TEC-0080

US Army Corps of Engineers
Topographic Engineering Center

El Nino — Its Far-Reaching Environmental Effects on Army Tactical Decision Aids

John Neander

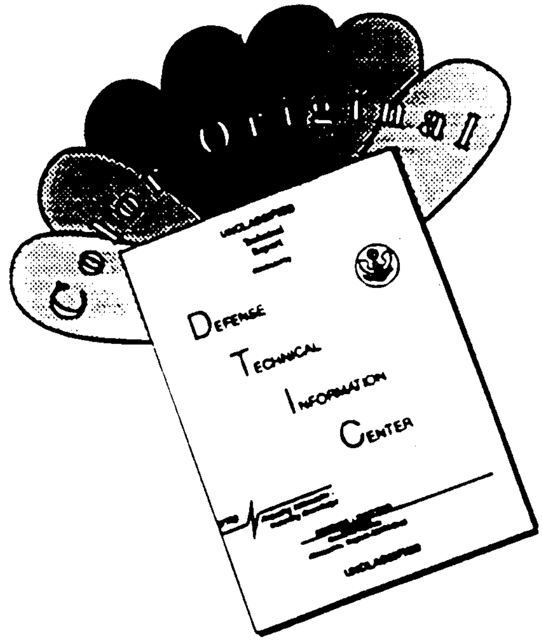
March 1996

19960425 033

U.S. Army Corps of Engineers
Topographic Engineering Center
7701 Telegraph Road
Alexandria, VA 22315-3864

T
E
C

DISCLAIMER NOTICE



REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	March 1996	Technical October 1994-September 1995

4. TITLE AND SUBTITLE	5. FUNDING NUMBERS
El Nino -- Its Far-Reaching Environmental Effects on Army Tactical Decision Aids	QG552CC501 WU 501
6. AUTHOR(S) John Neander	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army Topographic Engineering Center 7701 Telegraph Road Alexandria, VA 22315-3864	**8. PERFORMING ORGANIZATION REPORT NUMBER** TEC-0080
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**19. SPONSORING / MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES

To request additional report copies, please contact the U.S. Army Topographic Engineering Center, ATTN: CETEC-PAO (Public Affairs Office), 7701 Telegraph Road, Alexandria, VA 22315-3864; or telephone (703) 428-6022 / AUTOVON 328-6022.

12a. DISTRIBUTION / AVAILABILITY STATEMENT	12b. DISTRIBUTION CODE
Approved for public release; distribution is unlimited.	

13. ABSTRACT *(Maximum 200 words)*

El Nino. A series of benign changes in pressure and temperature over Darwin, Australia and Tahiti often results in significant changes in oceanographic and atmospheric patterns around the world. These, in turn, can produce short-term weather changes that impact vested interests of the United States on the world's political and military arenas. At the onset of an El Nino, the oceanographic changes are complemented by atmospheric changes that result in abrupt weather pattern reversals in a seasonal and a geographic context. The two weather extremes to consider from an El Nino event are droughts and floods. To know the likely implications of an El Nino event in advance will allow strategic and logistic planners to more accurately decide what type of weapons and support material will work best for the United States in the various world theaters.

14. SUBJECT TERMS			15. NUMBER OF PAGES
El Nino	Tactical Decisions	Ocean Currents	79
Logistical Planning	Weather Patterns	Climate Change	**16. PRICE CODE**

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

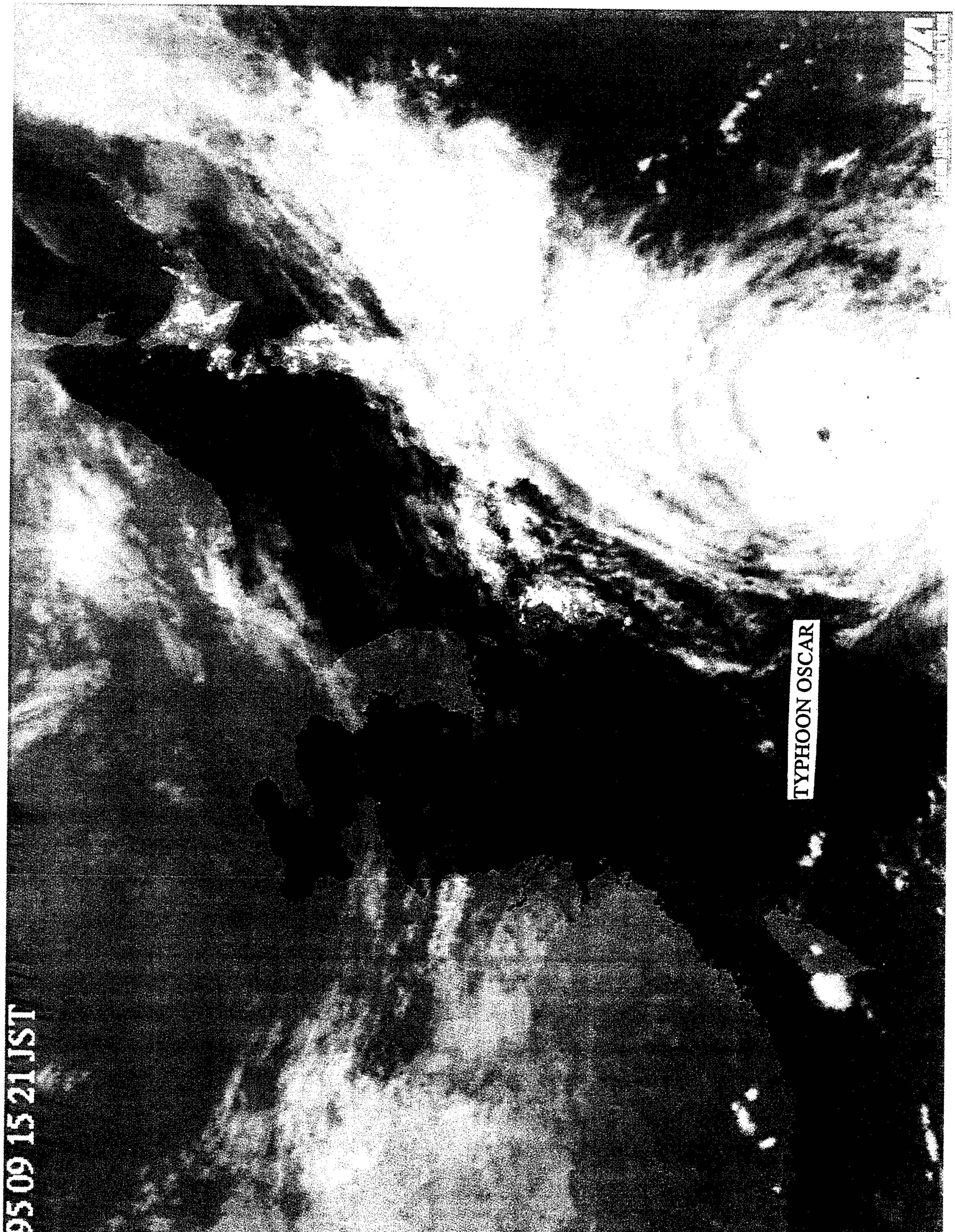

1995 09 15 21 JST
TYPHOON OSCAR

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF TABLES

PREFACE

This work was done under DA Project QG552CC501, Work Unit 501, "El Nino - Its Far-Reaching Environmental Effects on Army Tactical Decision Aids."

The work was performed during the period October 1994 to September 1995 under the supervision of Mr. Paul Krause, Project Leader, Ms. Betty Mandel, Chief of the Environmental Sciences Division, and Mr. John V. E. Hansen, Director of the Remote Sensing Laboratory.

The final editing and production sequence was performed during the period November 1995 to February 1996 with the help of Mr. Michael McDonnell, Team Leader, Mr. Juan Perez, Chief of the Modeling and Simulation Division, and Mr. Richard Herrmann, Director of the Topographic Applications Laboratory.

Mr. Walter E. Boge was the Director, and COL Richard G. Johnson was Commander and Deputy Director of the U.S. Army Topographic Engineering Center at the time of publication of this report.

ACKNOWLEDGMENTS

I would like to thank Mr. William Diego, Ms. Kathie Flood, Mr. David Capece, and Ms. Angela Straub for their technical expertise and assistance in defining and formulating the graphics used in this report. I also would like to thank Ms. Jean Diaz and Ms. Jackie Bryant for their expert advise and assistance in defining the editorial format of this report.

EXECUTIVE SUMMARY

An excellent example of chaos theory at work in the real world is the event known as "El Nino." The seemingly benign variations in pressure and temperature over Darwin, Australia and Tahiti often result in significant changes in oceanographic and atmospheric patterns around the world. These, in turn, can produce short-term weather differences that impact vested interests of the United States on the world's political and military arenas. At the onset of an El Nino, the oceanographic changes are complemented by atmospheric changes that result in abrupt weather pattern reversals in a seasonal and a geographic context. The two weather extremes to consider from an El Nino event are droughts and floods. The actual timing of when these weather patterns will develop over a particular region is directly related to the overall strength of the developing event, characterized as weak to very strong. This, in turn, is based on actual temperature differences between the warm waters that make up the heart of the El Nino and the surrounding ocean water, and the actual speed of this new warm water current. Occasionally, the opposite effect is detected as a cold water current, known as "La Nina."

Once these parameters are known, it is up to the strategic and logistic planners to decide what type of weapons and support material will work best in the various world theaters. If a major political or military statement is deemed necessary, the timing of naval resupply becomes critical. As many as nine major tropical storms can be active at one time (as during 14 September 1967) thus significantly altering shipping routes and time enroute. It should be noted that the best time for an opposing force to strike would be at the time of landfall of a tropical storm in the area of interest. During such a window of opportunity, the cornerstone of our military posture (the electronics surveillance umbrella) is either at its weakest or nonexistent. This, in turn, maximizes their threat capability, particularly in a mountainous region such as the Korean Peninsula. As much as 31 inches of rain was recorded there in 24 hours. Other parts of Indochina have recorded as much as 131 inches of rain in 72 hours. To know the likely implications of an El Nino event in advance, as noted by the more than $10 billion in worldwide damages produced by the 1982-83 El Nino pattern, will allow strategic and logistical planners to be better prepared in their efforts to diffuse chaos in the world's political and military arenas of tomorrow.

EL NINO - ITS FAR-REACHING ENVIRONMENTAL EFFECTS ON ARMY TACTICAL DECISION AIDS

INTRODUCTION

As an El Nino event develops in the southwestern part of the North Pacific, the initial impression is not one of concern. There is little immediate economic, political, or strategic (military) value in these waters. But as the event continues to expand and unfold, immediate weather and short-term periodic climate changes can be felt from the United States (U.S.) to South America, from Europe to Africa, and from Asia to Australia. This report describes the general world impact of an El Nino event, and then sharpens the focus on the Korean Peninsula. In this region, El Nino causes negative economic impacts in agriculture - rice, in general, and the fishing industry, in particular, that could lead to strategic conflicts in an attempt to feed a hungry population. Thus, tactical decision aids for either strategic or humanitarian situations can be in error if existing climatic data summaries are used. If military planners are trying to establish either military maneuvers or the logistics of resupply, they will inevitably discover that El Nino's regional impacts are usually quite different from the stated climate data for a given area, thus impacting on the type of systems to be used and the all important "reaction time."

Even the absence of an El Nino event can be cause for alarm. The 10-year gap between moderate to strong El Nino's from 1943 to 1953 could easily be seen as the key factor in the strength of the Siberian High in the winter of 1950-51. With the proper data set warnings, it is quite possible that decisions for the tactical deployment of the 1st Marine Division and the type of equipment they fielded would have been radically altered for the infamous battle of "The Chosin Reservoir." With proper planning, having the 1st Marine Division, or any other division, fighting for 14 days in -30 °F. temperatures against an enemy force of 120,000 should not happen again. Annual checks of the climate data sets should be considered by those in charge of tactical and logistical decision aids. One of the most important factors affecting climate data realism can be whether or not an El Nino mechanism is "on" or "off." Thus, these checks are necessary on an annual basis to ensure that short-term weather patterns that radically differ from the basic climatology for a given region are duly noted.

BACKGROUND

Early Spanish sailors who fished in small boats along the western-most shores of South America were familiar with the ocean currents of the region. Normally, the waters they fished were cold and flowed from south-to-north (Figure 1). During certain years, the waters would reverse their flow and become very warm. This would usually begin to occur shortly after the Christian Christmas holiday. Thus, the sailors named the odd occurrence El Nino, meaning "the Christ Child." A change to the El Nino pattern can be seen in the June 1985 to June 1986 sea surface temperature data shown in Figure 2.

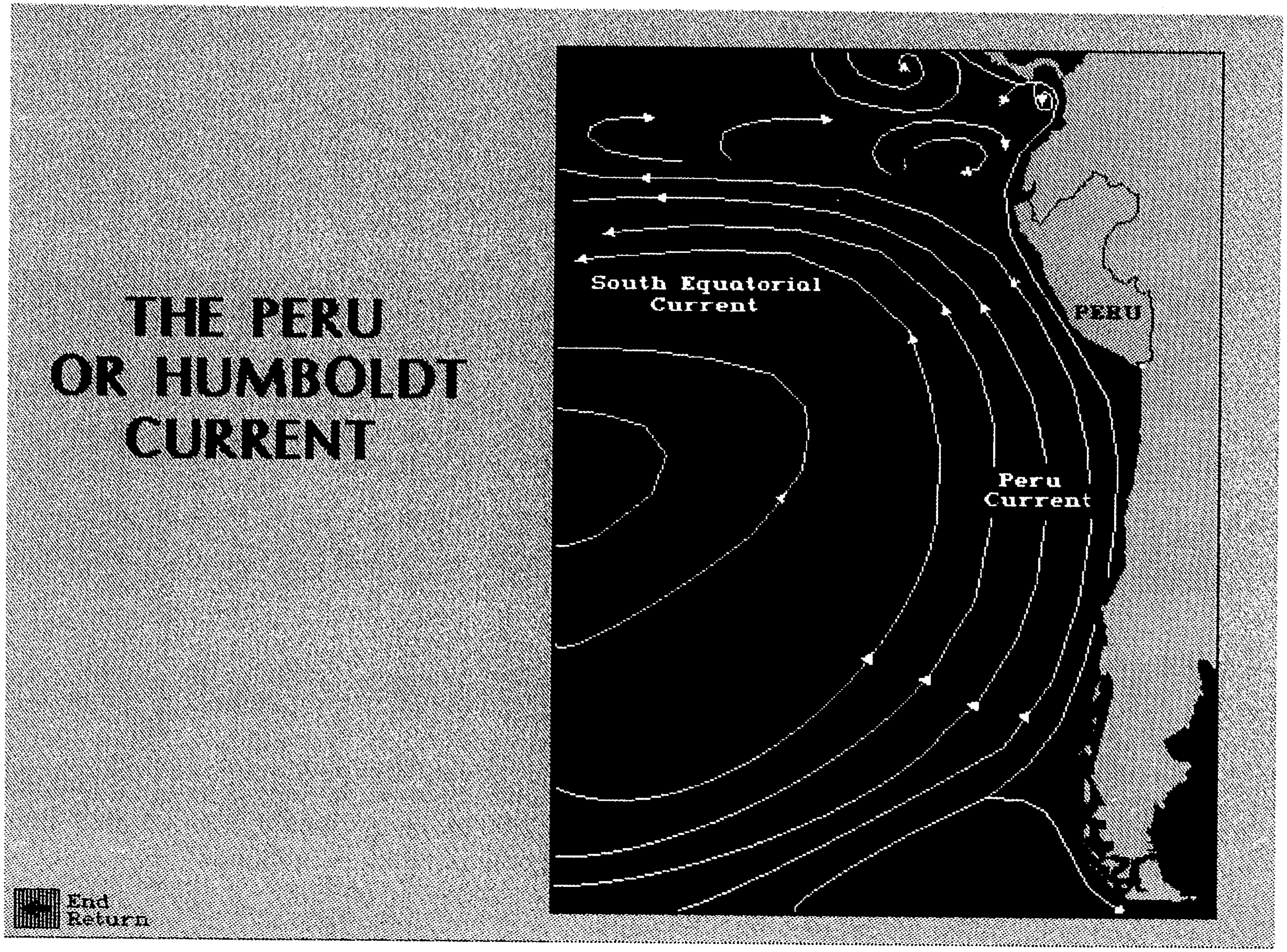


Figure 1. The Peru or Humboldt Current

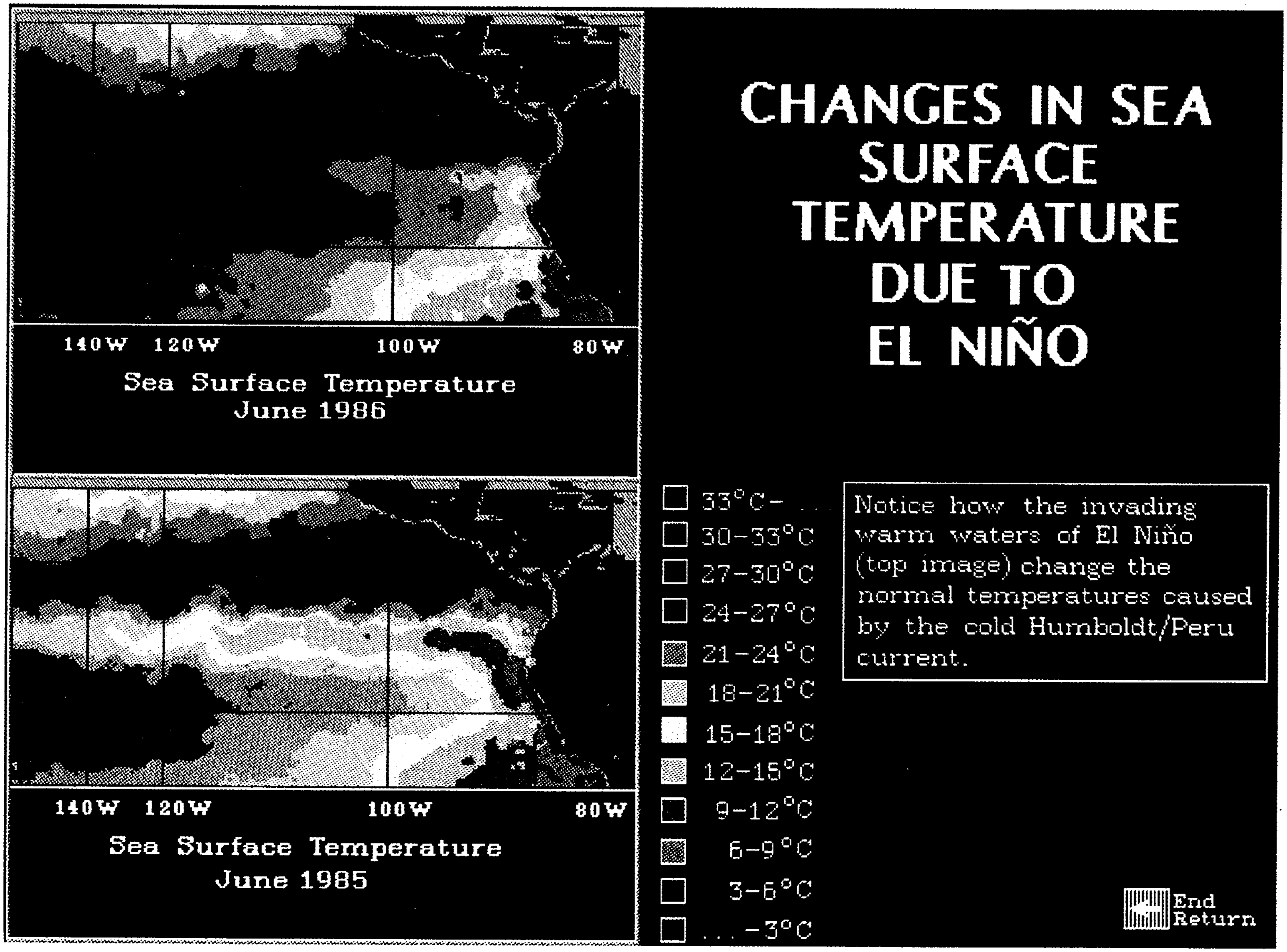


Figure 2. Changes in Sea Surface Temperature due to El Nino

El Nino is normally accompanied by a change in atmospheric circulation called the Southern Oscillation. Together, the El Nino - Southern Oscillation (ENSO) is one of the main sources of weather variability and periodic climate changes in the world. Over a quarter of a century ago, scientists began to recognize that the atmospheric and oceanic parts of ENSO are strongly linked (Figure 3). Therefore, it is imperative that military planners understand how the absence or appearance of an El Nino event can influence military or humanitarian operations. Whether or not this event is occurring, and at what level of intensity, can easily influence the type of military response. It also can have a profound impact on the timing and equipment needed for the logistical support of these operations.

The worldwide effects of a strong ENSO are shown in the damage reports compiled from the 1982-83 event (Table 1). Total damage reported worldwide exceeded $10 billion. A chronological sequence of these events gives another perspective of this far-reaching problem (Table 2). Military planners should note that climate data used for either military or humanitarian exercises may be in a state of flux during an El Nino occurrence.

How powerful can an El Nino event be? A direct indication of this power and the resultant generation of heat in the Pacific Ocean during such an event can be provided by satellite sensors. Measurements by NASA's TOPEX/Poseidon satellite (a collaboration between the U. S. and France) of the 1994-95 El Nino shows that Pacific sea levels were elevated 6 inches over an area the size of the U. S. (more than 3 million square miles) by the end of 1994.

EL NINO/ENSO - SHORT- AND LONG-TERM EFFECTS

To better understand an El Nino, its time lags, and its role within the ENSO mechanism, we begin with the Southern Oscillation (SO). The clearest sign of the SO is the inverse relationship between surface air pressure at two sites: Darwin, Australia, and the South Pacific island of Tahiti. High pressure at one site is almost always concurrent with low pressure at the other, and vice versa. The pattern reverses itself every few years. It represents a standing wave or a mass of air oscillating back and forth across the International Date Line in the tropics and subtropics. During the 1982-83 El Nino, the resultant atmospheric pressure for Darwin, Australia (Figure 4) was the highest in the last 100 years; while the atmospheric pressure concurrently recorded in Tahiti was the lowest in the last 50 years.

This two-dimensional picture was extended vertically to three dimensions by renowned meteorologist Jacob Bjerknes in 1969. He noted that in addition to the north-south circulation known as the Hadley Cell, trade winds across the tropical Pacific continued to flow from east-to-west. He theorized that to complete the loop, air must rise above the western Pacific, flow back east at high altitudes, then descend over the eastern Pacific.

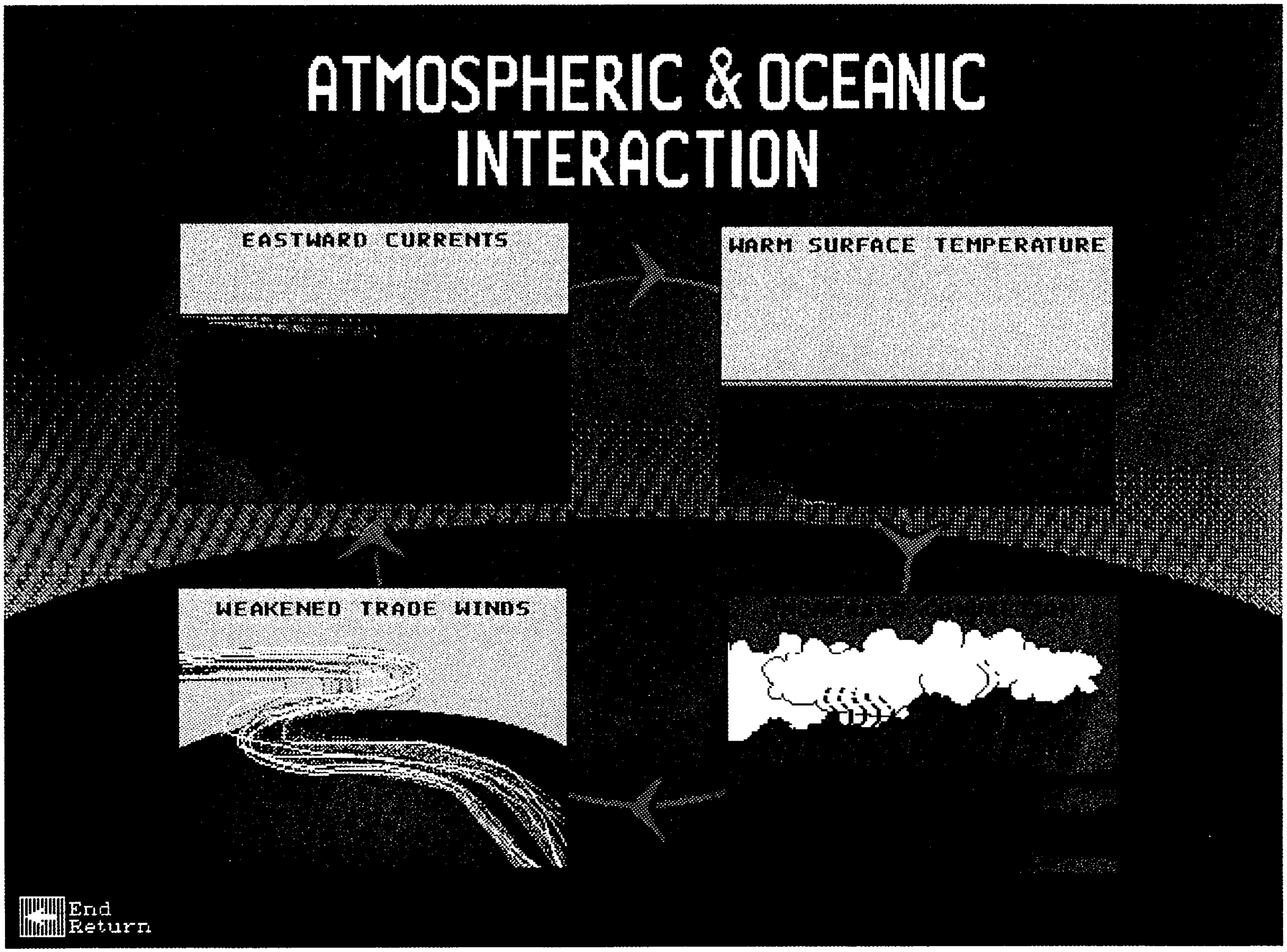


Figure 3. Atmospheric and Oceanic Interaction

Table 1. The Economic Effects of the 1982-83 El Nino

1. ***BOLIVIA***:

<u>DAMAGE</u>: $300 million.
<u>EFFECTS</u>: Storm related floods.
<u>VICTIMS</u>: 50 dead, 26,000 homeless.

2. ***CHRISTMAS ISLANDS***:

<u>EFFECTS</u>: 17 million birds disappear, abandoning their nestlings.

3. ***COAST OF CALIFORNIA***:

<u>EFFECTS</u>: Torrential rains, winds, and high tides erode coast and dislodge kelp beds. Fishermen find species of marine life that do not belong there, and could not find those that did. Los Angeles has nearly triple the amount of normal rainfall.

4. ***CUBA***:

<u>DAMAGE</u>: $17 million.
<u>EFFECTS</u>: Storm related floods.
<u>VICTIMS</u>: 15 dead.

5. ***ECUADOR AND NORTHERN PERU***:

<u>DAMAGE</u>: $650 million.
<u>EFFECTS</u>: Flooding and coastal destruction from high surf.
<u>VICTIMS</u>: 600 dead.

6. ***FRENCH POLYNESIA***:

<u>DAMAGE</u>: Unknown.
<u>EFFECTS</u>: Six major tropical storms. Several towns swept away by storm surges.

7. ***GALAPAGOS ISLANDS***:

<u>EFFECTS</u>: Massive bird migration off of Island. Bird and mammal nests abandoned. Nearly 100% of fur seal pups lost. Ninety-five percent coral reef mortality.

8. ***HAWAII***:

<u>DAMAGE</u>: $230 million.
<u>EFFECTS</u>: 1 hurricane.
<u>VICTIMS</u>: 1 dead.

9. ***IBERIAN PENINSULA AND NORTHERN AFRICA***:

<u>DAMAGE</u>: $200 million.
<u>EFFECTS</u>: Drought.

10. ***INDONESIA***:

<u>DAMAGE</u>: $500 million.
<u>EFFECTS</u>: Drought.
<u>VICTIMS</u>: 340 dead.

Table 1. The Economic Effects of the 1982-83 El Nino (Continued)

11. ***JAPAN***:

<u>EFFECTS</u>: Oyashio cold current extends further south reducing abalone harvest off the coast of Honshu Island.

12. ***KIRIBATO TO THE LINE ISLANDS***:

<u>DAMAGE</u>: Incomplete.
<u>EFFECTS</u>: Heavy storms.

13. ***MEXICO AND CENTRAL AMERICA***:

<u>DAMAGE</u>: $600 million.
<u>EFFECTS</u>: Drought.

14. ***MICRONESIA***:

<u>DAMAGE</u>: Incomplete.
<u>EFFECTS</u>: Severe drought and fires.

15. ***MIDDLE EAST (MOSTLY LEBANON)***:

<u>DAMAGE</u>: $50 million.
<u>EFFECTS</u>: Cold and snow.
<u>VICTIMS</u>: 65 dead.

16. ***PHILIPPINES***:

<u>DAMAGE</u>: $450 million.
<u>EFFECTS</u>: Drought.

17. ***SOUTHERN AFRICA***:

<u>DAMAGE</u>: $1 billion.
<u>EFFECTS</u>: Drought.

18. ***SOUTHERN BRAZIL, NORTHERN ARGENTINA AND EASTERN PARAGUAY***:

<u>DAMAGE</u>: $3 billion.
<u>EFFECTS</u>: Flooding.
<u>VICTIMS</u>: 170 dead and 600,000 Evacuated.

19. ***SOUTHERN CHINA***:

<u>DAMAGE</u>: $600 million.
<u>EFFECTS</u>: Wet weather.
<u>VICTIMS</u>: 600 dead.

20. ***SOUTHERN INDIA AND SRI LANKA***:

<u>DAMAGE</u>: $150 million.
<u>EFFECTS</u>: Drought.

21. ***SOUTHERN PERU AND WESTERN BOLIVIA***:

<u>DAMAGE</u>: $240 million.
<u>EFFECTS</u>: Drought.

22. ***TAHITI***:

<u>DAMAGE</u>: $50 million.
<u>EFFECTS</u>: 1 hurricane.
<u>VICTIMS</u>: 1 dead.

Table 1. The Economic Effects of the 1982-83 El Nino (Continued)

23. ***UNITED STATES -***

MOUNTAIN AND PACIFIC STATES:

DAMAGE: $1.1 billion.
EFFECTS: Storms.
VICTIMS: 45+ dead.

SOUTHWEST STATES:

DAMAGE: Incomplete.
EFFECTS: Storms.

GULF STATES:

DAMAGE: $1.1 billion.
EFFECTS: Storm related floods.
VICTIMS: 50+ dead.

NORTHEASTERN STATES:

DAMAGE: Incomplete.
EFFECTS: Storms.
VICTIMS: 66 dead.

24. ***WESTERN EUROPE***:

DAMAGE: $200 million.
EFFECTS: Storm related floods.
VICTIMS: 25 dead.

Table 2. Earth Space Research Group, 1982-83 El Nino Chronology

May 1982

- Slight rise in sea surface temperature off coast of Peru (less than ½° C.) detected by drifting buoys and satellites.

June 1982

- Sudden atmospheric pressure increase in Darwin, Australia.
- Dramatic atmospheric pressure decrease in Tahiti.
- Westward trade winds reverse direction along equatorial Pacific Ocean.
- Sea level rises over the central Pacific as the warm water pool (Kelvin Wave) starts moving eastward along the equator.
- Deep fog blankets the central Pacific.
- Dry spell begins in Australia, Indonesia and New Guinea.

July 1982

- Sea levels at Fanning and Christmas Islands are up almost 25 cm.
- Precipitation amounts in Tarawa are four times the normal for July.

August 1982

- Atmospheric pressure recorded in Darwin is highest in 100 years.
- Atmospheric pressure recorded in Tahiti is lowest in 50 years.
- Normally westward-flowing ocean current reverses.
- Five hurricanes form in the eastern Pacific.
- Rain begins in Christmas Islands during the traditional dry season.
- Extremely heavy rains are reported from Kiribati to the Line Islands.

September 1982

- In the eastern Pacific, a research ship observes:
  - Sea surface temperatures 5° C. higher than normal.
  - Upper ocean warm water layer four times thicker than normal.
  - The normal easterly cold under-current flows cease.
  - The usual abundance of marine wildlife disappears.

October 1982

- Kelvin Wave reaches the South American coast, sea surface temperature rises.
- Record rain and flooding strike Ecuador and northern Peru.
- Drought continues in Australia, Indonesia and New Guinea.

Table 2. Earth Space Research Group, 1982-83 El Nino Chronology (continued)

November 1982

- More than thirteen times the normal rainfall is recorded in Guayaquil, Ecuador.
- Fanning and Washington Islands suffer extensive erosion due to rough seas.
- A rare hurricane causes damage in Hawaii.
- French Polynesia is devastated by the first of six major tropical cyclones.
- Seventeen-million birds populating Christmas Islands disappear leaving nestlings for lack of food.

December 1982

- Remarkably deep warm water found near Panama-- as deep as 3,300 feet.
- Drought conditions spread from the Philippines to Hawaii.
- The tropical jet stream shifts north to California and the northern Pacific.

January - February 1983

- Indicators start to show a decline in the magnitude of the event; water temperature drops 5° C.
- Drifting buoys shift direction and start moving west-- back to normal.
- Atmospheric pressure readings return to their normal level in Darwin, Australia.
- El Nino appears to be waning.

March 1983

- Sea temperature surged upward again-- inexplicably.
- Along the Peru and Ecuador coasts, water suddenly warms by 7° C.
- Buoys that started moving westward changed direction again.

April-May 1983

- All readings of temperature and pressure surpass the previous December peaks.

Table 2. Earth Space Research Group, 1982-83 El Nino Chronology (continued)

June 1983

- Deserts of Peru, Ecuador and Bolivia receive 3.7 m of rain, instead of the usual 12.7 cm.
- Agricultural lands of northern Bolivia have received no rain for eight months.
- Ninety-percent of the potato crops in northern Bolivia perish from drought.
- Forty-thousand adobe homes melt down, and urban sewer systems burst in Bolivia.
- The Galapagos Islands receive more rain in six weeks than in six normal years.
- The Pacific part of Australia endures the driest summer in two centuries, resulting in high brush fires, crop and livestock losses.
- Nineteen African countries endure severe droughts.
- California and the Rocky Mountains suffer $1.1 billion damage from rains and floods.

November 1983

- Sea surface temperatures off the coast of Peru return to normal.

July 1984

- Water temperatures in the Gulf of Alaska return to normal.

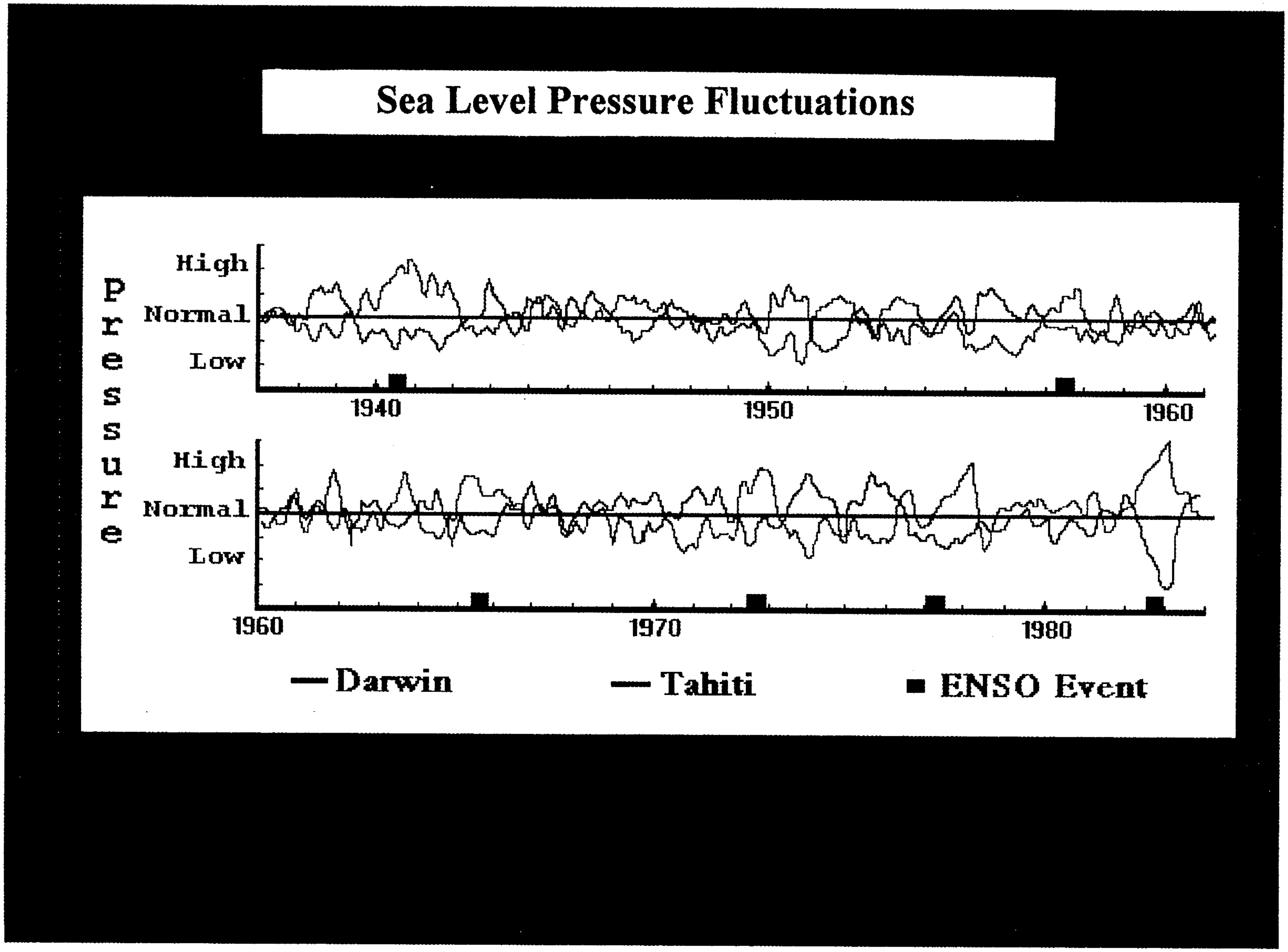


Figure 4. Darwin - Tahiti Annual Pressure Change

Dr. Bjerknes called this the Walker Cell circulation (in honor of Sir Albert Walker, a renowned meteorologist of the last century). He also was the first to recognize that it was closely connected to the oceanic changes of El Nino (warming waters) and La Nina (colder waters) (Figure 5). Thus, when the effects of the SO are coupled with the periodic mechanisms that stop the natural equatorial upwelling (whether cold or warm), you have two types of Pacific basin water masses to analyze (Figure 6).

The two primary considerations of military significance from an El Nino event are droughts and floods. With the U.S.'s strong emphasis on "electronic warfare and suppressive countermeasures," it should be noted that droughts produce great amounts of dust. During the 1982-83 El Nino event, the drought that enveloped eastern Australia (Figure 7) produced a dust storm that dumped more than 11,000 tons of dry soil on the city of Melbourne in 40 minutes. This drought became the driest summer in the Melbourne area in more than 200 years.

The converse of this tactical and logistical problem is the flooding that occurred in northern Peru (Figure 8) and Ecuador (Figure 9). Note the normal precipitation patterns for South America in June (Figure 10). Peru recorded its greatest rainfall amounts in more than 200 years during the El Nino period of 1982-83. Guayaquil, Ecuador recorded 13 times its normal rainfall during the same time period. The El Nino related storms that produced these heavy rains also produced an almost continuous heavy surf that resulted in widespread coastal damage to Peru and Ecuador that exceeded $650 million. The heavy rains soaked hillsides and brought thousands of homes tumbling down in the mudslides. Thus, any plans for logistical resupply and relief would be severely curtailed as local roads become impassable. The flood-swollen rivers, such as the Piura in Peru (Figure 11), wiped out prime banana and rice growing regions, swept away vital bridges, and, flooded towns causing widespread unsanitary conditions that resulted in virulent diseases' spreading throughout the area. The extent of these epidemic prone areas can be markedly changed by strong ENSO - El Nino (1982-83 warm), or the opposite effect of ENSO - La Nina (1988-89 cold) events that, in turn, influence the positioning of the average minimum temperature 10 °C. isotherm (50 °F.). Studies by Dr. Paul R. Epstein, Harvard Medical School, have shown that where this line develops becomes the boundary within which malaria and dengue fever epidemics are highly prone to start, and then expand with either poor or disrupted sanitation facilities (as in the example for Peru and Ecuador) (Reference 1).

These relatively recent events should act as a signal to planners and logistics experts that long-term action plans should be initiated. The cycle for these events can take up to 24 months to complete when involving moderate to strong El Ninos. It also should be noted that El Nino events that are very strong to extreme in their intensity can reduce the cycle time to as little as 12 to 18 months.

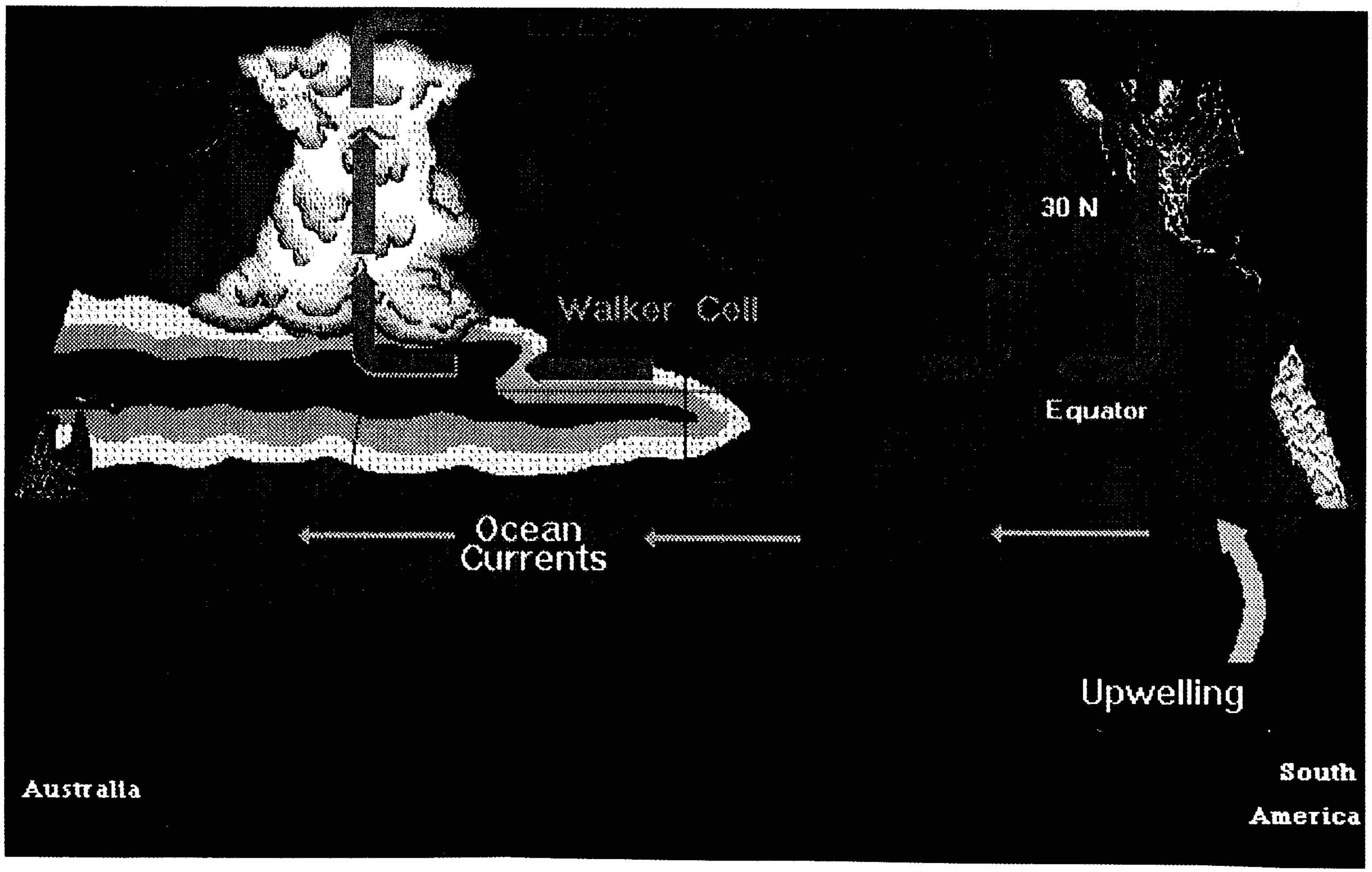


Figure 5. Non-El Nino Conditions

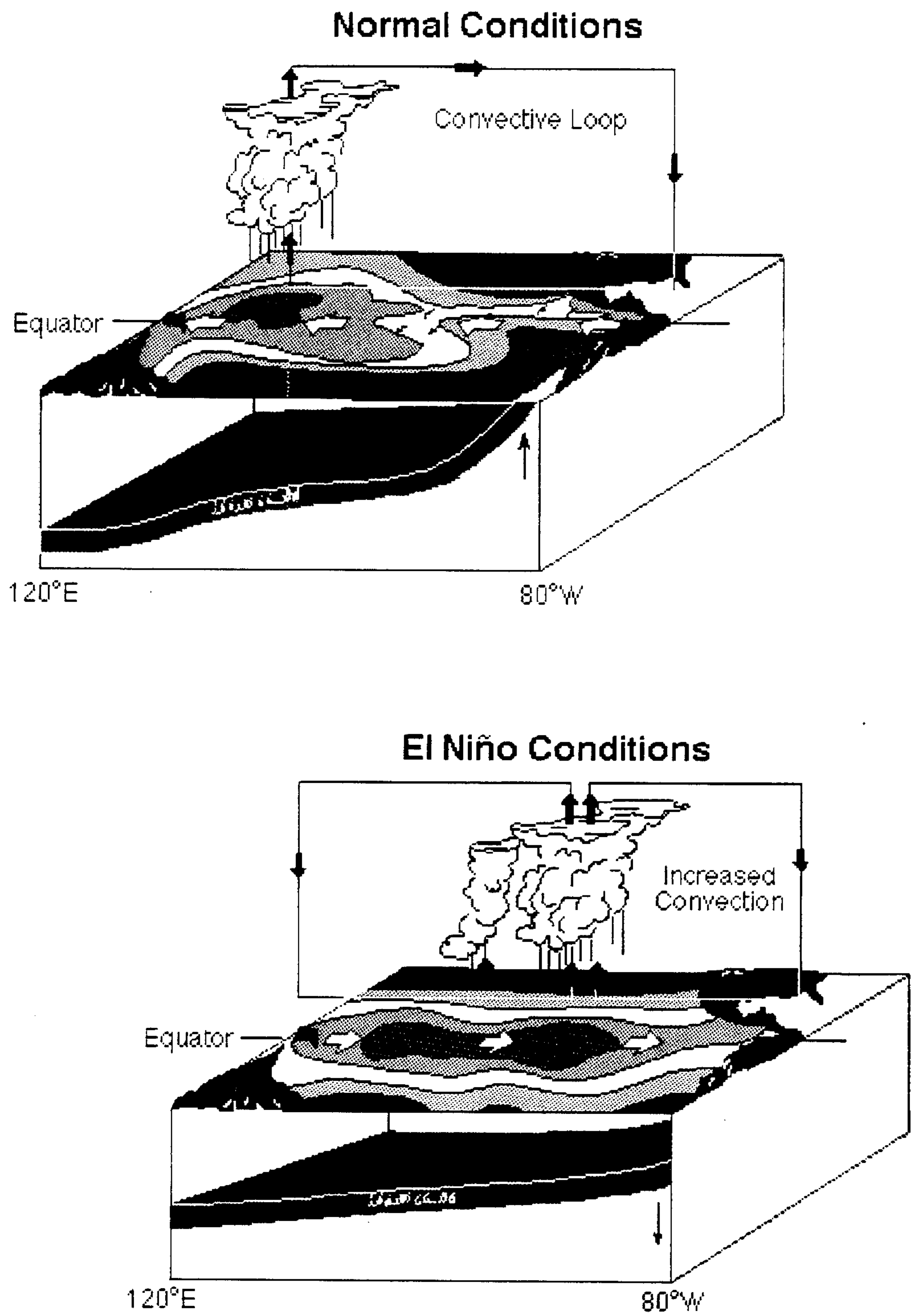


Figure 6. Normal versus El Nino Conditions

Figure 7. Map of Australia - Pacific

Figure 8. Map of Peru

Figure 9. Map of Ecuador

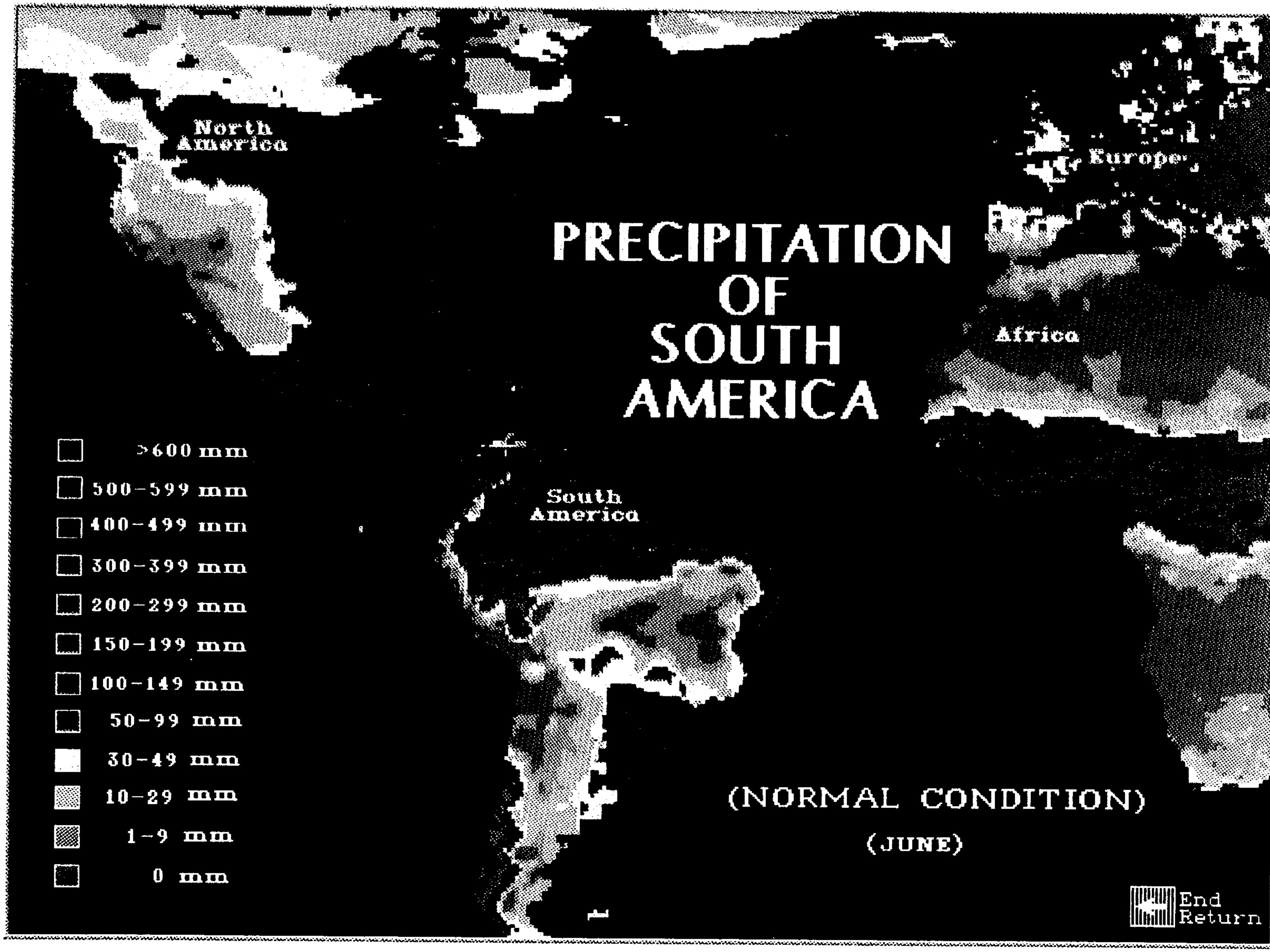


Figure 10. Precipitation of South America - Normal Condition (June)

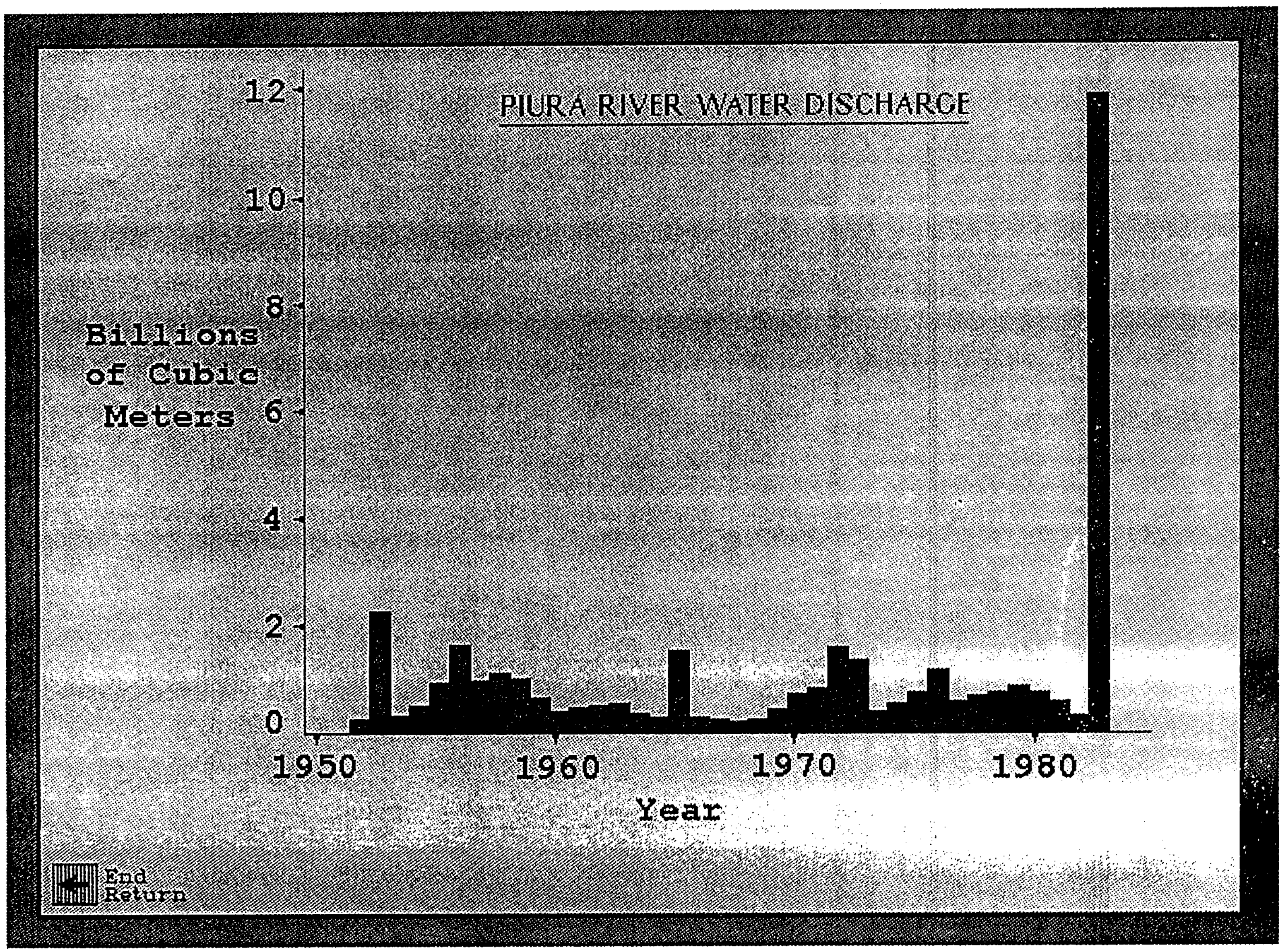


Figure 11. Piura River Water Discharge - Peru

The ENSO events of the last 300 years have been charted with their relative strengths and intensities (Figure 12 and Table 3). The event that is usually analyzed first is the 1982-83 El Nino, considered to be the strongest ENSO event to ever come under scientific scrutiny. The scientific community has shown that local effects off the coastline of Peru are actually linked to events in the central and western Pacific. It is now coming into focus that ENSO events, particularly the stronger ones, can affect conditions in the other two tropical basins (i.e. the Atlantic and the Indian Oceans) as well. Thus, the original "smoking gun" was the occasional loss of an anchovy harvest off the coast of Peru; however, the strategic implications for military planners, particularly in tropical waters, is immense.

This is a phenomenon of global proportions in terms of cause and effect. To further illustrate the plight of the local fishing industry, note the reverberations on the rest of the food chain. When food supplies should be most plentiful, an El Nino event diminishes them by reducing upwelling and the resultant primary food production. The magnitude of this problem can be better understood by the fact that more than 17 million birds populating the Christmas Islands disappeared for lack of food, which in turn, doomed their recently hatched nestlings. Albatross, cormorants, penguins, and marine iguanas are other species that are adversely affected by the lack of food. A compounding problem with El Nino events is the timing of the mechanisms. The warmest sea surface temperatures and their impacts occur when many species, mammals in particular, are breeding. This loss of food has particularly negative effects on either expectant females or their young. It has been reported that nearly 100 percent of the fur seal pups in the Galapagos Islands chain were lost during the 1982-83 El Nino event. Territorial male mammals also suffer because of their inability to follow the migrating food sources.

The widespread change in ocean currents to accommodate low-level wind field changes are further illustrated by the fact that in 1983, a triggerfish was spotted 2,800 km (more than 1,700 miles) farther north than any other triggerfish had been sighted. The fish must have followed the warm currents fed by the ENSO event northward from the tropics. This put a tropical fish in an area associated with almost arctic waters offshore of Alaska.

The above examples of ocean current changes will, in turn, illuminate another problem area for tactical decision planners. If warm and cold water ocean currents are changing their intensity and position depending on whether an ENSO event is occurring (along with which type of ENSO event it is), then the normal "string" of warm and cold water eddy pools associated with these currents also will change. Since submarines can hide in or near such conditions, anti-submarine tactics and techniques will have to be modified in order to more accurately reflect these ocean current changes. Shipping lanes will have to be modified, not only for ocean current speed and direction changes, but to ensure the highest possible safety margin for the ships, crews, and materiel in transit. Admirals on

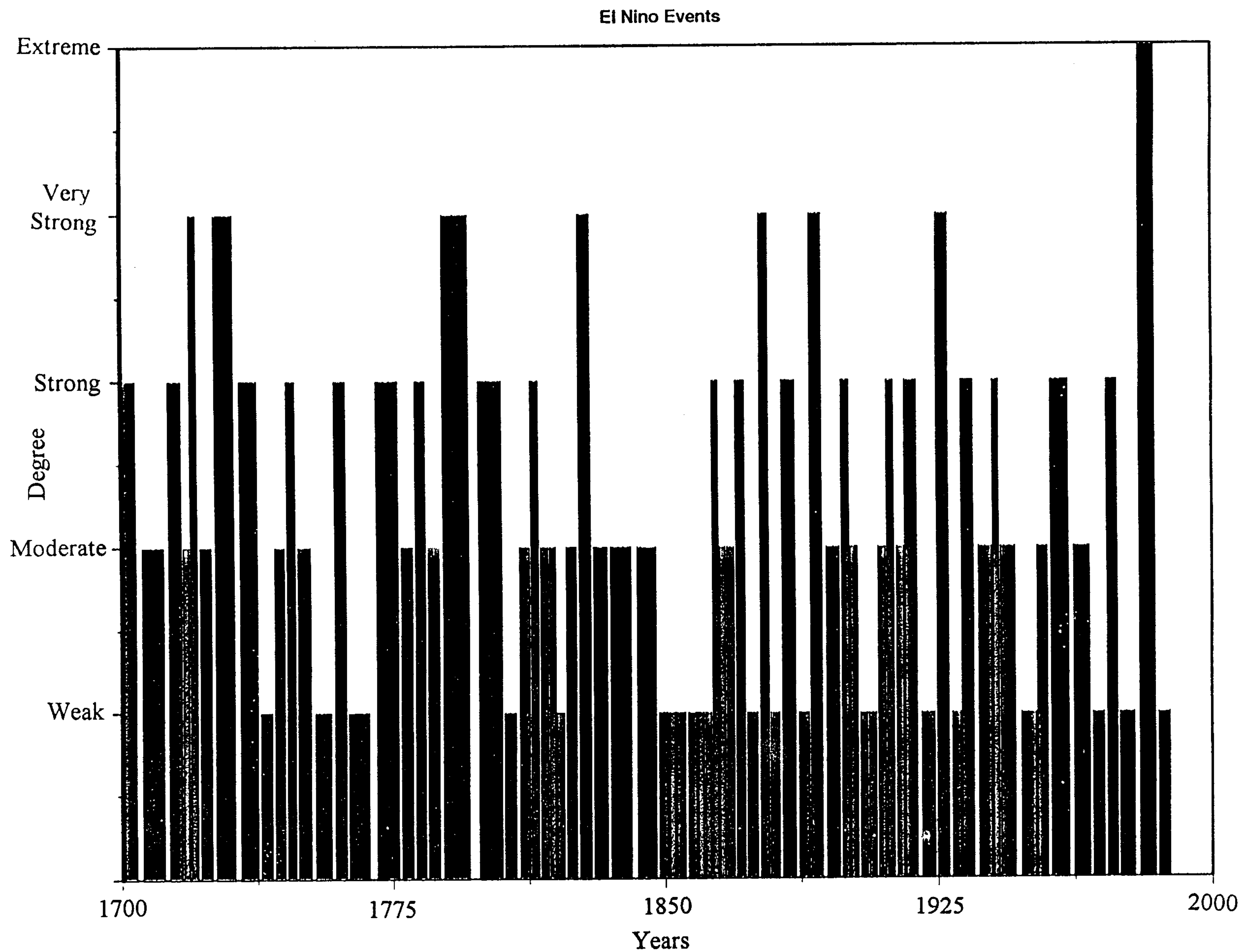


Figure 12. El Nino Events - Severity versus Year

Table 3. El Nino Events and Their Intensities

1 - WEAK **4 - VERY STRONG**
2 - MODERATE **5 - EXTREME**
3 - STRONG

YEAR	INTENSITY	YEAR	INTENSITY	YEAR	INTENSITY
1701	3	1819	2	1902	2
1709	2	1821	1	1905	1
1716	3	1824	2	1907	1
1718	2	1828	4	1910	2
1720	4	1832	2	1912	3
1723	2	1837	2	1915	2
1728	4	1846	2	1917	3
1736	3	1850	1	1923	1
1740	1	1852	1	1926	4
1744	2	1854	1	1931	1
1747	3	1858	1	1932	3
1750	2	1860	1	1939	2
1756	1	1862	1	1941	3
1761	3	1864	3	1943	2
1764	1	1866	2	1951	1
1775	3	1868	2	1953	2
1779	2	1871	3	1958	3
1783	3	1874	1	1965	2
1786	2	1878	4	1969	1
1791	4	1880	1	1973	3
1804	3	1884	3	1976	1
1807	1	1889	1	1983	5
1812	2	1891	4	1987	1
1814	3	1897	2		
1817	2	1900	3		

both sides of the Pacific have made a specific point to note the tactical advantages of understanding such data base changes as quickly as possible (Endnote 1).

A FOCUS ON KOREA

A particular case in point would be the Korean Peninsula (Figure 13A and B). The offshore effects are best illustrated by the ENSO-related change in low-level wind patterns that rapidly modify the strength and direction of the cold water current called "Oyashio." Normally, this current carries cold water from the arctic region southward, along the east coast of northern Asia. The "Kuroshio" current carries warm water from the equator poleward along the east coast of Asia (Figure 14). During the 1982-83 El Nino, the Oyashio current strengthened, while the Kuroshio current weakened. As a result, the stronger Oyashio current carried cold polar water much further south than normal. This, in turn, had a detrimental effect on the Korean and Japanese fishing industries. The abalone harvest off the coast of Honshu Island also was significantly reduced.

The change in weather patterns on the Korean Peninsula, when a moderate to strong ENSO event is in progress, results in a short-term climate shift that is best characterized as warm and dry (Figure 15). As noted in the four stations from South Korea during the May-September time frame (Figure 16), the precipitation values, with one exception, showed drier than normal values. It should be noted that the four El Nino periods used are rated the most severe of the last twenty years. At the same time, the west-to-east movement of the storm tracks across the northern Pacific Ocean become very noticeable in the areas of California, near San Francisco and Los Angeles. This can be noted by examining the results from over 20 primary National Weather Service reporting stations and related miltary weather stations along the central and southern California coastline. There, the precipitation amounts are all above normal (Figure 17), again using San Francisco and Los Angeles as specific examples. Once the ENSO event ends, the weather pattern will return to a more normal sequence. Southern California returns to a dry condition, and the Korean Peninsula becomes very wet from the increased frequency of tropical storms, as the storm tracks return to the western Pacific.

This region of the world is highly dependent on and sensitive to rice production for an ever enlarging population. The most recent example of a negative impact was the news in 27 May 1995 newspaper articles dealing with Japan's exporting rice to the People's Republic of Korea (i.e. North Korea). "The North is said to be importing rice already from Thailand, China, and South Korea." A North Korean government spokesperson (being refreshingly candid), was quoted as saying "North Korea is facing grain shortages due to bad weather" (Reference 2). The double-edged sword is that within 2 years of an ENSO event, the warm dry environment is replaced by a warm wet scenario. This is brought on by an increased frequency of heavy rainfall amounts in the summer/fall time frame, as more frequent tropical storm/typhoon actions move through the Korean Peninsula.

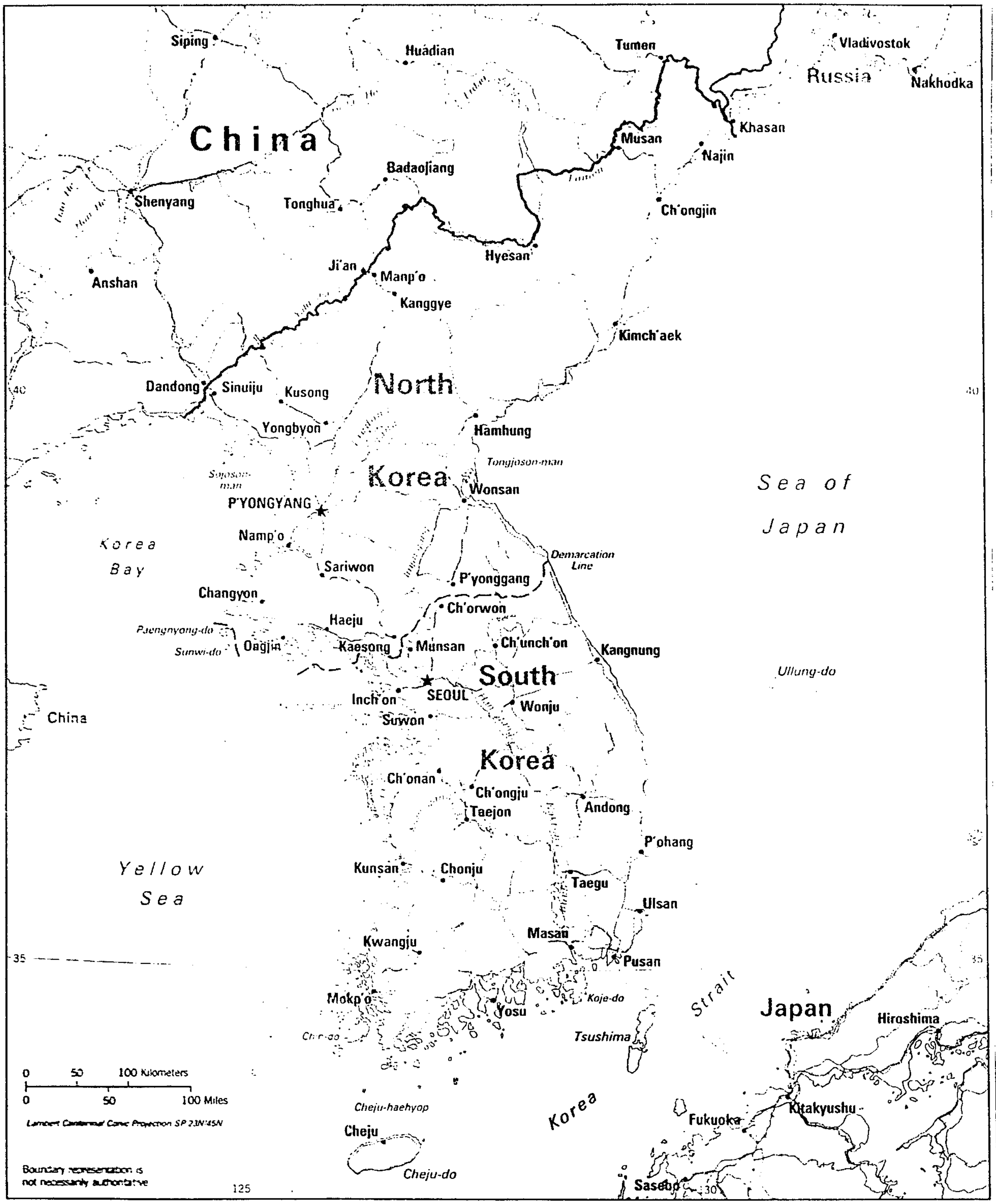


Figure 13 A. Map of Korean Peninsula

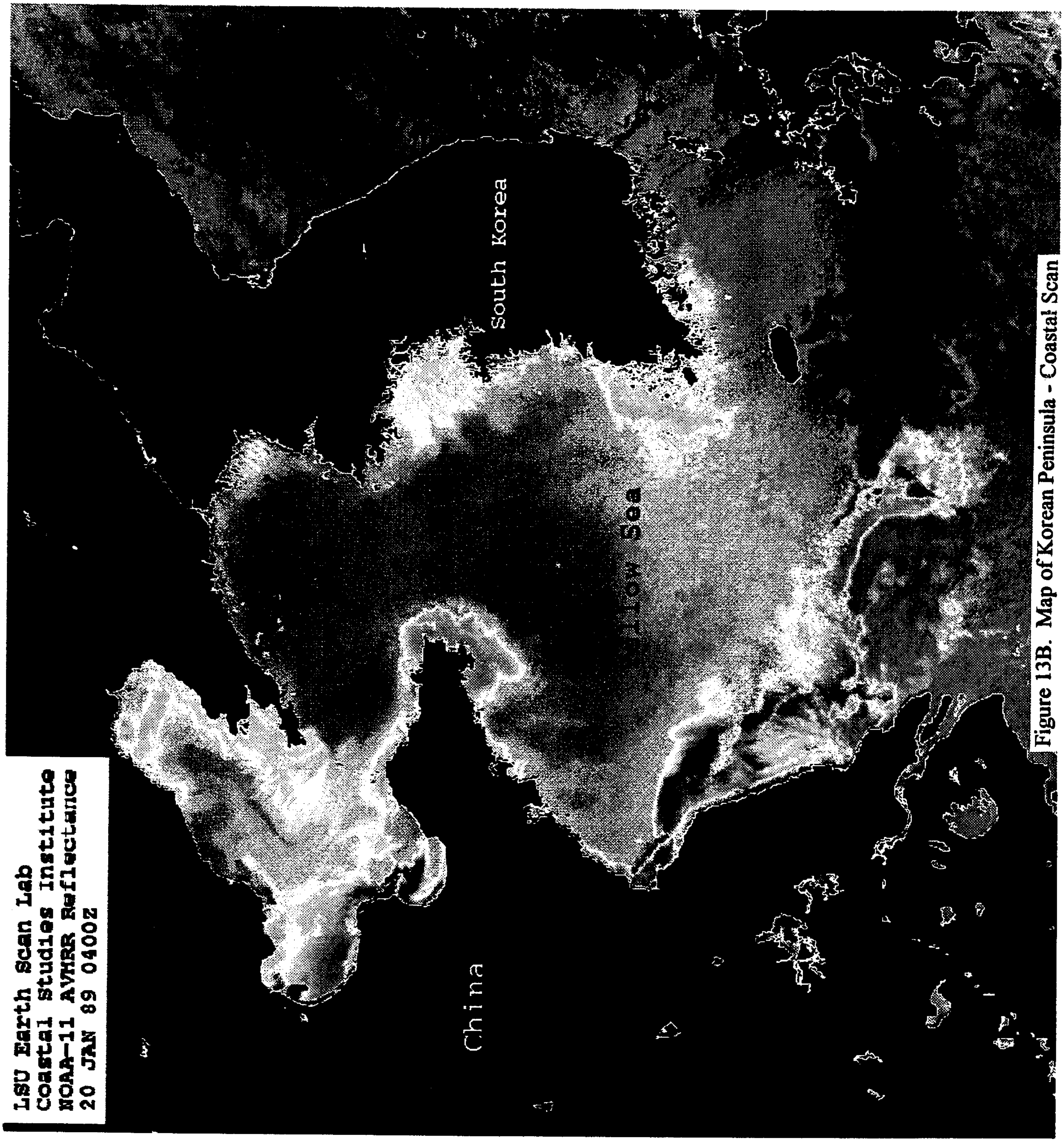


Figure 13B. Map of Korean Peninsula - Coastal Scan

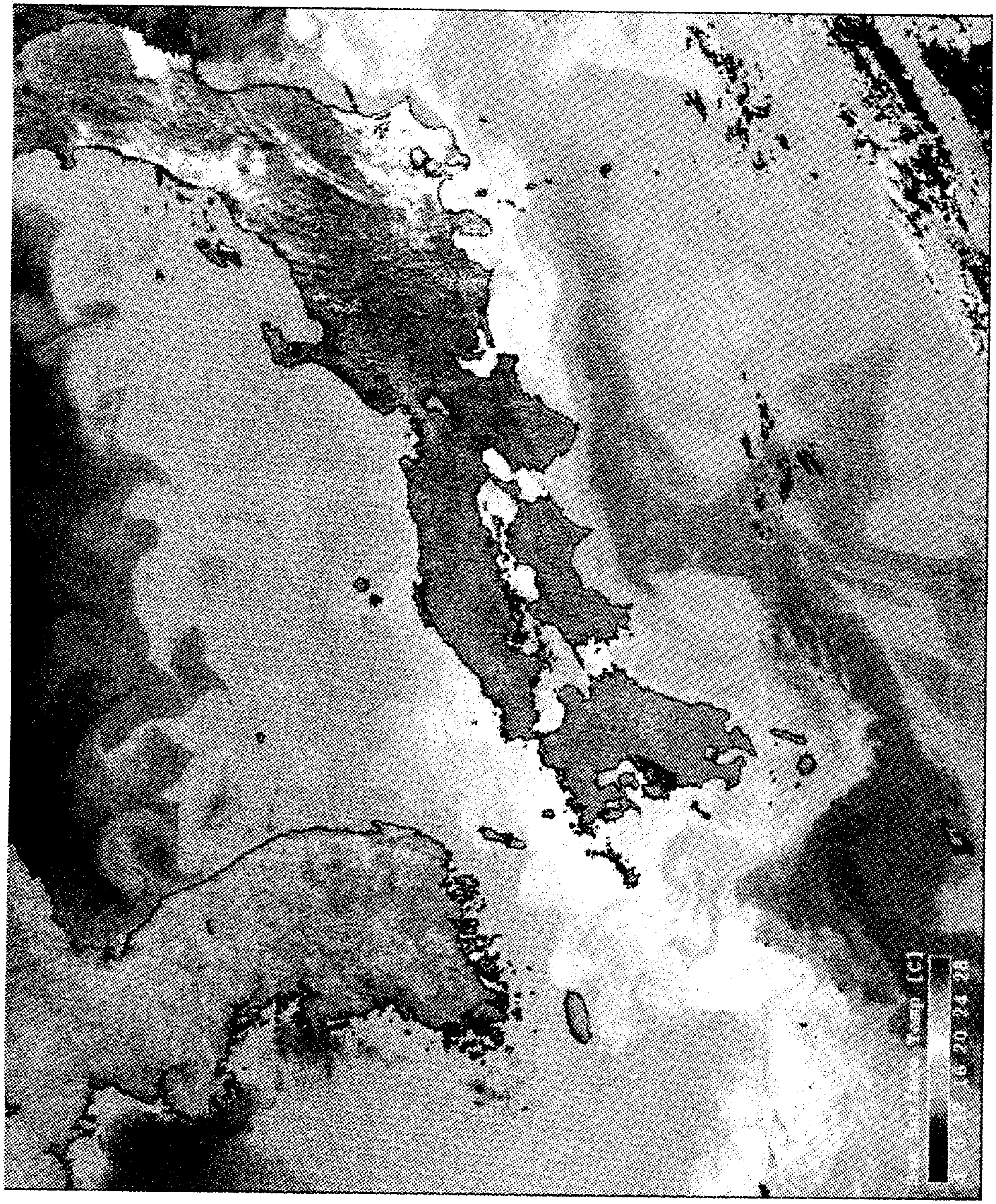


Figure 14. Kuroshio Current (warm) and Oyasio Current (cold)

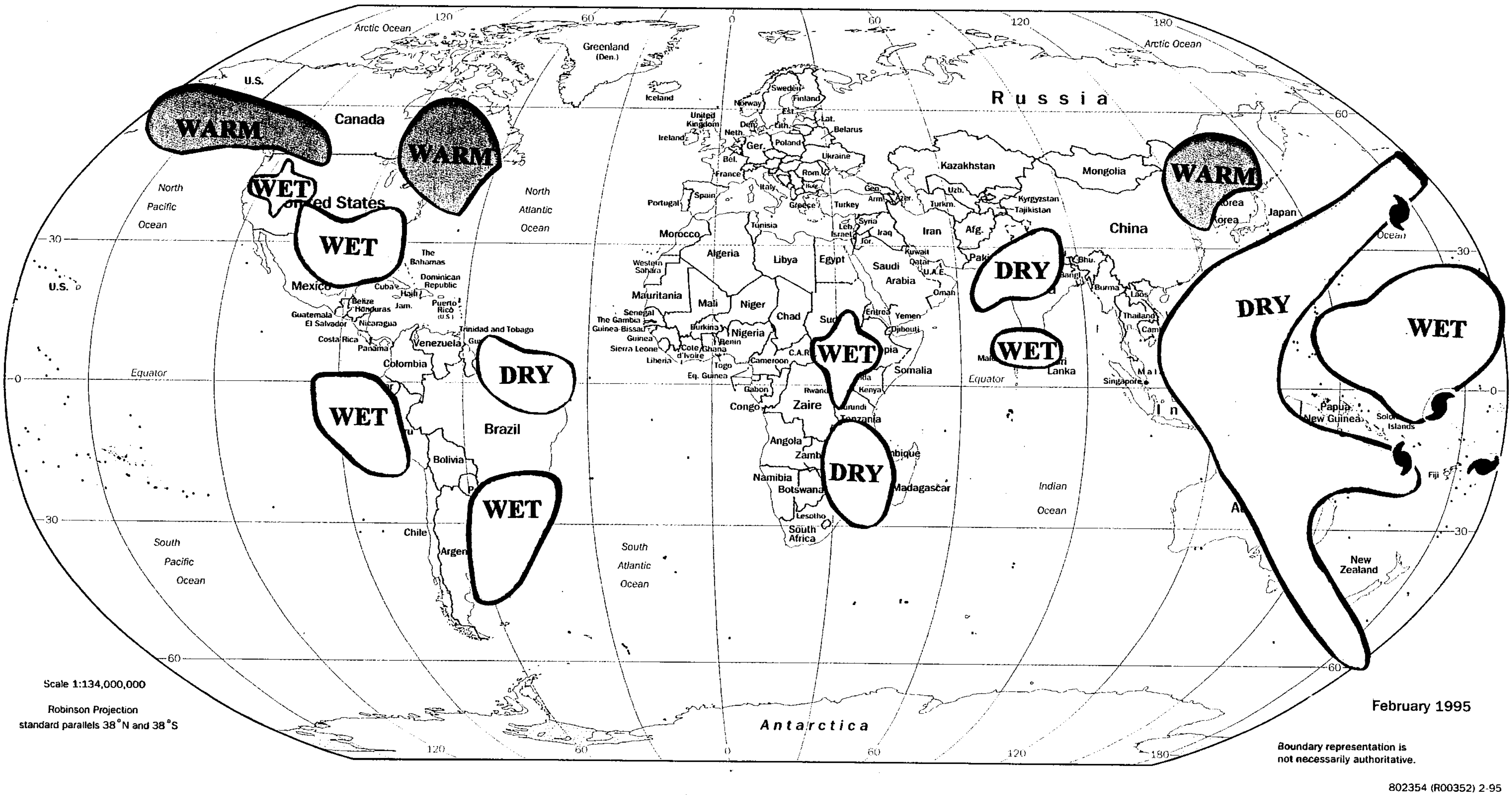


Figure 15. Rainfall Pattern During an El Nino

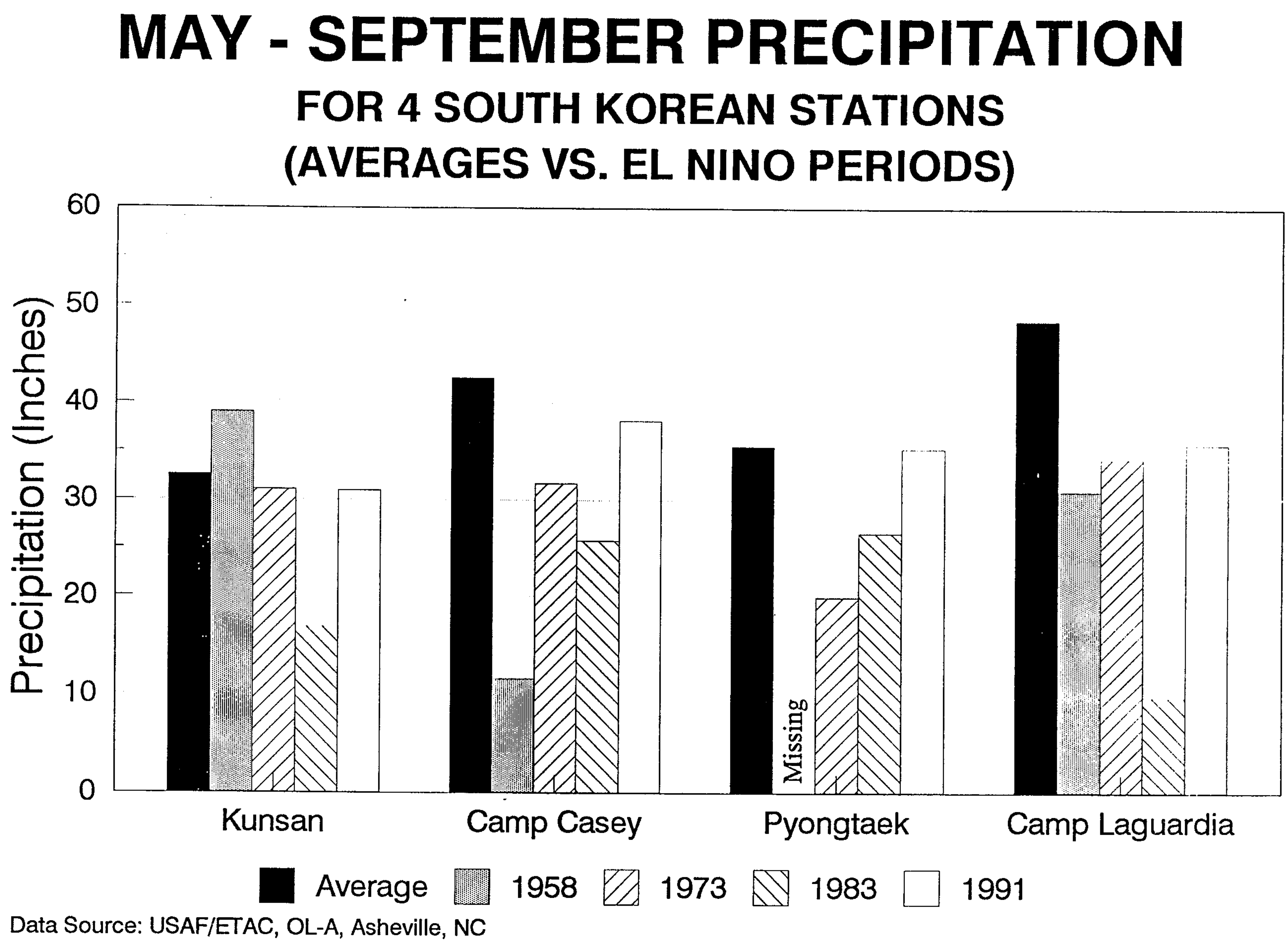


Figure 16. May - September Precipitation

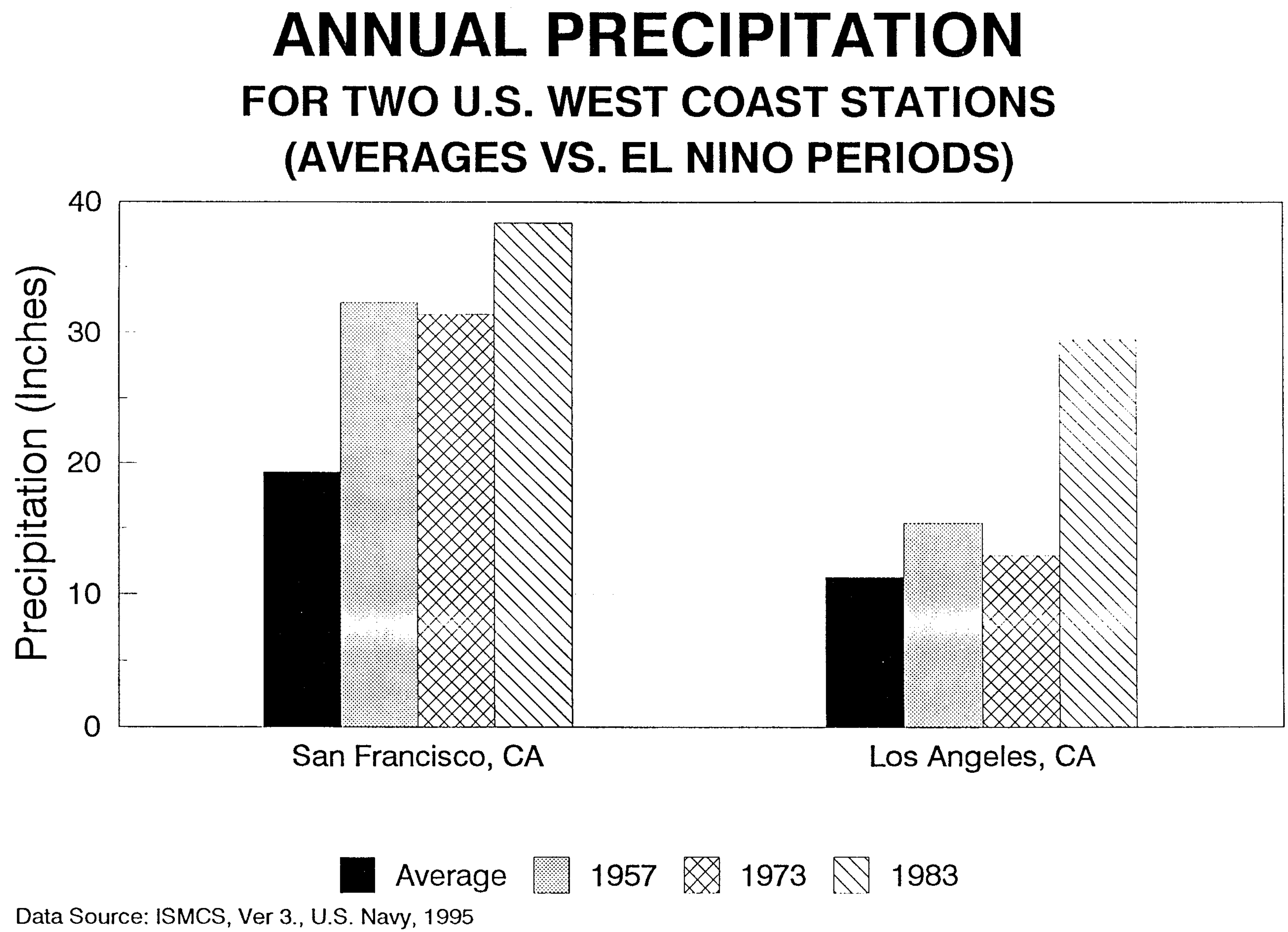


Figure 17. Annual Precipitation

Since the topography of the Korean Peninsula is mainly mountainous, any tropical storm/typhoon damage is rarely wind related; it is usually damage from heavy rains and the resultant flash flooding. Amounts of 10 to 20 inches or more can be quite common. The record is more than 31 inches in one 24-hour period (31.25 inches of rain fell on Camp Page, South Korea on 19 July 1988). Our military superiority is based, in large measure, on our electronic umbrella that is backed up with a ground presence of mobile infantry and mechanized heavy weapons. Both advantages, particularly our firepower advantage, are quickly negated during a 24-hour period that produces 20- to 31-inch rainfall totals (Reference 3). Thus, for one 24-hour day, our electronic surveillance and air superiority are negated by the effects of an ENSO-related tropical storm/typhoon path that produces such large amounts of rain. For days afterward, our mobility Tactical Decision Aids (TDA's) have no real relevancy to the current topographical situation! The TDA's for the proper placement of mechanized or armored tank battalions will suddenly become highly suspect (since most of Korea's natural soil surface is composed of clay composites that quickly turn to deep mud during this type of heavy rainfall) (Reference 3). The ability to implement short-term logistics support, such as Logistics-Over-The-Shore (LOTS) operations for both men and machines, will need review. Long-term support of the IX Corps logistics mission in Japan, in particular, the ability to use heavy weapon transports such as the "roll on - roll off" models (commonly referred to as RORO's), will be effected by multiple tropical storm/typhoon events (Endnote 2). Ship routings will be slow and complex, at best, as shown by the satellite shot taken on 14 September 1967 (Figure 18). As each storm generates its own set of storm waves, the overall sea conditions become even more chaotic as the four storms in the western Pacific meet the waves generated by the two storms in the eastern Pacific.

This could literally lead to the sudden loss of a heavily loaded ship due to an ocean mechanism that the scientific community continues to investigate. As certain hurricanes or typhoons approach a strong warm water current, such as the Atlantic's Gulf Stream or the Pacific's Kuroshio current, the energy of the warm water seems to complement the storm surge wave in order to produce rogue-like tsunamis that can approach 100 feet in height on the open sea! The right conditions are most likely to occur along the area of the main warm water current known as the "north wall." This phenomenon has been noted in a narrow band of extreme horizontal water temperature changes marking the north edge of the Kuroshio current in the Pacific Ocean and the Gulf Stream in the Atlantic Ocean (Reference 4). A recent case in point is the 16 September 1995 newspaper account of the British luxury liner, Queen Elizabeth 2, as she made another passage from the U.S. to Europe. "The 95-foot wave, caused by the seas being whipped up by Hurricane Luis, hit the ship bow-on while it was south of Newfoundland. The wave was so huge that its crest was at bridge level" (Reference 5). Thus, the sudden loss of a heavily loaded SL - 7, the largest of the RORO's, is not outside the realm of possibility (Endnote 2).

Another example of the strength and reach of these storms involves slow-moving tropical storms off the southeast coast of Australia in the Tasman Sea area (Figure 7) which can generate wave patterns that can significantly damage the beaches on the

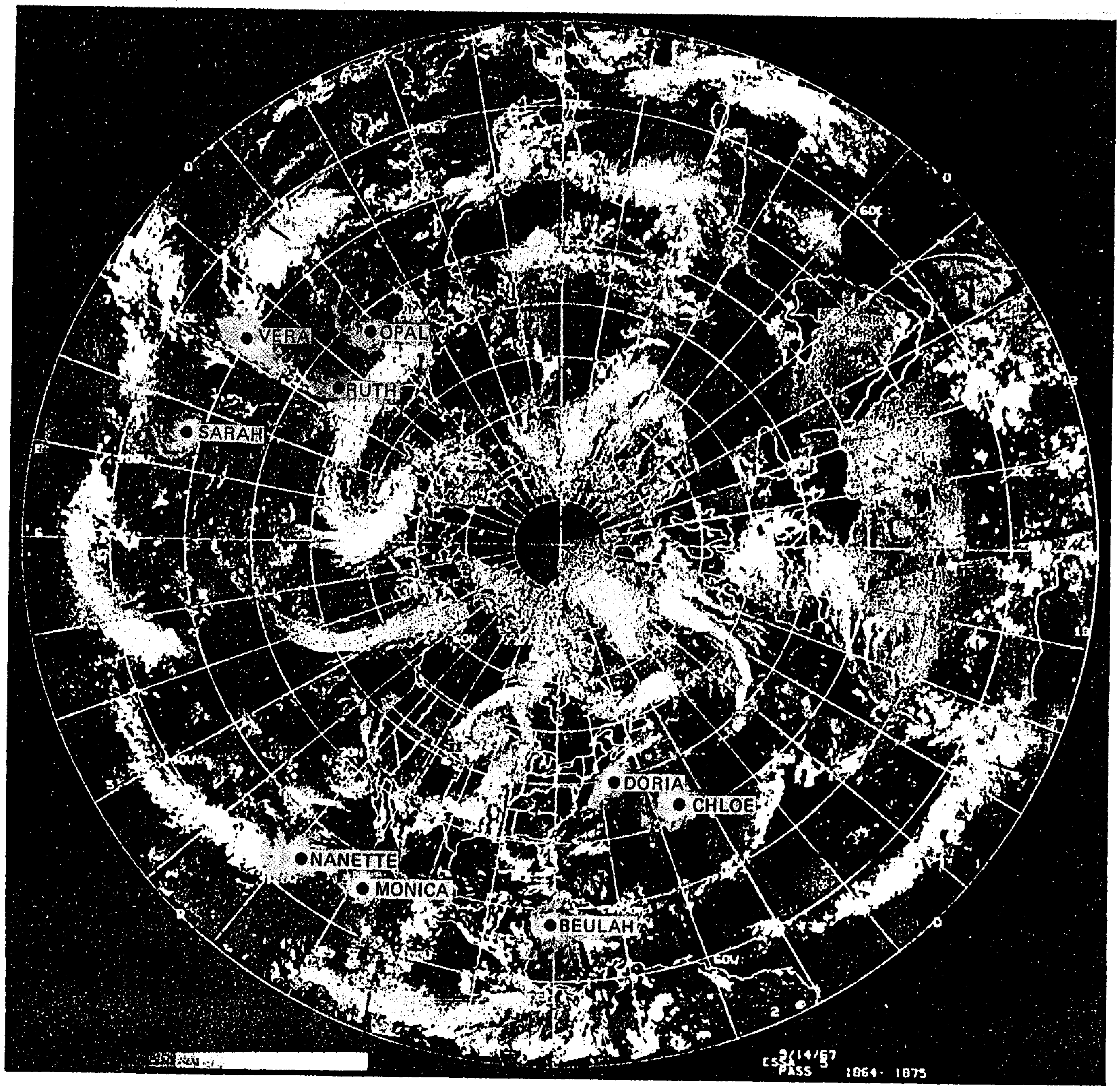


Figure 18. Nine Tropical Storms - ESSA Weather Satellite - 09/14/67

Hawaiian Islands, and the next day, begin damaging the beaches around the naval facilities in San Diego, CA. Even without these examples of worst case events, the accompanying graph of recent western Pacific Ocean basin tropical storm/typhoon counts by year (Figure 19 and Table 4), again shows the approximate 2-year lag in storm frequency. During an ENSO event, the upper level wind patterns that are necessary for continued storm development and intensification are either weak or nonexistent. As an ENSO event is ending, and the Walker Cell development returns to the western Pacific, the upper level wind pattern once again becomes conducive to tropical storm development. This is coupled with a shift in the Kuroshio current (Figure 14) that results in a pooling of warm water in the western Pacific (north of the Philippines, east of Taiwan, and just west of the Korean Peninsula). The amount of time necessary to cause an El Nino event, and the resultant wave action reflecting off the North American continent in order to force this cumulative pooling of warm water in the western Pacific, is usually between 18- to 24-months for moderate to strong events, and as little as 12 months for very strong to extreme events (Table 5 and Figures 20A/B/C/D/E/F). The difference in sea level between the western and the eastern Pacific can be as much as 2 meters, with the resultant water movement approaching 200 km (about 125 miles) a day. It should be noted that in Figure 20C, the central part of an El Nino is the strong warm water ocean current known as a Kelvin Wave. This extends for more than 6,000 km (over 3,700 miles) along the equator! Another problem with this western pooling of warm water that eventually feeds into the Kuroshio current (Figure 21A/B), is that it distorts the normal recurvature path of tropical storms/typhoons more to the west (note close-up in Figure 22). The strength of the El Nino events of 1973 and 1982-83 caused this type of scenario to appear in the western Pacific. Thus, storms that would normally recurve either under or through the Japanese main islands, even during an El Nino event (Figure 23), will now start to recurve just east of Taiwan. Remember, the El Nino event has ended, but the pooling of warm water west of the Korean Peninsula, and north and east of Taiwan, is still growing as an aftereffect. This, in turn, means that recurvature will bring the storm tracks further west, and then north, with its accompanying rain shield coming directly over the Korean mainland (Figure 24 and 25). This is a case of cause and effect that is similar to the low sun angle in the Northern Hemisphere in the winter season, that is normally followed by a 1- to 2-month lag in low (cold) temperatures for that winter season.

A particularly extreme example of western movement before recurvature, with excessive rainfall over the Korean Peninsula, involved tropical storm "June" in August 1984 (Figure 26). As it entered mainland China, west-southwest of Taiwan, the remains of June encountered an unusually strong, and consequently "further south than normal," polar cold front. This combination of polar air and a very moist tropical system acted as a giant conduit that funneled heavy rains over the Korean Peninsula, even though the actual tropical storm system was now far below the standards usually associated with a "named" storm. This flooding claimed 180 lives and drove 90,000 people from their homes (Reference 7).

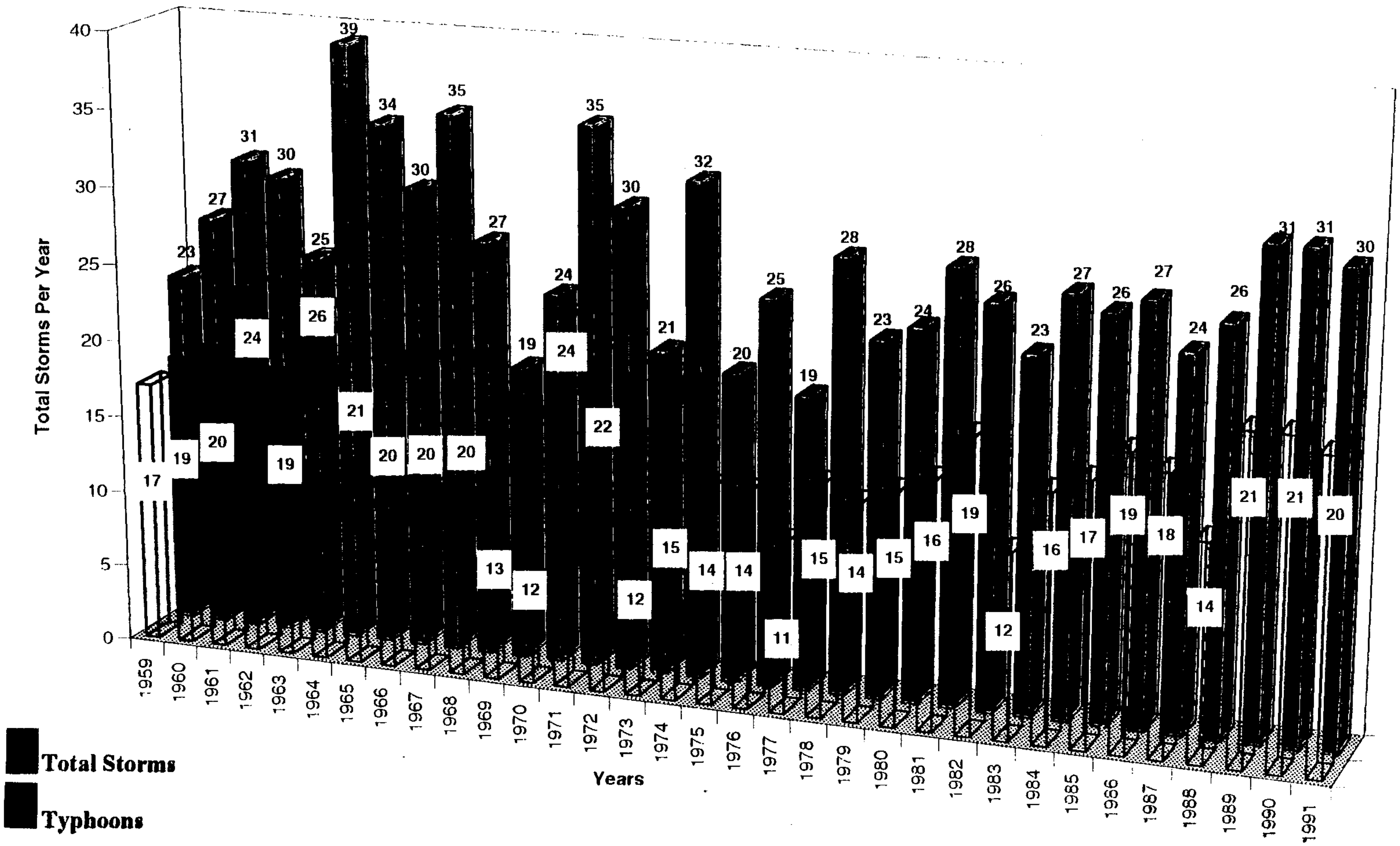


Figure 19. Typhoons and Tropical Storms in the N.W. Pacific Ocean

Table 4. Typhoons and Tropical Storms in the N.W. Pacific Ocean

YEAR OF OCCURRENCE	# OF TYPHOONS	# OF TROPICAL STORMS	ANNUAL SUM OF STORMS
1959	17	6	23
1960	19	8	27
1961	20	11	31
1962	24	6	30
1963	19	6	25
1964	26	13	39
1965	21	13	34
1966	20	10	30
1967	20	15	35
1968	20	7	27
1969	13	6	19
1970	12	12	24
1971	24	11	35
1972	22	8	30
1973	12	9	21
1974	15	17	32
1975	14	6	20
1976	14	11	25
1977	11	8	19
1978	15	13	28
1979	14	9	23
1980	15	9	24
1981	16	12	28
1982	19	7	26
1983	12	11	23
1984	16	11	27
1985	17	9	26
1986	19	8	27
1987	18	6	24
1988	14	12	26
1989	21	10	31
1990	21	10	31
1991	20	10	30

Table 5. Explanations of Figures 20A through 21B

FIGURE #	DATE	EXPLANATIONS
20A	03/30/94	Pooling warm water begins to move eastward as another El Nino begins.
20B	09/15/94	Warm water continues to expand eastward.
20C	10/25/94	Upwelling on the west coast of South America has ceased.
20D	12/26/94	Return flow to the west starts to build.
20E	01/28/95	Pooling of warm water, south and west of Japan and the Korean Peninsula , begins.
21A & B	07/23/95	Pool of warm water (20E) is in place, while upwelling returns off the west coast of South America.

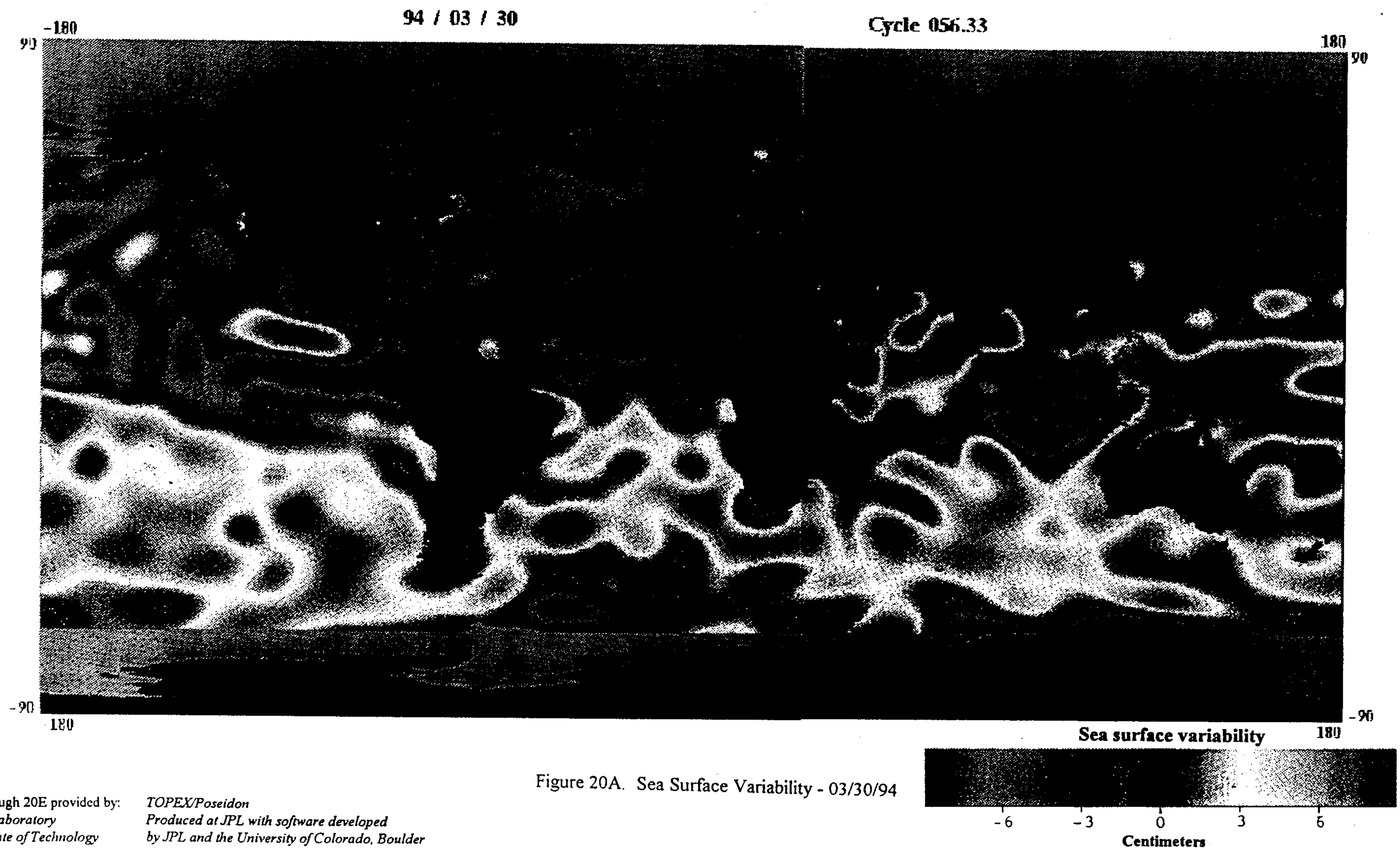


Figure 20A. Sea Surface Variability - 03/30/94

Figures 20A through 20E provided by:
Jet Propulsion Laboratory
California Institute of Technology

TOPEX/Poseidon
Produced at JPL with software developed
by JPL and the University of Colorado, Boulder

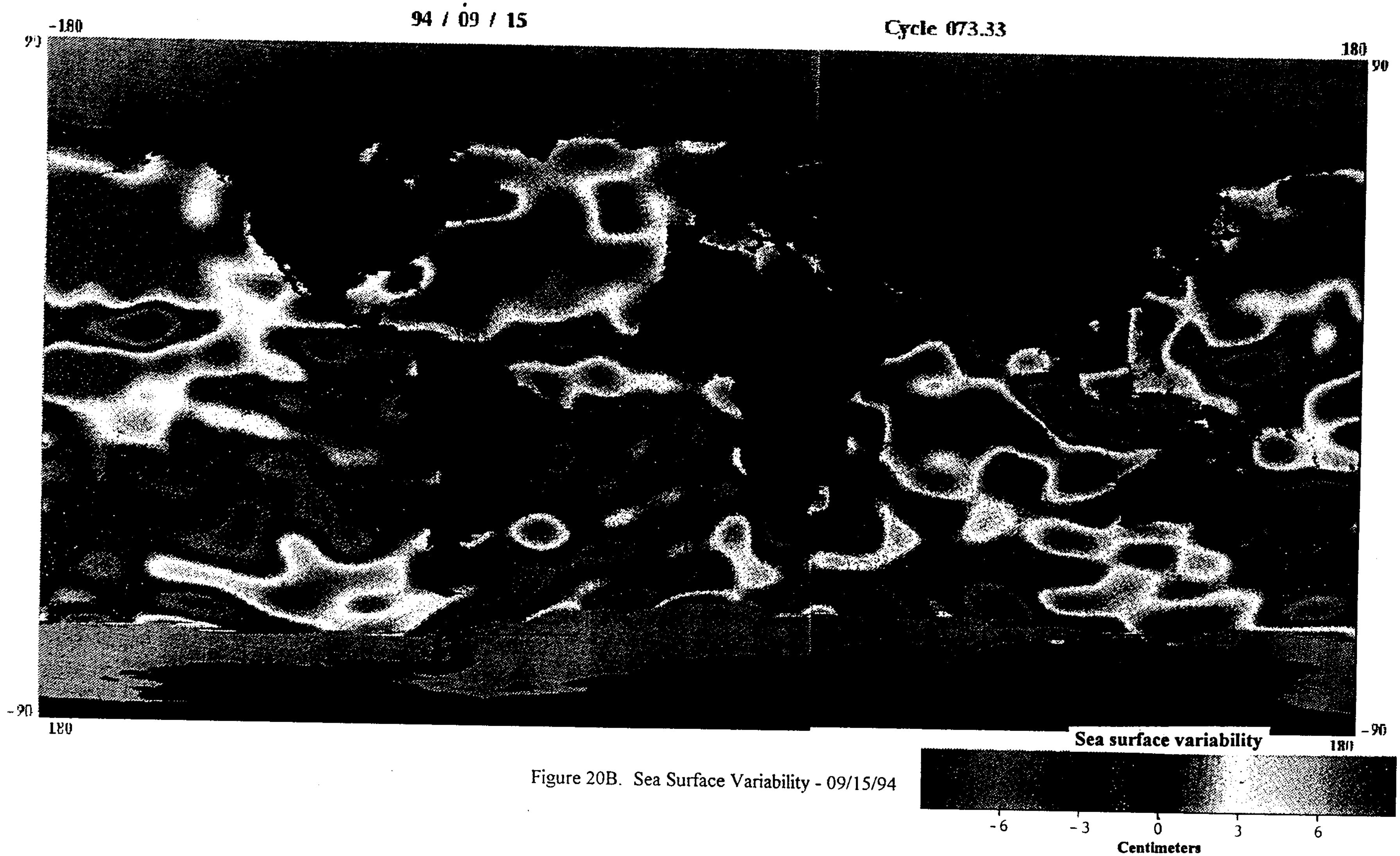


Figure 20B. Sea Surface Variability - 09/15/94

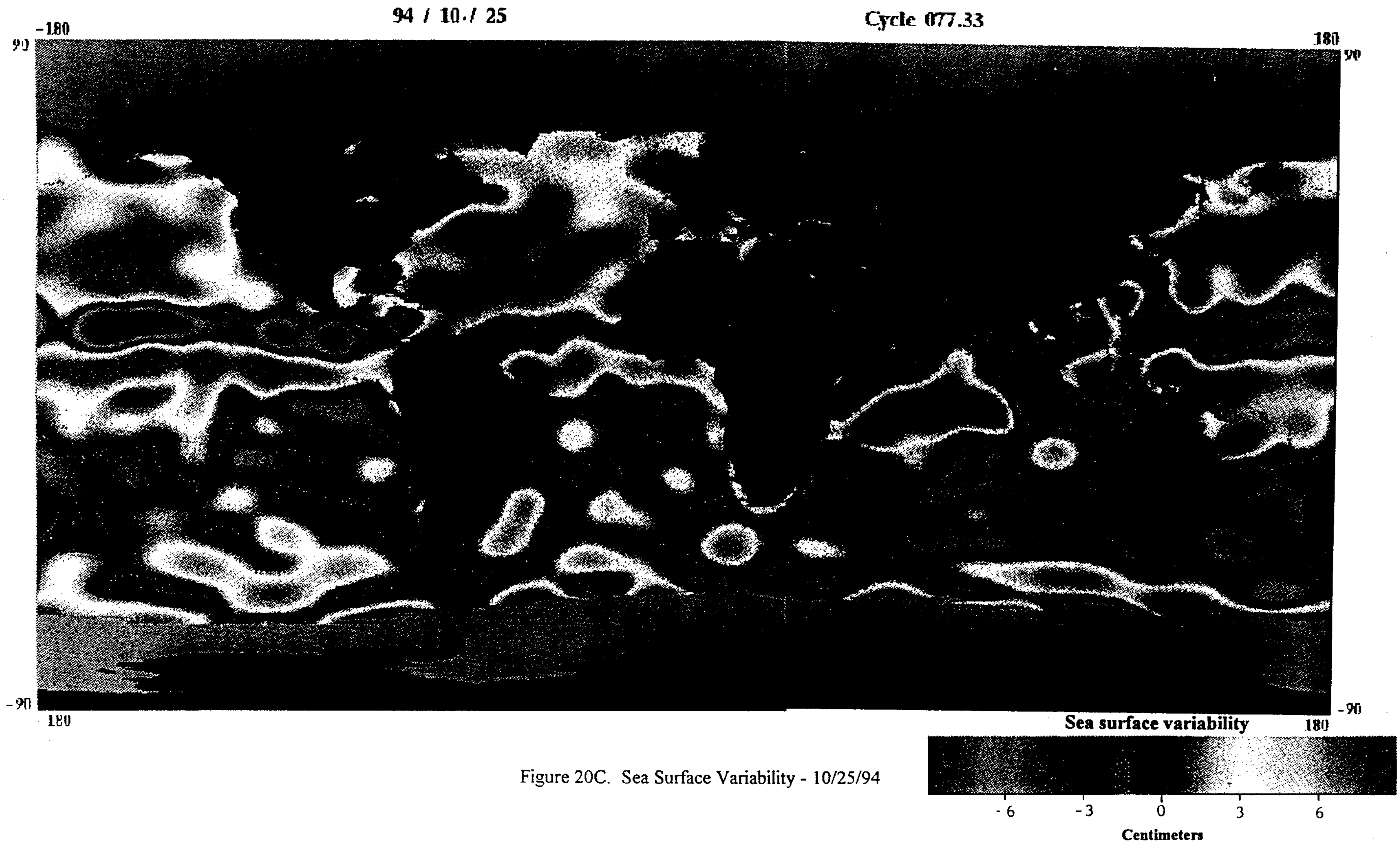


Figure 20C. Sea Surface Variability - 10/25/94

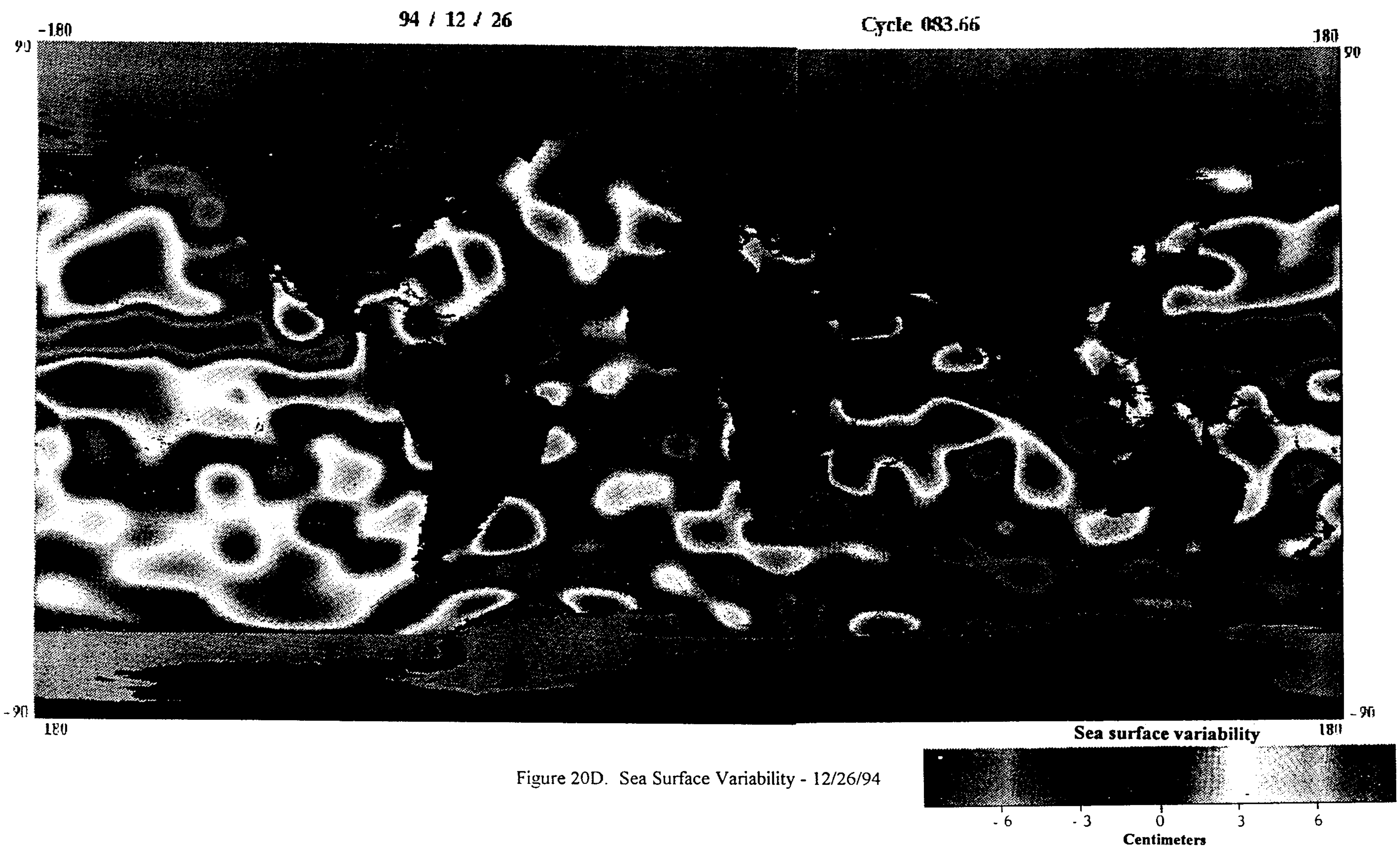


Figure 20D. Sea Surface Variability - 12/26/94

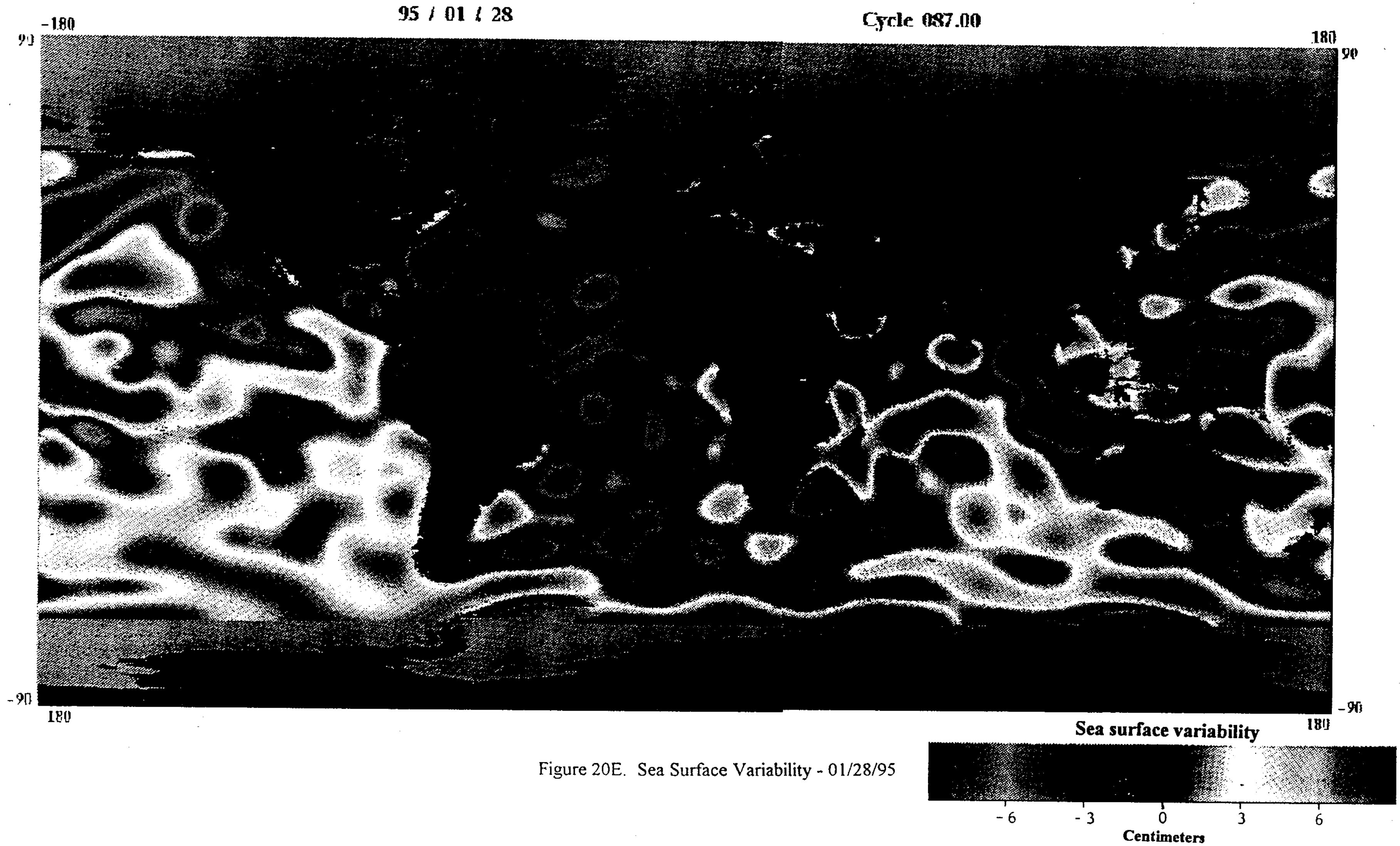


Figure 20E. Sea Surface Variability - 01/28/95

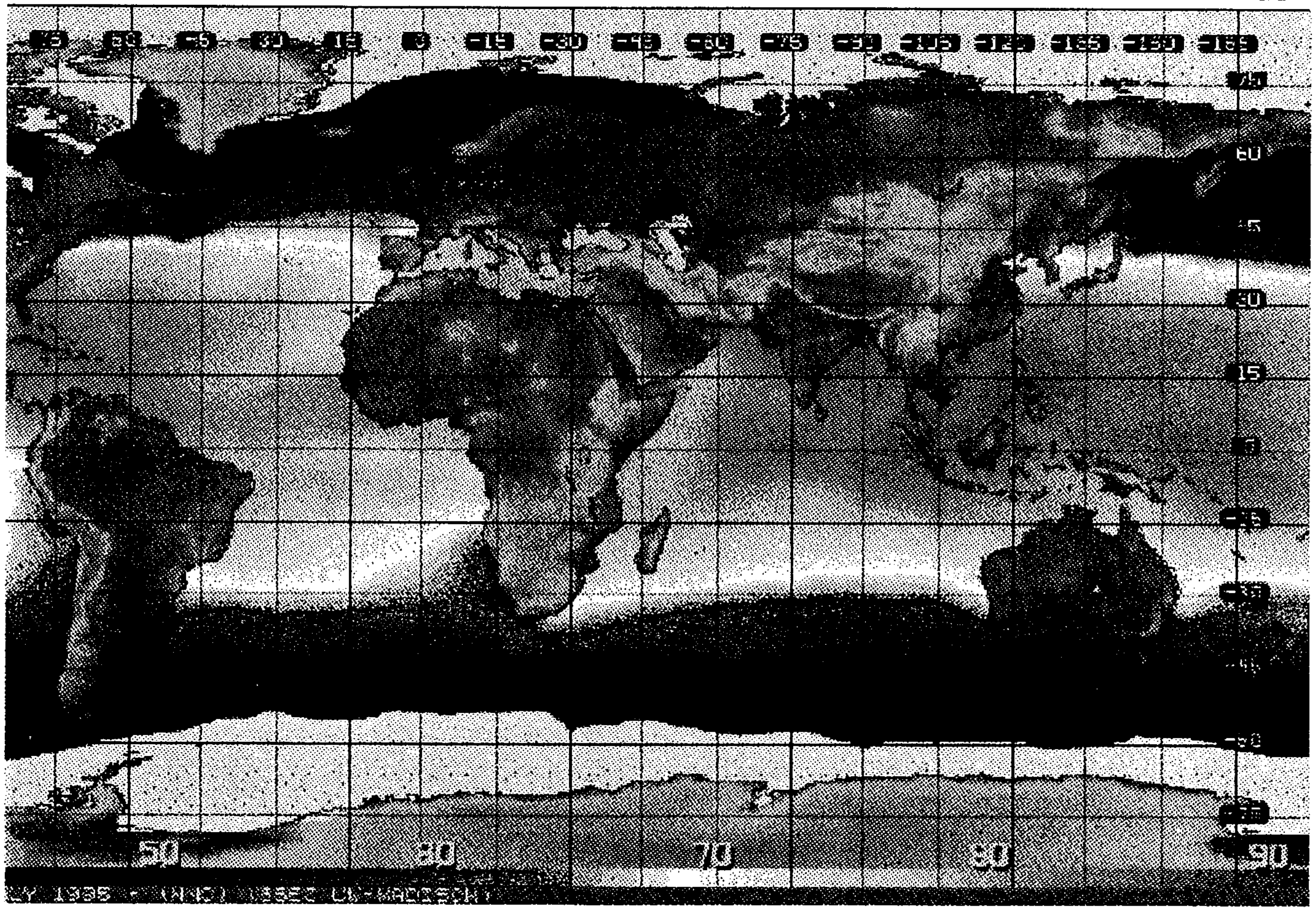


Figure 21A. Global Sea Surface Temperature Maps - 07/23/95

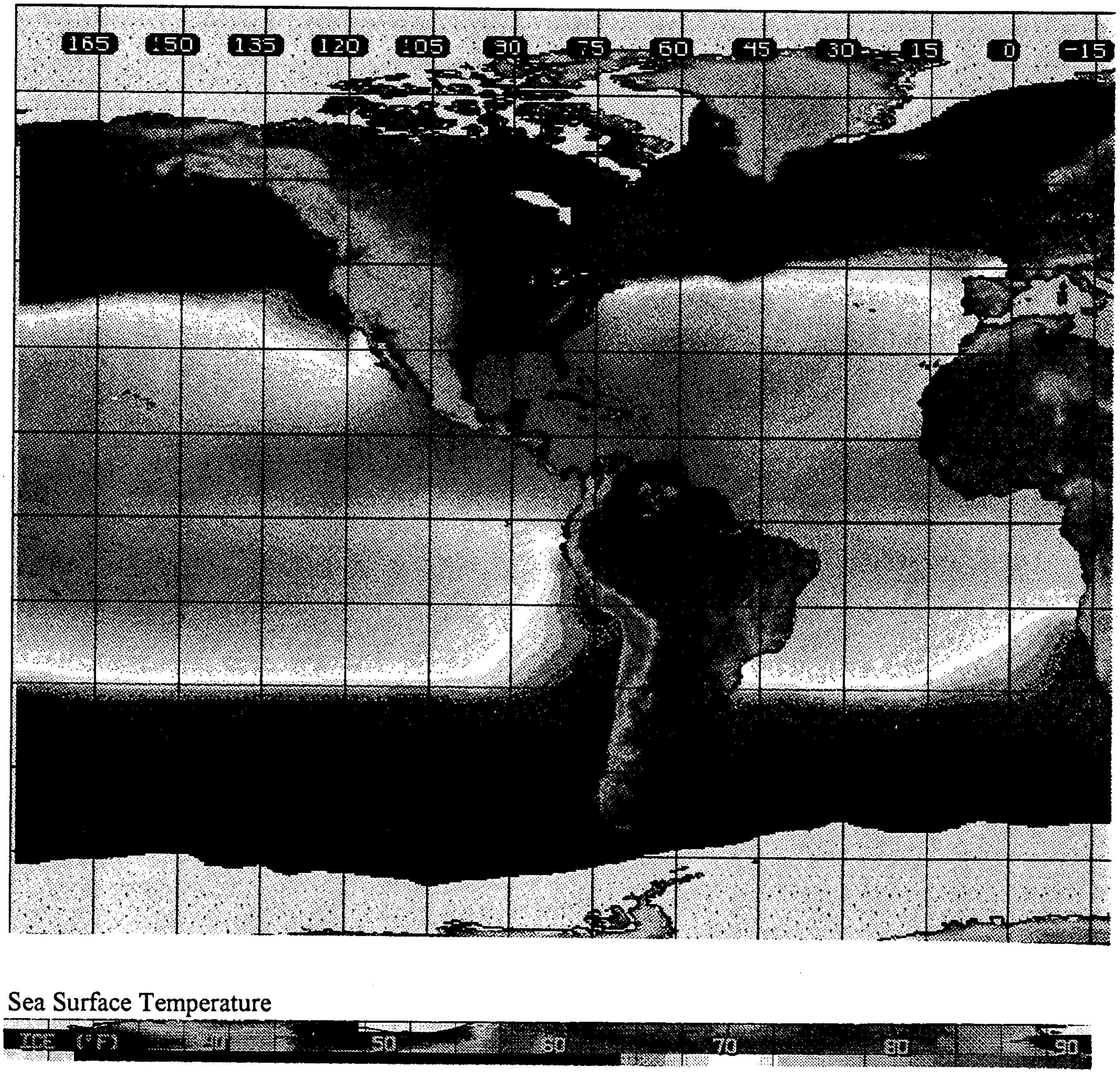


Figure 21B. Global Sea Surface Temperature Maps - 07/23/95 (Continued)

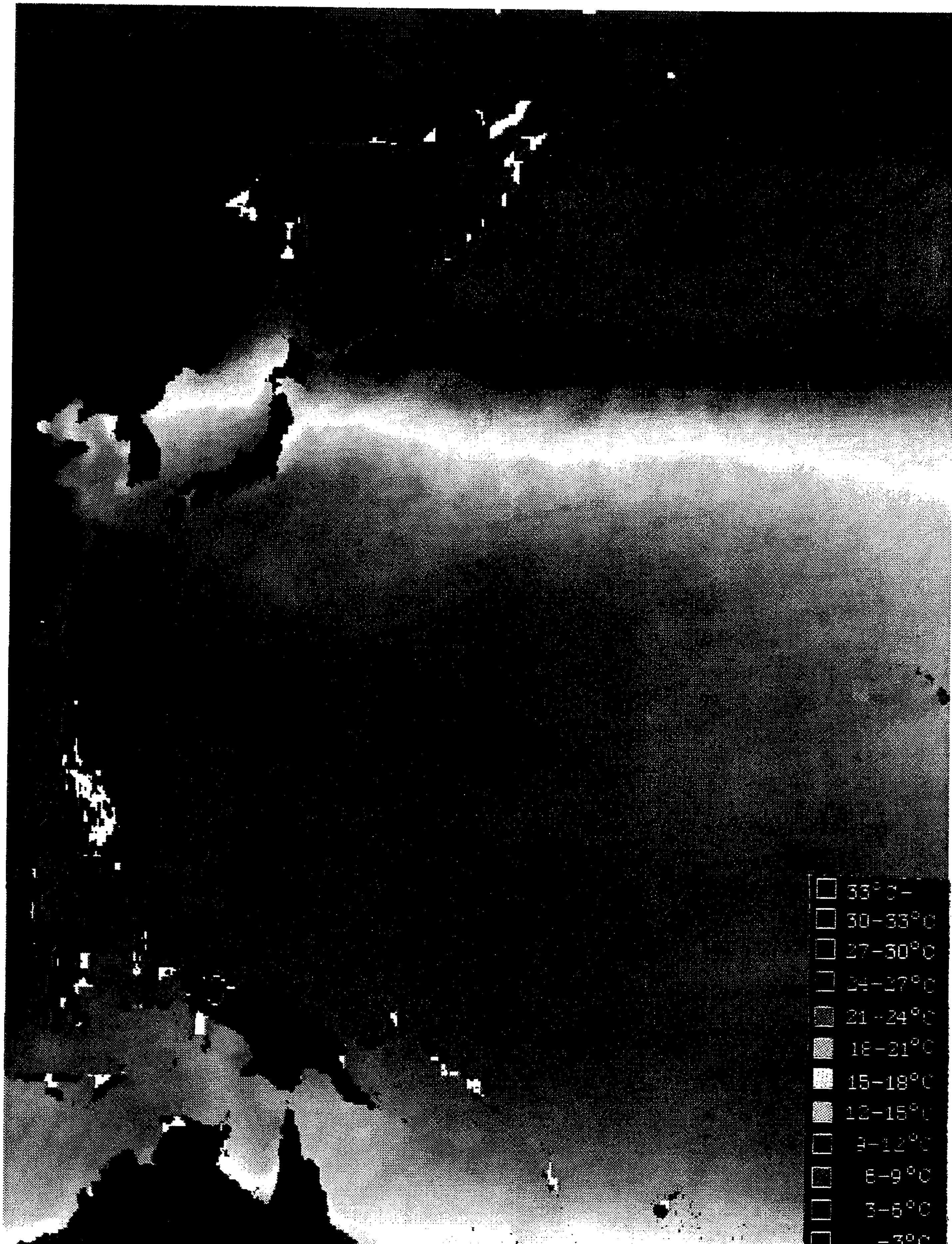
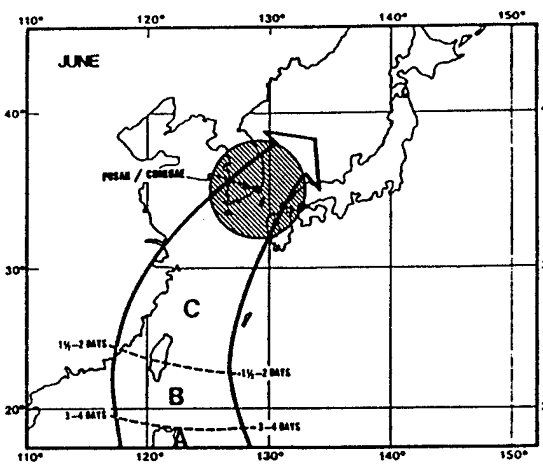
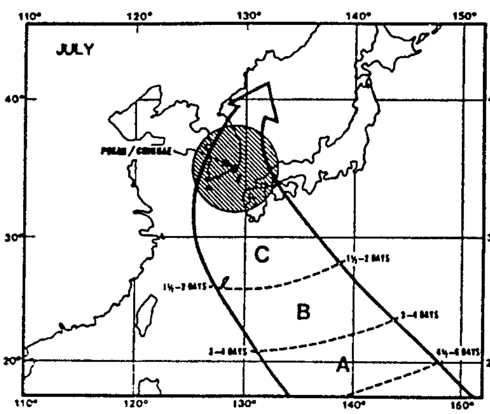


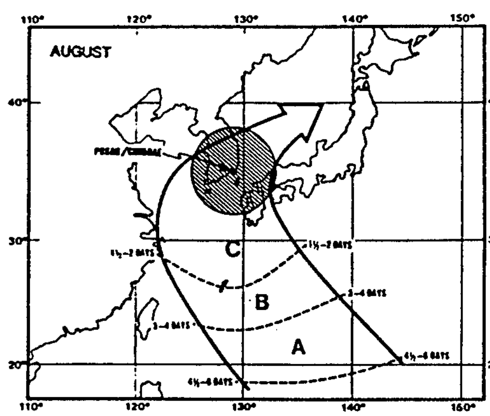
Figure 22. Modern Average Global Sea-Surface Temperature in the N.W. Pacific Ocean - 08/95



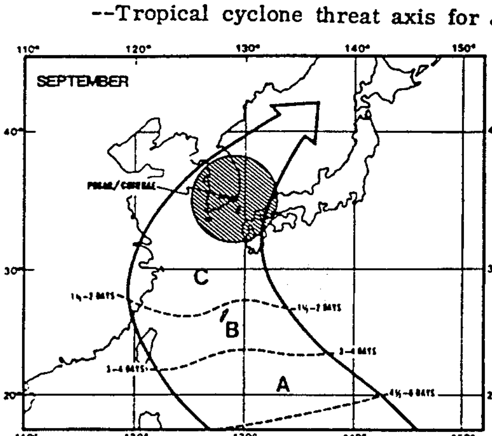
--Tropical cyclone threat axis for June.



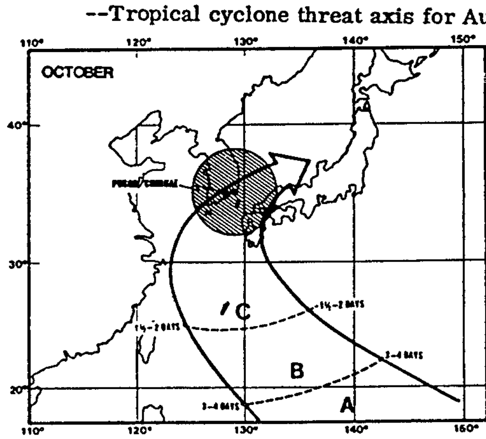
--Tropical cyclone threat axis for July.



--Tropical cyclone threat axis for August.

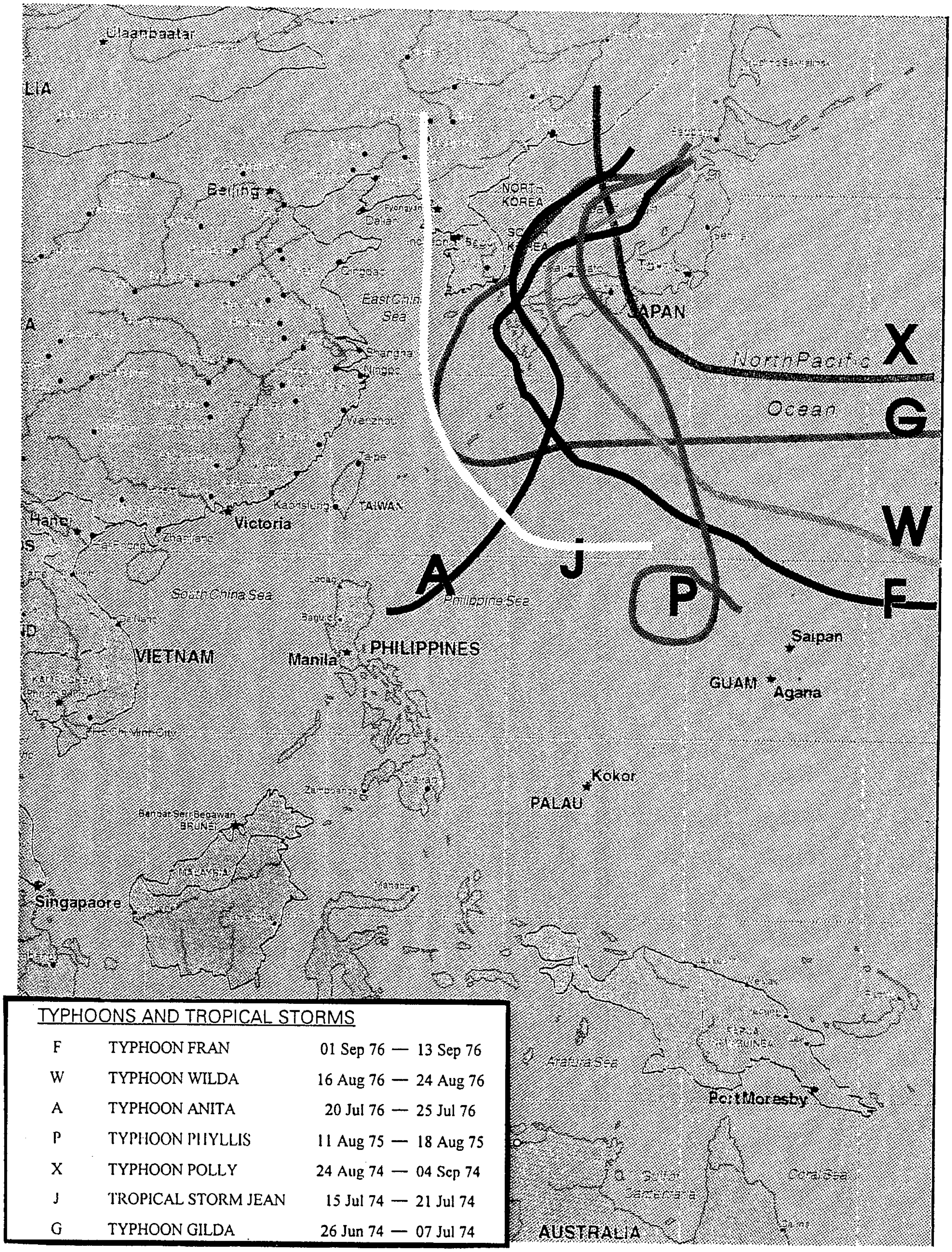


--Tropical cyclone threat axis for September.



--Tropical cyclone threat axis for October.

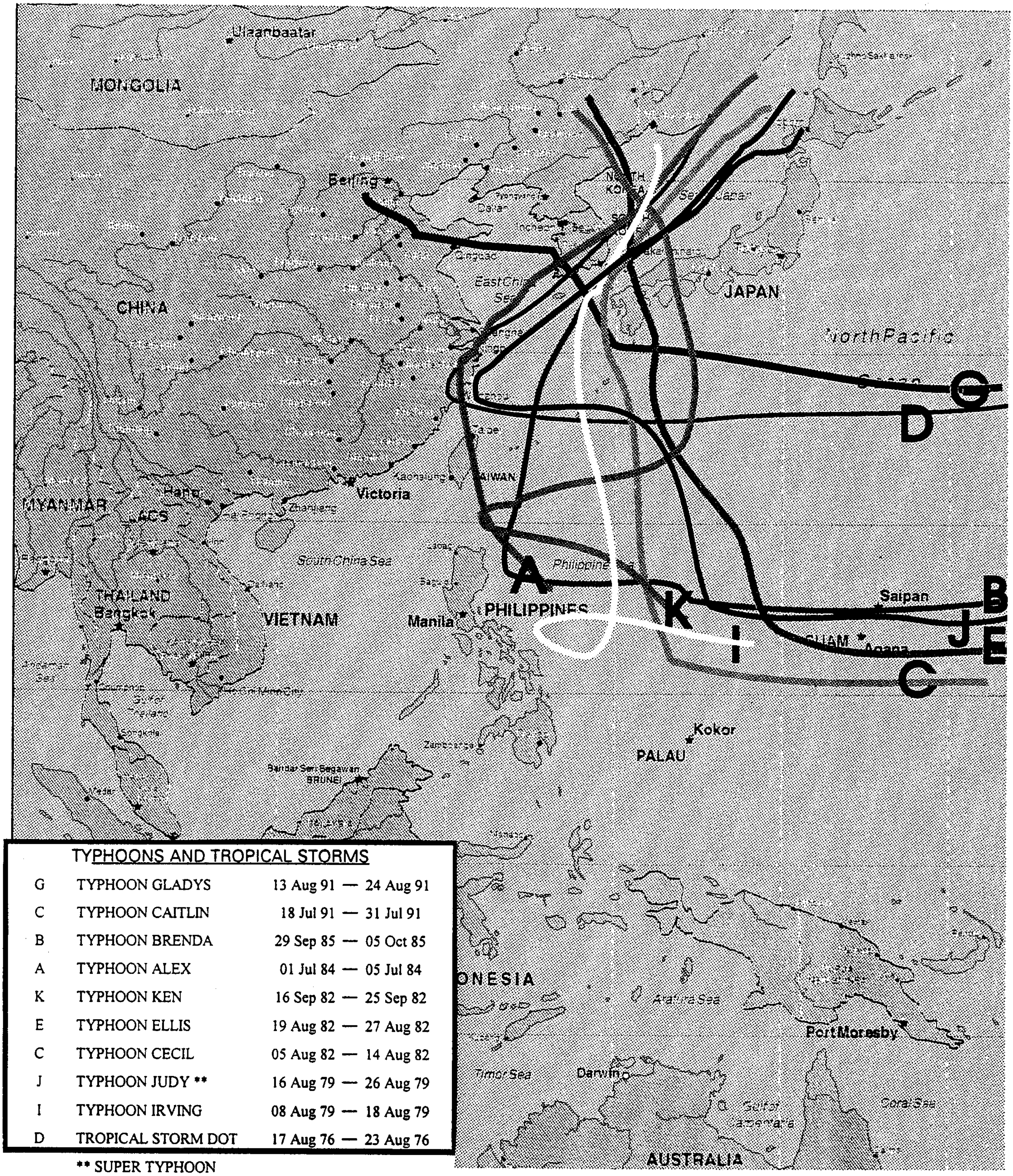
Figure 23. Tropical Cyclone Threat Axis



TYPHOONS AND TROPICAL STORMS

F	TYPHOON FRAN	01 Sep 76 — 13 Sep 76
W	TYPHOON WILDA	16 Aug 76 — 24 Aug 76
A	TYPHOON ANITA	20 Jul 76 — 25 Jul 76
P	TYPHOON PHYLLIS	11 Aug 75 — 18 Aug 75
X	TYPHOON POLLY	24 Aug 74 — 04 Sep 74
J	TROPICAL STORM JEAN	15 Jul 74 — 21 Jul 74
G	TYPHOON GILDA	26 Jun 74 — 07 Jul 74

Figure 24. Typhoons and Tropical Storms Affecting the Korean Peninsula (1976 - 1991)



TYPHOONS AND TROPICAL STORMS

G	TYPHOON GLADYS	13 Aug 91 — 24 Aug 91
C	TYPHOON CAITLIN	18 Jul 91 — 31 Jul 91
B	TYPHOON BRENDA	29 Sep 85 — 05 Oct 85
A	TYPHOON ALEX	01 Jul 84 — 05 Jul 84
K	TYPHOON KEN	16 Sep 82 — 25 Sep 82
E	TYPHOON ELLIS	19 Aug 82 — 27 Aug 82
C	TYPHOON CECIL	05 Aug 82 — 14 Aug 82
J	TYPHOON JUDY **	16 Aug 79 — 26 Aug 79
I	TYPHOON IRVING	08 Aug 79 — 18 Aug 79
D	TROPICAL STORM DOT	17 Aug 76 — 23 Aug 76

** SUPER TYPHOON

Figure 25. Typhoons and Tropical Storms Affecting the Korean Peninsula (1976-1991) (Continued)

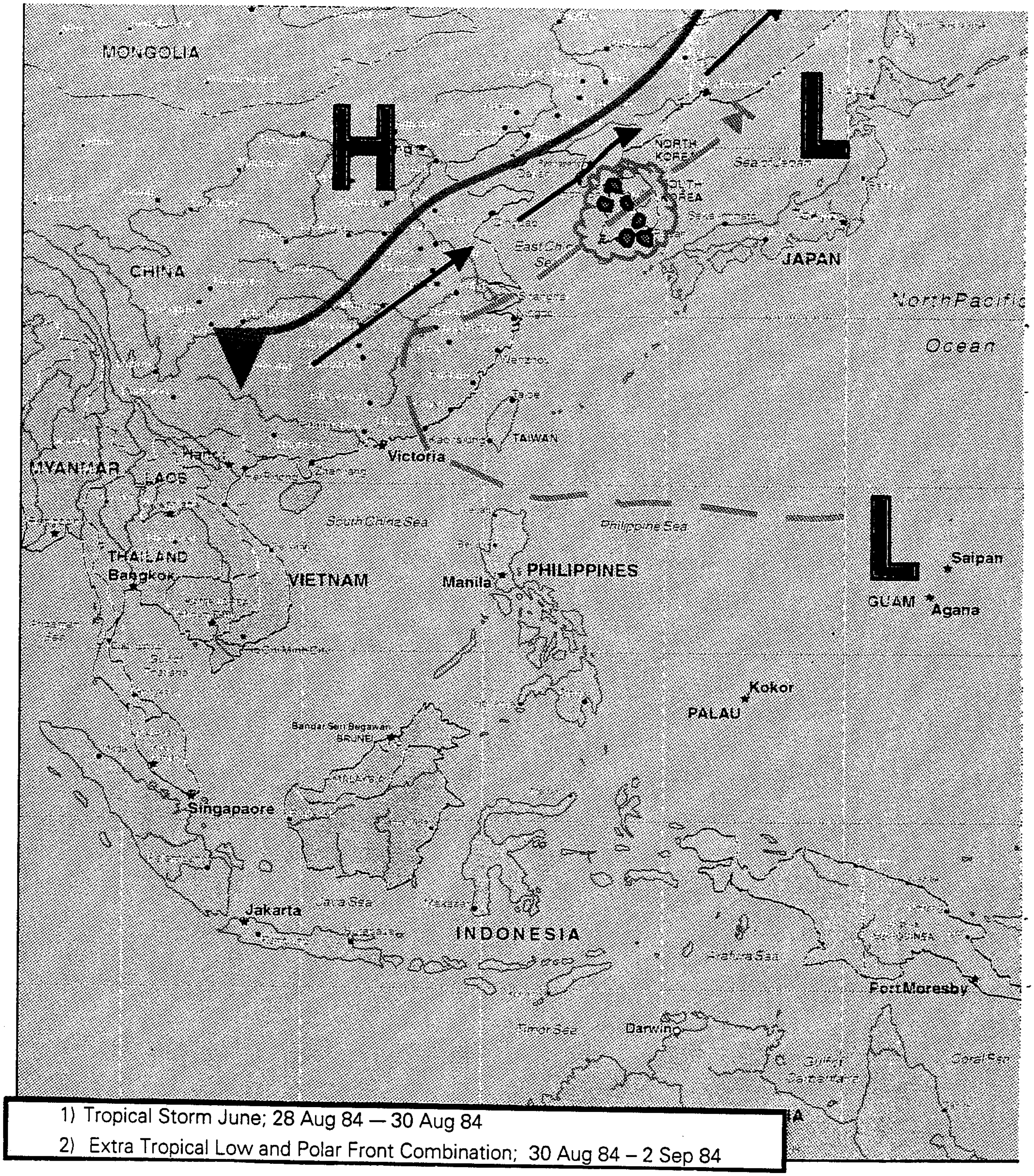


Figure 26. Tropical Storm June (08/28/84) (Special case)

Another problem to consider with strong typhoons is heavy rainfall amounts, coupled with high winds (approaching 150 mi/h), and landfall near high-density population centers. Two such events in the Tokyo, Japan area killed 1,269 people in 1958 and 5,098 in 1959. The inevitable confusion that surrounds such natural catastrophes would slow down any attempt to resupply that area. This, in turn, could easily be interpreted as a military weakness to be exploited by armies of North Korea, if such an event occurred near Seoul or Pusan, South Korea.

It is important to remember that the North Korean military leadership of 1950-54 believed so strongly in the importance of weather data as a strategic weapon that they tried to eradicate any external knowledge of Korean weather or climate data. It is the only conflict that the author has studied in which a concerted effort was made to either move weather libraries, in this case to North Korean military bases, or to destroy those libraries wherever they were found. Of more profound importance was the fact that any South Korean weather personnel, if captured, were summarily executed (Reference 8). With this type of extreme behavior toward weather personnel and weather data bases, strategic and logistic planners should remember that North Korean military planners will be strongly inclined to use their knowledge of local weather patterns to help negate any U.S. military advantages.

EL NINO INDUCED PROBLEMS: ECONOMIC - STRATEGIC - TACTICAL

The gradual development of adverse weather and oceanographic conditions as a result of an El Nino cycle can lead to poor rice farming and fishing seasons that can last 2 to 3 years in length. Thus, an area of economic concern (weak to nonexistent production for agriculture and fishing), can lead to military flash points as political leaders strive to feed their hungry people; or they can simply use this situation as a convenient ruse in order to stockpile donated food supplies near military installations for possible future military operations (Reference 9).

Considering world history, it is reasonable to note that a nation that is hungry will gradually come to the conclusion that its armies can solve the problem. Our dependence on electronic surveillance, early warning systems, and jamming countermeasures to protect our troops and equipment will be most vulnerable during the heavy storms that are possible during the final months of an El Nino event. Dr. Epstein's work on the gradual expansion of the average minimum temperature line (10 °C. [50 °F.]) in both its area and its vertical sense, is the best analytical proof yet that we are undergoing a very gradual, but steady, global warming effect. More heat energy put into the atmosphere causes more energy to be stored in the world's oceans. This, in turn, makes it easier for tropical storms to grow larger and become more intense. The meteorological values for the Korean Peninsula are not extreme for Southeast Asia, but the following values could be recorded in South Korea if conditions were to complement each other.

The conditions to watch for would be the following:

1. One year after a moderate to strong El Nino event.
2. The middle years of an 11-year sunspot cycle (to help increase tropical storm frequency) (Reference 10).
3. The alignment of a polar front as in this special case (Figure 26).
4. This, in turn, could lead to similar precipitation values in South Korea as those that were reported earlier at stations in Vietnam:
   a. 4.35 inches of rain in 1-hour - Phu Lien
   b. 8.66 inches of rain in 3-hours - Phu Lien
   c. 115.0 inches of rain in 1-month - Latrong, September 1930
   d. 131.0 inches of rain in 2-months - Dien Bien Phu, July and August 1937
   e. 313.0 inches of rain annually - Kas Kong, 1923 (Reference 3)

Thus, the final tactical decision formulations should be based on the following areas of significance:

- ECONOMIC: Have agricultural stress factors been noted in North Korea? Are unique requests for imports (such as rice) being observed (as in mid-1995)? Have unusually long periods of warm, dry weather been followed by heavy rains that have produced widespread flooding throughout the country?

- STRATEGIC: As economic stress factors rise due to the end of a moderate to very strong (even extreme) El Nino event, have sensors indicated any type of additional buildup in military forces? Are logistic supplies, military equipment and personnel ready for short notice advance and deployment, particularly during July, August, or September? (These are the months of very frequent and, often, most intense typhoon development).

- TACTICAL: Have weather satellites shown the sudden development of multiple typhoons (Figure 18)? If this is the time frame after an El Nino event, when typhoon recurvature over South Korea (instead of over Japan) is most likely, will our defensive alert posture be ready to compensate for the 12- to 24-hour loss of electronic "early warning" networks?

If a ruling group within North Korea has enough internal economic pressure, it becomes easier to blame "the enemy" for their problems. Especially if they think the U.S. is preoccupied with other world events, it becomes easier to believe that strategically we are not ready. It is, therefore, only a short step to "victory" to use a strong typhoon to cover their initial advance into South Korea (Reference 11). In the midst of winds, heavy rains, mud, and floods, chaos will rule. For their goals, the more chaos the better. The technical superiority of our satellite and communication systems was very evident in the U.S.'s execution of "Operation Desert Storm." To ignore this advantage is a mistake any potential adversary will try hard not to repeat. Thus, our strategic and logistical planners need to remember the potential problem areas for each area of concern, as noted by our use of the Korean Peninsula (note Table 6).

CONCLUSION

Military planners, either in the strategic, tactical or logistic fields of operation, must become aware of the obvious changes possible during and after a strong El Nino; and be cognizant of the more subtle, long-term effects these mechanisms can produce. The Korean Peninsula example of droughts and floods, that can assuredly destroy an agricultural system (based on rice production) despite the best efforts of the local population, is an excellent example of how a small nation can be pushed to the brink of war. Reacting after the fact will not work. The wide-ranging environmental effects of an El Nino can alter the timing sequences associated with the production of various Army tactical decision aids. As highlighted by the potential problem areas for Korea (Table 6), the environmental impacts of an El Nino can be fine-tuned to focus on any particular geographic area of interest around the world. Further research needs to be done to better understand the short- and long-term effects of El Nino's environmental impacts on Army TDAs. This research will improve the timetables required for more accurate logistical and tactical support of U.S. military units in the field. Recognizing the El Nino pattern early in its development will give military planners the necessary time to gradually build-up the personnel and supplies needed in order to quietly defuse any potentially dangerous situation.

The U.S. must understand that an El Nino event is not a threat; however, it is the catalyst that can lead to a real threat. It could be the start of a dangerous game of military brinkmanship brought on by economic hardship, and fueled by a mutual feeling of suspicion and mistrust. If military planners acquire a better understanding of the immediate and long-range effects of an El Nino mechanism, then strategically and logistically the U.S. will continue to have a strong deterrent force in the western Pacific area of operations, regardless of any "current" (i.e. typhoon) weather situation. Typhoon Oscar (inset photo), should continue to be a potential economic concern; it should not be allowed to become the first step in a reenactment of the 15 September 1950 amphibious landing at Inchon.

Table 6.

Potential Problem Areas

1. Assessment of flooding on the utility of North Korean tunnels.

2. Assessment of flooding on South Korean harbor facilities (i.e. will silting be a big concern?).

3. Assessment of heavy rains on armor mobility and artillery effectiveness.

4. How long after the ground becomes saturated before light vehicle traffic can be counted on?

5. How long after the ground becomes saturated before heavy armor can be tactically moved and used?

6. Are logistical storage areas/warehouses vulnerable to heavy rains or mudslides?

7. Will field elements be able to use Global Positioning System (GPS) capabilities during periods of heavy rains that are induced by tropical storms?

8. If RORO's are needed, can the facilities at most South Korean harbors handle such large ships or their heavy cargoes?

9. If the South Korean harbors cannot handle RORO traffic, how long of a time delay is expected for off-loading at Japanese ports before smaller shipments can be delivered to South Korean ports?

10. If severe flooding can change the salinity values of the nearby ocean waters, will this, in turn, effect the defensive positioning of our Anti-Submarine Warfare (ASW) elements?

FIGURE SOURCES

1. The Peru or Humbolt Current
http://www.crseo.ucsb.edu/geos/gif/s3.gif

2. Changes in sea surface temperature due to El Nino
http://www.crseo.ucsb.edu/geos/gif/1112a.gif

3. Atmospheric and Oceanic Interaction
http://www.crseo.ucsb.edu/geos/gif/atmocin2.gif

4. Darwin - Tahiti Annual Pressure Change Comparison
http://www.crseo.ucsb.edu/geos/gif/1121.gif

5. Non-El Nino Conditions
http://www.crseo.ucsb.edu/geos/13.html

6. Normal versus El Nino Conditions
http://www.pmel.noaa.gov/images/ElNino.gif

7. Map of Asia-Pacific (National Geographic Society,
Washington, D.C., November, 1989).

8. Map of Peru (Central Intelligence Agency,
C.I.A. Maps, May 1995).

9. Map of Ecuador (Central Intelligence Agency,
C.I.A. Maps, May 1995).

10. Precipitation of South America - Normal Condition (June)
http://www.crseo.ucsb.edu/geos/gif/JUNPSAM.gif

11. Piura River Water Discharge - Peru
http://www.crseo.ucsb.edu/geos/gif/1221.gif

12. El Nino Events - Severity versus Year

13A. Map of Korean Peninsula (Central Intelligence Agency
C.I.A. Maps, May 1995).

FIGURE SOURCES (Continued)

13B. Map of Korean Peninsula Coastal Scan
http://antares.csi.lsu.edu/demos/noaa/inter/n11.890120.04.korea.gif

14. Kuroshio Current (warm) and Oyasio Current (cold)
http://www.seaspace.com/images/kuroshio.gif

15. Rainfall Pattern During El Nino
http://www.crseo.ucsb.edu/geos/gif/13511.gif

16. May - September Precipitation for Four South Korean Stations

17. Annual Precipitation For Two U.S. West Coast Stations

18. Nine Tropical Storms - ESSA Weather Satellite - 09/14/67.
Mariner's Weather Log, volume 12, number 1,
January - February 1968.

19. Typhoons and Tropical Storms in the N.W. Pacific
Total Storms per Year vs. Years

20A. Sea Surface Variability - 03/30/94
http://topex-www.jpl.nasa.gov/ninowatch/S940330.gif

20B. Sea Surface Variability - 09/15/94
http://topex-www.jpl.nasa.gov/ninowatch/S940915.gif

20C. Sea Surface Variability - 10/25/94
http://topex-www.jpl.nasa.gov/ninowatch/S941025.gif

20D. Sea Surface Variability - 12/26/94
http://topex-www.jpl.nasa.gov/ninowatch/S941226.gif

20E. Sea Surface Variability - 01/28/95
http://topex-www.jpl.nasa.gov/ninowatch/S950128.gif

21A. Global Sea Surface Temperature Maps 23 July 1995
gopher://gopher.ssec.wisc.edu/11/mcidas.d/other.d/

FIGURE SOURCES (Continued)

21B. Global Sea Surface Temperature Maps 23 July 1995 (continued)
gopher://gopher.ssec.wisc.edu/1 1/mcidas.d/other.d/

22. Modern Average Global Sea-Surface Temperature in the
N.W. Pacific Ocean - August 1995.
http://geochange.er.usgs.gov/pub/magsst/FGDCmeta.html

23. Mariners Weather Log, volume 24, number 5,
September - October 1980.
Tropical cyclone threat axis
(June, July, August, September, and October).

24. Typhoons and Tropical Storms affecting the
Korean Peninsula (1974 - 1976).

25. Typhoons and Tropical Storms affecting the
Korean Peninsula (1976 - 1991).

26. Tropical Storm June (28 August 1984 - Special Case).

ENDNOTES

1. a. Watkins, J.D., Admiral. 19 April 1984. "The impact of the ocean environment upon tactical and strategic forces and their operations and system performance must be understood and accounted for, to most effectively employ our Navy." CNO Oceanography Policy Statement.

   b. Russokho, A.I., Rear Admiral. 1973. "It is my responsibility to ensure that every Soviet submarine understands the ocean and how to hide in it." Soviet Oceanographer, Paris, France.

2. When TDA's are being formulated for the strategic use of RORO vessels under a LOTS operation mandate, the following should be considered:

   a. The fastest RORO is the SL-7 which can average 33 kn.

   b. The average speed for most of these ships is 15-17 kn.

   c. Most RORO designated ships have a length of 500 feet, a width of 35 feet, and a draft of 28-30 feet.

   d. On a normal great circle route, storm generated sea swells will cause significant delays in the recurve area.

   e. If the RORO ships are ordered to move east, they can expect a delay in travel time of at least 2 ½-3 weeks because of the Panama and Suez Canal transits.

   f. If the southern route around the Cape of Good Hope is used, the worst case scenario would add another 20 days to the time interval, in addition to possible superstructure damage to individual vessels because of winter storm conditions (Reference 6).

REFERENCES

1. Epstein, P.R., M.D. May 1995. "Health Implications of Climate Variability and Change for National Academy of Sciences," Harvard Medical School.

2. Reid, T.R. 27 May 1995. *Washington Post Newspaper.* A22.

3. Sanderson, R.W., Captain. June 1954. "Notes on the Climate of Indochina." *Weatherwise.* Vol. 7, no. 3:56-59, 69.

4. James, R.W. December 1974. "Dangerous Waves Along North Wall of the Gulf Stream." U.S. Naval Oceanographic Office, Washington, D.C. *Mariners Weather Log.* Vol. 18, no. 6:363-366.

5. Reuter News. 16 September 1995. "Tidal Wave Hits QE2 Luxury Liner." *Washington Post Newspaper.* A21.

6. Dixon, P. Naval Atlantic Meteorology and Oceanography Center, Naval Air Station, Norfolk, VA. Personal communication with author, 4 April 1995.

7. LeComte, D. February 1985. "The Year of the African Drought." *Weatherwise.* Vol. 38, no. 1:8-15.

8. Taft, H.E., Jr. February 1953. "A Letter from Korea." *Weatherwise.* Vol. 6, no. 1:11.

9. Lea, J. "Kim Cites Military Takeover." *Pacific Stars & Stripes Newspaper.* 1, 4, 11.

10. Solar Sunspot Cycles http://www.mgdc.noaa.gov/s+p/SOLAR/SSN/ssn.html.

11. June 1951. "Air Weather Service Support to the Korean Effort." *Weatherwise.* Vol. 4, no. 3:60-61.

BIBLIOGRAPHY

Canby, T.Y., ed. 1984. El Ninos' Ill Wind. *National Geographic.* 165(2):144-183.

Davidson, K. 1995. "What's Wrong with the Weather? - El Nino Strikes Again." *Earth.* 26-33.

Gray, W.M. 1984. "Atlantic Seasonal Hurricane Frequency. Part I: El Nino and 30 mb. Quasi-Biennial Oscillation Influences." *Monthly Weather Review, 112.* 1649-68.

Hastenrath, S.; Ming Chin Wu and Pao Shin Chu. 1984. "Towards the Monitoring and Prediction of Northeast Brazil Droughts." *Quarterly Journal of the Royal Meteorological Society.* 411-25.

Hill, D.K. 1995. "Pacific Warming Unsettles Ecosystems." *Science.* Vol. 267:1911-12.

Johnson, E.S. and M.J. McPhaden. 1993. "On the Structure of Equatorial Kelvin Waves in the Pacific Ocean." *Journal of Physical Oceanography, 13.* 608-26.

Kessler, W.S. 1990. "Observations of Long Rossby Waves in the Northern Tropical Pacific." *Journal of Geophysical Research, 95.* 5183-5217.

Le Comte, D. 1983. "World Weather 1982." *Weatherwise, 36.* 14-17.

_______. 1984. "Worldwide Extreme Floods and Droughts." *Weatherwise, 37.* 8-18.

_______. 1987. "Highlights Around the World-- Water, Water Almost Everywhere..." *Weatherwise, 40.* 9-10.

_______. 1988. "Global Highlights." *Weatherwise, 41.* 10-13.

_______. 1995. "Highlights Around the World." *Weatherwise, 48.* 20-21.

Nials, F.L.; E.E. Deeds; M.E. Mosley; S.G. Pozorski; T.G. Pozorski; and R. Feldman. 1979. "El Nino: The Catastrophic Flooding of Coastal Peru." *Field Museum of Natural History Bulletin.* Vol. 50, no. 7:4-14; and no. 8:4-10.

Quinn, W.H.; V.T. Neal and S.E. Antunez de Mayolo. 1987. "El Nino Occurrences Over the Past Four and a Half Centuries." *Journal of Geophysical Research, 92.* No. C13:14, 449-61.

Quinn, W.H. and D.O. Zopf. 1984. "The Unusual Intensity of the 1982-83 ENSO Event." *Tropical Ocean-Atmosphere Newsletter.* D. Halpern, ed. NOAA Pacific Marine Environmental Laboratories, Seattle, WA. No. 26:17-20.

BIBLIOGRAPHY (continued)

Quiroz, R.S. 1983. "The Climate of the El Nino Winter of 1982-83. A Season of Extraordinary Climatic Anomalies." *Monthly Weather Review, 111.* 1685-1706.

Rasmusson, E.M. and J.M. Hall. August 1983. "El Nino: The Great Equatorial Pacific Ocean Warming Event of 1982-83." *Weatherwise, 36.* 166-175.

Schweigger, E.H. 1940. "Studies of the Peru Coastal Current with Reference to the Extraordinary Summer of 1939." *Proceedings of the Sixth Pacific Science Congress, 3.* 177-195.

Sheppard, G. 1930. "Notes on the Climate and Physiography of Southwestern Ecuador." *Geographic Review, 20.* 445-453.

Smith, R.L. 1983. "Peru Coastal Currents During El Nino 1976 and 1982." *Science, 221.* 1397-98.

Wyrtki, K.; E. Stroup; W. Patzert; R. Williams and W. Quinn. 1976. "Predicting and Observing El Nino." *Science, 191.* 343-46.

BIBLIOGRAPHY - INTERNET

Coastal Zone Color Scanner Data Sets and Imagery
http://seawifs.gsfc.nasa.gov/SEAWIFS/IMAGES/CZCS.html

U.S. Climate Anomalies Associated with ENSO Events
http://www.coaps.fsu.edu/research/matt/index.html

ENSO and Florida Precipitation
http://www.coaps.fsu.edu/research/todd/index.html

Sea Space Satellite Imagery (Water)
http://www.seaspace.com/demo_images_water.html

The Global Climate Perspectives System (GCPS)
http://www.ncdc.noaa.gov/gcps/gcps.html

National Climatic Data Center Home Page
http://www.ncdc.noaa.gov

ESRG GATEWAY
http://www.crseo.ucsb.edu/esrg.html

Major El Nino Events
http://www.crseo.ucsb.edu/geos/gif/15.gif

Temperature Sensor
http://www.crseo.ucsb.edu/geos/txt/11231.txt

Temperature Sensor
http://www.crseo.ucsb.edu/geos/txt/11232.txt

Monitoring, Detection, & Modeling
http://www.crseo.ucsb.edu/geos/11.html

Data Logger Transmitter
http://www.crseo.ucsb.edu/geos/txt/11233.txt

Current Meters
http://www.crseo.ucsb.edu/geos/txt/11234.txt

Wind Sensor
http://www.crseo.ucsb.edu/geos/txt/11235.txt

BIBLIOGRAPHY - INTERNET (Continued)

Salinity Meters
http://www.crseo.ucsb.edu/geos/txt/11236.txt

Pyronometer
http://www.crseo.ucsb.edu/geos/txt/11237.txt

In Situ Measurements
http://www.crseo.ucsb.edu/geos/112.html

Drifting Buoys
http://www.crseo.ucsb.edu/geos/1122.html

Moored Buoys
http://www.crseo.ucsb.edu/geos/1123.html

Computer Models (1)
http://www.crseo.ucsb.edu/geos/113.html

Computer Models (2)
http://www.crseo.ucsb.edu/geos/1131.txt

Ocean Productivity
http://www.crseo.ucsb.edu/geos/1116.html

Productivity - Phytoplankton Concentration
http://www.crseo.ucsb.edu/geos/11161.html

Ships Climatological Observations
http://www.crseo.ucsb.edu/geos/gif/1117.gif

Cloud Systems
http://www.crseo.ucsb.edu/geos/1113.html

GOES - West (Eastern Pacific)
http://www.crseo.ucsb.edu/geos/11131.gif

GMS (Western Pacific)
http://www.crseo.ucsb.edu/geos/11132.gif

METEOSAT (Africa)
http://www.crseo.ucsb.edu/geos/11134.gif

BIBLIOGRAPHY - INTERNET (Continued)

INSAT (Indian Ocean)
http://www.crseo.ucsb.edu/geos/11135.gif

Visible and Infrared
http://www.crseo.ucsb.edu/geos/11136.html

Hurricanes
http://www.crseo.ucsb.edu/geos/hurricane.mpg

Sea Surface Temperature
http://www.crseo.ucsb.edu/geos/1112.html

Atmospheric Window
http://www.crseo.ucsb.edu/geos/11121.html

Rainfall
http://www.crseo.ucsb.edu/geos/1114.html

Visible and IR and Cloud type
http://www.crseo.ucsb.edu/geos/11141.html

Microwave Radiometers
http://www.crseo.ucsb.edu/geos/11142.html

Average Monthly Precipitation (January)
http://www.crseo.ucsb.edu/geos/gif/h_rain.gif

Sea Surface Height
http://www.crseo.ucsb.edu/geos/1115.html

GEOSAT Wave Height
http://www.crseo.ucsb.edu/geos/11151.html

Satellite Oceanography Laboratory - GMS Data
http://www.satlab.hawaii.edu/gms.html

School of Ocean and Earth Science Technology
http://satftp.soest.hawaii.edu

Background on El Nino
http://topex-www.jpl.nasa.gov/ninowatch/El_Nino_background.html

BIBLIOGRAPHY - INTERNET (Continued)

El Nino Watch Page
http://topex-www.jpl.nasa.gov/ninowatch/index.html

Sea Surface January 1995
http://www.pmel.noaa.gov/toga-tao/el-nino/gif/tp-jan95-large.gif

El Nino and Climate Prediction
http://www.pmel.noaa.gov/toga-tao/el-nino-report.html

Impacts of El Nino and Benefits of El Nino Prediction
http://www.pmel.noaa.gov/toga-tao/el-nino/impacts.html

CPC - Data. Current Monthly Atmospheric and SST Index Values
http://nic.fb4.noaa.gov/data/cddb

Latest Sea Surface Temperatures
http://satftp.soest.hawaii.edu/compos.html#est

Satellite Oceanography Laboratory
http://satftp.soest.hawaii.edu

El Nino Southern Oscillation
http://kaos.erin.gov.au/air/climate/enso/enso.html