-83. A series of floods in west Georgia resulted in property and crop damage and even some deaths in early April and in the middle of June 1982. Flood damage to property and crops also occurred in Azerbaijan in early October. In the Leningrad region in December and January 1982-83, heavy rainfall, combined with strong westerly winds over the Baltic Sea, caused the Neva River to rise to a dangerously high level. Floods damaged property in the city of Leningrad and stimulated extra efforts to complete the construction of a dam in Baltic Bay to protect the city from similar occurrences in the future.

In early February 1983 severe storms along the Baltic coast led to coastal flooding. In addition, an oil spill from a tanker that broke up off the Baltic coast spread to the coastline, spoiling sands in recreational areas and having an extremely unfavorable impact on the environment of the region (e.g., killing fish and sea birds).

Glaze Deposition (Freezing Rain)

The cost and reliability of construction work on electric power lines, antenna systems, etc., during the winter months can be adversely affected by glaze deposition in many parts of the USSR. The mild and wet winter of 1982-83 produced conditions that were conducive to glaze deposition. Unusually thick glaze deposits were measured at some meteorological stations during this winter. In December, a southern Ural station reported the greatest deposition ever recorded in the USSR over the period of instrumental measurements, with 86.2 kilograms of ice per meter of cable (the diameter of the ice was 79 cm) (Podrezov and Naumov, 1985). Deposits of such magnitude or greater previously had been observed only on the western slopes of Scandinavian mountains affected by winds from the Gulf Stream.

Conclusion

Many extraordinary climatic events occurred in the USSR during 1982-83. It is difficult to say whether any of these phenomena had a direct connection with the 1982-83 ENSO event (Bousova and Tsvetkov, 1986). Nevertheless, as a documentary record, a summary of the various climate impacts that occurred during this period is valuable. It is important to note that many of the currently available statistical data that are used for identifying climate impacts are not entirely suitable for this task. Other non-climate-related impacts may obscure any climatic effects, thus presenting great difficulties for the analyst trying to conduct a quantitative climate impact assessment.

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CHAPTER 12

1982-83 CLIMATIC ANOMALIES OVER WESTERN EUROPE AND THEIR IMPACTS

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Introduction

This chapter examines climate anomalies in Western Europe from January 1982 to December 1983 in order to assess the impact of these events on climate-related economic activities. In addition, an attempt is made to identify whether there may be some linkage (teleconnection) between climate anomalies in the equatorial Pacific and in Western Europe. Such connections may be expected to exhibit a time lag over a number of months, and this is taken into consideration in the analysis. Attempts to link climatic series from the region with an index of the Southern Oscillation failed to produce significant results.

Climatic Events in Western Europe in 1982-83

The year 1982 was characterized over the Northern Hemisphere by a marked change toward a cooling from the relatively warm conditions experienced during 1981 (locations mentioned are shown in Fig. 12.1). Although perhaps half of this cooling can be attributed to the effects of volcanic explosions (Sear and Kelly, 1982), in fact the cooling commenced in January, some three months before the first major eruption of 1982 took place in April at El Chichon (Mexico).

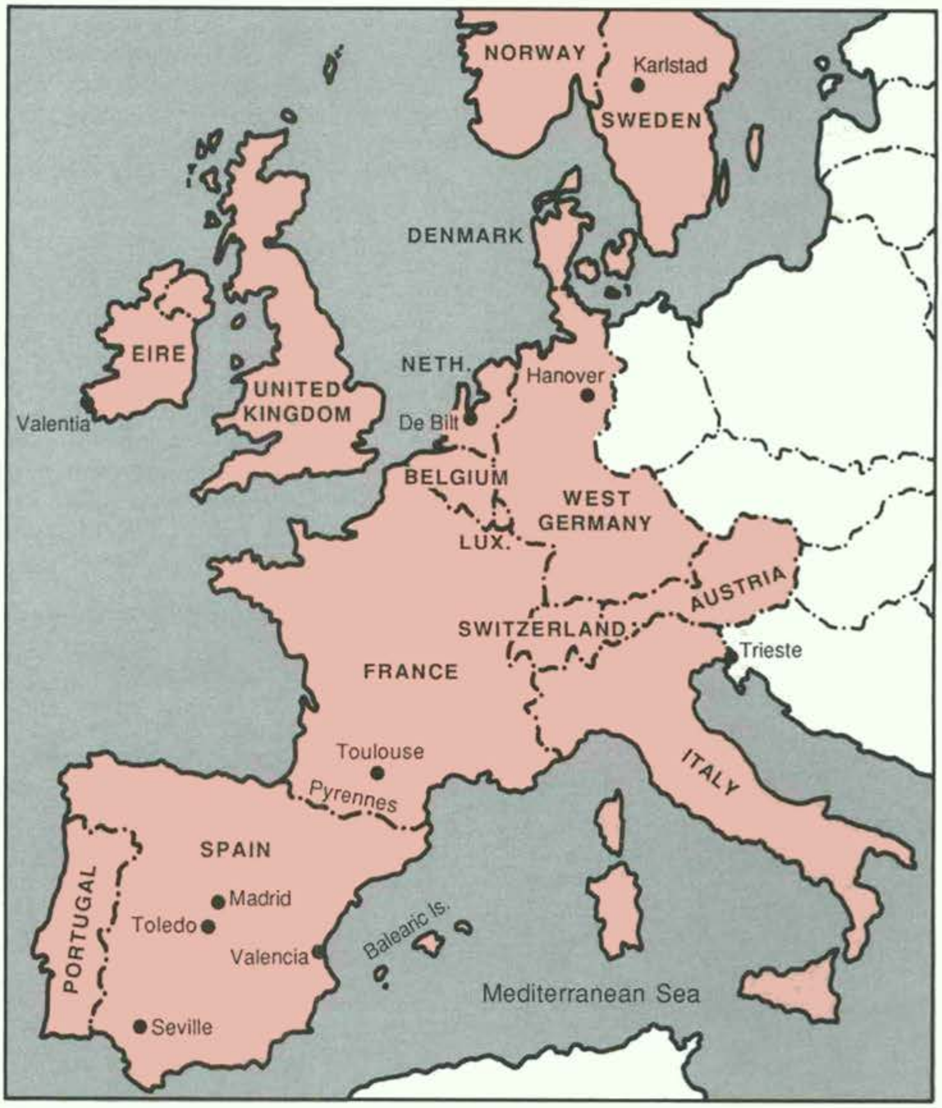

Fig. 12.1 Western Europe.

For Europe, January 1982 saw cooler-than-average temperatures north of 55°, but conditions to the south of this latitude remained warmer than the long-term average. As the year progressed into spring, temperatures in Western Europe remained within 2°C of normal values. April and May were both dry months, with rainfall in England and Wales only 38 and 69% of the respective monthly mean values . Summer temperatures remained near the long-term mean. June was wetter than usual over much of central Europe, France, the Benelux countries, and most of the United Kingdom, with rainfall in England and Wales being 214% of the long-term mean for that month. July and August saw a return to drier conditions over much of central and northwestern Europe. Autumn was warmer than average over western Europe, particularly in September and November. This season witnessed wetter than normal conditions over western coastal and northern Europe, with drier weather in the interior.

December 1982 was the only month of the year when the Northern Hemisphere temperature was significantly higher than the 1951-70 reference period (Jones, 1983). Over Eurasia, temperature anomalies reached +9°C in some locations. Northern and central Europe were wetter than average, and in France most stations reported about 200% of the mean monthly rainfall. Spain and Portugal were unusually dry, with rainfall in some areas as low as 10% of normal. Thus 1982 was characterized by a return to cooler conditions, after the exceptional warmth of 1981. December 1982 was the precursor of yet another warm year. The mean Northern Hemisphere temperature anomaly for 1983 was +0.43°C, the second warmest year since the start of the time series in 1851.

Over Western Europe the warmth of December continued through January. Britain experienced the fourth warmest January of the century, with a central England temperature anomaly of +3°C. Northern Europe was wetter than average but Spain and the Mediterranean coast had a persistence of dry conditions. In February most of Europe was colder than usual, dry in the north and wet in Spain and along the Mediterranean coast. The main feature over Europe during the spring season was the wet weather affecting northwestern areas. Denmark and the Netherlands experienced the wettest spring on record. March was warm over Europe, but April and May were marked by a return to colder weather, with anomalies of up to −3°C.

The summer was marked by exceptionally hot weather in July. Britain recorded the highest monthly value ever measured in the 300-year central England temperature series, 19.2°C (Burt, 1983), and new national records were established in West Germany, Austria, and Switzerland. This was in contrast to a relatively cool June, and an August in which the European anomalies did not exceed +2°C. In general, drier conditions prevailed throughout most of Europe, and the rainfall series in England and Wales produced the second driest summer value (after 1976) of this century. Farmer (1983) had this to say about the situation in Spain:

> *By mid-summer some areas of Spain had experienced three years of drought conditions. Worst hit was an area stretching from Extramadura on the Portuguese border to Valencia and the Balearics in the east, and from Toledo in the centre up to the Pyrenees. About 1.3 million people were affected by the drought. 174 towns and villages, containing 357,000 people, had little or no water.*

Autumn was generally dry, with temperature anomalies in September and October within 2°C of the long-term mean. In November anomalies of up to −7°C were recorded in central and northern Europe. The year ended with unexceptional conditions in December, marked only by some severe gales.[1]

While neither 1982 nor 1983 in Western Europe experienced marked climatic events on the scale of, say, the droughts in Australia or the floods in South America, there were certain events worthy of further consideration. For example, the spring of 1983 was, in many areas of northwestern Europe, the wettest on record. Also, the summer of 1983 was marked by an exceptionally hot July. Finally, by the end of 1983 drought conditions had persisted in parts of Spain and Portugal for as long as three years. Each of these events is analyzed in more detail with the assistance of appropriate climatic data.

In order to illustrate rainfall conditions over northwestern Europe in the spring of 1983, a long time series of rainfall from De Bilt in the Netherlands (beginning in 1849) was examined. Rainfall in the three spring months of March, April, and May 1983 totaled 289 mm, making it the wettest spring season since 1979 (when the rainfall was 311 mm) and the second wettest on record. Of the three months, May was the most severe, with 123 mm, ranking as the fourth wettest May in this century. March (81 mm) and April (85 mm) both ranked ninth wettest of their respective months in this century.

As noted, July 1983 was the hottest month on record at many stations in Western Europe. In order to assess the regional long-term significance of this month, we analyzed gridded monthly temperatures from the surface data set prepared by Jones et al. (1985). In this data set the temperatures are expressed as anomalies relative to a 1951-70 reference period. The June, July, and August values for the period 1900-84 were ranked for each month. The 1982 and 1983 ranked values for June and August were unexceptional. However, July 1983 registered the absolute greatest temperature anomaly (+1.69°C) for that month since 1900.

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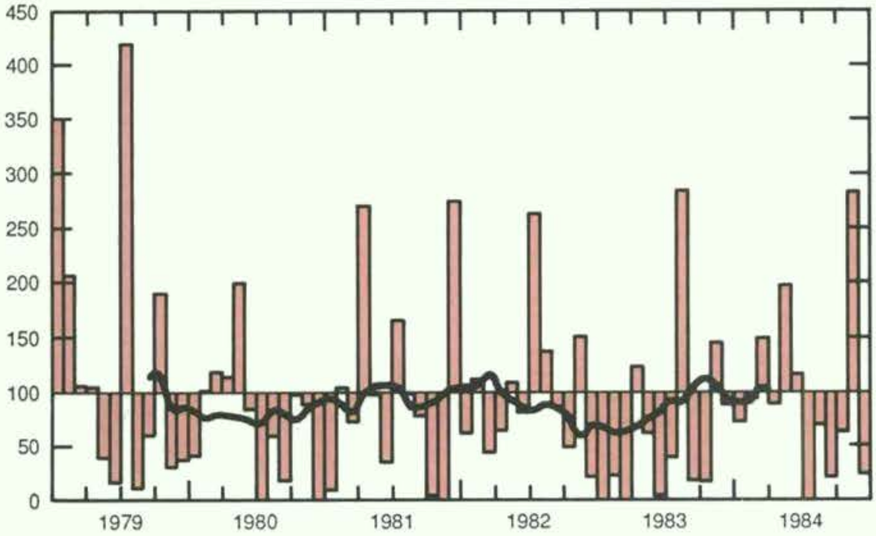
[1] The above descriptions are extracted from the seasonal and annual weather reviews produced in *Climate Monitor* volumes 11, 12 (Jones, 1982, 1983) and *Weather* volumes 37-39 (Ratcliffe, 1982, 1983, 1984).

Fig. 12.2 Rainfall series for Madrid expressed as percentage deviations from the 1900–84 monthly means (vertical bars show the observed values, line graph shows running 12-month means of these values).



Yet it was not the greatest of the summer season: in August 1947 the anomaly was +1.99°C. If we consider the series from the start year in 1851, then the order of July 1983 in the rankings of all July slips to second, after 1859 (+1.83°C). In the rankings of all summer months it moves to fifth (the absolute greatest anomaly being +2.22°C in June 1858).

In Spain and Portugal the dry conditions of 1982 and 1983 were simply a continuation of a drought that began in early 1980 (Farmer, 1981). Using the Madrid record, the percentage deviations were calculated for each month from the 1900–84 mean rainfall for that month. In the four years 1980–83 inclusive, 67% of all months (32 of 48) had rainfall below their respective long-term means. Figure 12.2 shows this time series, along with 12-month running means of the same series.

Climatic Impacts on the Economy of Western Europe

We examine three areas of economic activities that may, under certain circumstances, be sensitive to climatic variation: agriculture, industry, and transport. These are analyzed with respect to the climatic events that took place in 1982 and 1983.

Agriculture is perhaps the most obvious sphere of activity where a direct link with climate may be seen. Yet, this link is often extremely difficult to establish quantitatively, owing to the interactive effects of such variables as fertilizer application, seed type, and technology. (For a discussion of the effects of these variables, see National Defense University, 1980.) A survey of the 1982–83 period suggested that the climatic event most likely to demonstrate a climate/agriculture link would be the Iberian drought.

Yield series were extracted for Spain for three crops: wheat, olives, and grapes (FAO, 1961–84). The results for wheat are shown in Fig. 12.3. This shows that yields rose over the period 1961–84, while the planted area gradually declined. The increase

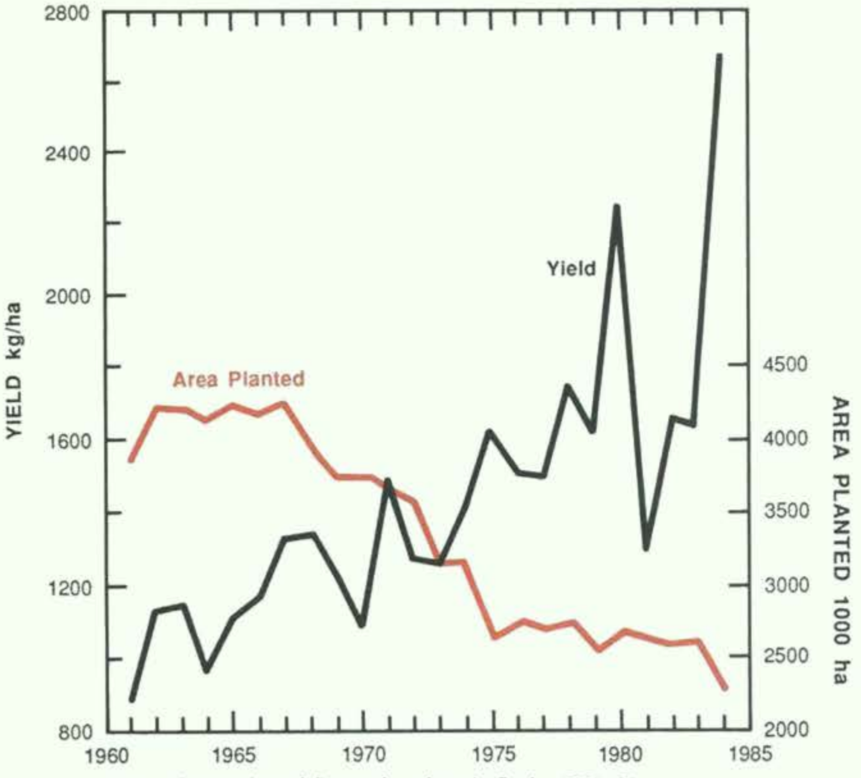


Fig. 12.3 Yield and area planted figures for wheat in Spain, 1961–84.

in yields up to and including 1980 was reasonably steady, but in the four succeeding years production was extremely erratic. Between 1980 and 1981 yields declined by nearly 100 kg/ha, recovering to just over 1,600 kg/ha in 1982 and 1983. A sudden upsurge then brought yields to over 2,600 kg/ha in 1984. It is reasonable to assume that at least some part of this yield reduction was induced by drought: 1981-83 were drought years, with a return to normal conditions in 1984.

The impact of the drought was twofold: not only was there an overall reduction in yields, but yields became more erratic, making even short-term planning very difficult for both farmers and the central government. As Fig. 12.3 demonstrates, the planted area was unaffected by the drought. Yield time-series for olives and grapes reveal similar characteristics to that for wheat.

The impacts of a climatic event such as the Iberian drought are not restricted to the direct effects on crop yields. Agriculture contributes around 6% of the gross domestic product (GDP) in Portugal and around 8% in Spain, and is a disproportionately large source of employment. Thus substantial secondary effects occurred in other sectors of the economy in both countries.

It is estimated (Lloyds Bank, 1984) that in Spain over the three years 1981-83 crop losses amounted to about £1 billion. The major reduction in agricultural production was between 1980 and 1981 when, contrary to the expected growth level in a good year of about 8%, production declined by 10 to 11%. Despite the continuing drought, modest gains in production were made both in 1982 (2.3%) and 1983 (2.5%).

One result of the drought was a dramatic increase in farmers' indebtedness, which rose by 20% for each of the two years 1981 and 1982 to a level equivalent to 55% of the total annual agricultural production. Despite state-backed loans with easy terms and a debt moratorium, Spanish agriculture was rendered substantially undercapitalized, with reduced purchasing power for inputs such as fertilizers. Secondary effects of the drought included a decline in the production and sale of tractors of about 35% between 1980 and 1981. Nonclimatic effects had already led to a reduction in the country's economic growth rate from 6% per year in the early 1970s to less than 2% by 1979. The effect of the drought reduced this figure to barely 1% in 1981.[2]

The first effects of the drought were felt earlier in Portugal than in Spain, in 1980 rather than in 1981. The value added in agriculture (that is, the value of the products sold less the cost of any inputs) increased by only 2% in 1980 – compared with 9% in 1979 – and fell by 6% in 1981, with a particularly sharp drop in crop production of about 20% (OECD, 1982). It was found necessary to introduce a £20 million emergency credit and subsidies program to alleviate the severest effects (Lloyds Bank, 1982b). The temporary stabilization of agricultural employment observed in 1979 at a time of exceptionally good harvests gave way to strong decline in 1980 (–4.8% change from the previous year) and 1981 (–5.5%), with accompanying increases in rural-to-urban migration. Despite the small contribution of agriculture to the GDP, this sector is a major source of employment, and in 1981 it still absorbed 26.7% of the work force.

Severe difficulties were experienced by hydroelectric producers in both nations during the drought. Currently Spain is reducing its dependence on this power source (one reason being the uncertainty of supply), from 43% of its electricity output in 1977, to a planned 28% in 1987. Portugal was in an even more vulnerable position at the start of the drought, with 70% of electricity output derived from hydropower producers in 1979. In 1981 this figure had dropped to 37%.

Palutikof (1983a) showed that industry in Great Britain is severely affected by extreme seasons such as cold, snowy winters and hot, dry summers. Apart from July 1983, there were no such events in the period under consideration. This month hardly bears comparison with the drought summers of 1975 and 1976 in the United Kingdom, which provided evidence for the Palutikof analysis. It was shown that during those summer droughts the decline in production occurred mainly in the ferrous metals (around 10%) and utilities (around 6%). Both are industries which require large quantities of water in their production processes. A climatically induced decline in output on this scale in a temperate country such as Great Britain can come only with a severe and prolonged extreme event, such as the 1975-76 drought. One exceptionally hot and dry month would have a much more limited effect.

Winter weather is known to have an influence on transport. A study by Palutikof (1983b) showed that several transport indicators, covering commercial and private mileages and the number of road accidents in Great Britain, were affected by winter weather conditions. In a set of analyses of February transport, snow depth and rainfall were shown to be important predictors. If anything, the winter weather of 1982-83 was warmer than average over Western Europe, and therefore would not have had any unfavorable impact upon transport.

Summary

Over the 24-month period of January 1982 through December 1983 there were three notable climatic events in western Europe: the wet spring of 1983, the exceptional heat of July 1983, and the continuing drought in central Spain and Portugal. There can be no doubt that the Iberian drought caused severe disruption of agricultural production and associated financial loss. For example, Spanish wheat yields were almost halved between 1980 and 1981, and did not return to normal until 1984. Severe related effects were experienced in other sectors of

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[2] The data in this paragraph are taken from Lloyds Bank, 1981, 1982a, 1983, 1984.

the economies of both Spain and Portugal. Furthermore, we suggest that in northwest Europe industrial production may have been affected by the wet spring and hot July 1983.

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CHAPTER 13
CLIMATE-RELATED IMPACTS IN THE UNITED STATES DURING THE 1982-83 EL NIÑO

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Introduction

This chapter documents climate-related impacts that occurred in the United States (Fig. 13.1) during 1982–83. Many of these impacts have been rightly or wrongly attributed to El Niño. The impacts of the summer drought and heat wave in the central United States and the decline of the fishing industry along the northwestern coast of the United States are discussed in greater detail.

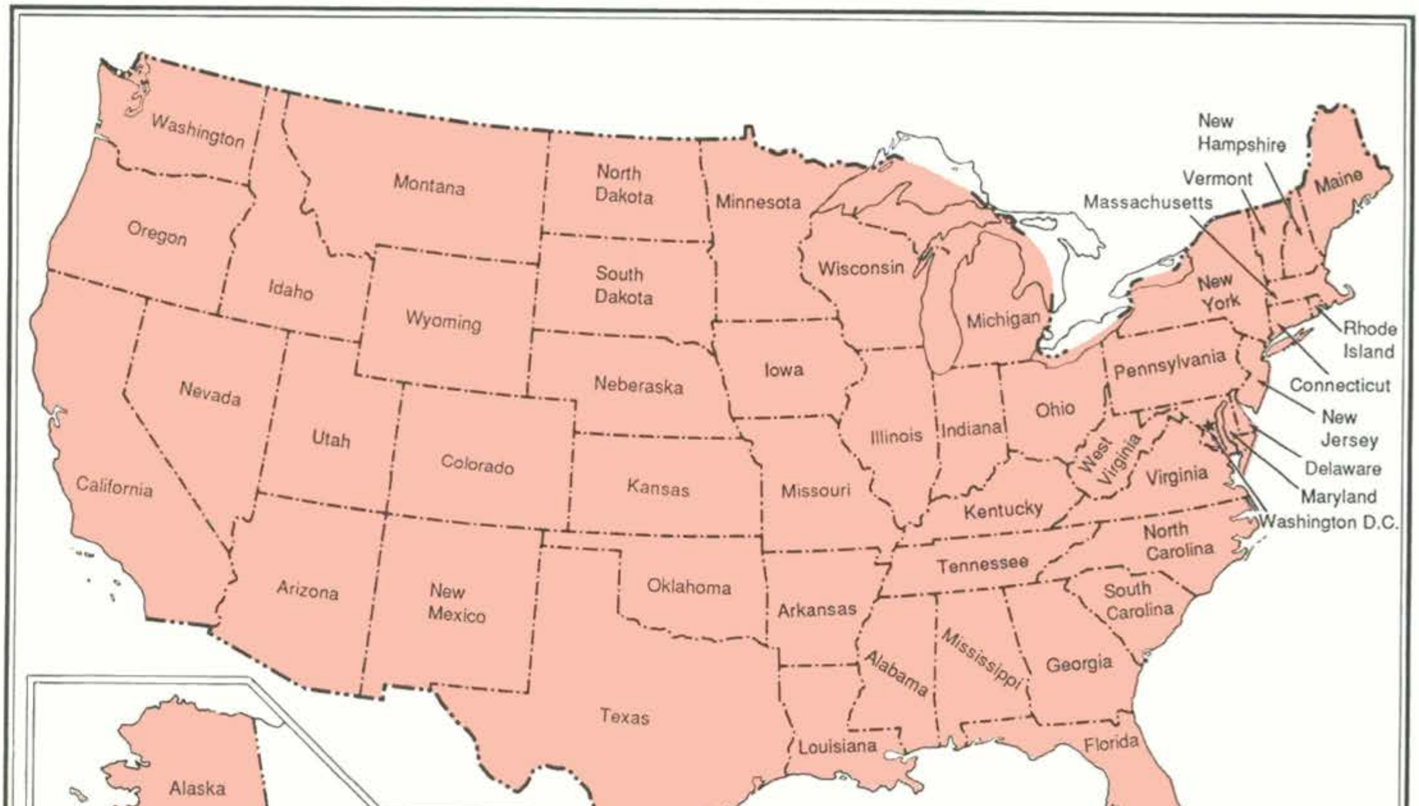

Fig. 13.1 United States of America.

General Climate-Related Impacts of the 1982-83 El Niño in the United States

Five events appear to be the most noteworthy: (1) the occurrence of Hurricane Iwa in the Hawaiian Islands; (2) severe winter storms, high winds, and flooding along coastal areas of California, Oregon, and Washington; (3) storms and flooding on the Gulf Coast and in Midwest states; (4) warm winter in the eastern portion of the nation; and (5) summer drought and heat wave over a large portion of the country. The several significant climatic events that occurred before November 1982 (for example, a cool August throughout most of the nation, especially the Midwest and Northeast), are not discussed here.

Hurricane Iwa

Beginning in the fall of 1982, in association with El Niño, there occurred an eastward shift in the area where tropical storms in the Pacific are formed. As a result, six major tropical cyclones struck French Polynesia from December 1982 to April 1983. It has also been suggested that the path that Hurricane Iwa took in late November 1982 may have been a consequence of these shifts. Iwa struck Hawaii from the southwest and was the first hurricane to hit the islands directly in 23 years, causing an estimated $234 million in damage, mostly to property ($200 million), and one death (*UPI News,* August 2, 1983). In addition, 7,000 people were evacuated from their homes, and Waikiki Beach hotels were also heavily damaged (*L.A. Times,* November 26, 1982).

Substantial impacts also occurred in Hawaii's agricultural sector, particularly to sugar cane fields and orchards. Also, 94% of the electrical power users on Oahu were affected and more than two weeks were needed to restore power to all of the islands (NOAA/NESDIS, 1983). Three islands – Kauai, Nihau, and Oahu – were declared major disaster areas by President Reagan.

West Coast flooding

As the winter of 1982-83 developed, a second series of extreme weather events occurred, this time along the West Coast. These storms were attributed to a series of meteorological and oceanographic events including high ocean temperatures near the equator, low ocean temperatures farther north and abnormally strong winds aloft (*L.A. Times,* March 2, 1983). The southward movement of the westerly winds resulted in frequent storms, first in northern and central California, and then, as the winter progressed, in southern California, Oregon, and Washington. The jet stream, normally at about 40°N along the Pacific Coast, had dropped southward to about 30°N, resulting in a shift in the normal storm track, driving storms into southern California. The exact cause of the shift was not known, but many attributed it to El Niño (e.g., Wooster and Fluharty, 1985).

The most severe storms occurred in December, January, and March, causing extensive damage to coastal shorelines and property; erosion and flooding of farmland; mudslides and rockslides; damage to highways; and losses in agricultural production, particularly in small grain crops, vegetables, and fruit quality. Fruit and vegetable prices increased substantially in response to the impact of these storms.

During March 1983, a series of storms in southern California resulted in an estimated $200 million in agricultural damage. Nearly 10,000 homes were also affected by mudslides and about 1,000 businesses were damaged or destroyed. Los Angeles rainfall from January to early March was 23 centimeters above normal, and March 1983 was the wettest March in Los Angeles since 1884. In early March, 33 California counties qualified for special federal assistance (*L.A. Times,* March 4, 1983). The California Coastal Commission, in response to the impacts associated with the winter storms of 1982-83, suggested that the governor appoint a panel to study the damage resulting from the storms and recommend changes in coastal building policies and highway construction (*L.A. Times,* March 13, 1983).

Gulf Coast and Midwest storms and flooding

Heavy rains and snows across the Gulf states and parts of the Midwest had extensive impacts during 1982 and 1983. The first storms were confined primarily to the Gulf states of Louisiana and Mississippi, extending northward into Arkansas, Missouri, Illinois, and Iowa. These storms began in early December 1982 and resulted in the deaths of eight persons in Illinois and two in Arkansas. During this same period, dams in the southern Mississippi Valley were weakened by heavy rains of more than 23 cm in two days. Thousands of people had to be evacuated throughout the affected area (*Chicago Tribune,* December 4, 1982, 8).

Rainfall in Illinois during the first three days of December was nearly three times the normal amount for the entire month (*Chicago Tribune,* December 4, 1982). Flooding continued into mid-December in Illinois; 34 counties were declared state disaster areas (*Chicago Tribune,* December 18, 1982), and 22 counties were designated as federal disaster areas (*Chicago Tribune,* December 12, 1982). The impact of these December storms was primarily in the form of severe soil erosion on farmland and damage to hay and other forages, as well as substantial property damage, especially to farm buildings, roads, and bridges. Flood damage in Illinois was estimated at $100 million (*Chicago Tribune,* December 12, 1982).

Heavy rains and flooding recurred in Mississippi and Louisiana during April and May 1983. In the Mississippi Valley, rivers were at near-record levels as floodwaters affected nearly 100,000 homes and blocked about 150 major roads. In New Orleans, almost 75% of the city's streets were about one and one-half meters under water (*Chicago Tribune,* April 7 and 8, 1983). Officials in Mississippi and Louisiana estimated that damages could reach $350 million (*Chicago Tribune,* April 11, 1983). The agricultural sector was the most seriously affected by the excessive rainfall and consequent flooding in Louisiana and Mississippi. During April more than 100,000 poultry and 1,000 cattle died as a result of storms. In May, 17% of the cotton crop was lost and approximately 120,000 hectares of farmland were flooded (NOAA/NESDIS, 1983). Total losses resulting from storms in this area between December 1982 and May 1983 were estimated at $1.1 billion ($900 million in property damage, $200 million in agriculture), and more than 50 persons were killed (Simon, 1983).

Warm winter in East

The warm winter of 1982–83 over the eastern United States is another in the series of major climatic events that occurred in 1982–83 and had significant societal impacts. During December 1982, temperatures were 5 to 10°F (2.8 to 5.6°C) above normal, reducing energy demands considerably. This pattern continued into January, with most of the country east of the Rocky Mountains experiencing temperature conditions much above normal. Impacts were mainly positive, such as a continued reduction in heating demand, reduced temperature-related livestock stress, and reduced snow removal requirements for municipal governments. It has been estimated that the mild winter saved American consumers approximately $2.5 billion in reduced heating costs (*UPI,* May 4, 1983). Negative impacts were primarily experienced by ski resorts and by utility companies because of lost revenue (NOAA/NESDIS, 1983).

Summer drought and heat wave

A summer drought and heat wave began in mid-July 1983 over a large portion of the nation. These hot and dry conditions followed a rather cool, wet spring for a portion of the nation. The drought and heat wave that ensued persisted through September in the Corn Belt and Great Plains states. The impacts of this drought and heat wave are discussed in more detail in the next section.

Impact of the Summer Drought and Heat Wave, July-September 1983

Extremely warm temperatures and below-normal rainfall occurred throughout most of the country, beginning in mid-July 1983 (Fig. 13.2). The area east of the Rocky Mountains was most severely affected. These conditions were an abrupt change from the cool and extremely wet conditions experienced during the spring and early summer months throughout most of the Plains states and in the Corn Belt. Because of the coincidence of these hot and dry conditions with critical developmental stages for corn, soybeans, sorghum, and cotton, this relatively short-term event caused a significant reduction in yields.

As hot and dry conditions continued through July, revised yield estimates projected losses of approximately $3 billion for corn, $480 million for cotton, and $670 million for soybeans (NOAA/NESDIS, 1983). The combination of the drought and government programs already in progress to encourage farmers not to cultivate crops in surplus reduced the U.S. corn harvest to its lowest level since 1974. This resulted in higher food prices for consumers.

The drought and heat wave continued through the month of August and into September in the Great Plains, Corn Belt, and Middle Atlantic states (Fig. 13.2). The northern Plains states experienced their second warmest August in more than 50 years. On September 1, estimates of crop yields showed that corn production was now expected to be 50% below 1982 levels. Losses were estimated to be $5.5 billion. Soybean losses in 1983 were projected at $3.4 billion; sorghum, $500 million; and tobacco, $1.1 billion. To mitigate drought-induced losses, states put political pressure on the federal government to provide assistance to affected farmers.

Other impacts associated with the drought and heat wave of 1983 appeared in the health and energy sectors. By late July, 180 deaths had been attributed to the heat wave (*Chicago Tribune,* July 27, 1983). By late August this number had increased to more than 200 (*Chicago Tribune,* August 25, 1985). Energy consumption for cooling increased

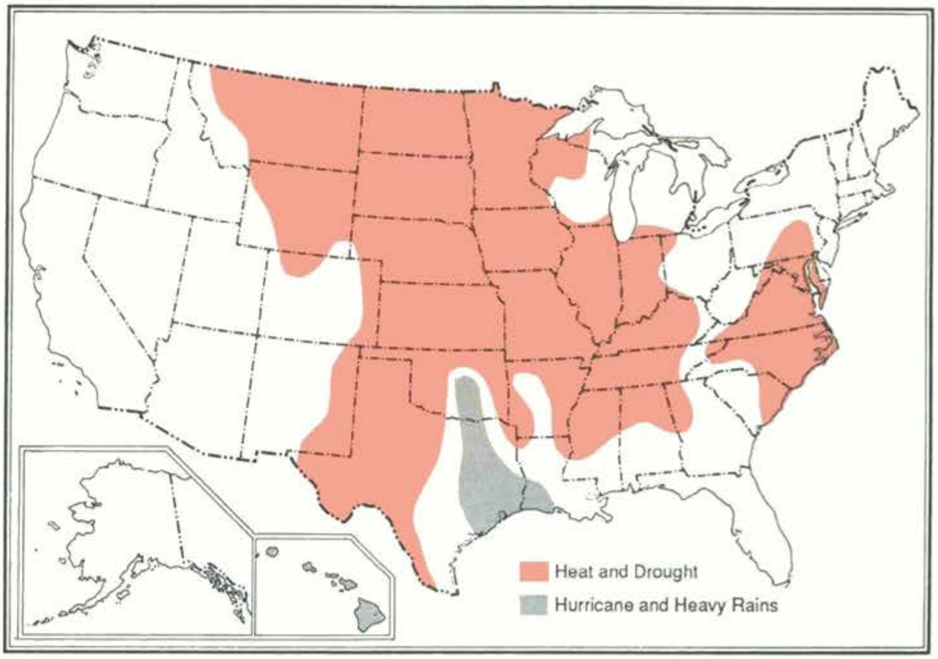

Fig. 13.2 Areas affected by heat and drought and by hurricanes during August 1983 (NOAA/NESDIS, 1983).

dramatically in the period from mid-July through mid-September because temperatures were much above normal. Illinois, for example, reported its hottest and driest summer since the mid-1950s (*Chicago Tribune,* August 26, 1983). From the last three weeks of July through the first two weeks of August, Americans spent more than $3.3 billion in air conditioning (energy costs) (*Chicago Tribune,* August 9, 26, 1983), about $1 billion above normal.

The Disruption of Northwest Coast Fisheries

El Niño was blamed for the disappearance or reduced numbers of certain species, displacement of others, and, in some cases, increased numbers of some species. The greatest declines in the Northwest Coast fisheries during the 1982-83 El Niño were associated with salmon. Commercial fishermen in Washington reported catches down more than 50% from expected numbers (*Port Angeles, Washington, Daily News,* September 10, 1983). The number of salmon caught off the coast of Oregon was also greatly reduced.

The disruption of the salmon fishery along the coast of Washington, British Columbia, and Alaska resulted in considerable conflict among commercial fishermen. A treaty signed in 1937 between U.S. and Canadian fishermen resulted in a 50-50 sharing of sockeye salmon returning to the Fraser River through the Strait of Juan de Fuca (*Seattle Times,* September 5, 1983). In normal years nearly 80% of the sockeye follow this route (*Seattle Post-Intelligencer,* August 19, 1983). In 1983, however, nearly all of the sockeye returned to the Fraser River through Johnstone Strait along the west coast of Vancouver Island, staying entirely within Canadian waters. Because U.S. fishermen cannot fish within Canadian waters, the result was bountiful catches for Canadian fishermen and severely reduced numbers for U.S. fishermen. Conflicts were equally intense between Canadian and Alaskan fishermen. This debate over the proper use and control of the salmon fishery continued well into 1984.

Income for Northwest Coast fishermen was sharply reduced during 1983, particularly for salmon fishermen. It was reported that the average commercial fisherman's income during 1983 was $1,318, down from the 1977-82 average of $13,258 (*Seattle Times,* November 24, 1983). The governor of Washington, along with other political leaders from the region, responded by requesting federal assistance in the form of low-interest loans to the salmon industry, justifying the request by citing NOAA's claim that El Niño was responsible for the disastrous salmon season (*Seattle Times,* November 24, 1983). The total impact of El Niño, or warm ocean temperatures, on Washington's fishing industry was estimated at $400 million (*New York Times,* December 17, 1983).

Migration patterns and the timing of these movements were also disrupted for other fish during 1983. Anchovies were found farther north and were more widely scattered than in previous years. There were also northward extensions of the bonito barracuda, red crab, popeye catalufa, and bocassio (Finley, 1983). Coho and pink salmon began moving up the spawning streams in Alaska a month or so early, reportedly because of water temperatures that were higher than normal (*Seattle Times,* June 20, 1983). The change in sea temperature had a pronounced effect on young Coho salmon runs between Monterey, California, and Puget Sound (*Herald,* August 29, 1983). Numerous other species were affected in a similar manner.

Warmer than normal sea temperatures had a positive impact on the fish populations of some species along the West Coast. For example, albacore tuna was projected to be more abundant, as were oysters. The yellowfin tuna was harvested in record numbers off the coast of San Diego (*UPI,* August 17, 1983). Alaskan salmon fishermen experienced a bountiful year, at the expense of their neighbors to the south.

Bird populations were directly affected by changes in the size, numbers, and species of fish along the West Coast. These changes were reportedly caused by disruptions of normal food sources which, in turn, affected nesting habits. Puffins, cormorants, and gulls declined in numbers (*Port Angeles, Washington, Daily News,* September 10, 1983) and terns, brown pelicans, and frigates migrated to new nesting grounds in the Northwest (*Seattle Times,* August 25, 1983).

Summary and Conclusions

Climate-related impacts attributed to the 1982-83 El Niño were global in extent. The consequences of these events were of staggering economic dimensions. In this paper, we have discussed the economic impacts of prominent climatic events that occurred in the United States between the fall of 1982 and the winter of 1983-84. These are: (1) Hurricane Iwa, the first hurricane to strike the Hawaiian Islands in 23 years – damage estimated at $234 million; (2) severe storms along the West Coast and associated high winds, coastal erosion, and flooding – damages and losses of several hundred million dollars; (3) heavy rainfall and flooding along the Gulf Coast states and in the Midwest – damages and losses in excess of $1 billion; (4) the warm winter of 1982-83 over most of the nation – consumer savings of $2.5 billion through reduced heating costs; (5) summer drought and heat wave of 1983 – crop losses of $10-12 billion.

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CONCLUDING COMMENTS

The Editors

It is important to reiterate that the case studies discussed in this volume are provided to illustrate some of the impacts on society, economy, and environment of climate anomalies that occurred during the 1982-83 ENSO event. They are necessarily not exhaustive. Many other countries could have been included in this preliminary assessment, but the available resources did not enable a full and comprehensive coverage of the globe. We call on researchers in other countries to undertake similar case studies for their country for the 1982-83 period in order to expand the data base on the societal impacts of hypothesized ENSO teleconnections. It is hoped that the existence of a large data base will, in the face of future ENSO events, provide us with a better understanding of the interrelationship of climate and society.

Each of the contributors has been given the leeway to identify those aspects of the society, economy, and environment that he or she felt were of interest or importance to the theme of the Lugano meeting and therefore to this report. It is clear that there are other aspects of the impacts of these climate anomalies that might also have been highlighted. But the main purpose of this report was simply to establish worldwide a common concern for ENSO events and their teleconnections, as well as for the possible societal impacts of those hypothesized teleconnections.

Time will tell which of the areas identified for investigation here, as well as of areas not represented in this report, will hold up as true teleconnections. In any event, the participants of this meeting believe that with continued improvements in our understanding of ENSO events and their teleconnections, cautious optimism may be warranted for the long-range forecasting of such events and for the mitigation of their adverse effects.

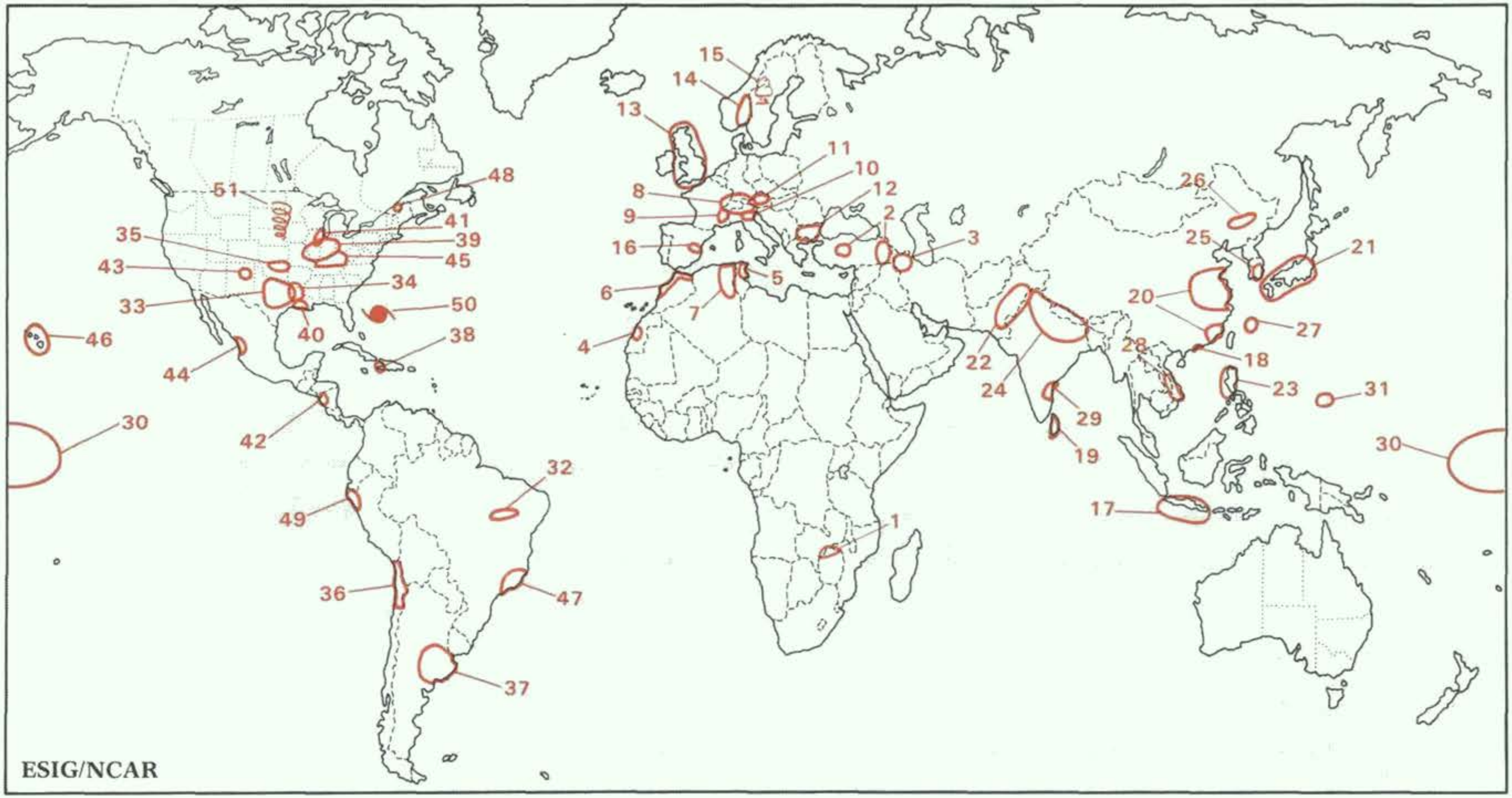
APPENDIX

Climate Impact Maps

The following maps and tables indicate the occurrence and location of droughts or of floods snd severe storms during the El Niño years of 1957-58, 1972-73, and 1982-83. Each climatic event on a map has a corresponding number in the table, describing the event and/or its impact. The extent of the description depends on the availability of information. The information was compiled from several sources, such as the *New York Times, London Times, Monthly Weather Review, Weatherwise, Climate Monitor,* and the biweekly Climate Impact Assessment reports of the U.S. National Oceanic and Atmospheric Administration. The maps and tables were compiled by Karen Robinson and Daniel Ely while they were visitors to ESIG.

1957 FLOODS/HEAVY RAINS/SEVERE SUMMER STORMS

March - December



Africa & Mid East

1. n Zimbabwe (Southern Rhodesia) - Mar 18
   a. Zambesi River floods, damage to hydroelectric facilities
2. Turkey - May 15-28; Sept 12-13
   a. May: e Turkey, rains cause widespread flooding, fatalities
   b. Sept: Bent River flash floods Ankara area, nearly hundred fatalities, heavy damages
3. nw Iran: Tabriz area - Sept 15-18
   a. Heavy rains, flooding, over hundred fatalities
4. Western Sahara (Spanish West Africa): El Aiun area -Nov
   a. Heavy rains, flooding, fatalities
5. Tunisia; Tunis - Nov 7-8
   a. Rain caused flooding, fatalities

21. Japan - July 25-28; Aug 9; Sept 7
    a. July: nw Kyushu; torrential rains, floods, landslides, thousands of homes inundated, heavy damage, nearly 600 fatalities
    b. Aug: c areas, torrential rains, fatalities
    c. Sept: s areas, typhoon, casualties
22. Pakistan - early July; mid Aug thru early Sept
    a. July: e Pakistan
    b. Aug: Lahore area, 2,000 homes destroyed, fatalities; later in period the Ravi, Chenab & Jhelum rivers flooded, nearly hundred fatalities, several villages washed away

34. s US: NW Louisiana - May 6-10
    a. Flooding on Red River, esp. Shreveport & Clarence
35. US: n Oklahoma - May 15-28
    a. Heavy rains (13.1" recorded in one 24-hr period), snowmelt, flooding, Arkansas & Cimarron rivers flood, heavy damage, fatalities
    b. Some areas under 12 feet of water, damage est. at $150M, declared disaster area May 19, worst flooding in 34 yrs
36. n Chile - May thru June
    a. Heavy rains, flooding, storm damage to n provinces

6. coastal Morocco - Dec 12-13
   a. Severe storms, high winds, heavy rains, on both Atlantic & Mediterranean coasts, heavy damage
7. e Algeria - dates not known
   a. "Devastating rains & floods" reported

Europe & USSR

8. c Europe: Alps - June 17-18
   a. Severe storms, fatalities, over $150M damages.
9. se France: Arc River basin - June 14-19
10. Italy: Po Valley - June 15-29; Nov 12-25
   a. June: Po River flooded in n lowlands, heavy crop & property damage; thousands affected
   b. Nov: Po again floods delta & Catania Plain areas
11. Austria: Salzburg area & along Danube River - late July
12. Bulgaria - late July thru early Aug
   a. Severe flooding, 40,000 "victims"
13. Great Britain - Aug 14
   a. Heavy rains, flooding
14. Norway - Aug 13-14; Sept 17-18
   a. Aug: Oslo area flooded by heavy rains
   b. Sept: e Norway hit by heavy rains & flooding
15. Sweden† - mid Sept
   a. Heavy & widespread rains, floods, 4 dams burst, heavy damage
16. Spain: Valencia area - Oct 15-31
   a. Heavy rains, severe flooding on Turia River, fatalities, heavy damage

Asia

17. Indonesia: Java - Mar 9; July 19; Dec 23
   a. Mar: e Java flooded
   b. July: Tijesell River floods w Java, thousands homeless, fatalities
   c. Dec: c Java flooded
18. Hong Kong - May 23; Sept 23
   a. May: heavy rain (11"), floods, landslides, fatalities
   b. Sept: typhoon, heavy damage, fatalities
19. Sri Lanka (Ceylon) - June 5; late Dec
   a. June: w coastal areas, city of Colombo, 2,000 homeless
   b. Dec: heavy rains, intense flooding, esp. to coastal areas, 20,000 homeless, several hundred fatalities
20. China - June 11, July 15-21
   a. June: Fukien province
   b. July: s Shantung, Kiangsu, Anhwei, Honan
      (i) Yi, Yellow & Shu rivers flood, 550 fatalities, thousands homeless, crop damage
23. Philippines: Luzon - July 17; Nov 11-13
   a. July: Pangasinan province, w Luzon, Agno River floods, several hundred fatalities, heavy damages
   b. Nov: typhoon, heavy rain, high winds
24. n India - Aug thru Sept
   a. Heavy rains, flooding, esp. Aug 18-19, flash floods near Tibetan border; Sept 1-10, Kashmir, 600 villages inundated, fatalities, heavy damage; Sept 23, Uttar Pradesh, hundred fatalities, heavy damage
25. S Korea - Aug
   a. Aug 3-5: Naktong River, n of Pusan, floods, 4,000 homeless, fatalities
   b. Aug 22-24: typhoon on e coast, heavy damage, hundreds of fatalities
26. ne China: Manchuria - Sept
   a. Sungari River floods, Harbin affected, 170,000 people worked to reinforce dikes
27. Okinawa - Sept 27-28
   a. Typhoon, heavy damage, fatalities
28. c Vietnam - Oct 26
   a. Typhoon, heavy rains, high winds, fatalities, damages
29. e India: Andhra Pradesh, Nellore area -Nov 10
   a. Heavy rains & flooding, river flooding, 43 villages washed away, heavy damage, fatalities

Australia & Oceania

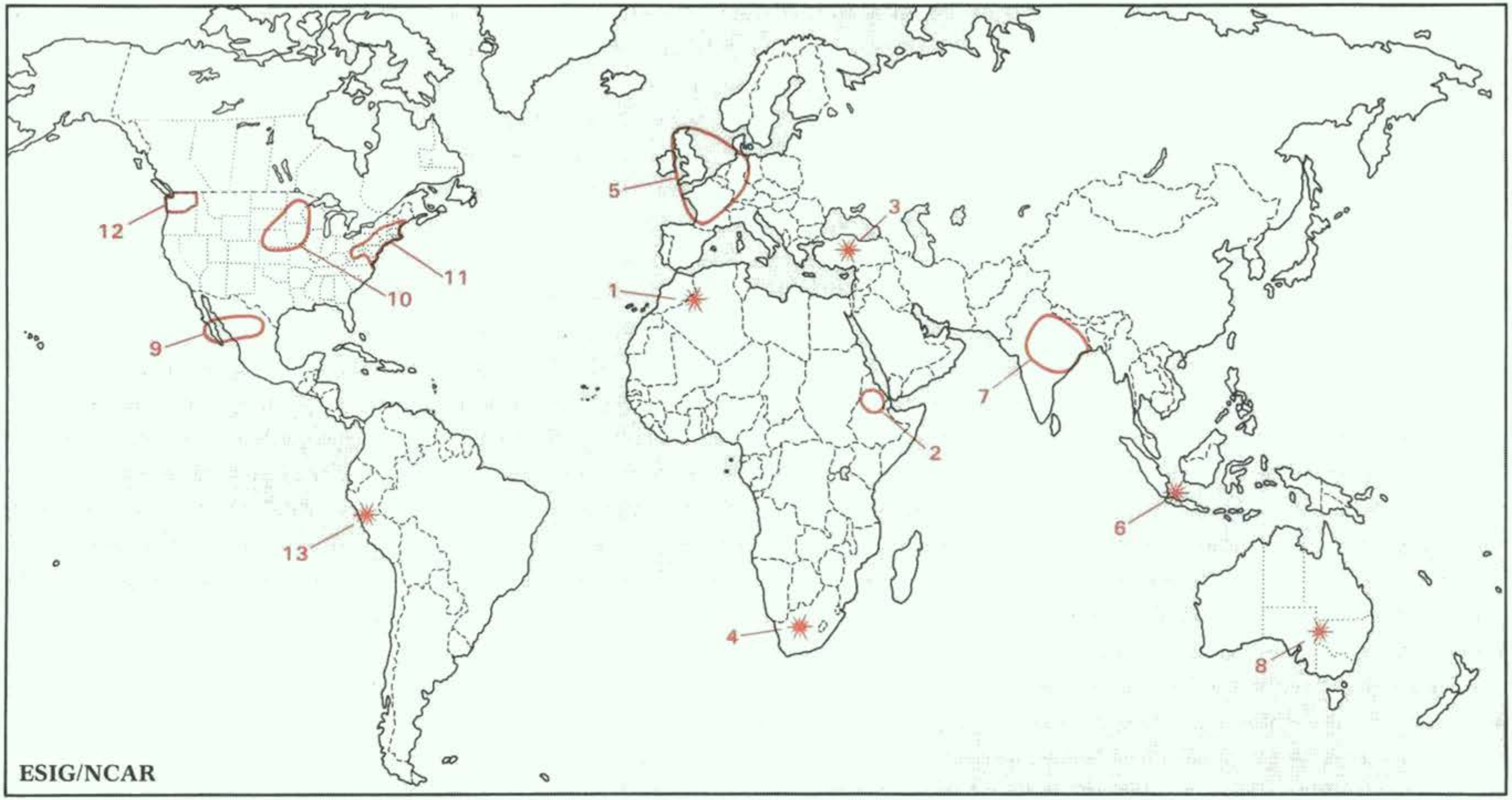
30. c equatorial Pacific Islands - Sept 1957 thru Feb 1958
   a. Reports of unusual series of heavy rainfalls (totals 5 to 20 times normal) disrupting ecology & economies of islands
      (i) Canton Is., Nov-Mar, 58.2" vs 6.1" average
31. Guam - Nov 16
   a. Typhoon, heavy damage

US, Canada, Latin America, & the Caribbean

32. n Brazil: n Bahia State - Mar 16-17
   a. Heavy rains, flooding on Sao Francisco River, 5,000 homeless, esp. Juaziero area
33. s US: c, nc, & ne Texas - mid Apr thru early June; late Sept; mid Oct
   a. Periodic heavy & intense rains, flooding, river flooding, heavy damage, fatalities, some areas repeatedly flooded
      (i) Brazos, Bosque, & Trinity rivers flood Dallas & Ft. Worth areas; Dallas had wettest May on record; Sabine River on Texas/Louisiana border; Lampasas River flooded some c areas; flooding also in Waco, Killeen, & San Antonio
37. Argentina: Buenos Aires province - June 1-3
38. Haiti: Port-au-Prince - June
39. c US: Missouri, Illinois, Indiana, sw Ohio -June
   a. Heavy rains, river flooding, flooding throughout area, heavy damage, fatalities
40. s US: w coastal Louisiana - June 28
   a. Hurricane Audrey, high winds, heavy rains, storm surge created tides nearly 11 feet above mean sea level & carried tidal wave 5 miles into Cameron Parish; over 500 fatalities, extremely heavy damage, 60-80% of Cameron destroyed, worst storm to hit Louisiana since 1856, over $150M in damages, also damage in Texas
41. c US: Illinois, Chicago & suburbs into c areas of state - July 14-16
   a. Flooded by record rains (6-10" in 24 hrs in some locations), damage, fatalities
42. nw Nicaragua: Leon area - Aug 14
   a. Heavy rains, floods, 15,000 homeless
43. w US: New Mexico, Las Vegas - Aug
   a. Heavy rains swell upper Gallinas River, break 3 earthen dams & flood Las Vegas and nearby communities, damage
44. w coastal Mexico: Mazatlan area - Oct 22
   a. Pacific storm, high winds, heavy rains, damage to shipping, property damage, fatalities
45. s US: Kentucky - Nov 18
   a. Flash floods
46. US: Hawaii - Dec 2
   a. Hurricane Nina
47. e Brazil: Rio de Janeiro State - Dec 6-9
   a. Heavy rains, fatalities, thousands homeless
48. se Canada: Quebec, Beauceville area - Dec 23-25
   a. Chaudiere River floods, 1,200 homeless
49. n Peru - dates not known
   a. Reported as "very wet," flooding experienced
50. Atlantic Hurricanes & Tropical Storms - Jan thru Dec 1957
   a. "Fairly light" season, 8 storms vs 10 average, 3 of which became hurricanes
51. Tornadoes: US - Jan thru Dec 1957
   a. 1,600 reported, new record (total also reported as 851 in another publication)
   b. May 57 was worst tornado month in US history

†Event represented on the map with a symbol because of significant geographic uncertainty regarding its location

1957 DROUGHTS
March - December



Africa & Mid East

1. Algeria & Morocco† - dates not known
    a. Drought reported in late Mar
2. n & c Ethiopia: Wollo & Tigrai - Mar thru Dec
    a. Severe drought, complete failure of rains, reported that affected areas had no more than 10 rainy days during entire year, famine, crop failure, widespread livestock losses
3. Turkey† - dates not known
    a. "Severe drought" reported in Apr
4. Republic of South Africa (Union of South Africa)† - dates not known
    a. Reported in 1958 that s Cape areas were in 3rd yr of drought; another report suggested that e areas were also affected during 1957

Europe & USSR

5. W Europe - June thru July
    a. Heat wave, very dry, hundreds of fatalities, 10-yr highs in many places, esp. France, Germany, England

Asia

6. Indonesia† - dates not known
7. c & e India - dates not known
    a. Drought reported in Oct, predicted losses to agriculture were 50%
    b. Affected areas included Uttar Pradesh, Madhya Pradesh, Orissa, W Bengal, Bihar

Australia & Oceania

8. Australia† -Mar thru Jan 58
    a. Reported in Oct that drought could cut wheat production 50%; heat wave late Dec thru early Jan in Sydney area; New South Wales esp. affected; rains broke drought in late Jan 1958

US, Canada, Latin America & the Caribbean

9. nc Mexico - May thru July
    a. Drought & periodic heat waves, fatalities, crop damage
    b. Esp. Monterrey area in late May; Torreon area in mid-June; lower California region in early July
10. Midwest US: esp. Minnesota, Iowa, Nebraska - June
    a. Heatwave & dryness throughout area

11. ne US: e New York, New Jersey, Massachusetts, Connecticut, Rhode Island, Delaware, Maryland, e Virginia, W Virginia -June thru Aug; for some areas thru Oct
    a. Drought & heat damage to crops
        (i) New Jersey & Massachusetts crop damage put at nearly $50M at end of July
        (ii) Connecticut farmers estimated crop losses at 40%
    b. 1957 was driest year on record at many places (i.e., Boston, Jan thru Sept driest in 140 yrs)
        (i) By late winter & early spring incipient drought in ne, shortage of spring rainfall, high temperatures in spring
        (ii) Some areas experienced drought into Oct (i.e., Atlantic City area until Oct 28)

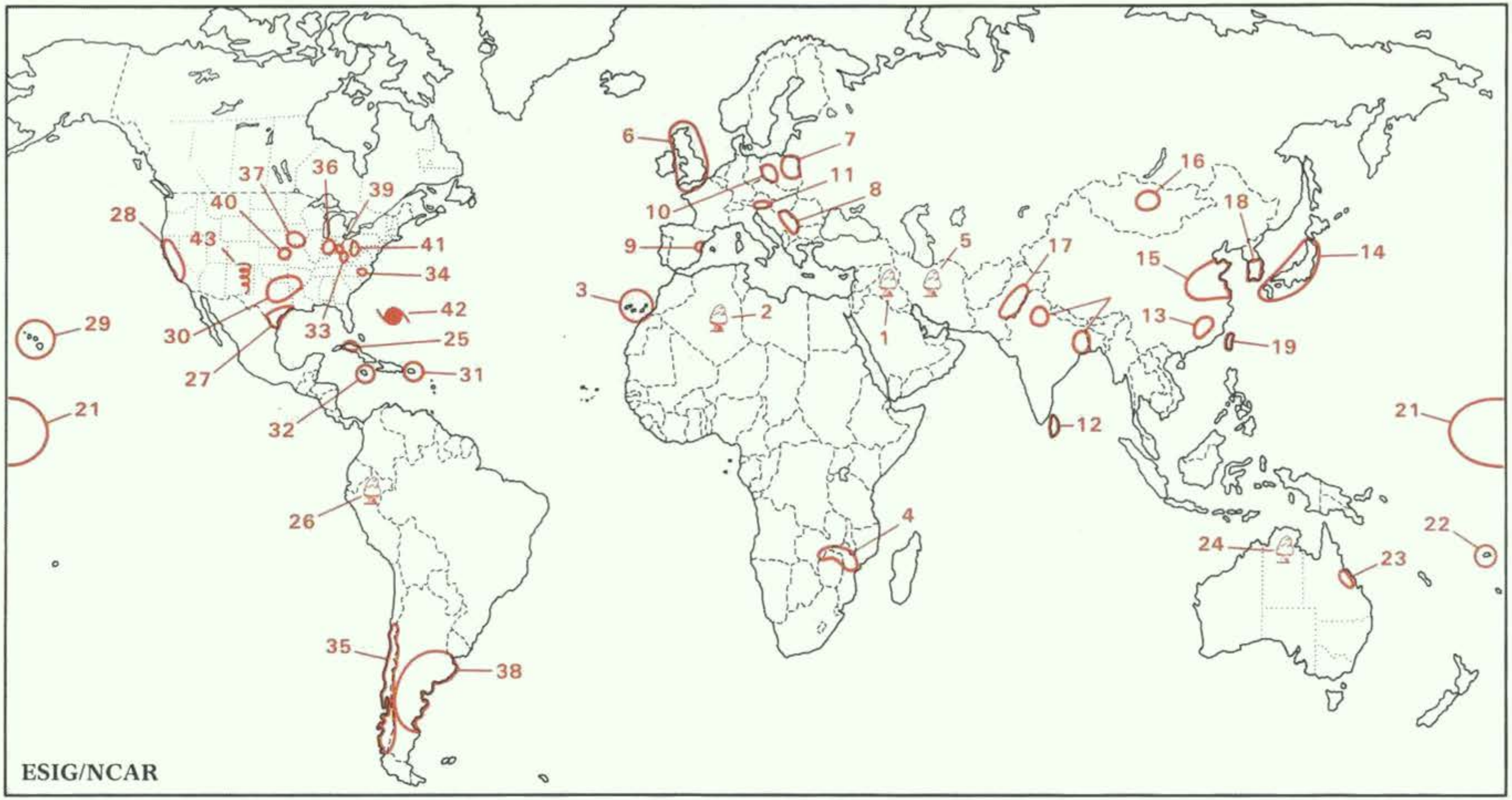
12. nw US: Washington - dates not known
    a. Fishing in rivers banned due to drought, reported Sept 29

13. Peru† - dates not known
    a. "Severe drought" reported

†Event represented on the map with a symbol because of significant geographic uncertainty regarding its location

1958 FLOODS/HEAVY RAINS/SEVERE SUMMER STORMS

January - August



Africa & Mid East

1. Iraq† - Jan 4-7
   a. Floods, thousands homeless, fatalities
2. Algeria† - early Feb
3. Canary Islands, Santa Cruz de Tenerife - Feb 16
   a. Hurricane damage
4. Zimbabwe (s Rhodesia), Mozambique: Zambesi River basin -late Feb thru Mar
   a. Heavy rains & flooding along river, damage to hydroelectric facilities in Rhodesia, crop & property damage
5. Iran† - May 23
   a. Heavy rains, flooding, fatalities

Australia & Oceania

21. c equatorial Pacific Islands -Sept 1957 thru Feb 1958
    a. Periods of heavy & unusual rains, 5-20x more than normal, i.e., Canton Is. Nov thru Mar: 58.2" vs 6.1" average
22. Fiji Islands - Jan 7
    a. Typhoon, damages
23. e coastal Australia: Queensland - Feb 18-19; Apr 3
    a. Feb: Pioneer River floods MacKay area
    b. Apr: typhoon hits Bowen area, heavy damage
24. Australia: N Australia† - Mar

Europe & USSR

6. Great Britain - Feb 12; late June thru Aug
    a. Feb: w England, Severn River floods, Yorkshire area affected
    b. June: record rains flood England, esp. c areas throughout period
7. ne Poland - Apr 12-21
    a. Vistula, Bug & Narew rivers flood 100 villages
8. e Yugoslavia: Serbia & n Macedonia - May 4-6
    a. Floods ruin tens of thousands of acres of crops
9. Spain: Valencia area - late June
    a. Turia River floods, area experienced devastating flood in Oct 1957 also
10. sw Poland: July 8-11
    a. Bobr, Niesse & Oder rivers flood, fatalities
11. s Austria: Carinthia - Aug 3

Asia

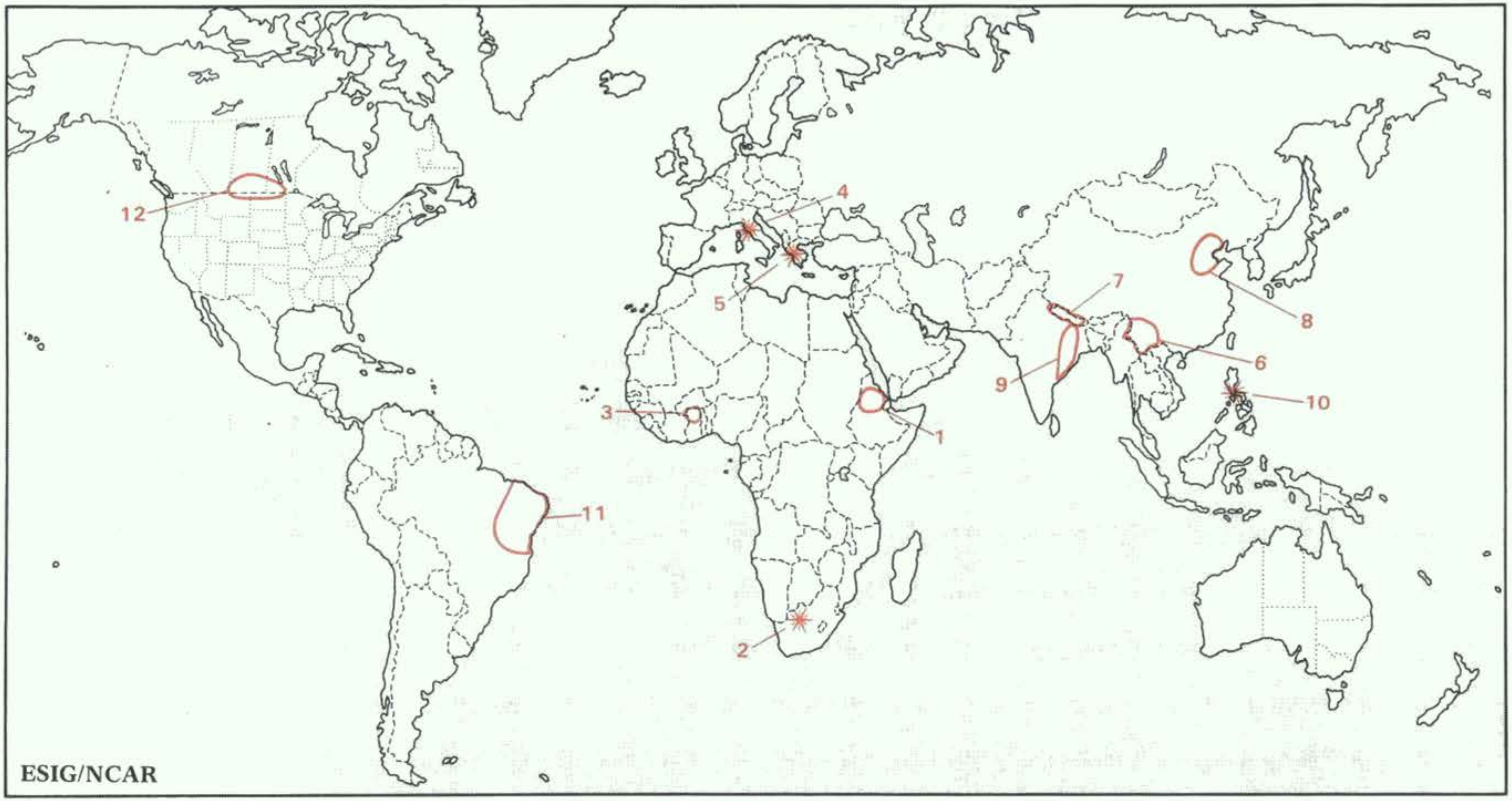
12. Sri Lanka (Ceylon) - late Dec 1957 thru Jan 1958
    a. Flooding, 75% of rice crop destroyed
13. se China: Kiangsi province - May 15
    a. 250,000 people organized to fight Gan River floods
14. Japan - July 2; July 27; Aug 27
    a. July 2: sw Japan, Hiroshima area, 13,000 homeless, fatalities
    b. July 27: n & c Honshu, typhoon, fatalities
    c. Aug 27: typhoon, 10,000 homeless, fatalities
15. China: Yellow & Yangtze river basins - July 23
    a. 3 million people organized to fight flooding Yellow & Yangtze rivers
16. Mongolia: Ulan Bator & nearby areas -July 28-30
17. Pakistan - July 23; Aug 25-26
    a. July: Indus River floods Punjab, fatalities
    b. Aug: flooding on other tributary rivers wash away 5,000 homes
18. S Korea - July 7-8
    a. Heavy rains, fatalities
19. e Taiwan: Hualien area -July 16-17
    a. Typhoon, fatalities, heavy damage
20. India -mid-July thru early Aug; Aug 19
    a. July: heavy rains, floods in New Delhi & surrounding areas, many villages marooned
    b. Aug 19: W Bengal flooded by heavy monsoon rains

US, Canada, Latin America, & the Caribbean

25. n Cuba: Havana area - Jan 3-5
    a. Heavy rains, high winds, heavy damage, fatalities
26. Peru† - Jan 18
    a. Flash flood destroyed small village, fatalities, heavy damage
    b. Also reported that n Peru was "very wet" in 1958
27. s US: s Texas - Jan 5-7
    a. Heavy rains, flooding
28. w US: California - Feb 24-25; Apr 1-8
    a. Feb: severe storm, heavy rain, high winds, hail, floods, crop losses, property damage
        (i) Sacramento $6-7M in damages, upper Sacramento River reached highest level since 1943
    b. Apr: heavy rains, floods, crop damage, inundated crop lands, fatalities; San Lorenzo, Merced, San Joaquin rivers flood; in Central Valley drainage precipitation during period equal to that usually received Apr thru June; most of California declared disaster area Apr 5
29. US: Hawaii -Mar 5
    a. Rains up to 10" cause widespread damage
30. s US: c & ne Texas, s & sw Arkansas, se Oklahoma -Apr 27 thru early May
    a. Heavy rains, flooding, river flooding, crop & property damage, fatalities
        (i) Trinity & Sabine rivers flood Dallas & Ft. Worth area; Sulphur & Cypress rivers flood parts of Oklahoma & Arkansas; Texas towns declared disaster areas June 7
31. Puerto Rico - early May; June 21
    a. May: s areas near Ponce
    b. June: e areas, Humacao district & town of Arroyo, torrential rains, heavy damage, fatalities
32. Jamaica -May 22
    a. Flooded by heavy rains, fatalities
33. US: ne Kentucky, Cattlesbury area - May
    a. Heavy rains, flooding on Big Sandy & Ohio rivers
34. US: N Carolina, Tarboro area - May
    a. Heavy rains, flooding on Tar River, damage
35. c & s Chile - June 16
    a. 8 killed, thousands homeless, flooding
36. c US: c & w Indiana -June 12-19
    a. Heavy rains, flooding on Wabash & White rivers, heavy damage, fatalities, crop damage, reported as most destructive floods of 1958 in US
    b. Esp. Peru, Wabash, Terre Haute, Vincennes
    c. River levels generally high since May, total damage est. at $60M, 1.25M acres of crops under water
37. c US: sw Iowa - July 1-6
    a. Heavy rains, flooding, Nishnabotna River flash flood killed 19, 12" rain in 3 hrs July 1-2; $6M damage at Audubon, Iowa; Hamburg area also damaged
    b. Heavy rains also flood Racoon River & Des Moines area
38. Argentina - July 28 thru early Aug
    a. July: heavy rains & flooding in Buenos Aires province, Buenos Aires flooded, fatalities
    b. Aug: Rio Negro & Rio Chubut flood central areas
39. c US: sw Ohio, Butler County -July
40. c US: ne Kansas, Atchison & Topeka areas - July 11
    a. Flash floods, damage in millions, fatalities
41. e US: W Virginia - July 11-12; July 26
    a. Flash floods in Chester & Spencer, fatalities, damages, also some flooding in Charleston area
42. Atlantic Hurricanes & Tropical Storms - Jan thru Dec 1958
    a. 10 cyclones, compares with average of 10 over past 20 years; 7 of which reached hurricane strength, season could be considered about normal
43. Tornados: US - Jan thru Dec 1958
    a. 624 reported

†Event represented on the map with a symbol because of significant geographic uncertainty regarding its location.

1958 DROUGHTS
January -August



Africa & Mid East

1. n & c Ethiopia: Wollo & Tigrai - Jan thru Aug*
   a. 2nd year of drought, complete failure of rainy season, famine, epidemics, severe crop damage, fatalities over 100,000
2. S Africa: Republic of South Africa (Union of S Africa)† -Jan thru Aug*
   a. Drought reported in stricken farms in southern Cape province, "3rd yr of drought"
   b. Another report suggested that drought was more concentrated in e areas in 1957 & shifted to w areas in 1958
3. n Ghana - Aug
   a. Drought reported Aug 16

Europe & USSR

4. Italy† - Aug 1-5
   a. Heat wave, 21 fatalities
5. Greece† - Aug 25-26
   a. Heat wave, temps up to 114°F, fatalities

Asia

6. s China: Yunnan province - Jan thru Aug
   a. 8-month drought reported in late June
7. Nepal - Feb thru June
   a. Drought, crop losses, famine
   b. Drought may have lasted thru Aug in some areas
8. n China: Hopei province - dates not known
   a. Reports in late Apr of drought & potential agricultural losses
9. India: Bihar & Orissa -late May thru June 20
   a. Heat wave, temps up to 115°F, over 600 fatalities
10. Philippines† - dates not known

US, Canada, Latin America, & the Caribbean

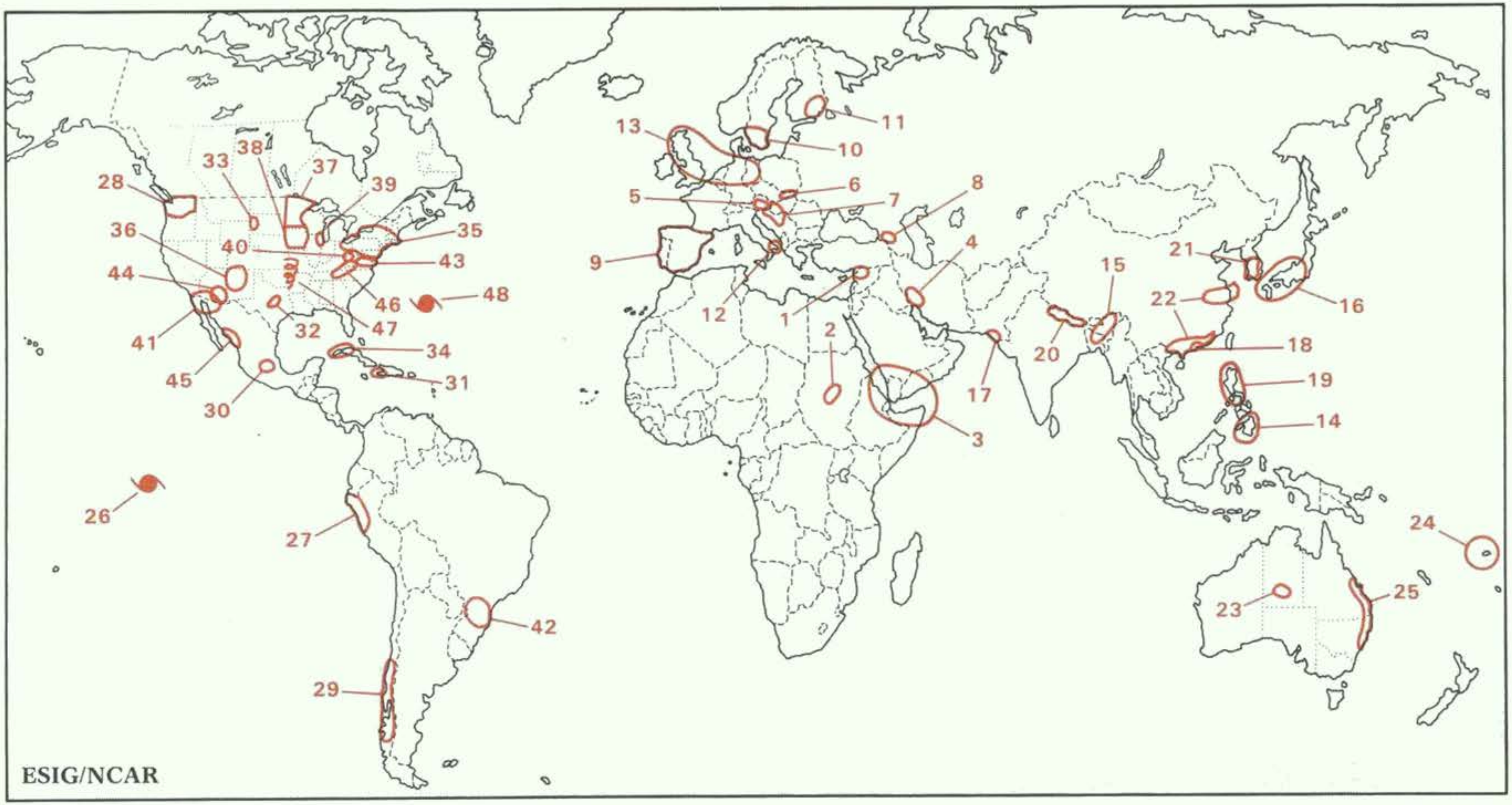
11. ne Brazil - Feb thru Aug
    a. Severe drought, crop failure, famine, livestock losses, 70% of crop lost in many areas, 90% of livestock succumbed, termed "catastrophic" & "most severe of the century," esp. in Ceara, Paraiba, Rio Grande del Norte & parts of other states in ne
    b. Feb thru May precipitation totals in Fortaleza area in Ceara were 72% below normal
12. s Canada: s prairies - June thru July
    a. Drought, crop damaged in July by worst drought since 1930s, dryness began in the spring in many areas
    b. Areas affected included prairie regions of Saskatchewan & Manitoba
        (i) n US from Great Lakes west to Montana also had very dry spring with monthly totals for May only 50% of normal; some places had very dry first 5 months of year: driest since 1871 for Detroit, 2nd driest on record in Minneapolis

*Drought experienced in area in 1957

†Event represented on map with a symbol because of significant geographic uncertainty regarding its location

1972 FLOODS/HEAVY RAINS/SEVERE SUMMER STORMS

March - December



Africa & Mid East

1. s Syria: esp. Aleppo province - Apr 23
   a. Heavy rains, flooding, fatalities
2. c Sudan: Khartoum area - Aug 26
   a. Heavy rains & floods, property & crop destroyed, 3 villages wiped out along White Nile
3. Djibouti (French territories of Afars & Issas), ne Somalia, Ethiopia, Saudi Arabia, Yemen, Aden area -Oct 24-28
   a. 1st cyclone in area, high winds, heavy rains, fatalities, thousands homeless, property damage
   b. Djibouti: 60 dead, 5,000 homeless, over 2 times annual average rainfall received
   c. Aden: 6 times annual average rainfall received

16. s Japan: -June 1-18; July 6-20; Sep 9, 16-17
   a. Series of heavy and intense rains, typhoons, floods, landslides, many fatalities, extensive damage to crops and homes
17. e coastal Pakistan - June 7
   a. Cyclone & tidal wave flood e coastal areas
18. Hong Kong -June 17-24
   a. Exceptionally heavy rains (652 mm between June 16-18), flooding, landslides, fatalities, property damage

32. sw US: Texas, ne of San Antonio - May 12-16
   a. Heavy rains, floods, Guadalupe river floods, fatalities, property damage, esp. in New Braunfels, Seguin, San Marcos
33. n US: S Dakota, Rapid City area - June 9-10
   a. Heavy rains in Black Hills area June 9 (281 mm in 6 hrs), dam break, flooding, hundreds of fatalities, extensive property damage
34. w Cuba - June 16-18
   a. Hurricane Agnes, crop damage, fatalities, property damage

4. sw Iran - early Nov
   a. Reported floods, fatalities & property damage
      (i) Iran's annual precip was 150% of normal
      (ii) ne, sw & along coast of Gulf of Oman (se Iran) local totals ranged from 300-400% of normal

Europe and USSR

5. Austria: Styria province - mid Apr thru July
   a. Series of torrential rains & major floods, fatalities, property damage, esp. Apr 19-24
6. se Czechoslovakia: Slana River area -May 16-19
   a. Intense thunderstorm activity, 500-yr flood on Slana River, property damage, fatalities
7. w & sw Hungary, n Yugoslavia - May 19; July thru Aug
   a. May 19: w Hungary around Lake Balaton, intense thunderstorm activity, high winds, hail, heavy damage to crops, vineyards & buildings
   b. July thru Aug: sw Hungary & n Yugoslavia along Drava River basin
      (i) Precipitation 3-4 times greater than normal in basin, "devastating" floods, crop damage
8. w USSR: Georgia - June
   a. Flash flood in Tbilisi, severe damage
9. Spain & Portugal - June 5; late Aug thru early Nov
   a. Abundant and, in places, record rainfall over Iberian Peninsula, esp. Spain; hailstorms, flooding, river flooding, crop damage, vineyards damaged
   b. Esp. June 5: Mediterranean provinces, hail damage to crops & property; Aug 29: Sueca Valencia, Sept 4, 8, & 22: Madrid area, series of floods; Oct 17-19: Valencia area, flooding of Murcia & Segura rivers; early Nov: Mediterranean provinces of Malaga, Granada, Alicante
   c. Above-normal rainfall almost all months of 1972, i.e., Madrid's 1972 total of 700 mm has been equaled only once since 1859
10. s Sweden - June 13
   a. Intense thunderstorms, extensive hailstorms, crop damage
11. se Finland - July 8
   a. Intense thunderstorms, high winds, crop, forest & property damage
   b. July & Aug precip totals for Finland approached the highest values on record
      (i) July was also the wettest since 1896 for Paris, France
12. Italy: Manfredonia - July 15
   a. Heavy rains cause dam to burst, fatalities, property damage
13. w & c Europe: United Kingdom (England & Wales), Netherlands, E & W Germany - Nov 12-13
   a. Destructive storm, heavy rains, high winds, widespread flooding, river flooding, property & forest damage, fatalities

Asia

14. s Philippines: Mindanao - Mar 19; Dec 5
   a. Two tropical storms: torrential rains, extensive flooding, millions of acres of crops destroyed, property damage, thousands homeless, fatalities
15. ne India, ne Bangladesh: esp. Sylhet area - June
   a. Series of monsoon floods, over 100,000 acres of crops destroyed, many homeless, property damage.
19. n Philippines: Luzon - late June thru Aug
   a. Series of typhoons & tropical storms, heavy and incessant monsoon rains, flooding, river flooding, over 1,000 fatalities, extensive property and crop damage
   b. s & c Luzon, Typhoon Ora - June 24-25
   c. Manila & w provinces - late July thru early Aug
      (i) Monsoon floods create worst natural disaster in Philippines history, July 19-20 Manila airport received 763 mm rain, 1,000 mm received during period July 18-25
   d. Typhoon Betty - Aug 17
20. Nepal - late July thru early Aug
   a. Heavy rains, floods, landslide, fatalities, property damage
21. S Korea - Aug 19; Sept 15
   a. Aug: heaviest & most intense rains ever recorded in S Korea (i.e., 441 mm in 22 hrs in Seoul), floods, landslides, several hundred fatalities, most damage in Seoul & 3 central provinces
   b. Sept: s part of peninsula; heavy rains, flooding, over a hundred fatalities
22. se & c China - Nov
   a. Extensive flooding in se reported in Nov, crop damage
   b. Also very wet in Jiangsu & Anhui provinces

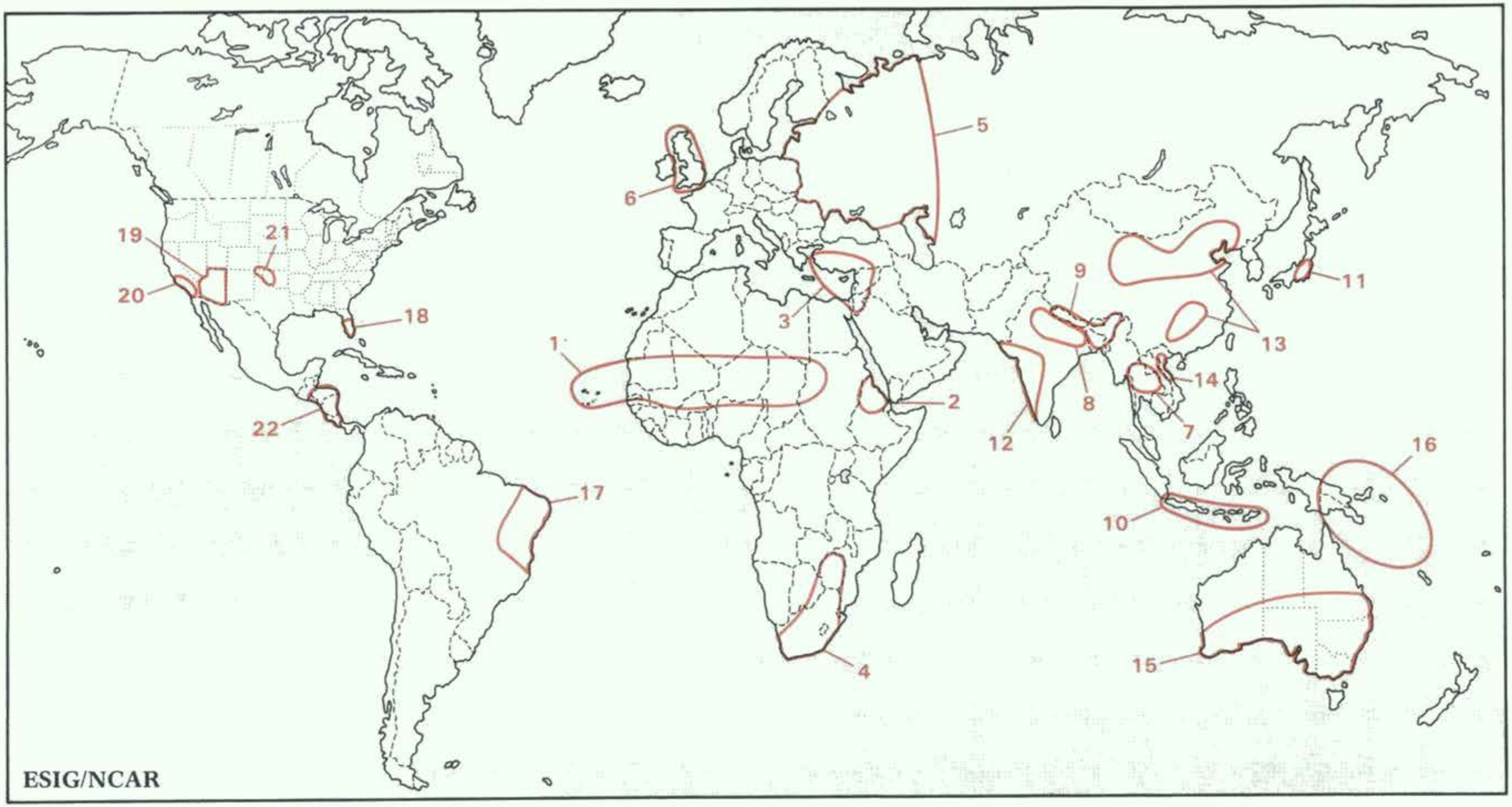
Australia & Oceania

23. c Australia: Alice Springs area - Mar
   a. 700% of normal for month, flooding, crop damage
24. Fiji & surrounding islands -Oct 25
   a. Hurricane Bebe, heavy rain, high winds, "devastating floods," property damage
25. e coastal Australia: Queensland & New South Wales -late Oct
   a. Intense rains, flooding, over 300 mm received in 1 24-hr period
26. Pacific Hurricanes, cyclones, tropical storms - Jan thru Dec 1972
   a. 18 tropical cyclones: 8 became hurricanes, 4 tropical storms
   b. "abnormally high number of cyclones"

US, Canada, Latin America, & the Caribbean

27. n & w Peru: states of Amazonas, Pirua, San Martin, Ancash -Mar thru May
   a. Heavy rains, flooding, esp. Mar, river flooding (Lacramarca & Piura rivers), landslides, fatalities, property destroyed, many homeless, heaviest rains & worst floods since 1925, esp. between Tumbes & Salaverry
28. nw US: Washington - Mar thru late May
   a. Mar: flooding from heavy rains & melting snows, declared major disaster area Mar 25
   b. May: nc parts of state flood as Methow & Okanogan rivers spill their banks, declared major disaster area June 1
   c. Olympia, Wash., wettest Apr on record; Eugene, Ore., 2nd wettest Apr, & wettest 4-month period (Jan-Apr) on record
29. s Chile - early May
   a. 6 days of rain end on May 9, thousands homeless, flooding, almost one-third of Chile affected s of Santiago
30. c Mexico: vicinity of Mexico City -May 3; June 15
   a. May: heavy rains, thunderstorms, hail, San Buenaventura River floods, many fatalities, property damage
   b. June: torrential rains, flash floods in outskirts of Mexico City, fatalities
31. s coastal Haiti - late May
   a. Heavy rains, winds, floods in s coastal areas
35. US: Virginia, Washington, DC, Maryland, Pennsylvania, New York, Ohio, New Jersey, s Connecticut - June 18-24
   a. Tropical Storm Agnes, high winds, heavy rains, extensive flooding, river flooding, fatalities, over $3 billion in damages, "costliest natural disaster in US history"
   b. Esp. in upstate New York & c Pennsylvania: Wilkes-Barre & Harrisburg
   c. ne & s US experienced wet spring into mid-June, causing occasional flooding & crop damage prior to Agnes
      (i) New York City & adjacent coastal areas had wettest yr since 1869
36. sw US: New Mexico - mid July; late Aug thru Sept
   a. July: heavy rains & flooding, declared major disaster area on Aug 1
      (i) Gallup area flash floods July 17, after heavy rains
      (ii) New York City & adjacent coastal areas had wettest yr since 1869
   b. Late Aug & Sept: heavy rains & flooding, state declared major disaster area on Sept 20
      (i) Flooding on Perchas River
37. n US: Minnesota - July 21-22
   a. Most damaging storm & flooding in state's history, state declared major disaster area on Aug 1
38. c US: Iowa - early Aug
   a. Extreme flooding in 4 counties, state declared major disaster area Aug 18
39. c US: n Illinois, Chicago & suburbs - Aug
   a. Torrential rains, high winds, property damage, flooding
   b. Esp. Aug 18 & 25-26
40. se US: sw W Virginia - Aug
   a. Flooding in 4 sw counties, state declared major disaster area Aug 23
41. n Mexico: n Baja California, Sonora & into Arizona - late Sept
   a. Hurricane Joanne, high winds, heavy rains, considerable local flooding
42. s Brazil: Parana - early Oct
   a. Heavy rains, floods destroy up to 30% of coffee crop in Parana state
43. se US: c Virginia - Oct 6-9
   a. Flooding in James River swelled by heavy rains, fatalities, property damage
44. sw US: se Arizona - Oct
   a. Flooding on San Francisco & Gila rivers, fatalities, property damage
45. w Mexico: Sinaloa - mid Nov
   a. Torrential rains including periods of up to 300 mm in 24 hrs caused flooding, destroyed crop
46. se US: ne Tennessee & sw Virginia - Dec 17
   a. esp. Knox County, Tenn., & Smyth County, Virginia
47. Tornados: US - Jan thru Dec 1972
   a. 743 total, lowest death toll in 57 yrs even though 19-yr average number of tornados is 655
48. Atlantic Hurricanes & Tropical Storms - Jan thru Dec 1972
   a. 4 hurricanes, 8 hurricane days
   b. Quietest season in 42 yrs, both in total number of storms named & the strength of those that developed
   c. Few number of named storms despite fact that essentially same number of hurricane "seedlings" were observed as in 1971 when above-normal hurricane activity occurred

1972 DROUGHTS
March - December



Africa & Mid East

1. African Sahel: Mali, Mauritania, Senegal, Cape Verde Islands, Niger, Upper Volta, Chad, w Sudan - Mar thru Dec
   a. Drought in Sahelian region that began in 1968 intensified in 1972, crop failures, livestock deaths, water shortages, famine
   b. Chad: 1972 annual rainfall lowest since 1943
   c. Agades, Niger: 1972 rainfall total 30 mm vs 164 mm average
2. n & c Ethiopia: Tigre, Wollo, Eritrea, Showa provinces - Mar thru Dec
   a. Drought began in 1971, extensive crop losses, 80% of cattle lost, famine

8. n India: W Bengal, Uttar Pradesh, Bihar - May thru early June
   a. Heat wave & drought, temps consistently over 100°F, death toll over 600, New Delhi severely affected, damage to crops, livestock
9. ne India, Nepal, Bangladesh - June thru Aug
   a. Failure of summer monsoon
   b. Assam province, India received 855 mm rain in July compared to 2,855 mm average
10. Indonesia: Java, Madura, Bali & se areas - June thru Oct
11. Japan: Tokyo area - June thru early July
   a. Drought, worst water shortage in area since 1964

US, Canada, Latin America, & the Caribbean

17. ne Brazil: esp. Ceara, Bahia, Piaui -Mar thru Dec
   a. Effects of drought began to be felt in Apr, severe in some locations by Aug
   b. Area experienced very severe drought in 1970-71
18. se US: s Florida - Mar thru Nov
   a. Reported in Nov that previous 29 months had below-normal precip, crop losses, Everglades "threatened"
19. sw US: Arizona - Mar thru May
   a. Jan thru Apr in Phoenix & Tucson completely rainless, driest 4 months on record
   b. Extended drought on Navajo reservation, esp. severe by end of May

3. Mediterranean Mid East: Jordan Valley, Syria, Turkey, Israel, Lebanon, Cyprus - Sept thru Dec
    a. Drought said to be worst of century, water shortages in many urban areas, livestock losses, crop damage, no rainfall in some areas during all of 1972
4. s Africa: Zimbabwe (Rhodesia), Republic of S Africa -Nov thru Dec
    a. Failure of summer rains, crop and livestock losses

Europe and USSR

5. USSR: European areas - May thru Sept
    a. Worst drought in century: less than 25% of normal rainfall in July and Aug over large area
    b. Mid July thru Aug heat wave in ne USSR caused fatalities, crop damage, forest and peat fires (over large areas of e Russia)
        (i) Hottest summer on record in Moscow, heat wave extended into n Finland
    c. Unusually cold & dry winter also hurt wheat crop, spring also dry
6. United Kingdom: Britain - July thru Dec
    a. Many locations reported 1972 annual precip as lowest since 1921
    b. Water shortages in many areas, esp. Scotland & e areas, crop damage Asia
7. Thailand - Apr thru June
    a. Drought during beginning & middle of rainy season, crop & livestock losses

12. w coastal India - July thru Dec
    a. Severe monsoon drought in 4 western states along coast, esp. Maharashtra, crop damage
13. China - July thru Dec
    a. Widespread drought, crop damage, livestock losses, water shortages
14. n Vietnam: 5 provinces s of Hanoi - Nov thru Dec

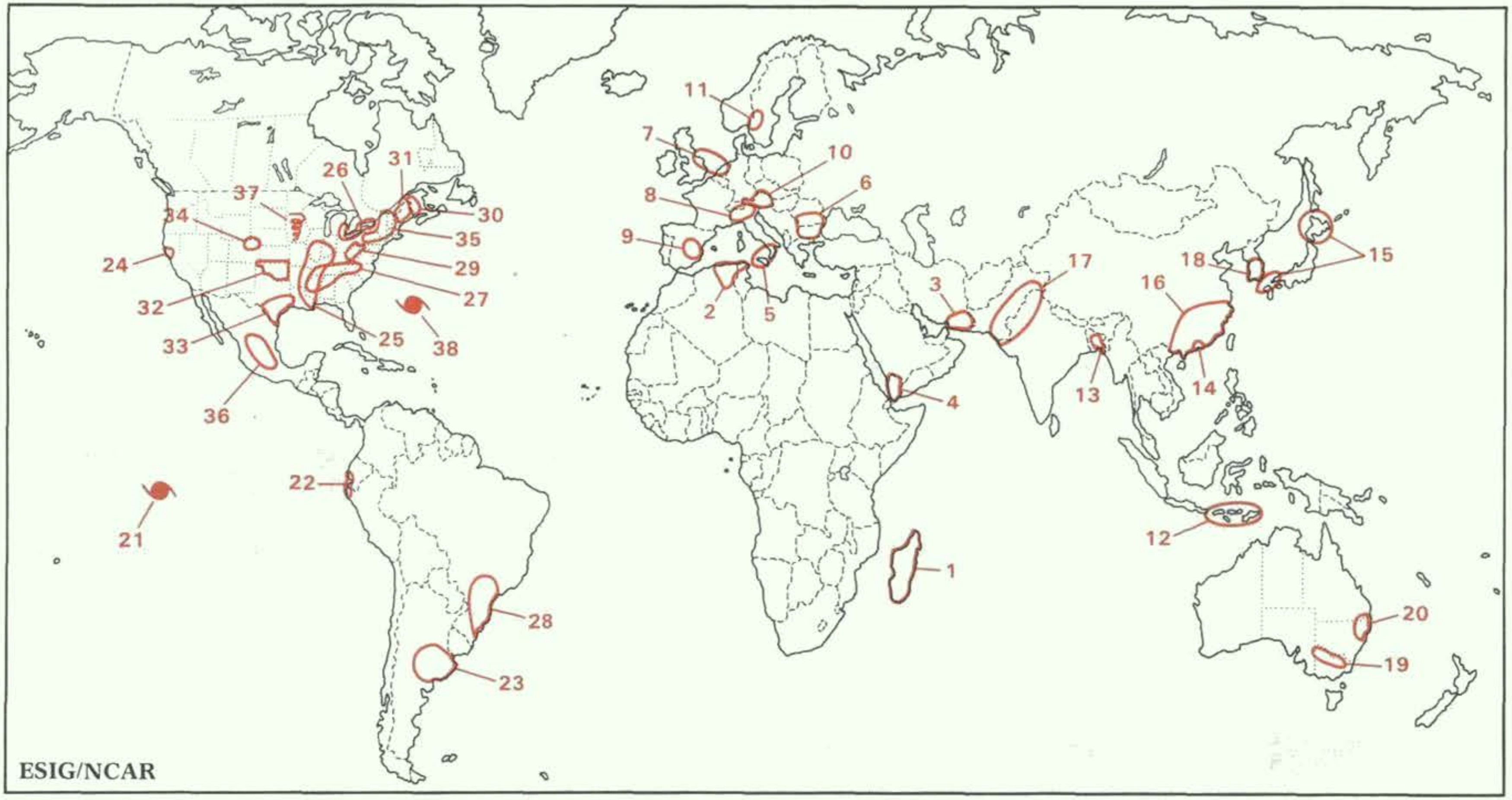
Australia & Oceania

15. s Australia - Mar thru Jan 1973
    a. Severe drought; sw W Australia in 3rd yr of dry weather, winter 1972 rains below average for most areas in s Australia, conditions worsened as drought extended into summer rainfall areas of se, drought ended late Jan 1973 & into Feb with heavy rainfall
    b. Affected areas included: sw W Australia, S Australia, New South Wales, s Queensland, s Northern Territories, Victoria (esp. Victoria)
    c. Heat waves
        (i) May 1972: Sydney & neighboring areas, bushfires in New South Wales & Victoria
        (ii) Dec 1972: se areas, esp. Victoria, persistent heat heightened effects of drought
        (iii) Jan 20-23, 1973: Melbourne areas, fatalities
16. Papua New Guinea & Melanesian Islands - Apr thru Aug

20. w US: s California - Mar thru Dec
    a. Los Angeles area rainless from Mar 28 thru end of year
    b. San Diego, 1st 4 months of 1972 driest on record
        (i) 1st 4 months of 1972, Apr in particular, also very dry in other parts of s & w US: El Paso, 90 consecutive days of no rain reported at end of Apr; Grand Junction, Colo., driest Jan thru Apr on record; Cheyenne, Wyo., Apr was 6th consecutive very dry month; Charleston, S. Car., driest Apr on record; Macon, Ga., 2nd driest Apr on record
21. US: w Oklahoma - Mar thru May
    a. Worst drought in w Oklahoma since 1930s, loss of 25% of wheat crop, reported as 2nd yr of drought in area
22. Central America: Honduras, Nicaragua, Costa Rica -June thru Dec
    a. Abnormally light rains during summer rainy season, crop damage
    b. Drought also reported in El Salvador during June & July
    c. Nicaragua reported severe 1972 crop losses: 80% corn, 35% beans & rice, 20% wheat (reported in Jan 1973)

1973 FLOODS/HEAVY RAINS/SEVERE SUMMER STORMS

January - August



Africa & Mid East

1. Madagascar - Jan thru Feb
   a. 4 tropical cyclones & depressions hit island, damage to property & crops, fatalities
2. e Algeria, n & nw Tunisia - Mar 25-30
   a. Torrential rains (el Kala, Algeria, 147 mm Mar 27), floods, crop damage, fatalities, thousands homeless, heavy livestock losses
3. se Iran - July 20-24
   a. Heavy rains, floods, fatalities, property damage
4. Yemen - late Aug
   a. Flooding, fatalities, property damage

14. Hong Kong - May thru Aug
    a. Heavy rains, typhoons, flooding, landslides, crop & livestock damage
    b. 1973 was wettest yr since 1853, 43% above normal, May thru Aug period highest ever recorded (2,413 mm)
15. Japan - May 8; July 30-31; Aug 14-19
    a. May & July: sw areas, heavy rains, flooding, landslides, fatalities
    b. Aug: Hokkaido, Typhoon Iris, high winds, heavy rains, flooding, crop & property damage, fatalities

26. n US: New York, Michigan, Ohio, areas adjacent to Lakes Ontario & Erie - Mar 15-20; Apr 10-15
    a. Mar: New York, flooding, declared major disaster area Mar 22
    b. Apr: Michigan & Ohio, flooding along areas adjacent to Lake Erie
    c. As of Mar, 14 of previous 17 months above normal precip in n US Great Lakes area
27. se US: Tennessee, Mississippi, Alabama, N Carolina - Mar 16-17
    a. Heavy rains, floods, flooding on Elk & Tennessee rivers, property damage, fatalities

Europe & USSR

5. s Italy: Calabria & Sicily -Jan 1-14
    - a. Heavy rains, floods, landslides, property damage, fatalities
6. Romania, Bulgaria -mid Mar; Apr 14-17
    - a. Mar: s Romania & n Bulgaria; snowmelt, floods, landslides, property damage, fatalities
    - b. Apr: Bulgaria, heavy rains, extensive flooding, property & crop damage
7. e England (Norfolk), Netherlands - Apr 2-3
    - a. Intense depression, severe storm, rain, high winds, heavy damages in Netherlands, fatalities, crop & forestry damages reported, property damage
8. n Italy - early May; June
    - a. Heavy rains, flooding in Turin, Veneto, Piedmont region, fatalities, crop damage
9. Spain - June
    - a. Torrential rains in s areas & river flooding on the River Yeguas in s Cuenca province, extensive crop & property damage
    - b. 5-hr hailstorm destroyed orchards at Cieza in n Murcia province
10. Austria -June 2; 21-23
    - a. June 2: widespread rain & thunderstorms in Wachau region, mudflows, crops & vineyards destroyed
    - b. June 21-23: Styria province, severe thunderstorms, mudflows, extensive flooding, crop & property damage
11. sw Sweden: Varmland - July
    - a. Heavy prolonged rains & thunderstorms caused collapse of dam, severe damage, daily rain totals often exceeded 100 mm

Asia

12. Indonesia: Islands e of Bali - mid Apr thru July
    - a. Series of severe storms, floods, property damage, nearly 2,000 fatalities (esp. fishermen)
13. c & coastal Bangladesh - Apr 12-27; early June
    - a. Apr: Faridpur area; 2 weeks of storms, heavy rains, high winds, flooding, river flooding, several hundred fatalities, crop & property damage
    - b. June: coastal areas; torrential rains, heavy monsoons, floods, crop damage
16. se China - dates not known
    - a. Very wet throughout yr in se areas
    - b. Reports of "crops drowning" under flood waters in June
17. Pakistan: Sind, Punjab provinces, & Karachi area; w & n India: Punjab, Kashmir, Jammu, Rajasthan - July thru Aug
    - a. Heavy rains, extensive & unprecedented flooding, flooding in Indus River basin, up to 8 million acres of crops affected, over 3,000 fatalities, up to 10 million people affected, esp. Aug 11-30
18. S Korea - late Aug
    - a. 2 typhoons, heavy rains, high winds, flooding, damage to shipping, crops & property

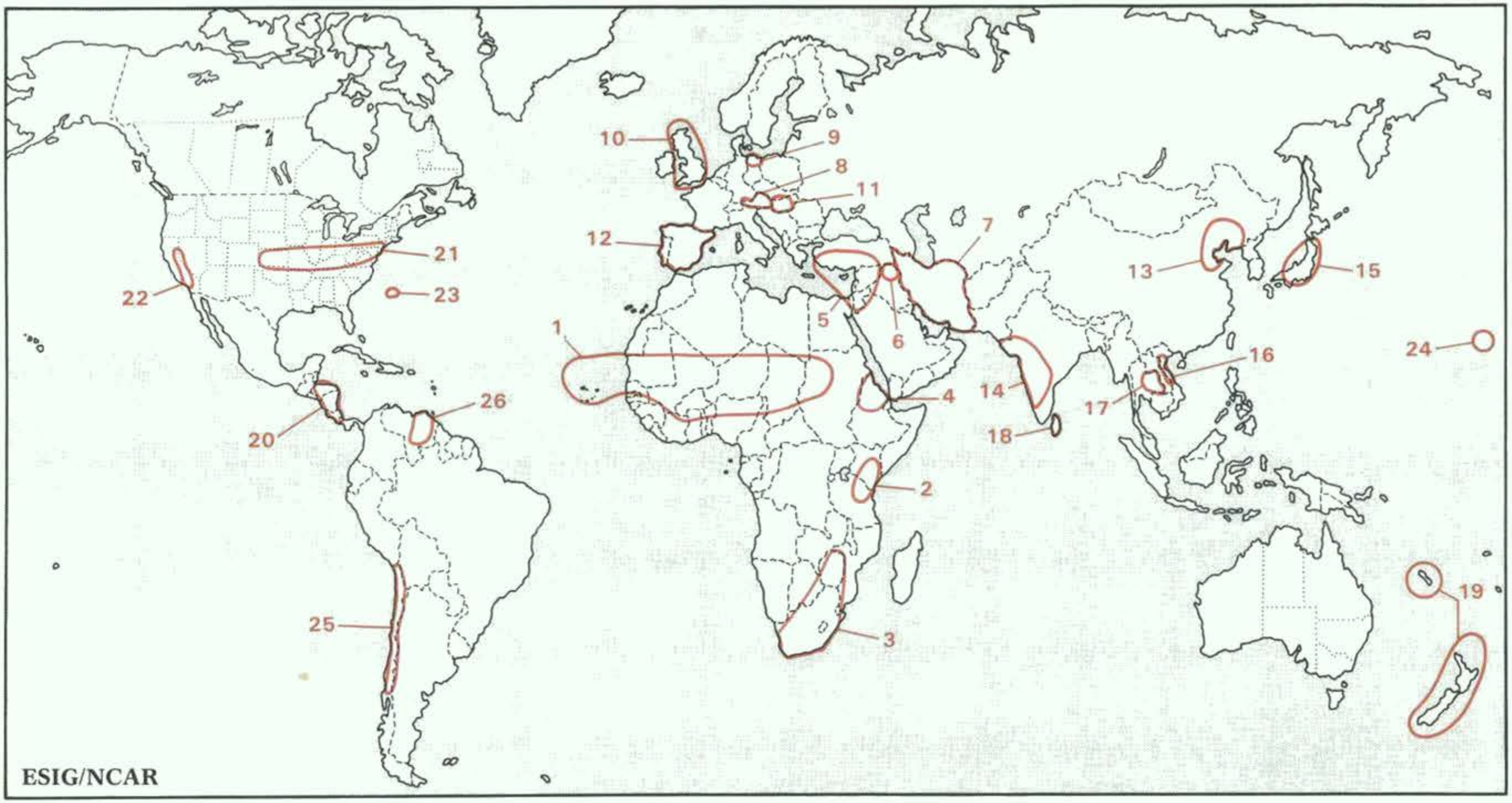
Australia & Oceania

19. n Victoria - June thru Aug
    - a. Severe flooding, damage to crops
    - b. 1973 was quite wet for much of Australia: many inland areas of S Australia reported the wettest conditions in living memory; the dry season in the N Territory was unusually wet & several locations had 50-60 times their normal
20. se Australia: ne New South Wales - July
    - a. Widespread & intensely heavy rains, flooding, i.e., Dorrigo 475 mm in one 24-hr period
21. Pacific Hurricanes, Cyclones, Tropical Storms - Jan thru Dec 1973
    - a. 7 hurricanes, 5 tropical storms, 6 tropical depressions
    - b. "One of least active seasons"

US, Canada, Latin America, & the Caribbean

22. w coastal Ecuador & nw Peru - late Dec 1972 thru Jan 1973
    - a. Heavy rains, flooding (701 mm in Jan in Guayaquil)
23. Argentina: Buenos Aires province - Jan thru Apr
    - a. Heavy & occasionally intense rains (up to 6 times normal in Feb), severe flooding in basin of Salado River
24. w US: California, coastal areas into Napa Valley - Jan 16
    - a. Torrential rains, high tides & winds, flooding, damage
25. c US: Mississippi River & tributaries, Illinois to Louisiana - Mar thru May
    - a. Heavy rains, extensive flooding, Mississippi River at flood stage for 77 days (new record), greatest flood crests in history on the Mississippi recorded in many locations, up to 11 million acres inundated, heavy crop damage, significant delays in spring planting
    - b. Damage in Illinois, Kentucky, Missouri, Tennessee, Mississippi, Louisiana
28. s Brazil - Mar 25-30
    - a. Esp. near Tubaro in Santa Catarina state
        - (i) Over 1,000 fatalities, extensive crop & property damage, noted as worst flood in nation's history
    - b. Also along Caratinga River basin, Minas Gerais state
29. se US: W Virginia - Apr
30. se Canada: New Brunswick - late Apr
    - a. Excessive rain & snowmelt in St. John River basin, worst flooding in province's history
31. ne US: Maine - Spring 1973
    - a. State declared major disaster area on May 23 due to severe storms & floods of recent months
32. s US: Oklahoma - Spring 1973
    - a. State declared major disaster area on June 13 due to severe storms & floods that began in Apr
33. s US: Texas - Spring 1973
    - a. Heavy rains, flash floods (esp. Apr 15), property & crop damage, fatalities, state declared disaster area June 29 due to spring storms
34. w US: n Colorado, along Platte River - May 7
    - a. State declared major disaster area May 23 due to severe snows in Apr, heavy rains & flooding in May
35. ne US: e New York, New Jersey, Pennsylvania, Connecticut, Vermont, New Hampshire, June 27 thru July 5; July 27 thru Aug 5
    - a. Series of severe thunderstorms, flooding, flash flooding, fatalities, property & crop damage
    - b. New Hampshire declared major disaster area July 12; e New York declared major disaster area July 20; New Jersey declared major disaster area Aug 8, Pennsylvania declared Aug 24
36. c Mexico - July thru Aug
    - a. Widespread storms, heavy rains, flooding, property & crop damage, fatalities
    - b. Esp. July 8 (near Guadalajara), Aug 15-18 & Aug 25 (flooding in Mexico City)
37. Tornados: US - Jan thru Dec 1973
    - a. 1,109 tornados
    - b. Season had the most tornados, lasted the longest, involved more states & produced more supertornados than any yr since records began
    - c. Frequency was at record level in Jan 1973; record frequency of tornados, 160 in 72 hrs on May 28
38. Atlantic Hurricanes, Tropical Storms - Jan thru Dec 1973
    - a. 7 named storms: 4 hurricanes, 3 tropical storms
    - b. Relatively quiet season, 1st yr since 1962 that a hurricane did not cross the US coastline, number & intensity of tropical cyclones in the Atlantic were below normal for the 3rd time in the last 4 yrs

1973 DROUGHTS
January - August



Africa & Mid East

1. African Sahel: Mali, Mauritania, Senegal, Chad, Niger, Cape Verde Islands, Upper Volta, w Sudan - Jan thru mid Aug*
   a. Continuation of 5-yr drought, intensified in 1972-73
   b. Crop failures, famine, livestock deaths, forest & brush fires, water shortages
   c. Niger & Mali most severely affected
      (i) June 1973: Lake Chad at lowest level in over 10 yrs; Niger River in Mali at lowest level in living memory
   d. Sahel-like areas in W African countries also affected: esp. n Ghana, n Cameroon, ne Nigeria (10% normal harvest)

Europe & USSR

8. Austria - Jan thru mid Feb
   a. Deficient snows, reduced hydropower, financial losses in winter tourist industry
9. n E Germany - Jan thru Mar; June thru Aug
   a. Persistent below-normal precip causing decreased crop yields
10. United Kingdom: Britain - Jan thru Mar*
   a. July 1972 thru Mar 1973 driest period since 1749 for England & Wales, esp. eastern areas, very dry winter, water shortages, crop damage

Australia & Oceania

19. New Zealand & New Caledonia - dates not known
   a. "Extended droughts" during 1973 caused severe damage to agriculture & livestock

US, Canada, Latin America, & the Caribbean

20. Central America: Honduras, Nicaragua, Costa Rica - Jan thru May*
   a. Worst drought in 50 yrs, began in 1972
   b. Abnormally light rains during last year's rainy season created acute drought situation in dry season lasting until May, water rationing in Apr, heavy crop damage

2. E Africa: e parts of Kenya & Tanzania - dates not known
   a. Drought spread to E Africa in 1973 & peaked in 1975 in Somalia & se Ethiopia
3. S Africa: Zimbabwe (Rhodesia), Republic of S Africa - Jan thru Mar*
   a. Almost complete failure of summer rains, heavy crop losses
   b. Heat wave in Jan
4. c & n Ethiopia: Wallo, Tigrai, Eritrea, Showa provinces - Jan thru Aug*
   a. Drought began in 1971, intensified in 1972, esp. severe Sept 1972 thru May 1973 in Wallo, crop failures, many livestock deaths, famine related deaths estimated at over 250,000
5. Mediterranean Mid East: Jordan Valley, Syria, Turkey, Cyprus, Lebanon, Israel - Jan thru Mar*; for some areas thru July
   a. Drought that began in 1972 in most areas said to be worst of century, water shortages in urban areas, crop damages, livestock losses, some locations little rain for 18 months
   b. Cyprus: winter 1972-73 driest on record, 20% of normal in central plains
6. n Iraq: Kurdish areas - Winter 1972-73
   a. Lack of precip, crop damage & losses
7. Iran - dates not known
   a. 50% of normal precip for 1973, crop damage & losses
11. Hungary - Apr thru May
   a. Very dry, crop losses, esp. May
   b. Many locations between the Danube & the Austrian border reported less than 5% of normal precip for May
12. Spain & Portugal - July thru Aug
   a. Portugal: water shortage at end of Apr in many areas after hot dry summer
   b. Drought continued in many areas into Nov 1973
      (i) Barcelona, July-Nov total rain 70 mm, lowest total for that period in over a century

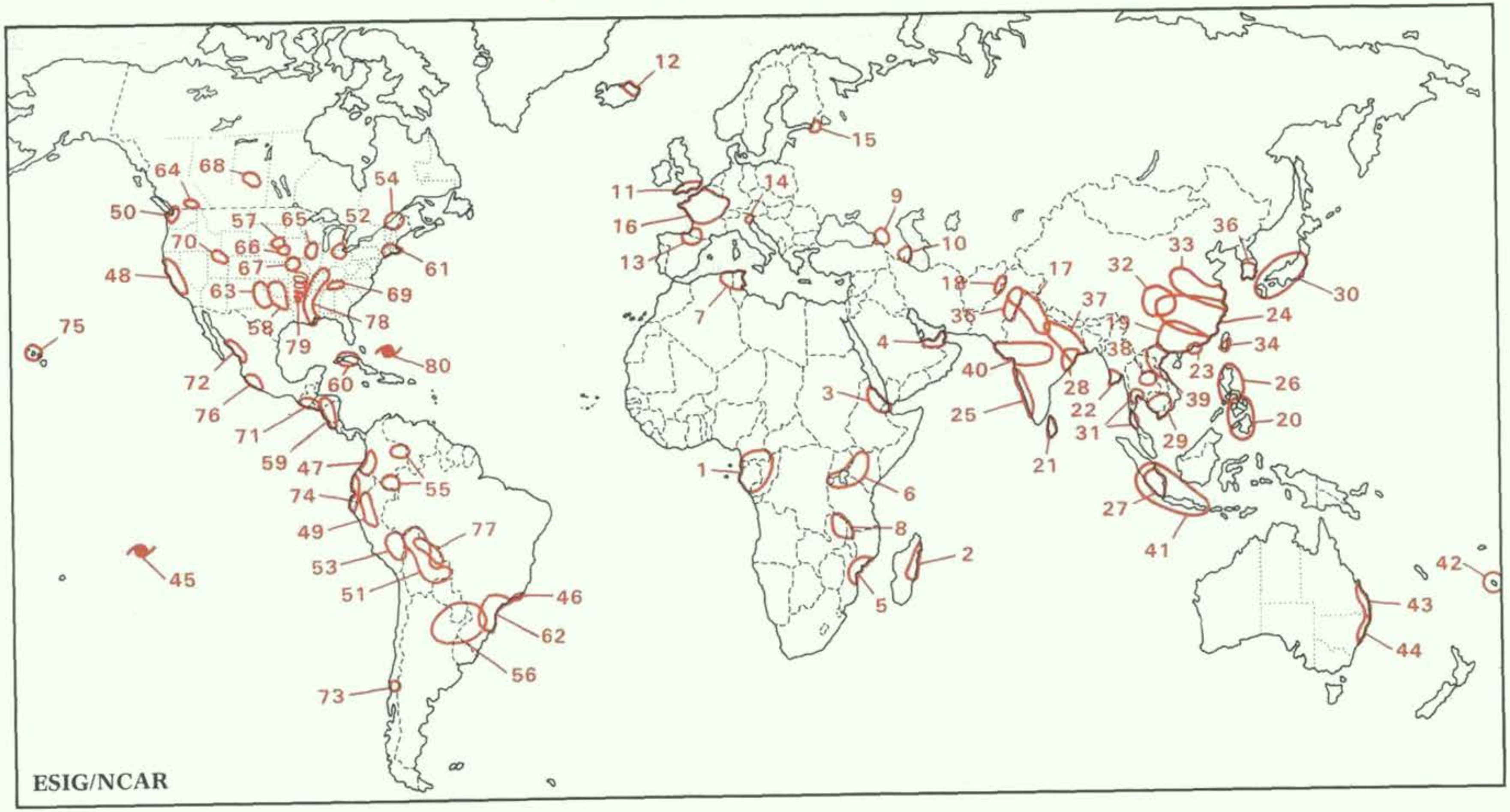
Asia

13. n China: esp. Hebei province - Jan thru Aug*
   a. 2-yr drought, surrounds Peking
   b. Many tributary rivers dried up by June
14. India: Maharashtra, Gujarat, Rajasthan, Karnatka, Andhra Pradesh, parts of Orissa - Jan thru July*
   a. Worst drought in decade, esp. Maharashtra & Andra Pradesh
15. Japan: Honshu - Mar thru Aug
   a. One of the worst & prolonged droughts on record, extensive crop damages, Tokyo affected by water shortages
   b. 3-30% of normal for Mar
16. n Vietnam: 5 provinces s of Hanoi - Jan thru July*
   a. No rain since Nov 1972, crop losses
17. e & ne Thailand - Apr thru May*
18. Sri Lanka - May thru Aug
21. c US - Winter 1972-73
   a. Deficient winter moisture: strip of c US states from New Jersey to Kansas had no snow during winter, established series of new monthly & seasonal precip lows
22. w US: parts of California - Jan thru Aug*
   a. Very dry winter in Sierra Nevada Mountains, esp. Mar
      (i) Least Mar snowfall in many areas of Sierras within "recent" record, top snowpack was at Lake Spaulding with 12" reported end of Mar
   b. Los Angeles area experienced a rainless period from Mar 28, 1972 thru Oct 8, 1973, ending Oct 8 with .02", longest dry spell in history
23. Bermuda Island - Apr thru June
   a. 3-month drought ended by Hurricane Alice on July 5
24. US: Wake Island - May
   a. Driest May in 30 yrs
25. Chile - dates not known
   a. Annual rainfall for most of country 35-45% below normal, in n coastal provinces rainfall deficits were 85-100%, serious agricultural impacts & crop losses, lack of drinking water in many places
26. Venezuela - dates not known
   a. Drought in Unare low plains & high central plains

*Drought also experienced in the area in 1972

1982 FLOODS/HEAVY RAINS/SEVERE SUMMER STORMS

January - December



Africa & Mid East

1. W Africa: w Congo, s Cameroon, Gabon - Jan thru Mar; Oct-Dec
2. ne Madagascar - Jan thru Mar
   a. Series of cyclones, esp. cyclone Justine - Mar 19-20
   b. Extensive flooding, high winds, crop damage, fatalities
3. ne Africa: coastal Ethiopia, Djibouti - Jan 14-17; Feb 7-20
4. United Arab Emirates - Feb thru Mar
   a. Excessive rain throughout year, esp. Feb and Mar
   b. Bateen Airport 1982 total 195 mm; combined 1977-81 total 151.9 mm
5. c Mozambique - Feb 7-20

26. n & c Philippines: Luzon & central islands - June thru Oct
   a. Severe typhoon season, periods of severe flooding, crop & property damage, fatalities
   b. Esp. Typhoon Nancy - Oct 12-16
27. Indonesia: s Sumatra -June 3-5
   a. Heaviest monsoons in 75 yrs, severe flooding, property damage & fatalities
28. ne coastal India: Orissa province - June 4
   a. Cyclone, severe winds, extensive flooding, property damage, hundreds of thousands homeless, fatalities

49. s Ecuador, n Peru - mid Jan thru July
   a. Heavy rains, flooding, river flooding, extensive property damage, fatalities
   b. Esp. Jan 23-25, Feb 20
50. nw US: nw Washington, esp. Bellingham area - Feb 13-14 & 23-24
   a. Severe storms, heavy rains, snowmelt
51. n, e & c Bolivia - Mar
   a. Heavy rains, flooding, landslides, crop damage, fatalities
   b. Esp. Mar 2-5 in Beni & Mamore River valleys
   c. Esp. mid-Mar in e Bolivia, Santa Cruz area

6. e Africa: Burundi, Rwanda, w Kenya - Oct thru Dec
7. nw Africa: ne Algeria, n Tunisia - Oct 10 & 30-31
8. se Africa: n & c Malawi, low-lying parts of Zambia - mid Nov thru Dec

Europe & USSR

9. s USSR: w Georgia - Apr thru mid June
    a. Heavy rains, snowmelt, floods, hail, property & crop damage, fatalities
    b. Esp. Apr 7 & mid June period
10. s USSR: Azerbaidzhan - early Oct
    a. Heavy rain under 10., crop damage, extensive flooding
11. United Kingdom: sw & se England - Oct 17-20
    a. Heavy rains, flooding
    b. 3rd wettest Oct of the century
12. ne Iceland - Nov 15-16
    a. severe flooding, intense storm
13. sw Europe: Andorra, e & n Spain, sw France - late Oct thru Nov
    a. Periods of torrential rains, widespread flooding, property & crop damage
    b. Esp. Nov 6-7
14. n Italy: Venice - Nov 26-29
    a. Heavy rains, 4 ft of water in streets
15. nw USSR: Leningrad area - Dec 1982 thru Jan 1983
    a. Series of floods
16. France - late Dec
    a. Heavy rains, widespread flooding, crop & property damage
    b. Esp. n France & sw France (Charente River basin)

Asia

17. ne Pakistan, n & nw India: Punjab, w & e Uttar Pradesh - Feb thru June
18. nw Pakistan - Feb 7-20
19. s China: Guangdong, Guangxi - mid Feb thru mid Aug
    a. Periods of torrential rains, high winds, extensive flooding, property & crop damage, fatalities
    b. Esp. May 2-15, June 27 thru July 10, Tropical Storm Dot Aug 15-18
    c. May totals for s China 200-600% normal; worst flooding in 30 yrs in se Guangdong
20. s & c Philippines - Mar 20-29
    a. Typhoons, flooding, high winds, property & crop damage, fatalities
    b. Typhoon Mamie: Mindanao - Mar 20
    c. Typhoon Nelson: Visayas - Mar 23-29
21. Sri Lanka -May; late Nov thru late Dec
    a. Esp. Nov 21-27 & Dec 19
22. sw coastal Burma - May 4
    a. Cyclone, crop & property damage, fatalities
23. Hong Kong - late May
    a. Torrential rains, landslides, fatalities
    b. Esp. May 28-29
24. c & e China: Hunan, Jiangxi, Zhejiang, Fujian, Sichuan - June
    a. Extensive flooding, property & crop damage, fatalities
    b. Esp. s Fujian, worst flooding in 30 yrs
25. coastal w India - June
    a. coastal flooding from heavy monsoonal rains
29. Kampuchea, sw Vietnam - June 1-10
    a. Heavy rains, flooding
30. Japan: Kyushu & s Honshu - July thru Sept
    a. Severe typhoons, heavy rains, strong winds, flooding, mud & landslides, crop & property damage, fatalities
    b. Worst flooding in 25 yrs, esp. in Nagasaki area on Kysuhu
    c. Esp. July 23-24, Aug 1- & 26-27, Sept 11-12 & 24
31. sw & sc Thailand - July 1-10; Dec 7-9
32. c China: ne Sichuan - July 15-17
33. c & e China: s Henan, e Hubei, Anhui, Jiangsu - July 19-23
    a. Between Huai & Yangtze rivers
34. se Taiwan - July 29
    a. Typhoon Andy
35. c Pakistan: Punjab - Aug 1-16
36. S Korea - Aug 12-13 & 26-27
    a. Heavy rains, flooding, typhoons, landslides, property & crop damage, fatalities
37. ne India, sw Bangladesh: Ganges River basin - Aug 28 thru Sept 10
    a. Esp. Indian provinces of Orissa, Bihar & e Uttar Pradesh; worst monsoon flooding in memory, displaced up to 8 million people
38. ne Thailand - Sept
    a. Heavy rains, flooding
    b. Esp. Tropical Storm Hope early Sept
39. n & c Vietnam, ne Laos - Oct 18
    a. Typhoon Nancy, extensive flooding, high winds, property & crop damage, fatalities
40. w coast thru c India - Nov 8-9
    a. Cyclone, high winds, heavy rains, property & crop damage, fatalities
    b. Esp. Gujarat province
41. Indonesia: s Sumatra & Java - Nov thru Dec

Australia & Oceania

42. Tonga Islands - Mar 2
    a. Typhoon Isaac, severe damage
43. e Australia: s coastal Queensland - Sept 20
44. e Australia: coastal New South Wales - Oct 9-11
45. Pacific Hurricanes & Tropical Storms - Jan thru Dec 1982
    a. 19 named storms (14.4 is 16-yr average)
    b. 11 were hurricanes, 8 tropical storms (plus 7 tropical depressions)
    c. One of the most active seasons on record

US, Canada, Latin America, & the Caribbean

46. coastal Brazil: Rio de Janeiro - Jan 5
    a. Heavy rains, floods, landslides, fatalities
47. sw Colombia - early Jan
    a. Torrential rains, flooding, landslides, esp. Jan 4 & 8
    b. Esp. Nanino province & Manizales area
48. w US: California - Jan thru Apr; Sept; Dec
    a. Periods of torrential rains & severe storms, high winds, flooding, mud & landslides, property & crop damage, fatalities
    b. San Francisco region - Jan thru Apr (esp. Jan 1-6)
    c. Entire San Joaquin Valley - Sept (esp. Sept 23-25)
    d. San Francisco region into n & c areas - Dec
52. n US: n Indiana, s Michigan, nw Ohio - Mar 14-22
    a. Rain, snowmelt, flooding
53. se Peru: esp. Cuzco - Mar 23-26
    a. Heavy rains, landslides, floods, fatalities
54. se Canada: se Quebec, E Township & Beauce regions - mid Apr; Aug
    a. Worst flood at Shebrooke in 42 yrs
55. e Colombia - mid Apr
56. ne Argentina, e Paraguay, s Brazil - May thru Dec
    a. Frequent storms, heavy rains, flooding, river flooding, crop & property damage, fatalities
57. c US: se S Dakota - May
    a. Heavy rains, hail, high winds, crop damage
    b. 3 counties declared disaster areas
    c. 2nd wettest May on record; in general Plains states suffered severe weather May thru June: Nebraska, N Dakota, Oklahoma
58. s US: n Texas & s Oklahoma - May 10-14
    a. Flooding, hail, heavy rains
    b. Wichita Falls, wettest May on record, also flooding & hail damage in Oklahoma City
59. w Costa Rica, c Honduras, Nicaragua - May 20-27
    a. Tropical disturbance, high winds, heavy rains, flooding
60. w Cuba - June thru early July
    a. Periods of intense rainfall, severe storms, major flooding, property damage
    b. Esp. June 1-5, including Hurricane Alberto (June 3), & June 19-20
61. ne US: Connecticut, Massachusetts, Maine, Rhode Island - June 5-6
    a. Heavy rains, flooding
    b. Conn., Mass., Rhode Island had wettest June on record
62. se Brazil: Parana & Sao Paulo states - June 24-27
    a. Windstorms, heavy rains, property & crop damage, fatalities
63. s US: nc Texas - June 10-20; July 29 thru Aug 1
    a. Hail, rain, high winds, crop & property damage
    b. Some flooding in Amarillo
64. sw Canada: s British Columbia - mid June thru July
    a. Heavy rains, crop damage
    b. s of Penticton
    c. 400% of normal rain in July for s British Columbia
65. c US: se Iowa, ne Illinois - July
    a. Heavy rains, flooding
66. c US: ne Nebraska - July 19
    a. Severe hail, wind
67. c US: Missouri, Kansas City area - Aug
    a. Esp. Aug 12-13
68. c Canada: c Saskatchewan - Aug
    a. Hail, heavy rain, crop damage
    b. Near Prince Albert
69. se US: c & e Tennessee - late Aug
70. w US: Utah, Salt Lake City area - Sept
    a. Wettest in 76 yrs

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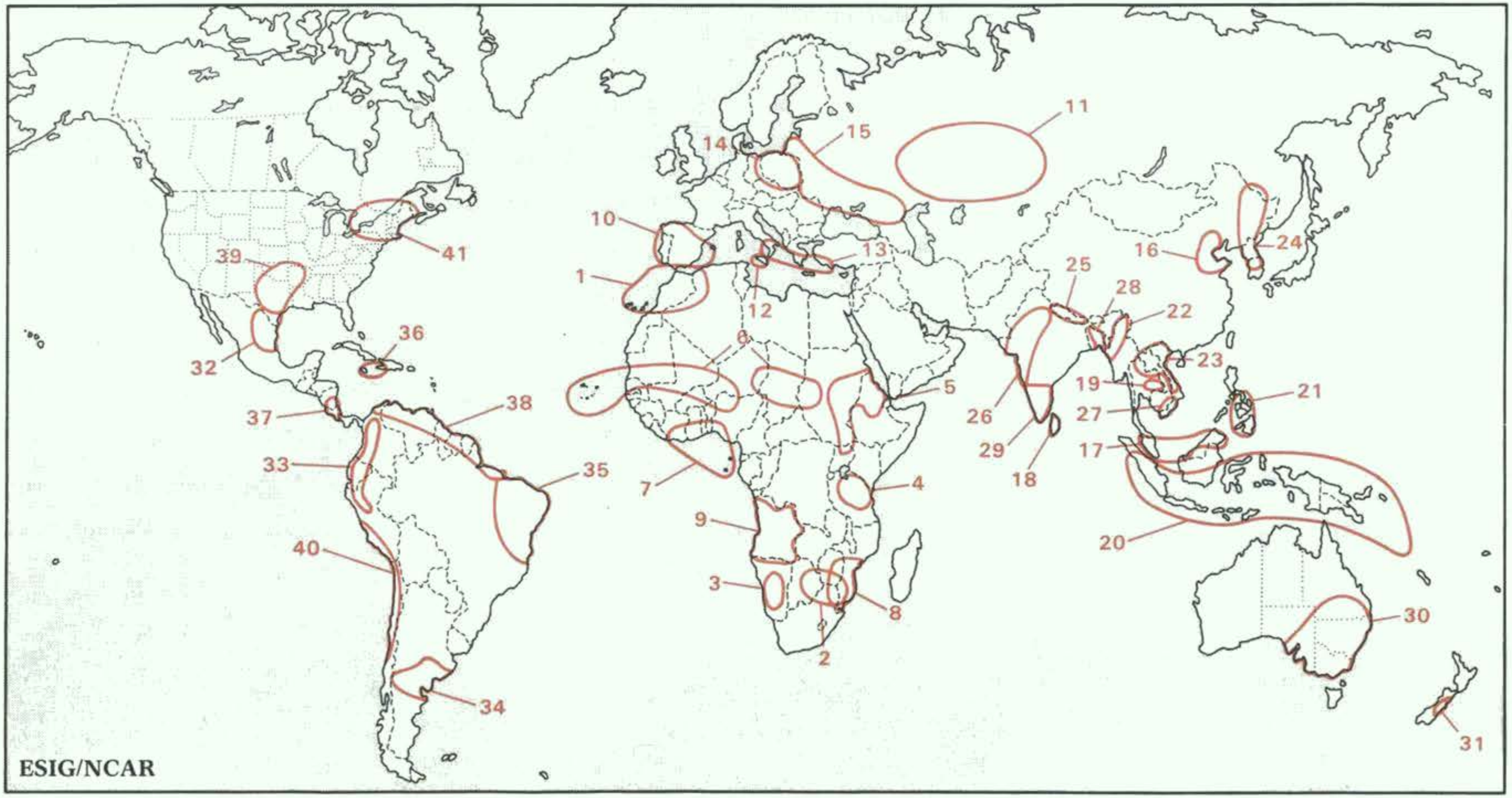
US, Canada, Latin America, & the Caribbean (cont.)

71. coastal Guatemala, El Salvador - Sept 17-22
    a. Hurricane Paul, heavy rains, floods, large landslides, property & crop damage, esp. in El Salvador
72. n Mexico: Sinaloa - Sept 29-30
    a. Hurricane Paul, heavy rains, high winds, flooding, property & crop damage
73. c Chile: Temuco region - Sept 30
74. coastal Ecuador, n Peru - Nov thru Dec 1975. US: w Hawaiian Islands - Nov 24
    a. Hurricane Iwa
    b. Kauai, Oahu Islands
76. w Mexico: Manzanillo area - Nov 25-26
77. n Bolivia: Baures River basin -Dec
78. US: Mississippi Valley - Dec
    a. Illinois, Arkansas, Missouri, early Dec
    b. Louisiana, Mississippi - late Dec
    c. Illinois, Iowa, Missouri, Louisiana, Mississippi, Arkansas had wettest Dec on record
79. Tornados: US - Jan thru Dec 1982
    a. Total of 1,047 (30-yr mean is 739)
    b. 23.6% strong (average is 33%), .5% were violent (average is 2%)
    c. Mar thru May 1982 had highest frequency of tornados on record, 365 (previous record 275)
        (i) Damage concentrated in s & c states in Mar; s Mississippi Valley in Apr; s Illinois in May
80. Atlantic Hurricanes - Jan thru Dec 1982
    a. 2 named hurricanes
    b. Least active season in more than 50 years (usual is 10 named storms with 6 becoming hurricanes)

1982 DROUGHTS
January -December



Africa & Mid East

1. nw Africa: w Algeria, Morocco, Canary Islands - Jan thru Mar or Apr; Morocco - Nov thru Dec
2. se Africa: e Botswana, s Zimbabwe, s Mozambique, n Republic of S Africa - Jan thru Apr or May
3. c Namibia - Jan thru Apr
4. n Tanzania, e Rwanda - Mar thru June
5. ne Africa: e Sudan, ne Uganda, n Ethiopia: Gondor, Wollo, Eritrea, Tigrai - June thru Aug
6. African Sahel: Cape Verde Islands, coastal & n Senegal, n Gambia, s Mauritania, c Mali, n Upper Volta, w Niger, n Nigeria, c Chad, c Sudan - June thru Oct (considerable variability throughout period)
7. w coast Africa: Ivory Coast, Ghana, Togo, Benin, Nigeria, Sao Tome Island, Principe Island - Aug thru Dec
8. se Africa: e Zimbabwe, s Mozambique, ne Republic of S Africa - Sept thru Dec
9. Angola - no dates or exact locations available

Europe & USSR

10. Spain, Portugal - Mar thru Apr; July thru Aug; Dec
    a. Widespread & scattered drought continued from 1981, heat waves, forest fires, crop damages, water rationing
    b. Dec only 10% of normal precip
11. c USSR: w Kazakhstan, s Urals, w Siberia - Apr thru Aug
12. s Italy: Sicily - May thru July
13. Mediterranean states: s Italy, Greece, w Turkey - late June
    a. Heat wave related deaths, forest fires, crop losses
14. Poland - July thru Nov
    a. Also parts of Yugoslavia & E Germany
15. sw USSR: n Caucasus, Ukraine, Baltic states - Sept thru Nov
    a. i.e., Krasnodar only 12-40% normal precip for period

Asia

16. n China plain: Shandong & Hebei - Jan thru May
17. Malaysia - Jan thru Apr; e Sabah - thru May
18. Sri Lanka - Jan thru Apr; mid June thru Oct
19. se Thailand - Jan thru Mar
20. Indonesia, Papua New Guinea, Melanesian Islands - Mar thru Dec
    a. Beginning in Indonesian archipelago & n Sulawesi, spreading to entire area by July; worst drought in 10 yrs
21. s & c Philippines - Mar thru May; mid Sept thru Dec
22. s Burma - May thru Oct
23. Laos, n Thailand, n & c Vietnam, parts of Kampuchea & s Vietnam - May thru Aug; c Vietnam - thru Dec
24. N & S Korea, ne China - June thru July
25. Nepal - June thru Dec
    a. Failure of summer monsoon, severe drought
26. w to n India: Uttar Pradesh, Rajasthan, Gujarat, Maharastra -July thru Sept
27. s Vietnam, e Kampuchea - July thru Aug
28. ne & coastal Bangladesh - Aug thru Nov
29. s India: Kerala, Tamil Nadu - Aug thru Dec

Australia & Oceania

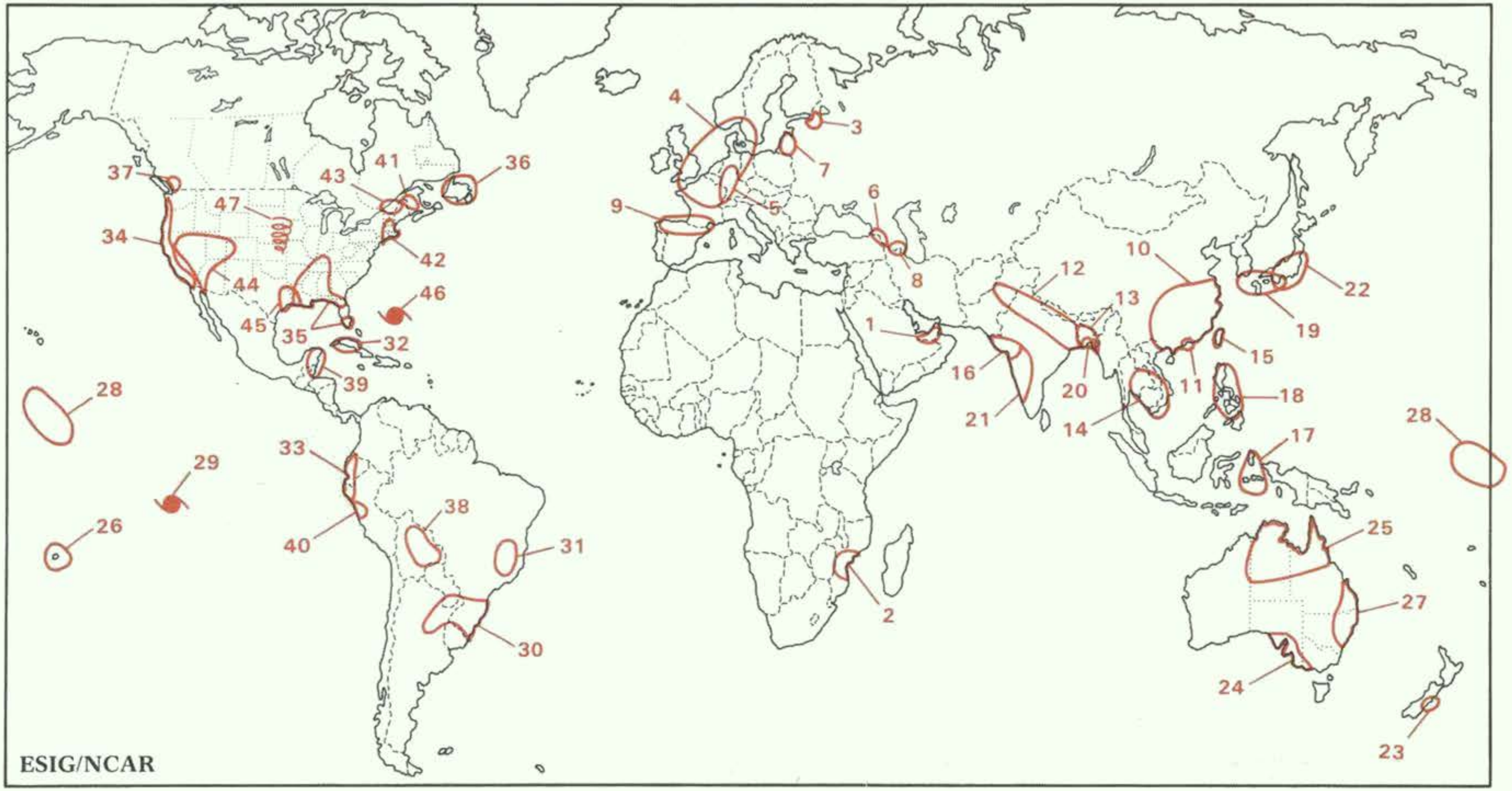
30. se Australia - Apr thru Dec
31. New Zealand: e coastal South Island, Canterbury Plains - June thru Aug
    a. Dry in New Zealand entire year except s & w South Islands

US, Canada, Latin America, & the Caribbean

32. c & ne Mexico, se Texas - Feb thru Mar; June thru Nov
    a. i.e., ne Mexico 20-40% of normal in Feb & Mar
33. n Peru, Ecuador, Columbia: Cauca & Magdalena River valleys -Feb thru Dec
34. Argentina: Buenos Aires province - Mar thru May
35. ne Brazil - Mar thru July; Sept thru Dec
36. s Haiti & Jamaica - Mar thru June; Sept thru Dec
37. Costa Rica, s Nicaragua - July thru Aug
38. nw Colombia, n Venezuela, Guianas - Sept thru Dec
39. s US: Texas, parts of Oklahoma, Arkansas - Sept thru Oct
40. w coast S America: s Peru, Chile - Nov thru Dec
    a. Heat wave, dry
    b. Late Dec, many heat-related deaths in Lima
41. ne US & se Canada: s Ontario & Quebec - Nov thru Dec
    a. Deficient snows, ski areas hurt
    b. Mt. Washington, New Hampshire no snow cover on Dec 25, 1st time in 50 yrs
    c. n Maine, lowest snow in Dec on record
    d. at least a dozen major cities in east had one of the warmest Dec on record, i.e., Dec 25 warmest in 142 yrs in Toronto

1983 FLOODS/HEAVY RAINS/SEVERE SUMMER STORMS

January - August



Africa & Mid East

1. United Arab Emirates - Jan thru Apr
    a. Excessive rain continued from 1982, 4-month total double 10-yr average
2. Mozambique - Feb 15-19

Europe & USSR

3. nw USSR: Leningrad area - Dec 1982 thru Jan 1983
    a. Series of floods

Asia

10. China - Jan thru Aug
    a. Widespread flooding, heavy rains, river flooding
    b. se provinces: Guangxi, Guangdong - Jan thru May
        (i) Esp. Jan 4-7
    c. e provinces, e parts of Yangtze River valley: Zhejiang, Fujian, ne Jiangxi - early Apr
        (i) Esp. Apr 10-16
    d. coastal into c provinces: n Anhui, s Shandong, n Jiangsu, n Jiangxi, sw Hunan, Henan - June thru July
        (i) Between Yellow and Yangtze rivers
    e. s provinces: se Ghizhou, sw Hunan, n Guangxi - June 12-25
        (i) Torrential rains, flooding, crop damage

US, Canada, Latin America, & the Caribbean

30. ne Argentina, s & e Paraguay, s Brazil: Parana, Sao Paulo, Santa Caterina, Rio Grande de Sul - Jan thru Aug
    a. Heavy rains, flooding, river flooding
    b. Esp. s Brazil June thru July
31. se Brazil: Belo Horizonte region - Jan
    a. Esp. Jan 1-2 & 19-22
32. w & c Cuba - Jan thru Apr
    a. Heavy rains, flooding, high winds, crop damage
    b. Esp. Feb 20-28 & Mar 15-17
    c. 500% of normal precip for period

4. W Europe - Apr thru May
    a. Flooding, crop & property damage
    b. One of the wettest such periods of this century, i.e., Netherlands had wettest spring on record; Belgium 76 days of rain; Brussels least sunshine since 1887; Denmark wettest in over 100 yrs
5. ne France, w W Germany - mid Apr; May thru early June
    a. Flooding, heavy rains, river flooding
    b. Esp. near Nancy in France on the Moselle River
    c. Esp. near Cologne in W Germany on the Rhine River
6. s USSR: Georgia - May 23; July
    a. Torrential rain, hail, crop damage
7. w USSR: Latvia, Lithuania - late May
    a. Heavy rain, crop damage
8. s USSR: Armenia, Azerbaidzhan - early June
    a. Hail, heavy rain, wind, crop damage
9. n Spain, s France - Aug 21-27
    a. Heavy rains, flooding

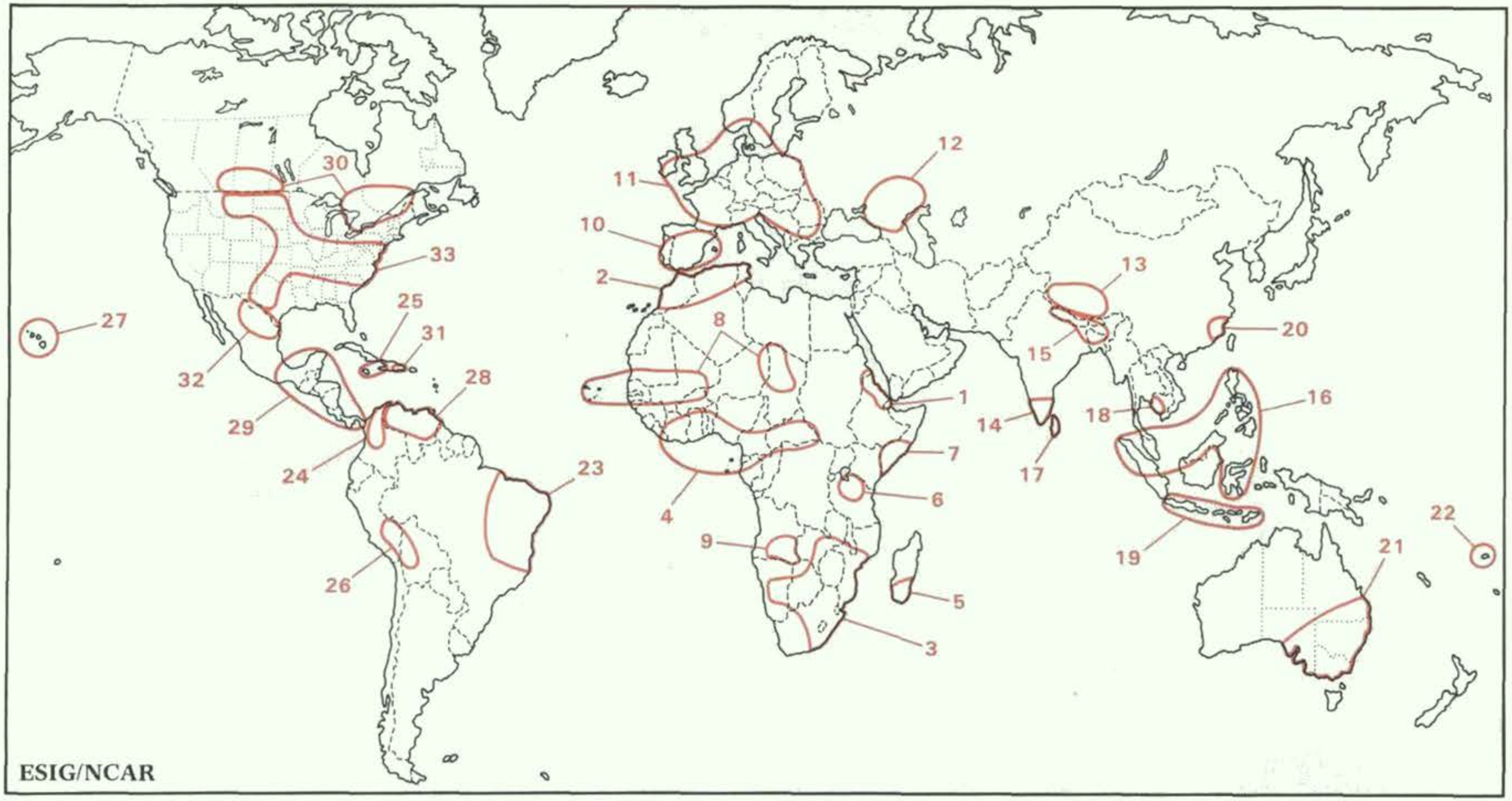
    f. se provinces: Guangdong, Fujian - July
    g. c coastal province Zhejiang - Aug 21-28
        (i) Torrential rains, flooding
11. Hong Kong - Jan thru June
    a. Floods, landslides
    b. Wettest Mar on record, Jan-June totals highest since 1887
12. n & c Pakistan, s Nepal, Bangladesh, nw India: Punjab, Uttar Pradesh, Bihar & Bengal - Apr 10-16
    a. Series of major storms, heavy rains, flooding
13. Bangladesh - Apr 24-30 a. Severe storms, major flooding
14. se & s coastal Thailand, Kampuchea, s Vietnam - May thru July; in Thailand - thru Aug
15. Taiwan - late May
    a. Unusually heavy rains, flooding
16. w India: Gujarat - June 19-24
    a. Tropical depression, torrential rains, flooding
17. e Indonesia: Maluku - June 19-24
18. s & c Philippines - July thru Aug
    a. Esp. Typhoon Vera July 14
19. w Japan, S Korea - July 20-25
    a. Heavy rains, flooding, mudslides
    b. Esp. in w Japan
20. s Bangladesh - Aug 3-5
    a. Torrential rains, flooding
21. w & s India: Maharashtra, Gujarat, Konkan, coastal Karnataka -Aug 7-16
22. Japan: Honshu - Aug 17
    a. Typhoon Abbey

Australia & Oceania

23. New Zealand: South Island, Christchurch region - Jan 19
    a. Severe storms, hail
    b. sw South Island, Milford Sound, wettest Jan on record
24. coastal S Australia - Mar 1-3
25. n Australia: Northern Territory & n Queensland - Mar 1-15
26. Society Islands: Tahiti - Apr 12
    a. Cyclone Veena, worst in Tahiti's modern history
    b. French Polynesia had 6 major cyclones from Dec 1982 thru Apr 1983, usual frequency 1 or 2
27. e coastal Australia: s Queensland & c New South Wales - mid Apr thru June
28. Kiribati Islands - no dates available
    a. Intense periods of very heavy rains
    b. Including Gilbert Island, Christmas Island & the Line Islands
29. Pacific Hurricanes & Tropical Storms - Jan thru Dec 1983
    a. 24 named
    b. Most active season on record in e Pacific

33. w coastal Ecuador & n coastal Peru - Jan thru July
    a. Heavy rains, severe flooding, mudslides
    b. Esp. Jan 1-20, Mar 20 & 25-30
    c. Heavy rains & flooding continued from 1982: Nov thru June totals 163", 450% of normal for Guayaquil
34. w coastal US: esp. California - late Dec 1982 thru Apr 1983
    a. Excess rain, high winds, mud & land slides
    b. Esp. Jan 26-28, Feb 26 thru Mar 2, & flooding in San Joaquin & Sacramento valleys in early Apr
35. s US: Gulf & s states - Jan thru Feb; Apr thru May
    a. Heavy rains, floods, tornados, river flooding
    b. s Florida - Jan thru Mar
        (i) Wettest winter in southernmost Florida out of last 52 yrs
    c. s Louisiana (west of New Orleans) into s Mississippi - Jan 1-7
        (i) Heavy rains, floods
    d. Mississippi, Tennessee, se Texas, Louisiana (esp. Baton Rouge to New Orleans), s Alabama, s Georgia -Apr thru May
        (i) Esp. Apr 5-8 in La., Miss., & Ala.
        (ii) May 18-24 mostly in Miss. (flooding, tornados, 1.2 million acres flooded)
36. se Canada: c & s Newfoundland - Jan 11-14
37. sw Canada: sw British Columbia - Feb 8-14
    a. Snowmelt, mudslides
38. Bolivia - Mar
    a. n areas near San Joaquin, Mamore River in early Mar
    b. e areas Santa Cruz province (esp. Piray River basin) & e areas later in Mar, esp. Mar 18-19
39. s Mexico (Yucatan), Belize, n Guatemala - Mar 13-16
    a. Heavy rains, flooding, high winds
40. n Peru: Ancash region - Mar 15-22
    a. Heavy rains, flooding, land & mudslides
41. se Canada: w New Brunswick - Apr
    a. Heavy rains, flooding along St. John River
42. ne US: New York, New Jersey, Connecticut, Vermont - Apr 17-22
    a. Flooding, heavy rain
    b. New York City's wettest Apr
43. se Canada: s Quebec - late Apr thru May
    a. Quebec City & Trois Riviere, wettest month ever recorded
44. US: w & sw states into n Mexico - Apr thru Aug
    a. Heavy rains, heavy snowmelt runoff, scattered flooding, river flooding, mud & landslides
    b. se California (Central Valley), Utah (esp. Salt Lake area & to n), Nevada (esp. near Reno), w Colorado (esp. Grand Junction) - Apr thru June
    c. w Arizona, n Mexico - June thru Aug
        (i) Lower Colorado River flooding
45. s US: se Texas - May 10-14; Aug 17-18
    a. May: tornados, rains, floods
    b. Aug: Hurricane Alicia, esp. Galveston & Houston area
46. Atlantic Hurricanes - Jan thru Dec 1983
    a. 4 named storms
    b. 5 days when a hurricane was present
    c. Quietest season in 52 yrs
47. Tornados: US - Jan thru Dec 1983
    a. Total for 1983: 917 (average 739)
        (i) 3 violent, 21% were strong or violent (average 35%)

1983 DROUGHTS
January -August



Africa & Mid East

1. ne Africa: Djibouti, n Ethiopia: Wollo, Tigrai, Eritrea -Jan thru Aug*
2. nw Africa: Morocco, n & w Algeria, n Tunisia -Jan thru Apr or May*
3. s Africa: s, c, & nw Mozambique, Zimbabwe, Republic of S Africa (except w & sw areas), Swaziland, Botswana, Lesotho, e Namibia, s Malawi, s Zambia - Jan thru Aug*
    a. Widespread and scattered drought, worst drought on record for many areas

Asia

13. sw China: Tibet - Jan thru Aug
    a. Worst drought in 50 yrs
14. s India: Kerala, Tamil Nadu, Karnataka - Jan thru May*; Tamil Nadu - thru July
15. Nepal, ne India, Bangladesh - Jan thru Apr*

US, Canada, Latin America, & the Caribbean

23. ne Brazil: esp. Bahia & Ceara - Jan thru Aug*
    a. Area has experienced intermittent drought during last 5 yrs
    b. Water rationing in Fortaleza, capital of Ceara, in midsummer
    c. As of Aug, drought affected an area 5 times size of Italy: *1,439,000 sq.km.*
24. Colombia: Cauca & Magdalena valleys - Jan thru Feb
25. Haiti (esp. southern areas) & Jamaica - Sept 1982 thru July 1983*

4. w & coastal W Africa:
    a. e Liberia, Ivory Coast, Ghana, Togo, Benin, Nigeria, Cameroon, Central African Republic, Equatorial Guinea, Gabon, Sao Tome Island, Principe Island - Jan thru Mar
    b. e Liberia, Ivory Coast, Ghana (esp. n & upper areas), Togo, Benin, Nigeria - July thru Aug
5. s Madagascar - Feb thru Mar
6. c & ne Tanzania - Mar thru June
7. s Somalia - May thru June
8. African Sahel: Senegal, Gambia, n Guinea-Bissau, n Guinea, s Mauritania, c Mali, n Upper Volta, n & c Chad, e Niger, Cape Verde Islands - July thru Aug*
9. s Angola: Kwando-Kubango, Cunene -no dates available*

Europe & USSR

10. Spain, Portugal - Jan thru mid-Apr; se Spain thru July*
    a. Drought spreading temporarily to s France & n Italy thru mid-Feb
11. Europe - June thru Aug
    a. Widespread heatwave & drought, crop damage (mostly sugar beets and corn), heat-related deaths
    b. Reports of drought & heatwave in virtually all of Europe for July: extensive parts of Europe had one of hottest & driest Julys on record
    c. Austria: July 7: 70% of normal rainfall
    d. Switzerland: n of Alps, warmest July on record
    e. Belgium: 3rd warmest summer
    f. Italy: high temps in July, forest fires
    g. Drought persisted in n & e Europe in later periods
12. USSR: ne Caucasus, lower Volga regions - June thru July

16. se Pacific - Jan thru June
    a. Widespread drought
    b. s & c Philippines - Jan thru June*
    c. n & c Philippines - mid-Apr thru June
        (i) Drought in Philippines worst since 1958
    d. Malaysia - Jan thru Apr*
        (i) esp. e coast of peninsula (parts of s Thailand also)
    e. e Indonesia: Sulawesi - Jan thru Apr*
    f. c & nw Indonesia: n Sumatra, n Kalimantan - Mar thru mid-Apr*
17. Sri Lanka - Jan thru May*
18. sw Kampuchea - Mar thru Apr
19. s Indonesia: Java & Nusa Tengarra - mid-June thru Aug
20. se coastal China: Fujian - July thru Aug

Australia & Oceania

21. se Australia - Jan thru Apr*
    a. Worst drought since 1890s
    b. Thru Apr in interior New South Wales & Queensland
    c. Heatwave, brushfires, & dust storms in Feb
        (i) Melbourne 110° F Feb 8
        (ii) Feb 15-17, brush fires Victoria & S Australia
22. Fiji - Apr thru July

26. s Peru, w Bolivia: Altiplano region - Jan thru July
    a. Drought more persistent in Bolivian areas
    b. Nov 1982-Apr 1983 was 30% of normal precip
27. US: Hawaiian Islands - Dec 1982 thru June 1983
28. n Venezuela - Sep 1982 thru Mar 1983
29. s Mexico & Central America: Belize, Honduras, Guatemala, Nicaragua, Costa Rica, El Salvador, Panama - Apr thru July or Aug
    a. Intermittent & scattered drought & dry periods
30. s Canada: s Ontario, s Quebec & s prairies - June thru July; s prairies thru Aug
    a. Heat wave, dry, crop damages
    b. Toronto's combined June & July precip 2nd lowest in 143 yrs
    c. Quebec worst fire damage in 50 yrs
    d. Major corn losses in Ontario
31. s Dominican Republic - June thru July
32. n central Mexico - July thru Aug
33. US: except nw states - July thru late Aug
    a. Drought, heat wave, crop damages, heat-related deaths (200 by July 31)
    b. Rainfall less than 25% of normal in w sections of Texas & Oklahoma & in parts of Kansas, Nebraska, Missouri, Iowa, & Illinois
    c. Precip less than 50% for mid-Atlantic states
    d. Heat wave across entire country, esp. e of Rockies

*Drought also in area in 1982

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Effects and side effects of unusually harsh climate conditions in the early 1980s played havoc with the lives of millions of people around the world. This book describes the consequences and asks: was there a link with the enigmatic *El Niño* phenomenon which periodically disrupts the pattern of warm and cold currents in the world's largest ocean?

ETHIOPIA

Stan Grossfeld/Boston Globe (USA)