The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1956-1

Targeted Training Activity: Seasonal Predictability in Tropical Regions to be followed by Workshop on Multi-scale Predictions of the Asian and African Summer Monsoon

4 - 15 August 2008

El Niño and the Southern Oscillation (ENSO)
Introduction

Cane Mark

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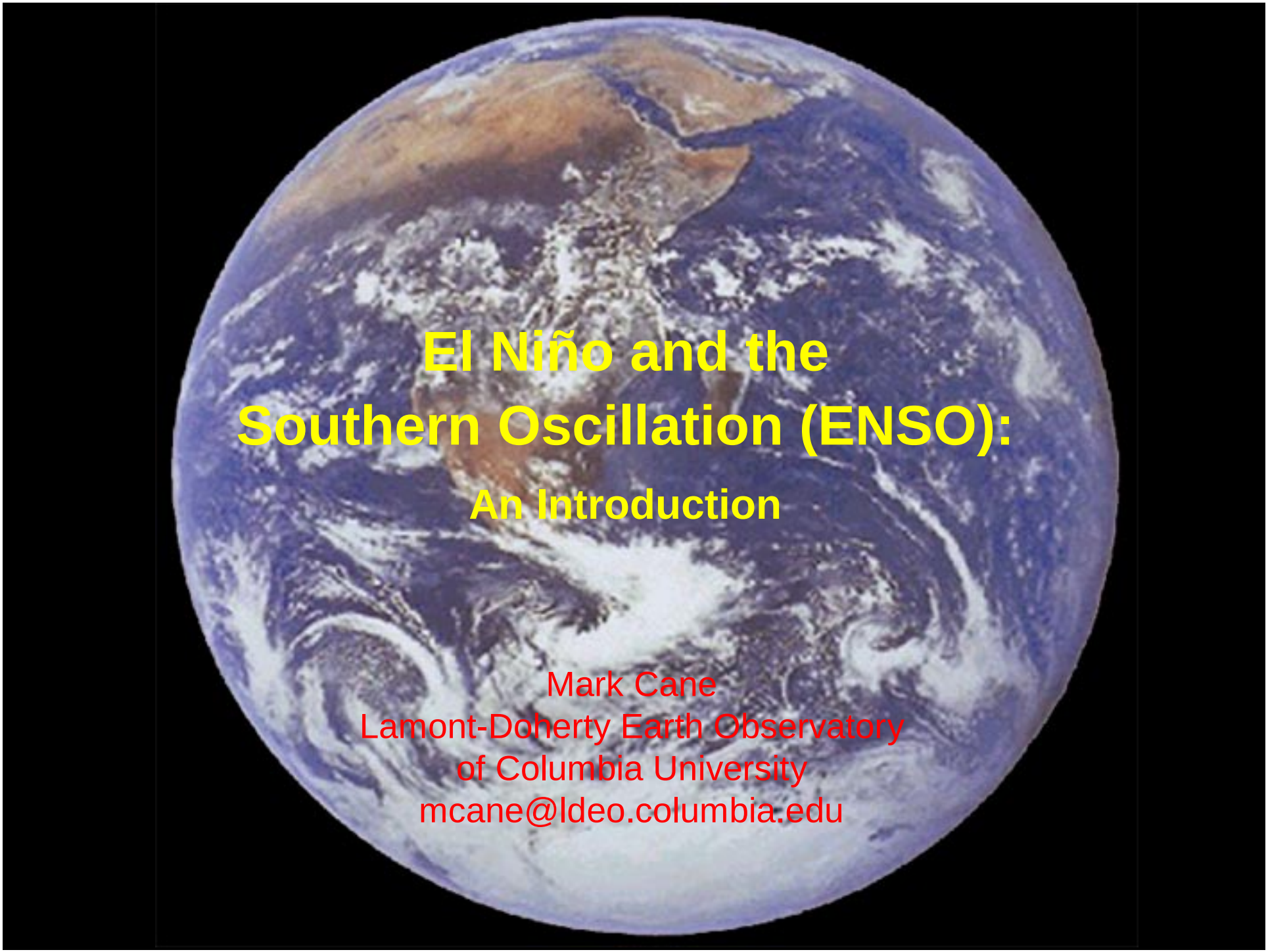
UNITED STATES OF AMERICA



El Niño and the Southern Oscillation (ENSO):

An Introduction

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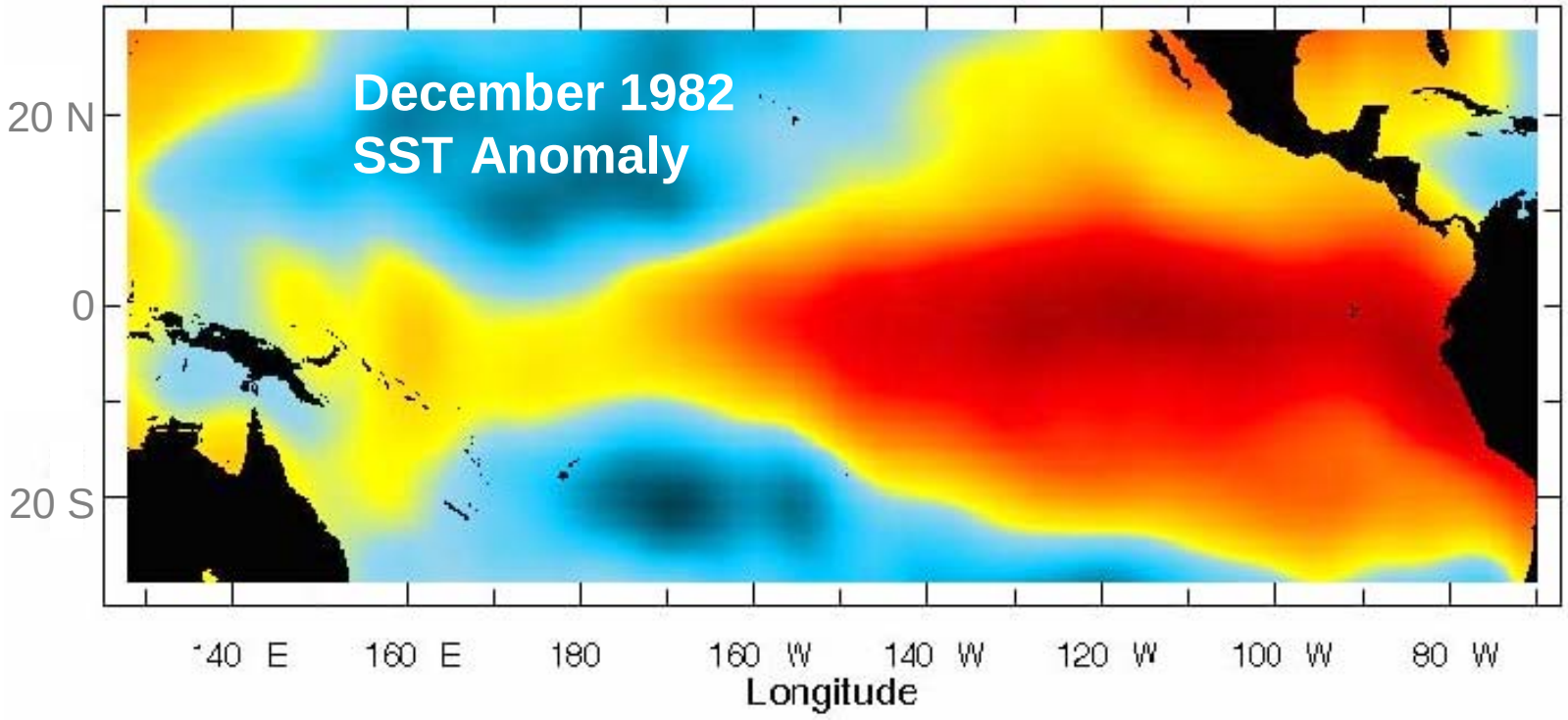
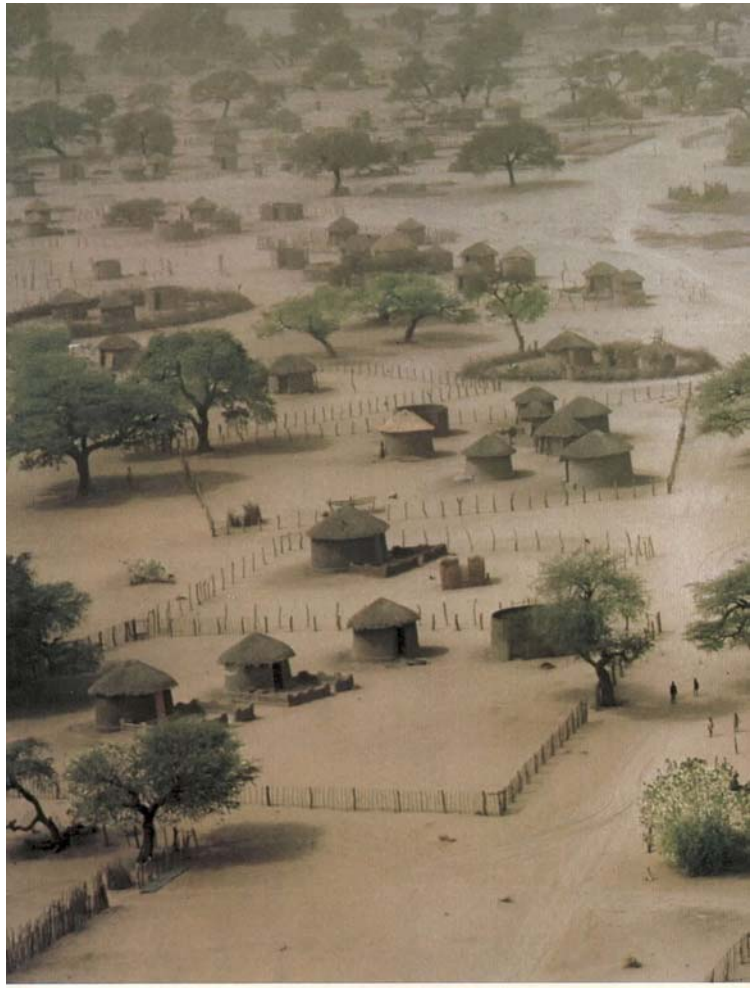
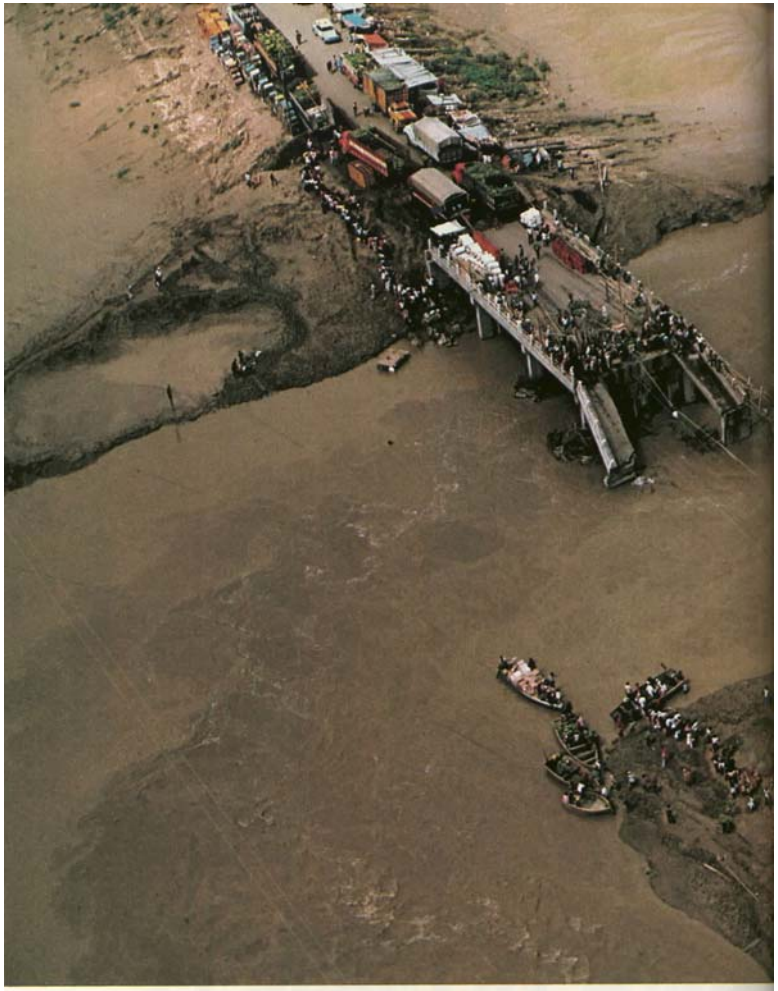
El Niño
and the
Southern Oscillation





AFRICA *Grazed to the nub, denied rain, and blown by dust, the village of Rakops in north-central Botswana seems lifeless but for a few trudging figures. Southeastern Africa had already suffered two dry years before El Niño blocked the deliverance of returning rains. For Botswana, a nation of cattle herders, the effect was*



ECUADOR *Strung with utility and conveyor lines, the abutments of a bridge washed out between Guayaquil and Salinas stand loaded with supplies and passengers awaiting makeshift ferry service. Warm water pushing against the coast triggered floods and landslides that killed scores of Ecuadorians and caused about 400 million*

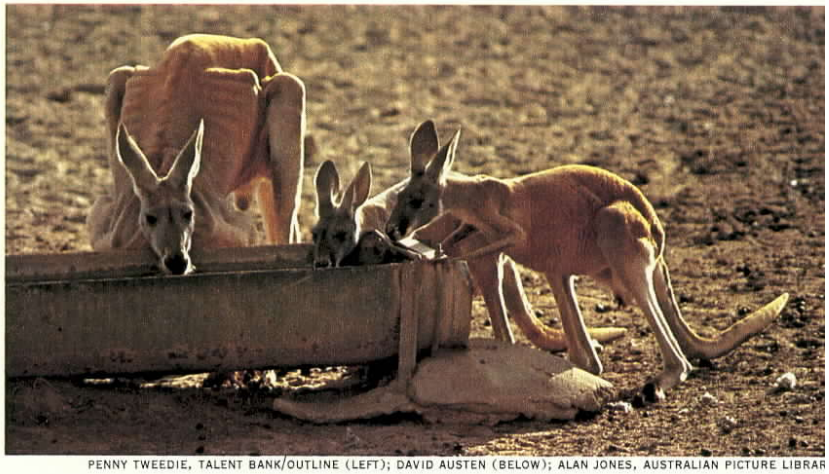
AUSTRALIA

Drought and fire storms

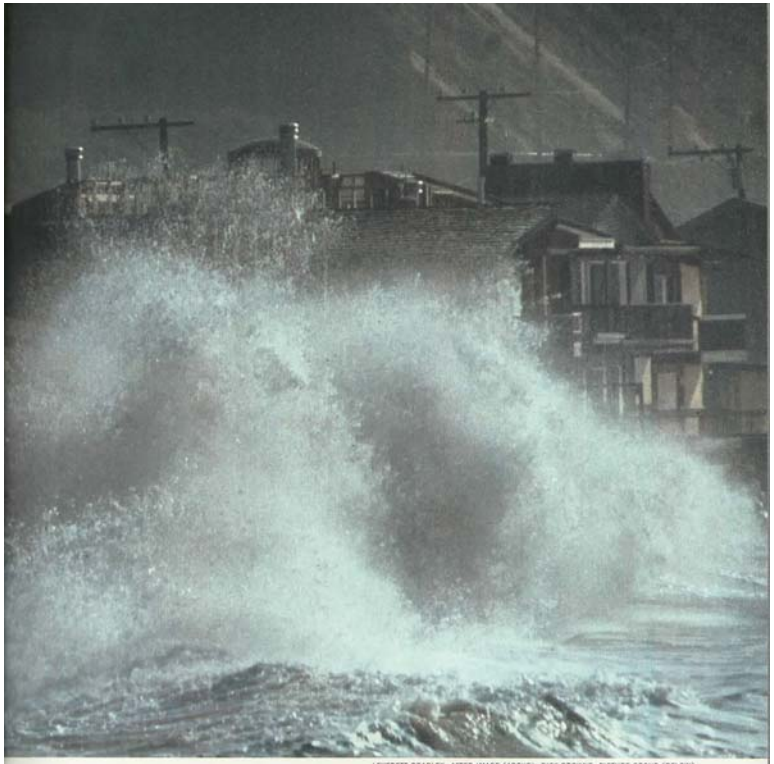
*Bone weary after months on the move, Snowy Miners and his son, Ashley (**left**), face another day of "the dry" in Australia's New South Wales. The Miners family was forced by drought to lead their 3,000 head of stock on a constant search for feed. They camped by night and pushed on at morning, looking for the next patch of scrub even as the weakest animals perished in the search.*

*Emaciation branded on their ribs, kangaroos (**below**) come in from the bush to water at a stock trough. Depleted in the early 1970s, kangaroos have multiplied greatly since, returning in strength just when herds could least bear competition. Although the animals are culled, kangaroo shooters receive less than ten dollars a carcass and skin, and hunting quotas have not been met. Some ranchers believe that during the drought they were feeding three to four kangaroos for every one of their own sheep.*

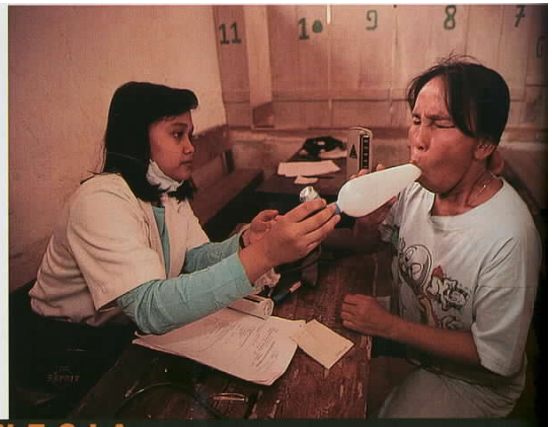
*Water finally became so scarce that at the Wardell Station, or ranch, it had to be trucked in (**bottom**) to replenish stock ponds.*



PENNY TWEEDIE, TALENT BANK/OUTLINE (LEFT); DAVID AUSTEN (BELOW); ALAN JONES, AUSTRALIAN PICTURE LIBRAR



LEVERETT BRADLEY, AFTER IMAGE (ABOVE); RICK BROWNE, PICTURE GROUP (BELOW)



INDONESIA

BOTH BY MICHAEL YAMASHITA

WORLDWIDE IMPACT As brush fires raged in drought-stricken Sumatra, motorists were shrouded in smoke, and clinics were filled with patients (above). Flames charred trees and utility poles in Bunnell, Florida (below left), which endured severe drought last summer. Too much winter rain near Chino, California (below right), sent rescuers in front loaders to save cattle neck deep in mud. Fires fueled by droughts claimed more than 19,000 square miles of

UNITED STATES

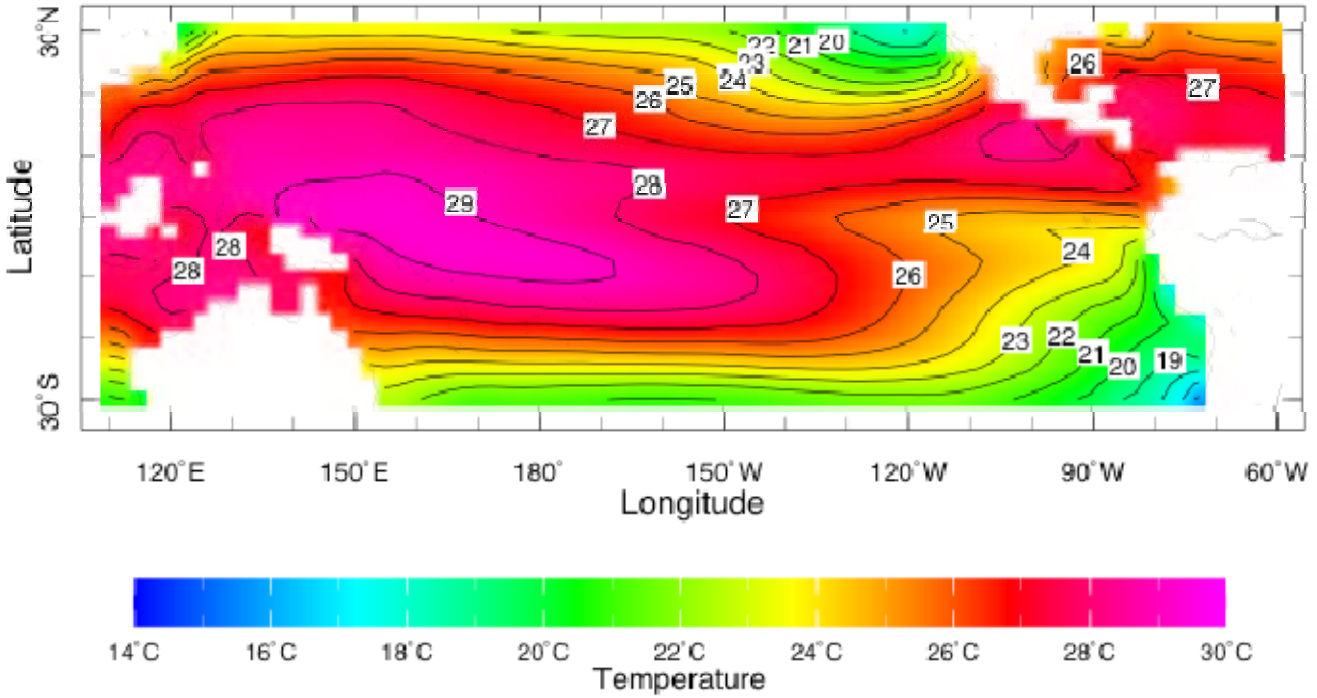
TONY RANZE, AGENCE FRANCE PRESSE (ABOVE LEFT); CON KEYES, LOS ANGELES TIMES

BOTH BY JOANNA B. PINNEO

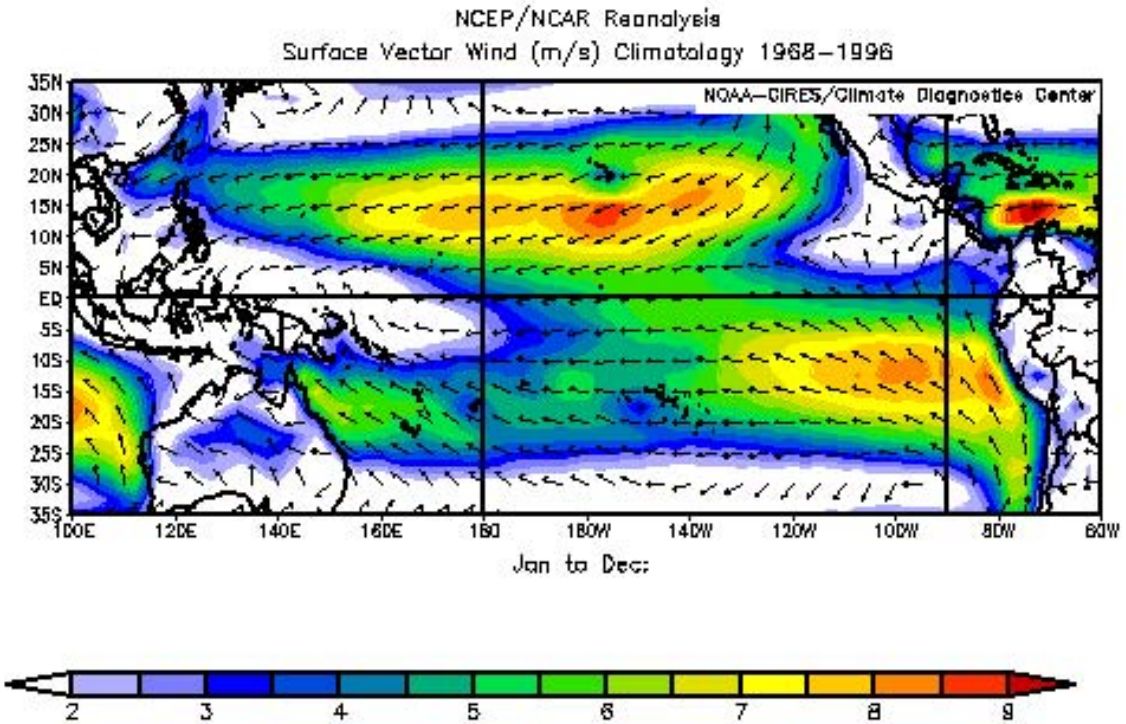
LAKE OF THE DUNES
Like a 90-mile-long mirage, an El Niño-fed lake ten feet deep spread across the floor of Peru's Sechura Desert, usually one of the driest places on Earth. Over the centuries native people have given the periodic lake temporary names. This time Lake La Niña prevailed. No humans were displaced by the flooding.

President Alberto Fujimori (above), declaring that some good should come of El Niñ helped stock the lake with fish. They will be harvested until the lake, which drains to the Pacific Ocean, dries u in about two years.

Pacific Annual SST



Surface winds



units: m/s

Temperature along the equator

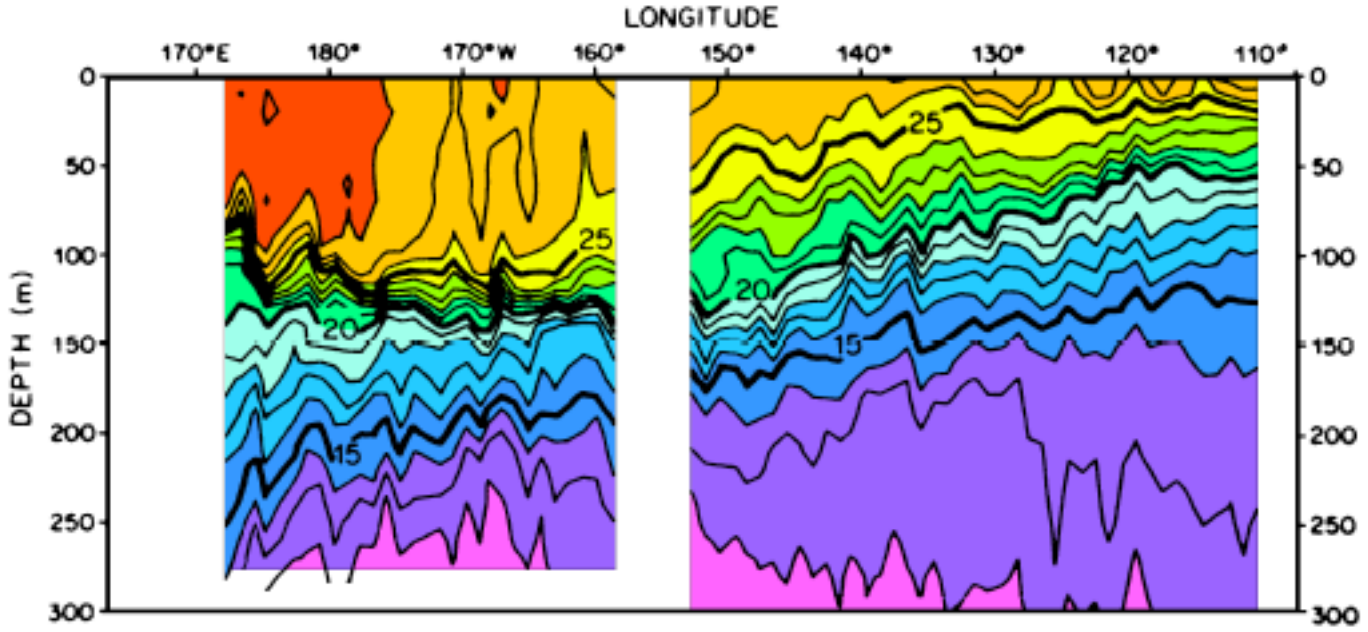
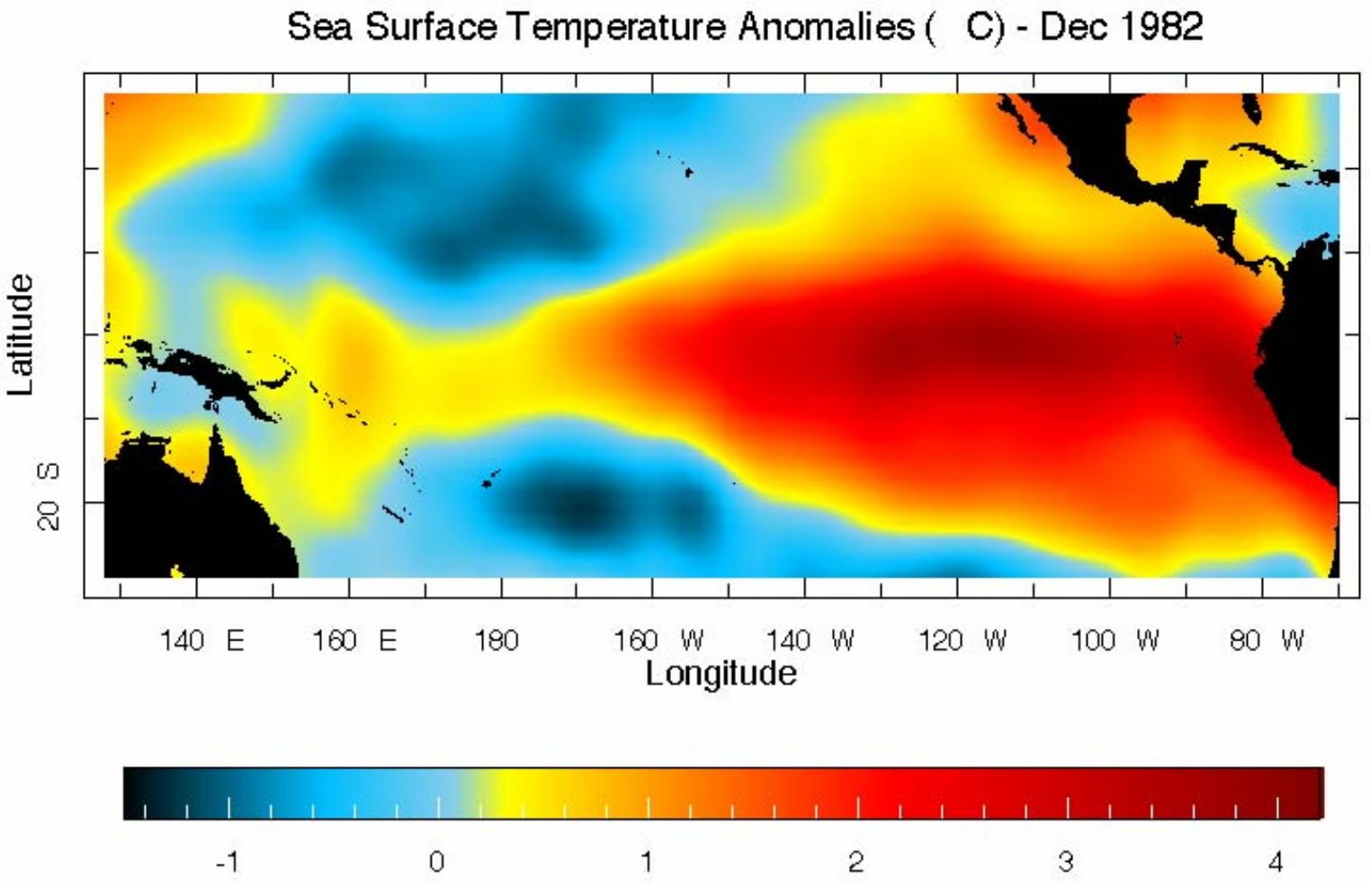


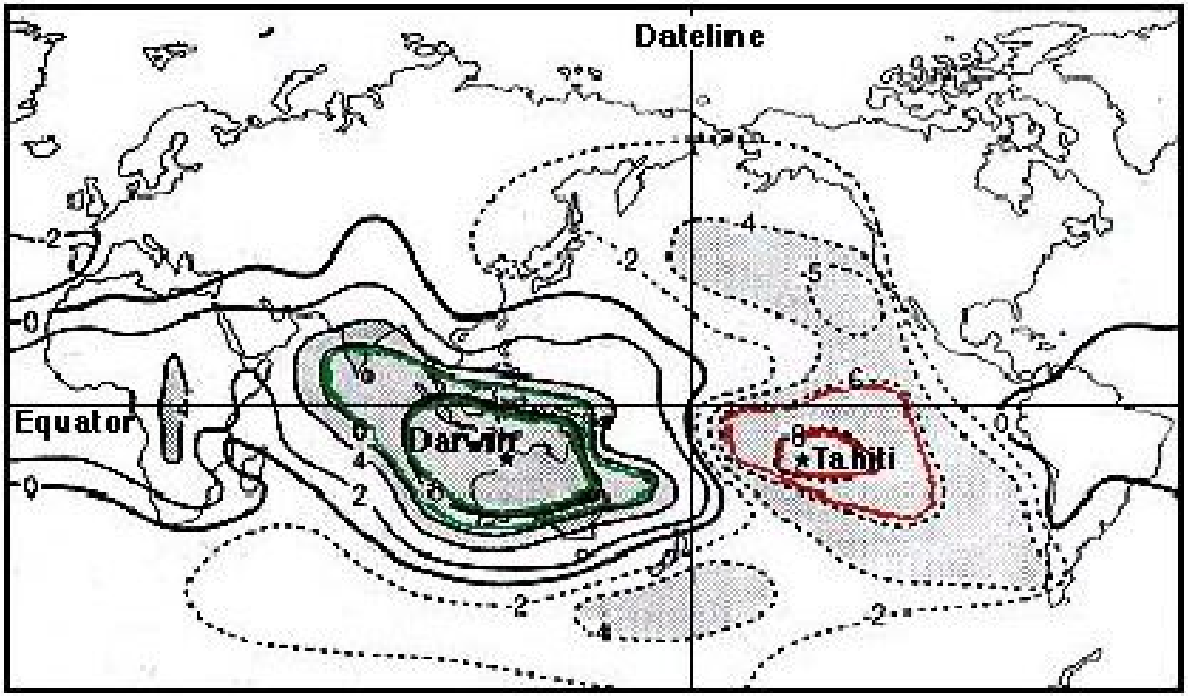
Fig. 8.9. A hydrographic section along the equator. Note the variation in the thickness of the nearly isothermal layer (temperatures above 26°C) from 100 m in the west to less than 20 m in the east, and the upward slope of the thermocline (temperatures between 15°C and 20°C) from west to east from 200 m to 70 m. From Halpern (1980).

El Niño

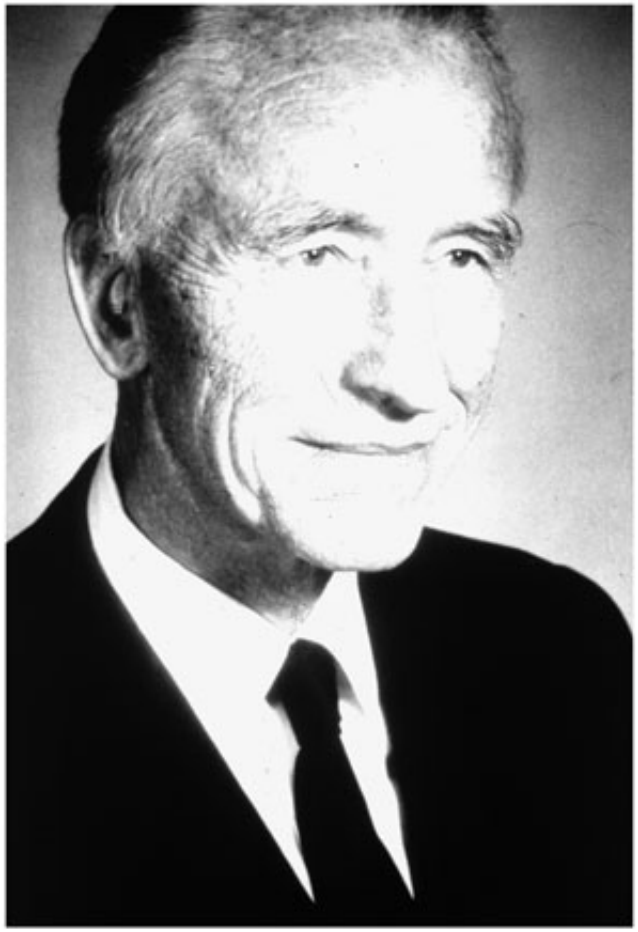

Sea Surface Temperature Anomalies (C) - Dec 1982
Latitude
20 S
140 E
160 E
180
160 W
140 W
120 W
100 W
80 W
Longitude
-1
0
1
2
3
4

Sir Gilbert Walker
1920s

SOI: Tahiti and Darwin as "centers of action",
mslp correlations between two locations

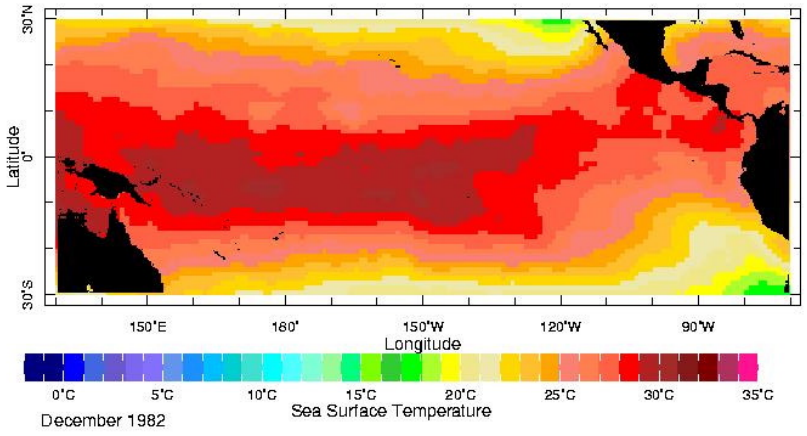


Tahiti and Darwin are at opposite ends of the Southern Oscillation's seesaw, and so the difference in pressure between them is used to measure the Southern Oscillation. The numbers represent a statistical measure called the correlation coefficient. The figure shows that the pressure variation at Tahiti is as closely related to Darwin as are locations near to Darwin, but with the opposite sign (i.e., if the Pressure is high at Darwin, it is low at Tahiti and vice versa). (After Rasmusson, 1984.)

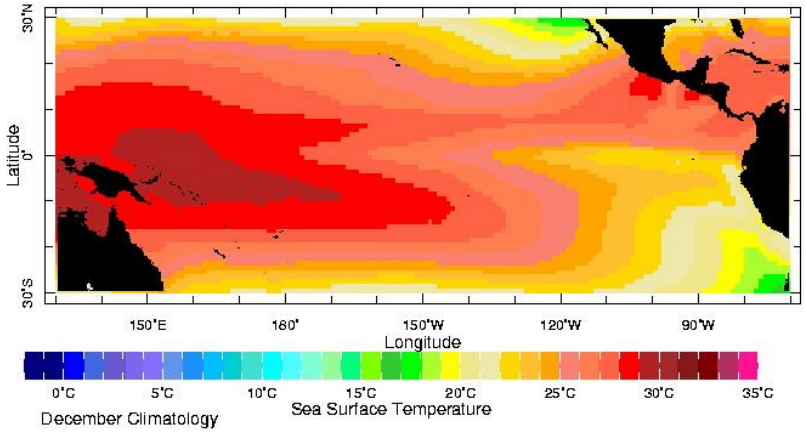


Jacob Bjerknes
1960s

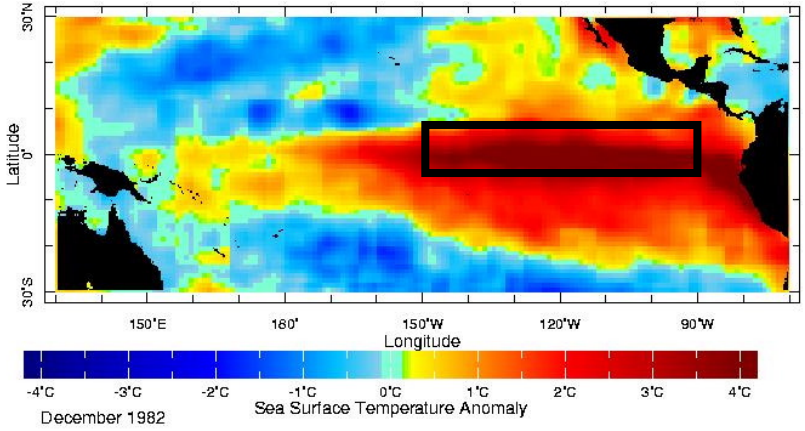
December 1982 SST

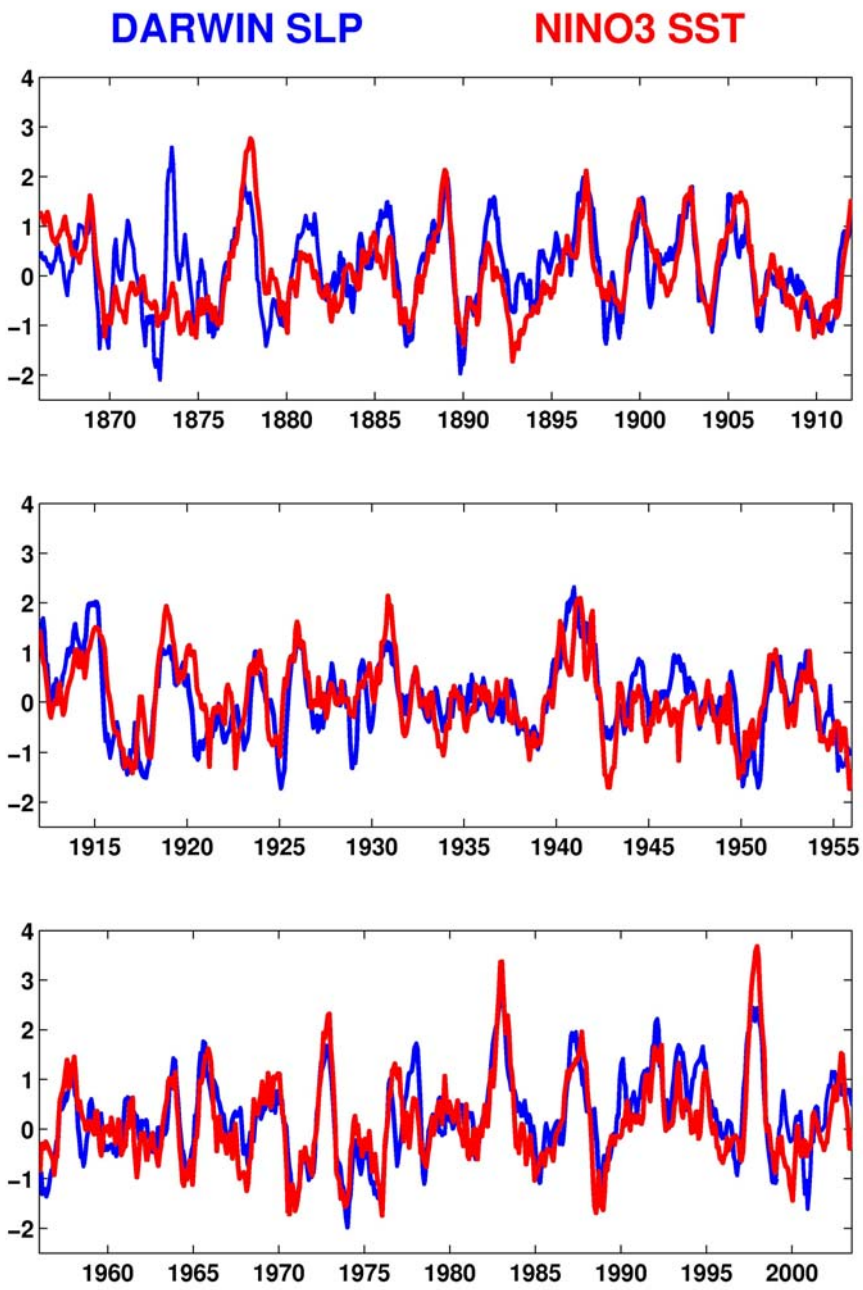


December Climatological SST



December 1982 SST Anomaly




DARWIN SLP
NINO3 SST
4
3
2
1
0
−1
−2
1870
1875
1880
1885
1890
1895
1900
1905
1910
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1955
1960
1965
1970
1975
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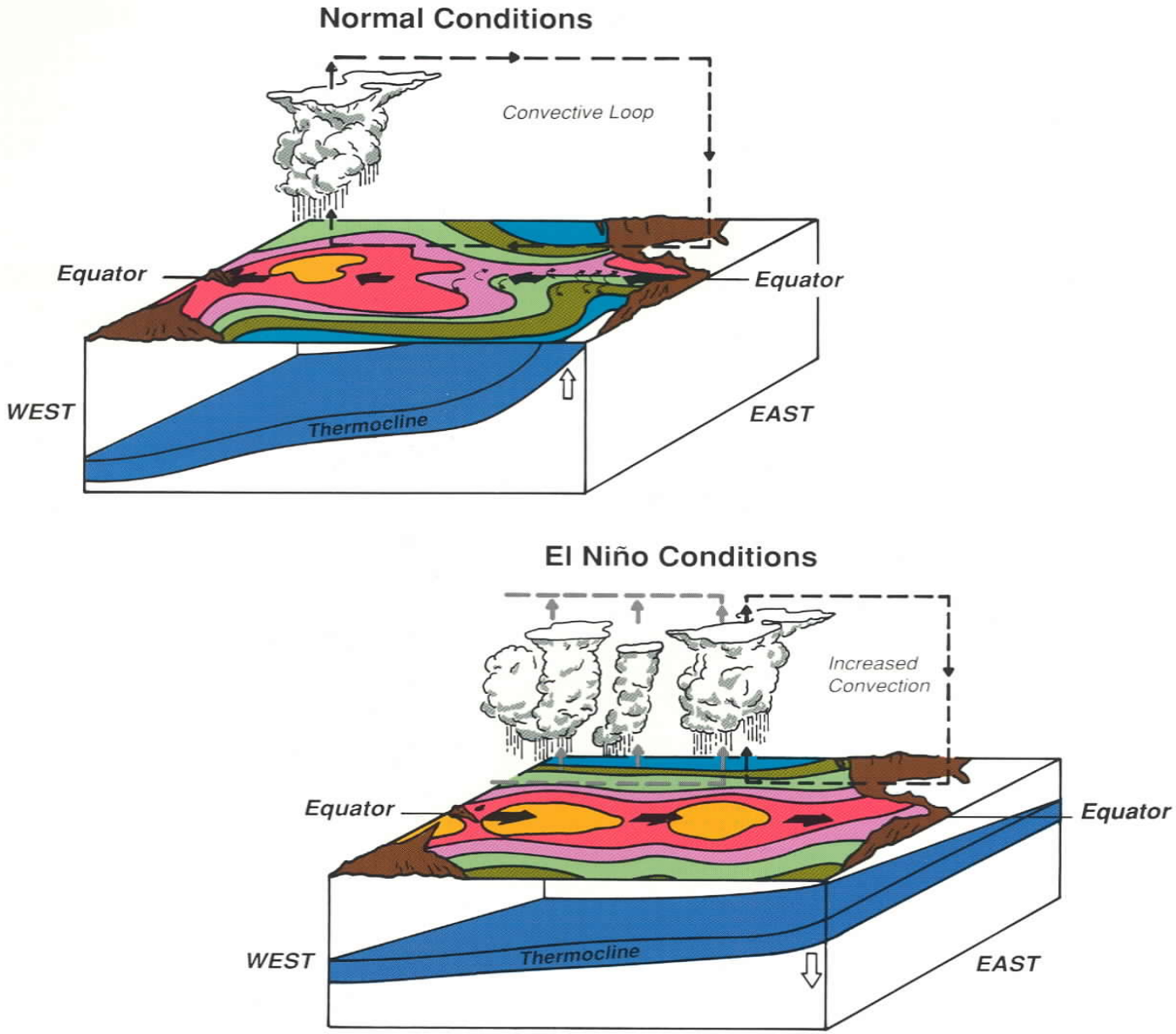
1990
1995
2000

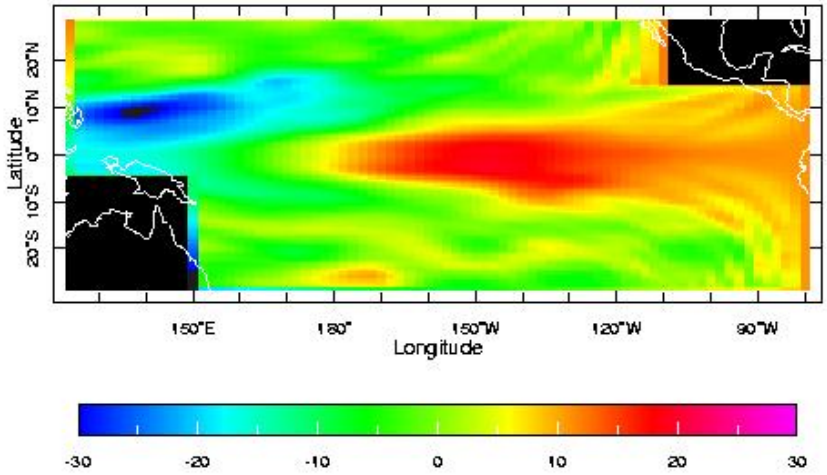

Normal Conditions
Convective Loop
Equator
Equator
WEST
Thermocline
EAST
El Niño Conditions
Increased
Convection
Equator
Equator
WEST
Thermocline
EAST

“There is thus ample reason for a never-ending succession of alternating trends by air-sea interaction in the equatorial belt, but just how the turnabout between trends takes place is not yet quite clear.”

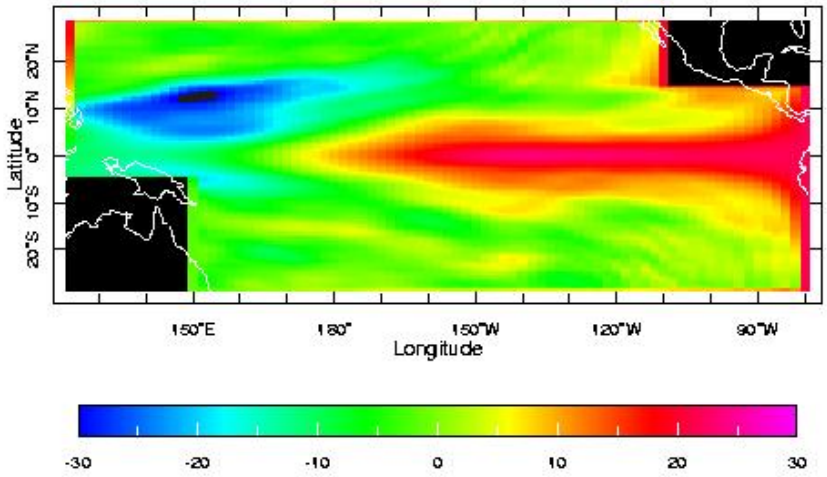
J. Bjerknes
1969

Sea Level Difference

Oct 76 – Oct 75



Oct 82 – Oct 81



Among the fruits of the Bjerknes hypothesis:

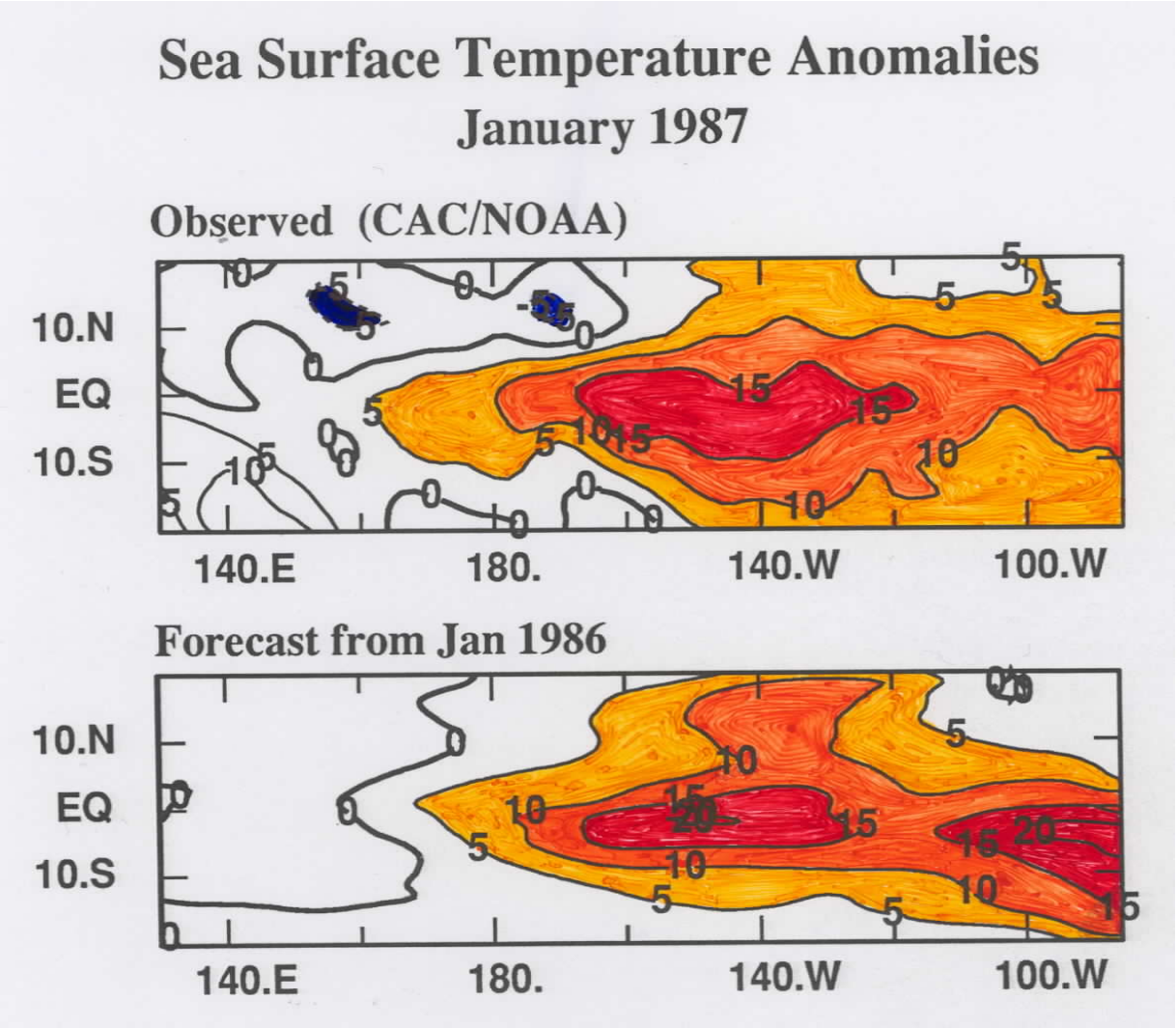
ENSO events can be predicted

ENSO events have been predicted

ENSO is understood to be

a *coupled instability* of the Atmosphere/Ocean system in the *Tropical Pacific*

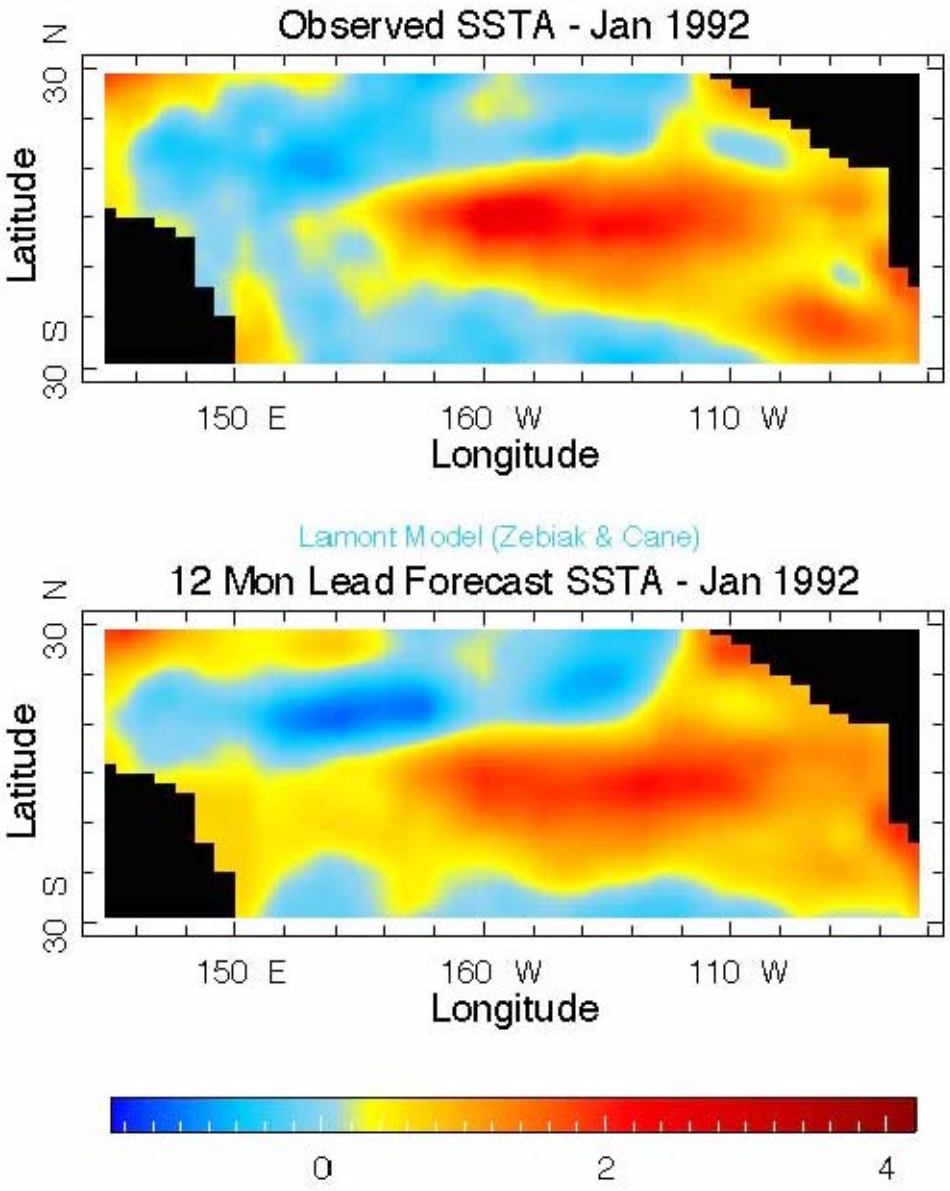
Bjerknes Hypothesis + equatorial ocean dynamics

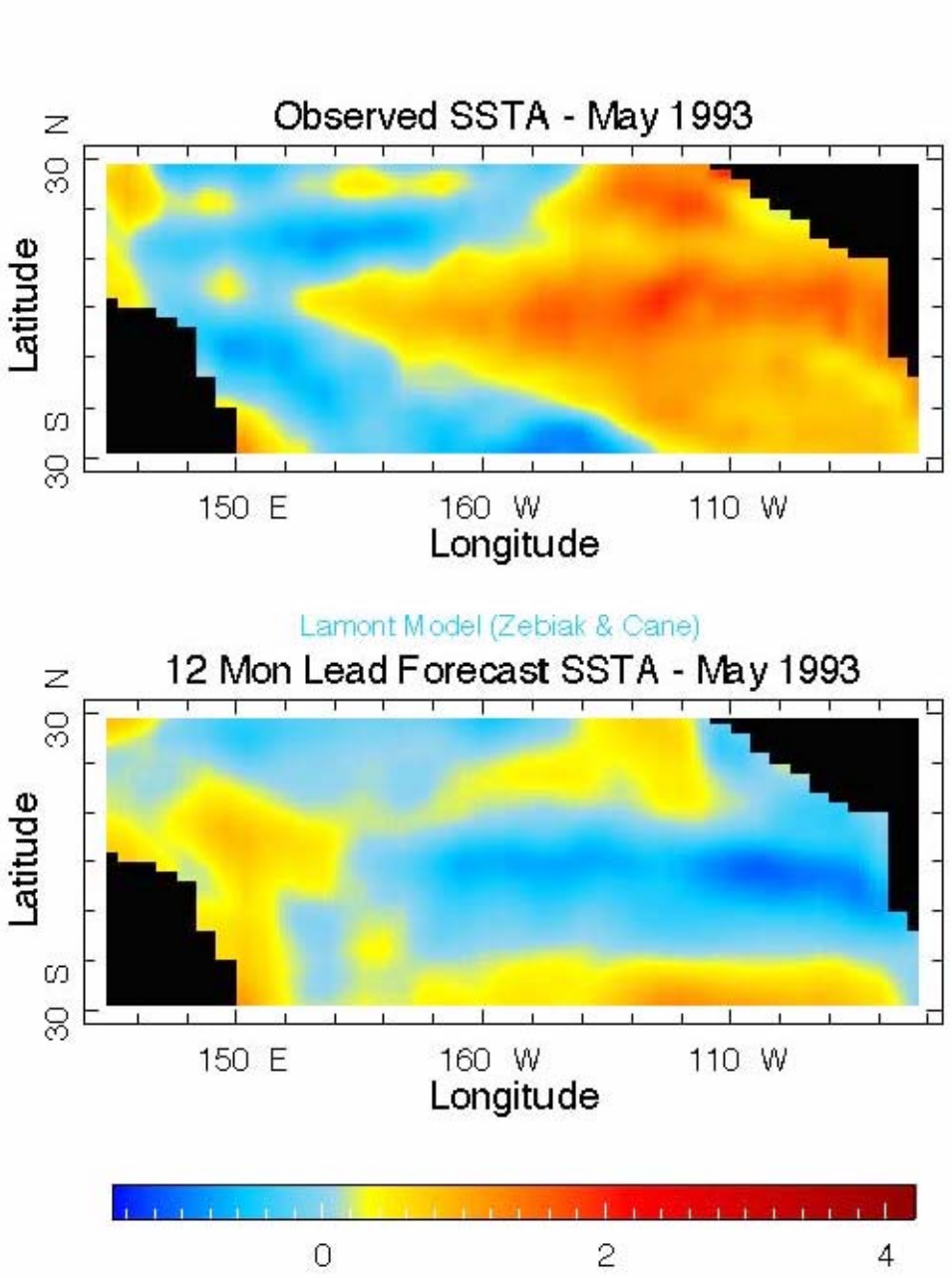


After Cane, Zebiak and Dolan - Nature 1986 and see

Barnett, Graham, Cane, Zebiak, Dolan, O'Brien and Legler, Science 1988

Contours at 0.5°C

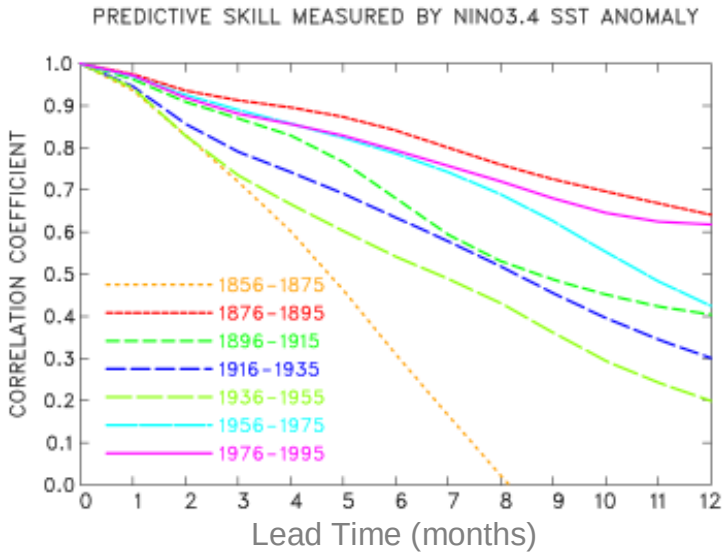

Observed SSTA - Jan 1992
30 N
30 S
Latitude
150 E
160 W
110 W
Longitude
Lamont Model (Zebiak & Cane)
12 Mon Lead Forecast SSTA - Jan 1992
30 N
30 S
Latitude
150 E
160 W
110 W
Longitude
0
2
4


Observed SSTA - May 1993
30 N
30 S
Latitude
150 E
160 W
110 W
Longitude
Lamont Model (Zebiak & Cane)
12 Mon Lead Forecast SSTA - May 1993
30 N
30 S
Latitude
150 E
160 W
110 W
Longitude
0
2
4

Factors limiting the current skill of forecasts:

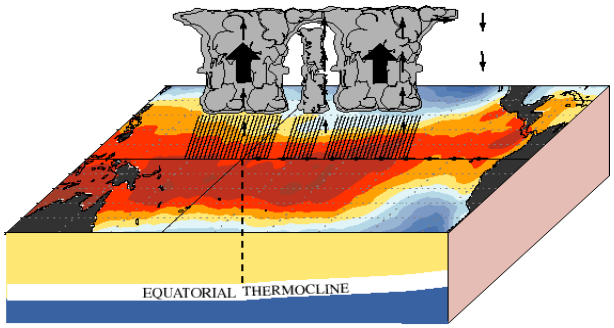
- **Model flaws**
- **Flaws in the way the data is used**
  (data assimilation and initialization)
- **Gaps in the observing system**
- **Inherent limits to predictability**

  forecast skill is different in different decades - some times are more predictable than others



Chen, et al 2004 *Nature*

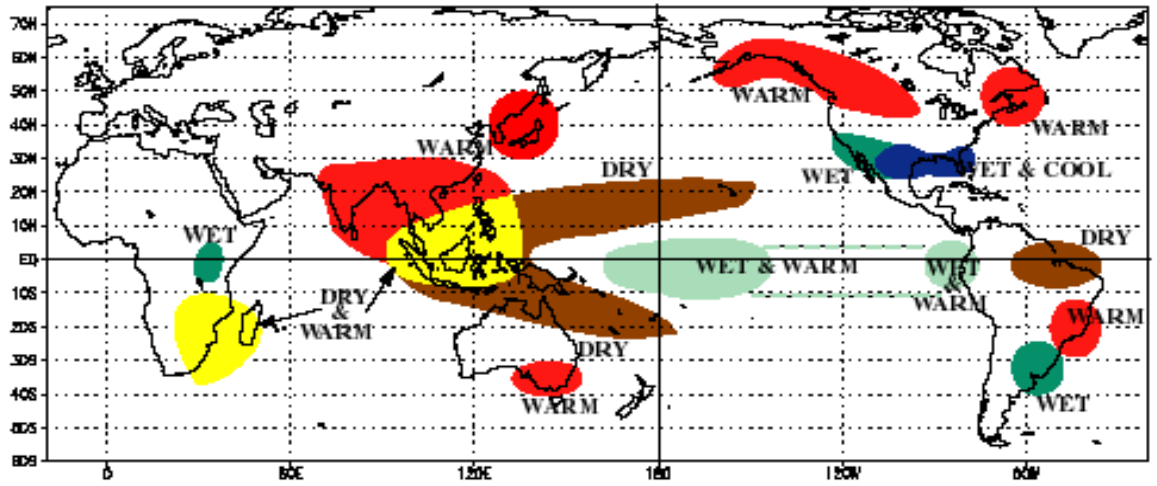
December - February El Niño Conditions



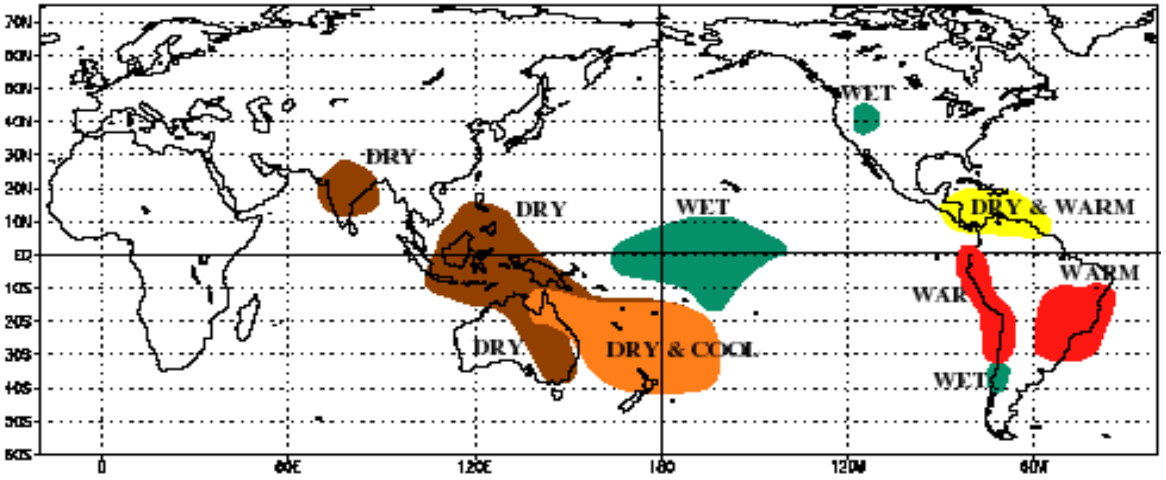
Global Impacts of the warm phase

El Niño

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

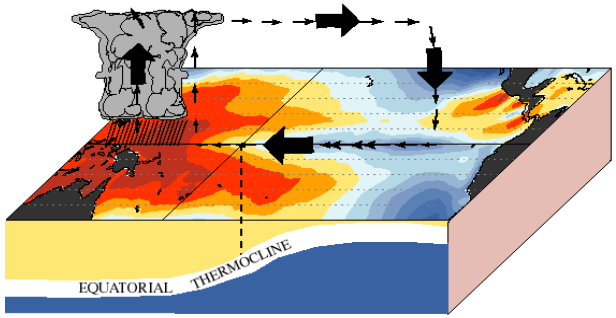


WARM EPISODE RELATIONSHIPS JUNE - AUGUST



Climate Prediction Center
NCEP

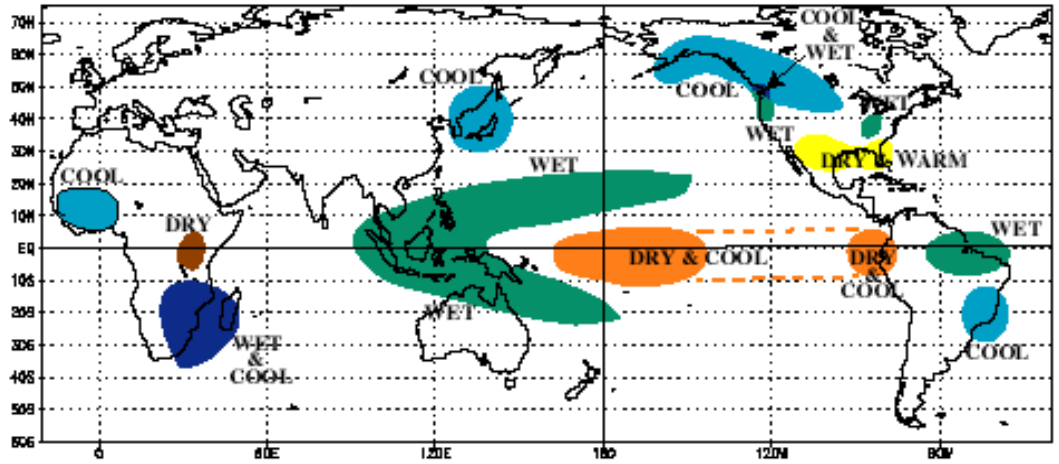
December - February La Niña Conditions



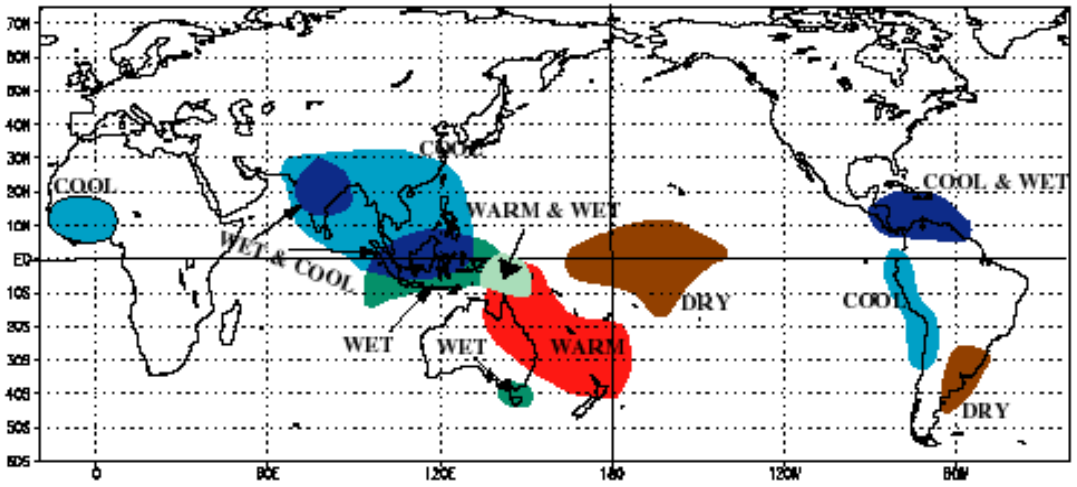
Global Impacts of the cold phase

La Niña

COLD EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



COLD EPISODE RELATIONSHIPS JUNE - AUGUST



Climate Prediction Center
NCEP

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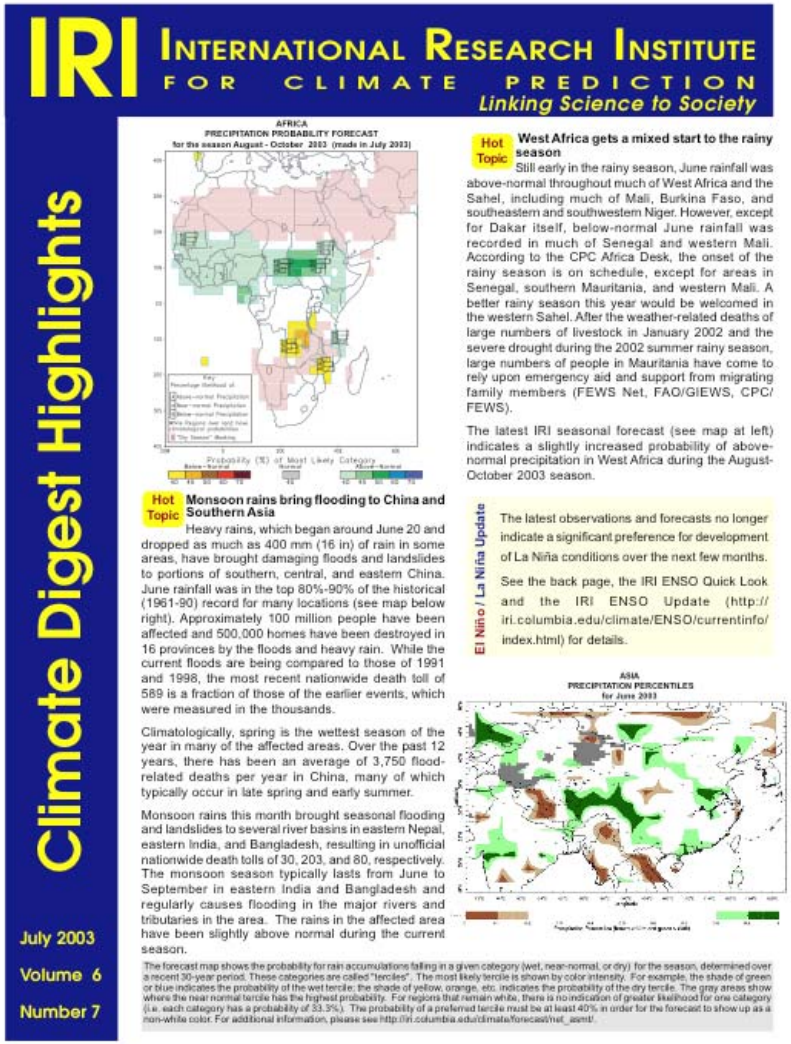

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Climate Digest Highlights

July 2003
Volume 6
Number 7

AFRICA
PRECIPITATION PROBABILITY FORECAST
for the season August - October 2003 (made in July 2003)

Probability (%) of Most Likely Category
Below-Normal | Normal | Above-Normal

Hot Topic **West Africa gets a mixed start to the rainy season**

Still early in the rainy season, June rainfall was above-normal throughout much of West Africa and the Sahel, including much of Mali, Burkina Faso, and southeastern and southwestern Niger. However, except for Dakar itself, below-normal June rainfall was recorded in much of Senegal and western Mali. According to the CPC Africa Desk, the onset of the rainy season is on schedule, except for areas in Senegal, southern Mauritania, and western Mali. A better rainy season this year would be welcomed in the western Sahel. After the weather-related deaths of large numbers of livestock in January 2002 and the severe drought during the 2002 summer rainy season, large numbers of people in Mauritania have come to rely upon emergency aid and support from migrating family members (FEWS Net, FAO/GIEWS, CPC/FEWS).

The latest IRI seasonal forecast (see map at left) indicates a slightly increased probability of above-normal precipitation in West Africa during the August-October 2003 season.

Hot Topic **Monsoon rains bring flooding to China and Southern Asia**

Heavy rains, which began around June 20 and dropped as much as 400 mm (16 in) of rain in some areas, have brought damaging floods and landslides to portions of southern, central, and eastern China. June rainfall was in the top 80%-90% of the historical (1961-90) record for many locations (see map below right). Approximately 100 million people have been affected and 500,000 homes have been destroyed in 16 provinces by the floods and heavy rain. While the current floods are being compared to those of 1991 and 1998, the most recent nationwide death toll of 589 is a fraction of those of the earlier events, which were measured in the thousands.

Climatologically, spring is the wettest season of the year in many of the affected areas. Over the past 12 years, there has been an average of 3,750 flood-related deaths per year in China, many of which typically occur in late spring and early summer.

Monsoon rains this month brought seasonal flooding and landslides to several river basins in eastern Nepal, eastern India, and Bangladesh, resulting in unofficial nationwide death tolls of 30, 203, and 80, respectively. The monsoon season typically lasts from June to September in eastern India and Bangladesh and regularly causes flooding in the major rivers and tributaries in the area. The rains in the affected area have been slightly above normal during the current season.

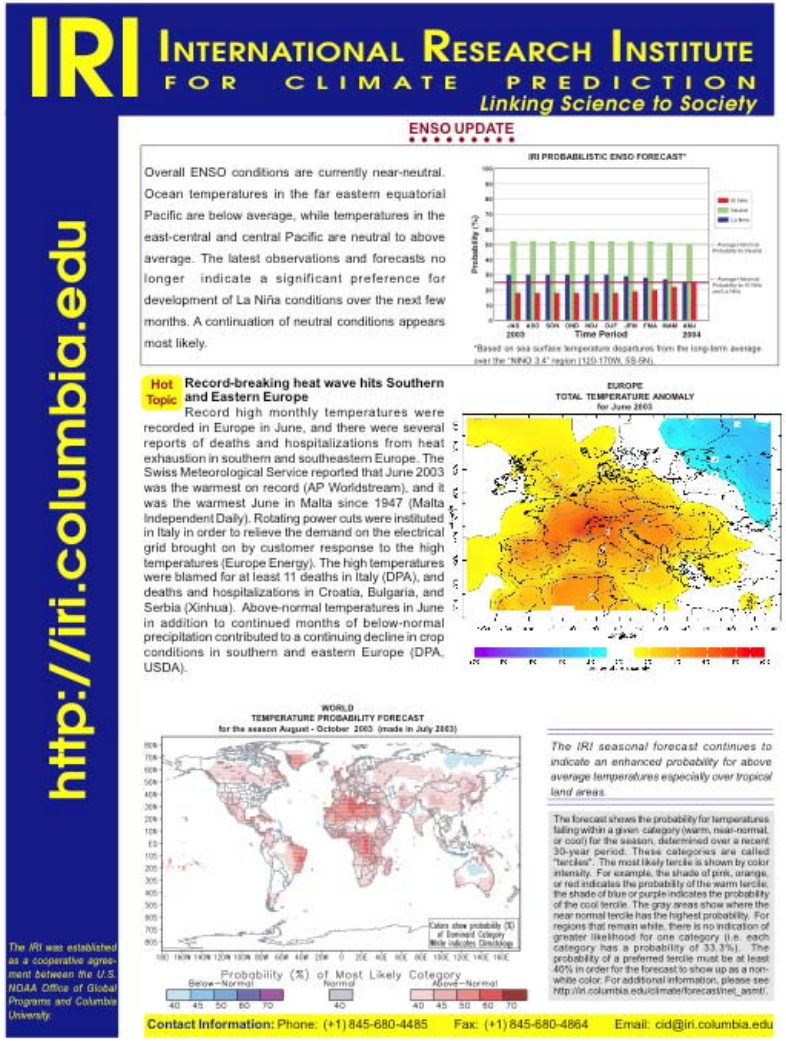
El Niño / La Niña Update

The latest observations and forecasts no longer indicate a significant preference for development of La Niña conditions over the next few months.

See the back page, the IRI ENSO Quick Look and the IRI ENSO Update (http://iri.columbia.edu/climate/ENSO/currentinfo/index.html) for details.

ASIA
PRECIPITATION PERCENTILES
for June 2003

The forecast map shows the probability for rain accumulations falling in a given category (wet, near-normal, or dry) for the season, determined over a recent 30-year period. These categories are called "terciles". The most likely tercile is shown by color intensity. For example, the shade of green or blue indicates the probability of the wet tercile; the shade of yellow, orange, etc. indicates the probability of the dry tercile. The gray areas show where the near-normal tercile has the highest probability. For regions that remain white, there is no indication of greater likelihood for one category (i.e. each category has a probability of 33.3%). The probability of a preferred tercile must be at least 40% in order for the forecast to show up as a non-white color. For additional information, please see http://iri.columbia.edu/climate/forecast/net_asmt/.



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The IRI was established as a cooperative agreement between the U.S. NOAA Office of Global Programs and Columbia University.

ENSO UPDATE

Overall ENSO conditions are currently near-neutral. Ocean temperatures in the far eastern equatorial Pacific are below average, while temperatures in the east-central and central Pacific are neutral to above average. The latest observations and forecasts no longer indicate a significant preference for development of La Niña conditions over the next few months. A continuation of neutral conditions appears most likely.

IRI PROBABILISTIC ENSO FORECAST*
Probability (%)
Time Period
2003 2004
*Based on sea surface temperature departures from the long-term average over the "NINO 3.4" region (120-170W, 5S-5N).

Hot Topic **Record-breaking heat wave hits Southern and Eastern Europe**

Record high monthly temperatures were recorded in Europe in June, and there were several reports of deaths and hospitalizations from heat exhaustion in southern and southeastern Europe. The Swiss Meteorological Service reported that June 2003 was the warmest on record (AP Worldstream), and it was the warmest June in Malta since 1947 (Malta Independent Daily). Rotating power cuts were instituted in Italy in order to relieve the demand on the electrical grid brought on by customer response to the high temperatures (Europe Energy). The high temperatures were blamed for at least 11 deaths in Italy (DPA), and deaths and hospitalizations in Croatia, Bulgaria, and Serbia (Xinhua). Above-normal temperatures in June in addition to continued months of below-normal precipitation contributed to a continuing decline in crop conditions in southern and eastern Europe (DPA, USDA).

EUROPE
TOTAL TEMPERATURE ANOMALY
for June 2003

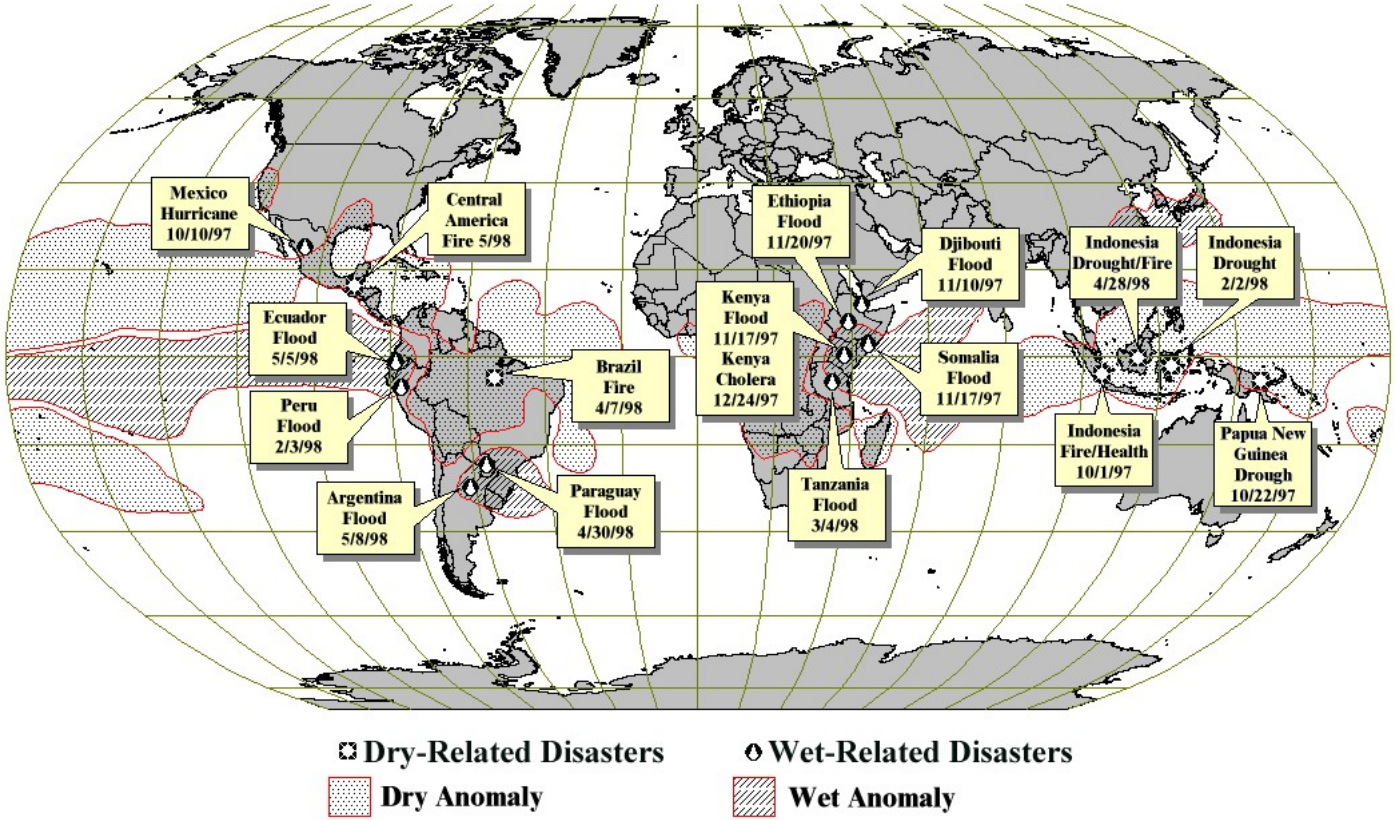
WORLD
TEMPERATURE PROBABILITY FORECAST
for the season August - October 2003 (made in July 2003)

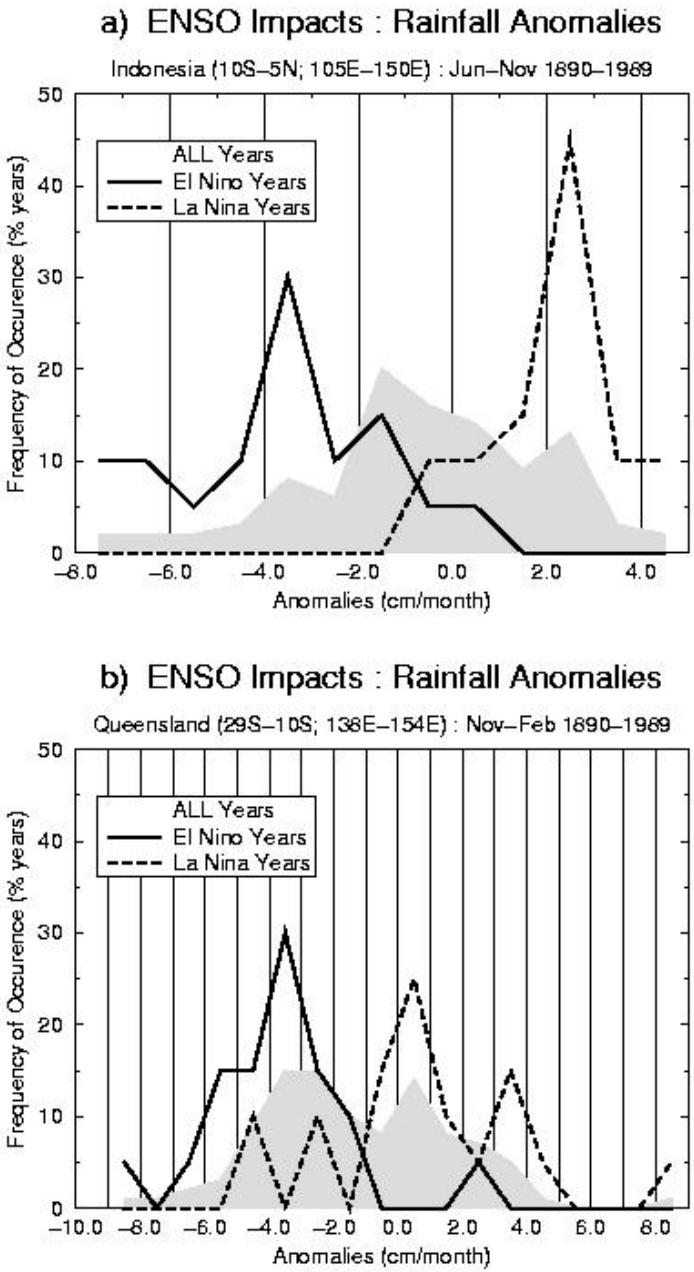
Probability (%) of Most Likely Category
Below-Normal | Normal | Above-Normal

The IRI seasonal forecast continues to indicate an enhanced probability for above average temperatures especially over tropical land areas.

The forecast shows the probability for temperatures falling within a given category (warm, near-normal, or cool) for the season, determined over a recent 30-year period. These categories are called "terciles". The most likely tercile is shown by color intensity. For example, the shade of pink, orange, or red indicates the probability of the warm tercile; the shade of blue or purple indicates the probability of the cool tercile. The gray areas show where the near-normal tercile has the highest probability. For regions that remain white, there is no indication of greater likelihood for one category (i.e. each category has a probability of 33.3%). The probability of a preferred tercile must be at least 40% in order for the forecast to show up as a non-white color. For additional information, please see http://iri.columbia.edu/climate/forecast/net_asmt/.

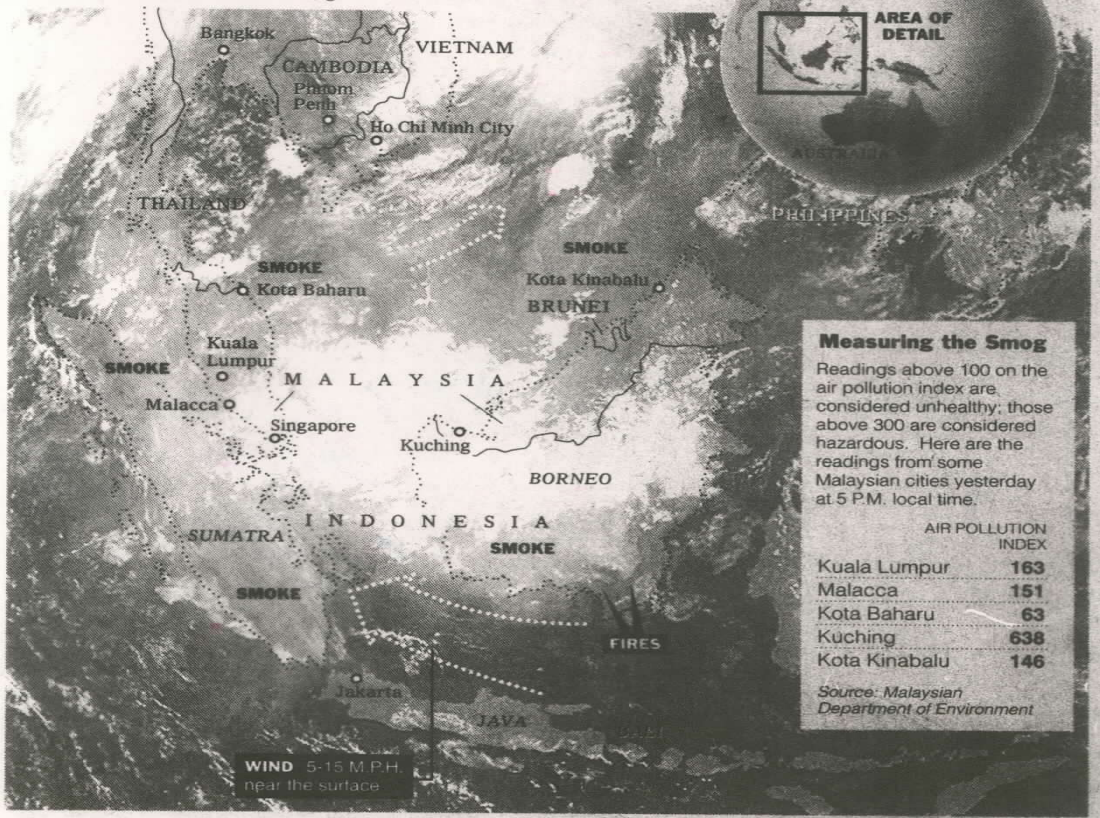
Contact Information: Phone: (+1) 845-680-4485 Fax: (+1) 845-680-4864 Email: cid@iri.columbia.edu


Mexico Hurricane 10/10/97
Central America Fire 5/98
Ecuador Flood 5/5/98
Peru Flood 2/3/98
Brazil Fire 4/7/98
Argentina Flood 5/8/98
Paraguay Flood 4/30/98
Ethiopia Flood 11/20/97
Kenya Flood 11/17/97 Kenya Cholera 12/24/97
Djibouti Flood 11/10/97
Somalia Flood 11/17/97
Tanzania Flood 3/4/98
Indonesia Drought/Fire 4/28/98
Indonesia Drought 2/2/98
Indonesia Fire/Health 10/1/97
Papua New Guinea Drough 10/22/97
Dry-Related Disasters
Wet-Related Disasters
Dry Anomaly
Wet Anomaly


a) ENSO Impacts : Rainfall Anomalies
Indonesia (10S–5N; 105E–150E) : Jun–Nov 1890–1989
ALL Years
El Nino Years
La Nina Years
Frequency of Occurence (% years)
Anomalies (cm/month)
b) ENSO Impacts : Rainfall Anomalies
Queensland (29S–10S; 138E–154E) : Nov–Feb 1890–1989
ALL Years
El Nino Years
La Nina Years
Frequency of Occurence (% years)
Anomalies (cm/month)

A Pall Over Southeast Asia

The widespread effects of huge forest fires are visible in this satellite photo. White areas are high clouds.



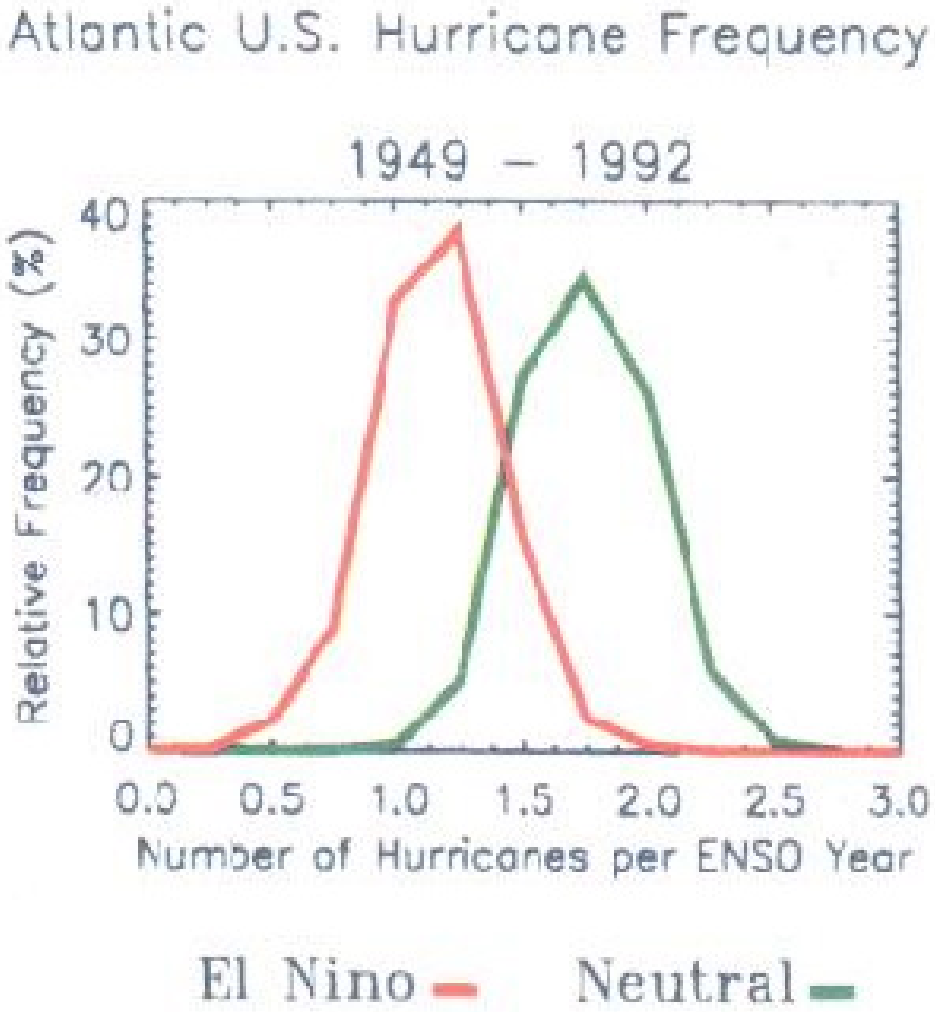
Measuring the Smog

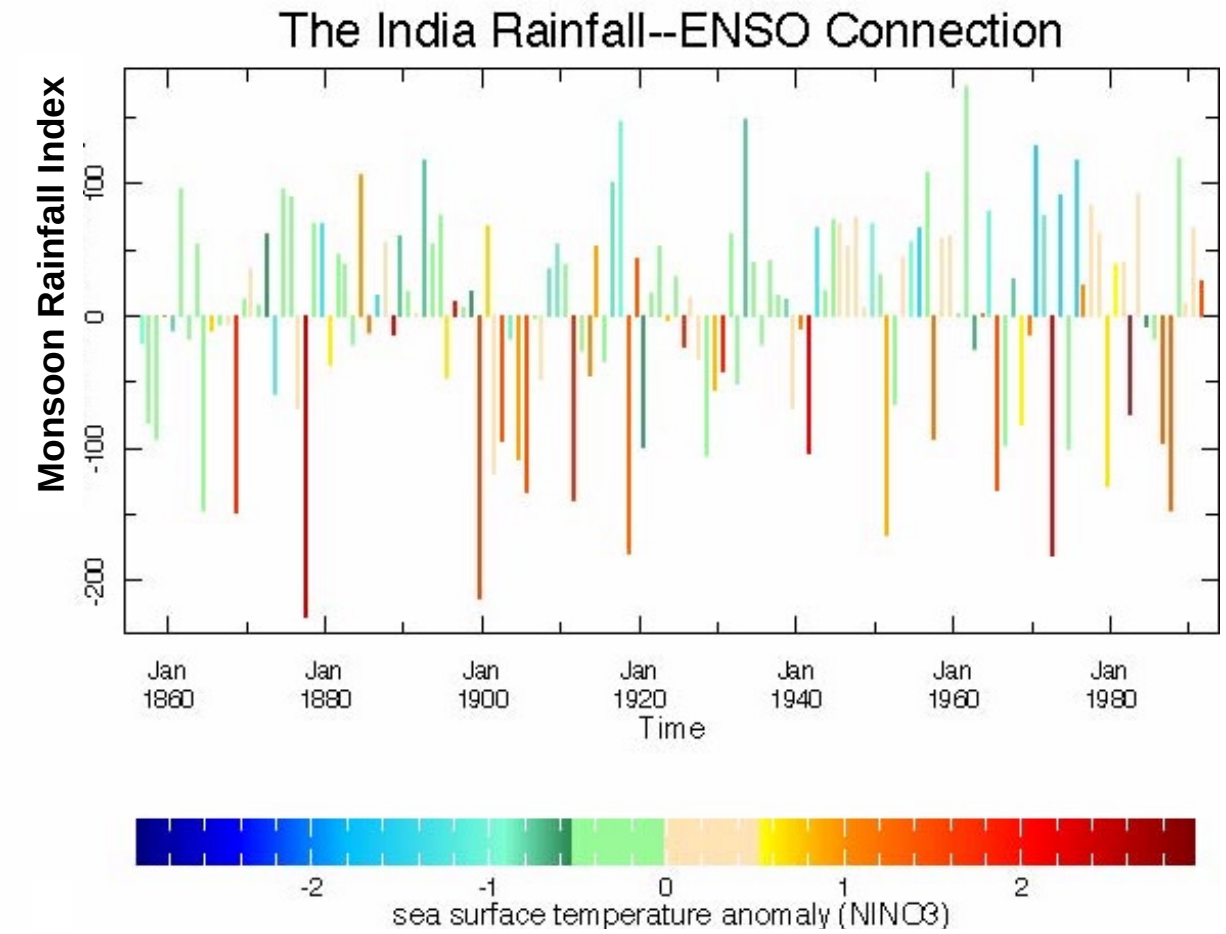
Readings above 100 on the air pollution index are considered unhealthy; those above 300 are considered hazardous. Here are the readings from some Malaysian cities yesterday at 5 P.M. local time.

	AIR POLLUTION INDEX
Kuala Lumpur	163
Malacca	151
Kota Baharu	63
Kuching	638
Kota Kinabalu	146

Source: Malaysian Department of Environment

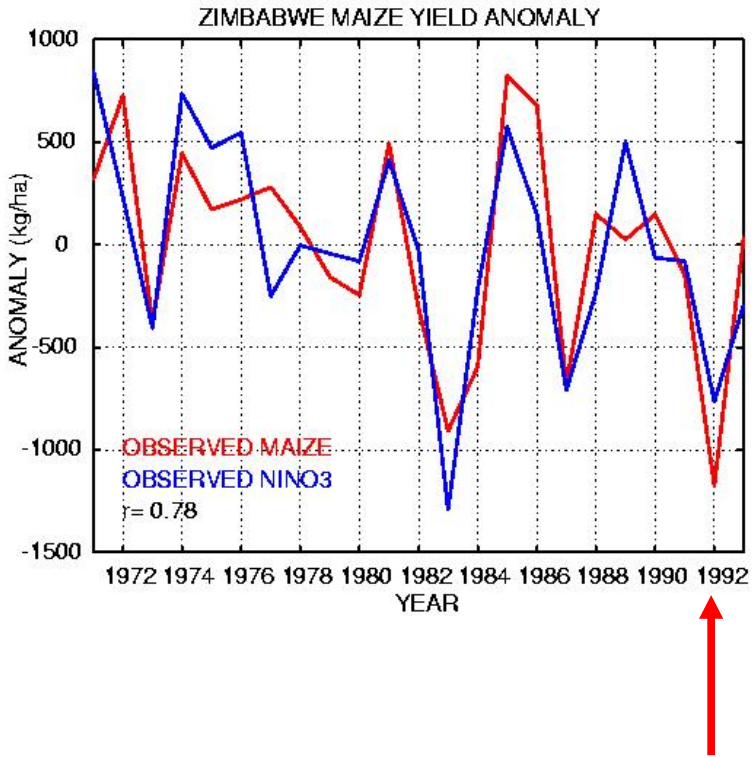
Satellite image via National Oceanic and Atmospheric Administration/The New York Times

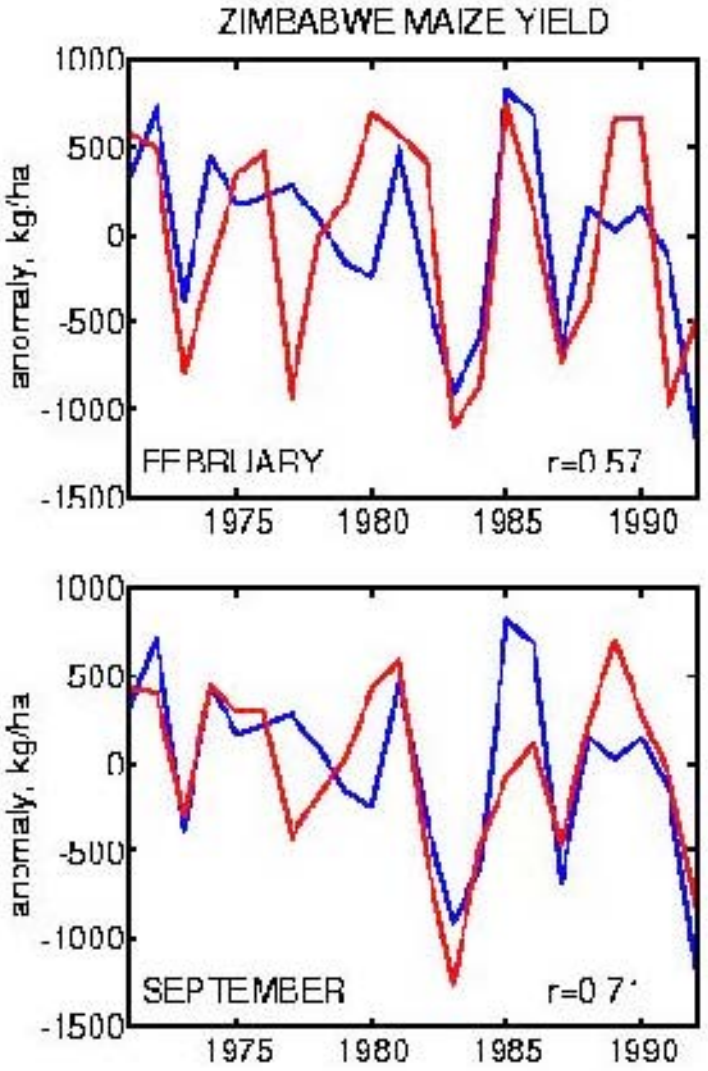

Atlantic U.S. Hurricane Frequency
1949 – 1992
Relative Frequency (%)
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Number of Hurricanes per ENSO Year
El Nino
Neutral



Red = warm NINO3 SSTA - El Niño

Blue = cold NINO3 SSTA - La Niña





After Cane, Eshel and Buckland
Nature 1994

Observed

Forecast

Summary

- **The basic ENSO mechanism is the Bjerknes Feedback + equatorial ocean dynamics**
- **ENSO events can be predicted**
- **But prediction skill is limited by**
  - **Model flaws, data assimilation methods, limited data, inherent limits to predictability**
- **ENSO events have global impacts**
  - **Many occur reliably,**
  - **but most are just more likely with an El Niño or La Niña**