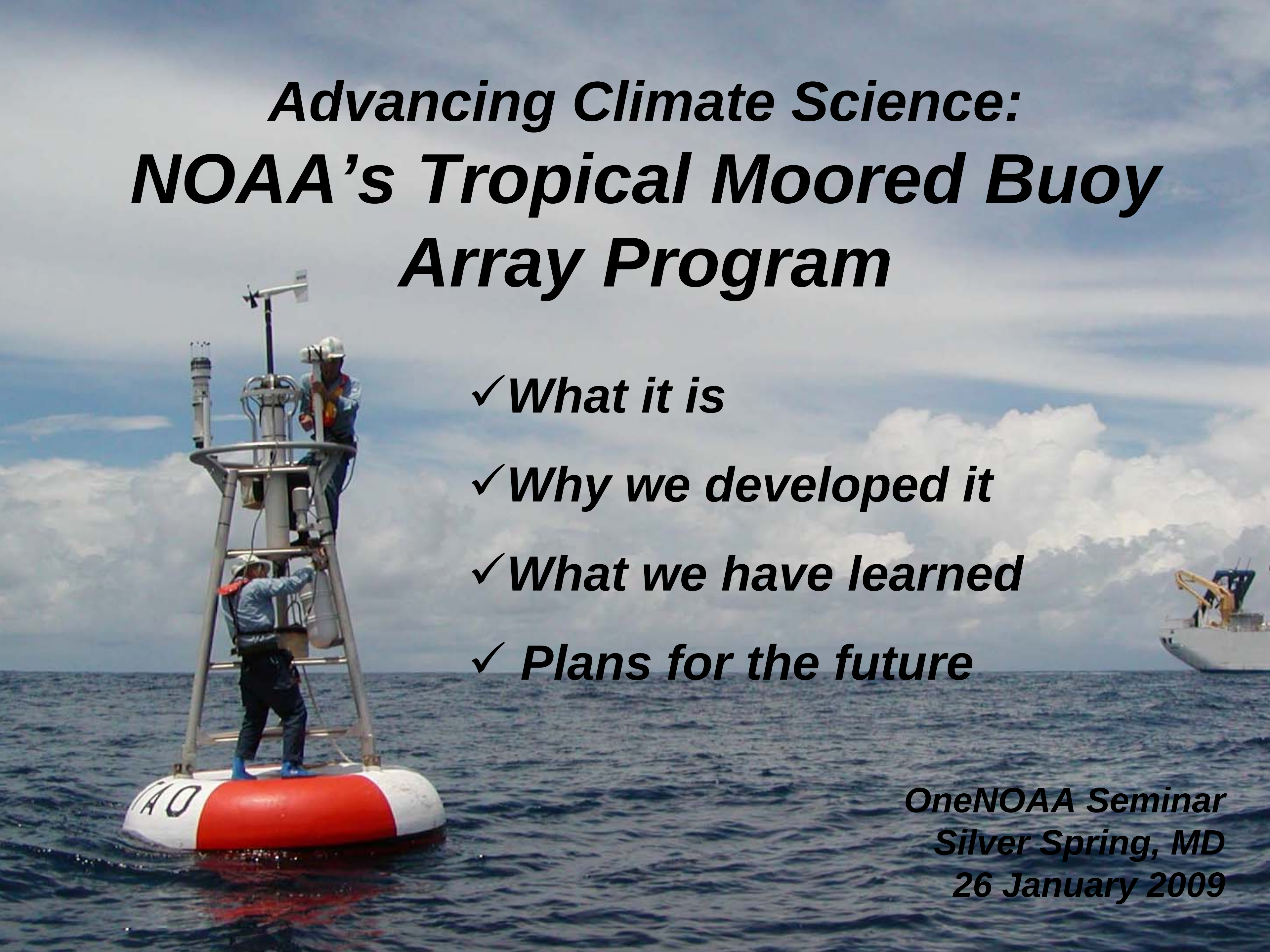


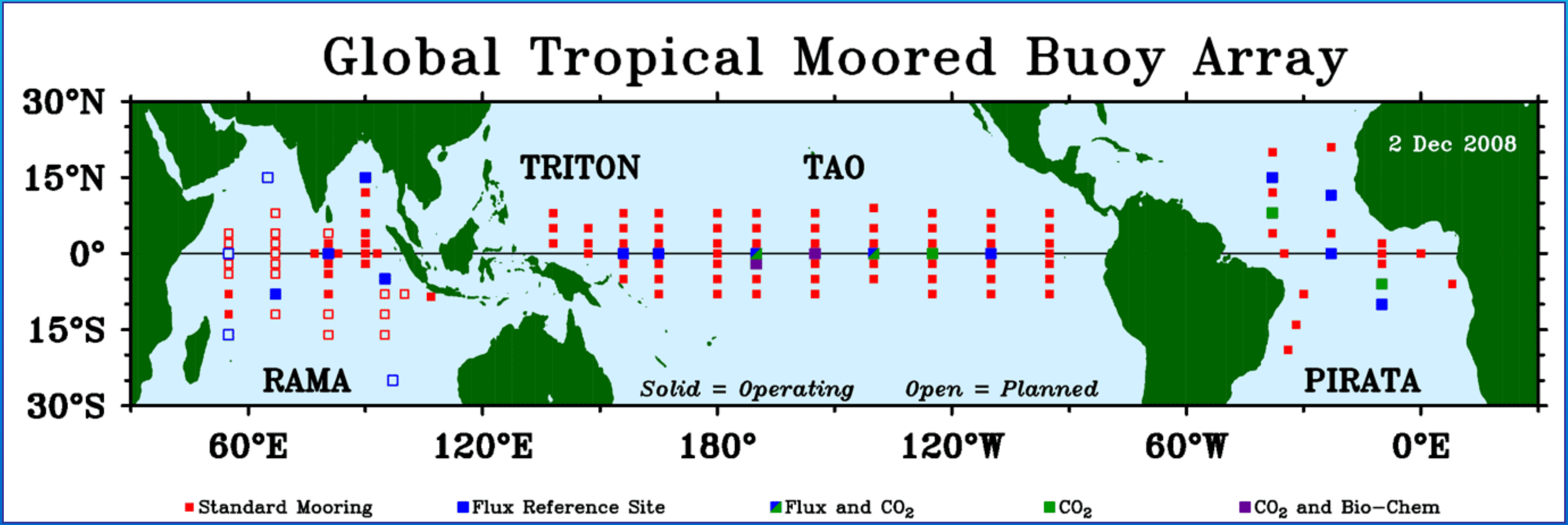
Advancing Climate Science:
NOAA's Tropical Moored Buoy Array Program

- ✓ *What it is*
- ✓ *Why we developed it*
- ✓ *What we have learned*
- ✓ *Plans for the future*

OneNOAA Seminar
Silver Spring, MD
26 January 2009

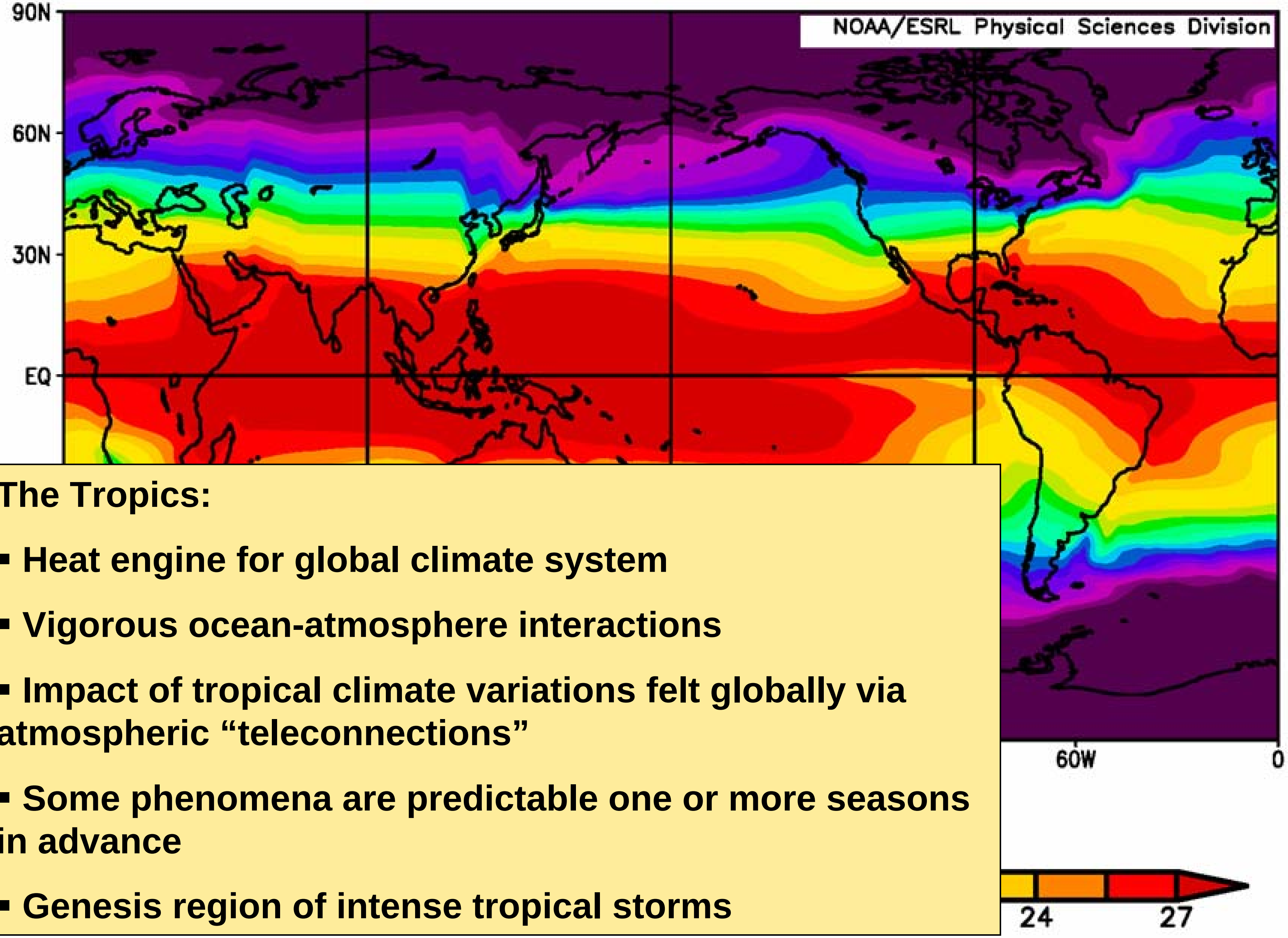
Tropical Moored Buoy Array Program:
A coordinated, multi-national effort to implement a sustained moored buoy observing system in the global tropics for climate research and forecasting

NOAA Strategic Plan Goal:
Understanding climate variability and change to enhance society's ability to plan and respond.



- Developed by research scientists
- A contribution to GOOS, GCOS, and GEOSS

Surface Temperature (°C)



The Tropics:

- **Heat engine for global climate system**
- **Vigorous ocean-atmosphere interactions**
- **Impact of tropical climate variations felt globally via atmospheric “teleconnections”**
- **Some phenomena are predictable one or more seasons in advance**
- **Genesis region of intense tropical storms**

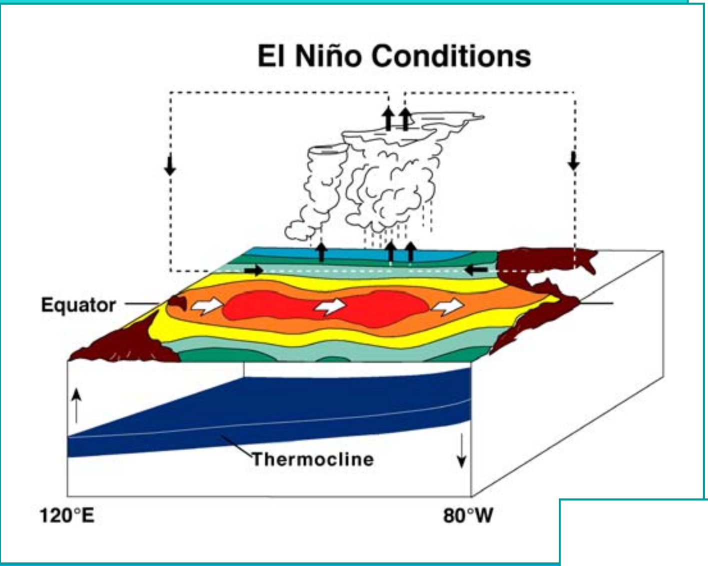
Pacific Ocean

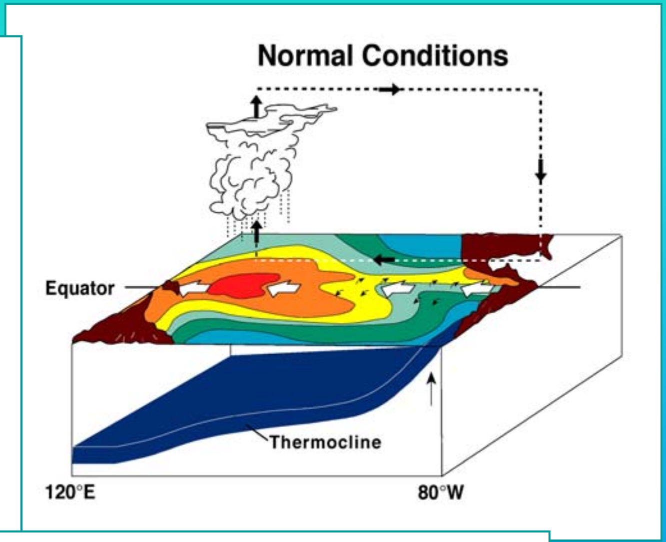
TAO/TRITON

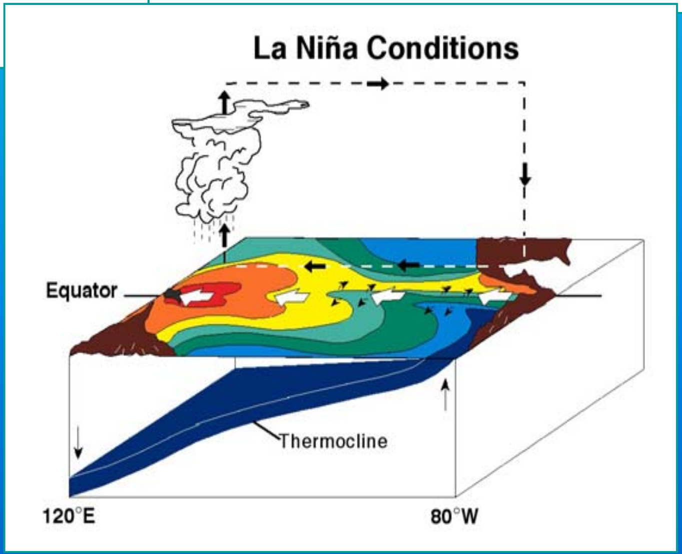
TAO=<u>T</u>ropical <u>A</u>tmosphere <u>O</u>cean Array

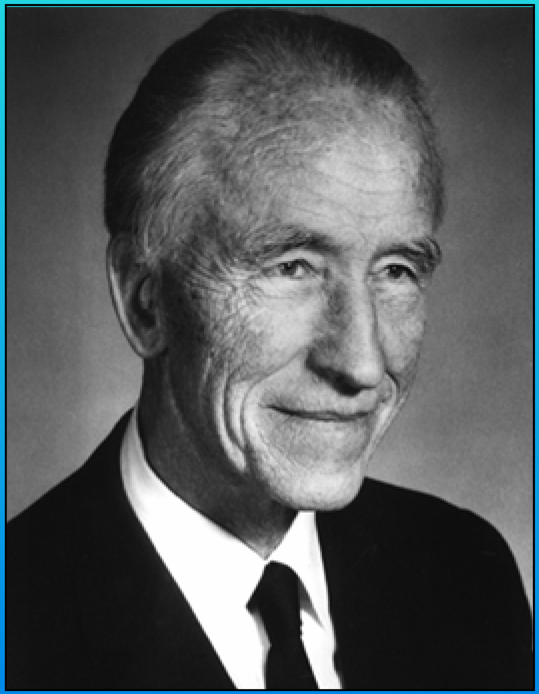
TRITON=<u>TRI</u>angle <u>T</u>rans <u>O</u>cean Buoy <u>N</u>etwork

El Niño and the Southern Oscillation (ENSO)









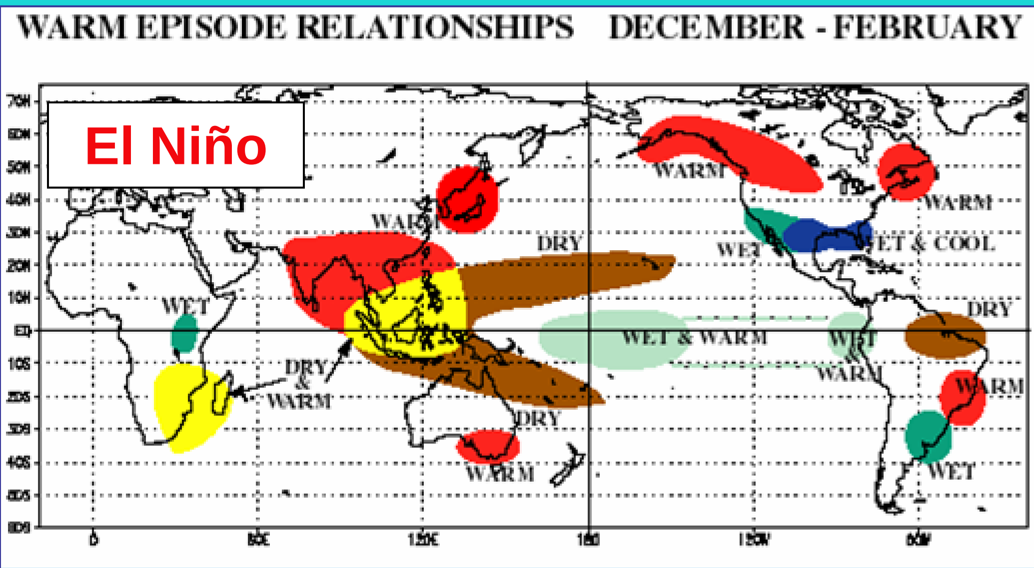
El Niño=Warm Phase ENSO

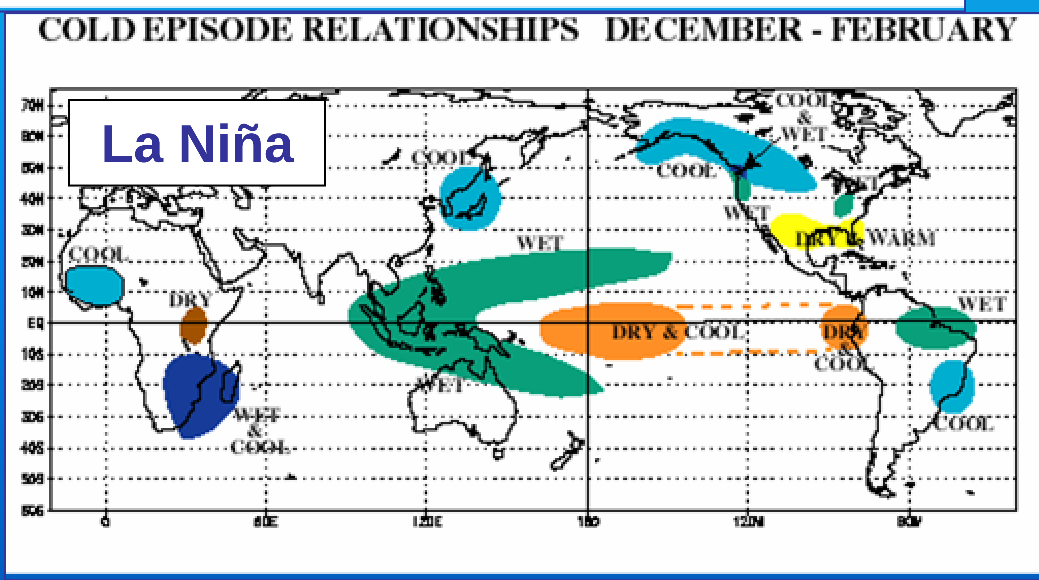
La Niña=Cold Phase ENSO

Jacob Bjerknes

1897-1975

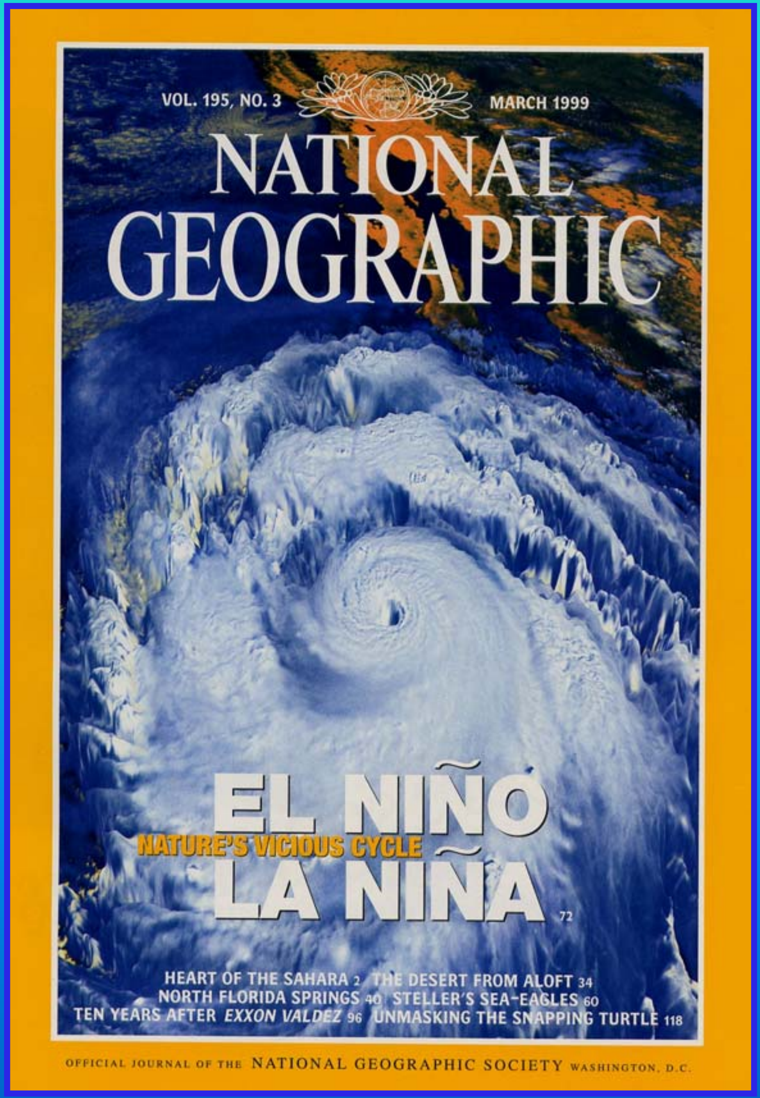
El Niño & La Niña Impacts on Patterns of Weather Variability





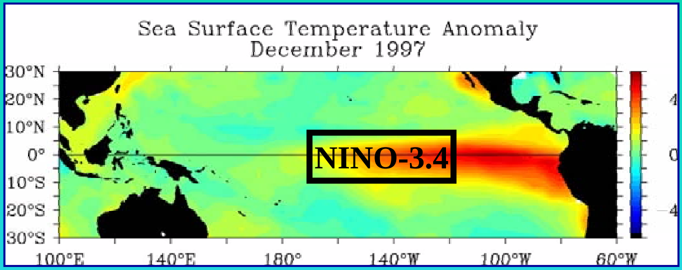
El Niño and La Niña shift the probability for droughts, floods, heat waves, extreme weather events around the globe

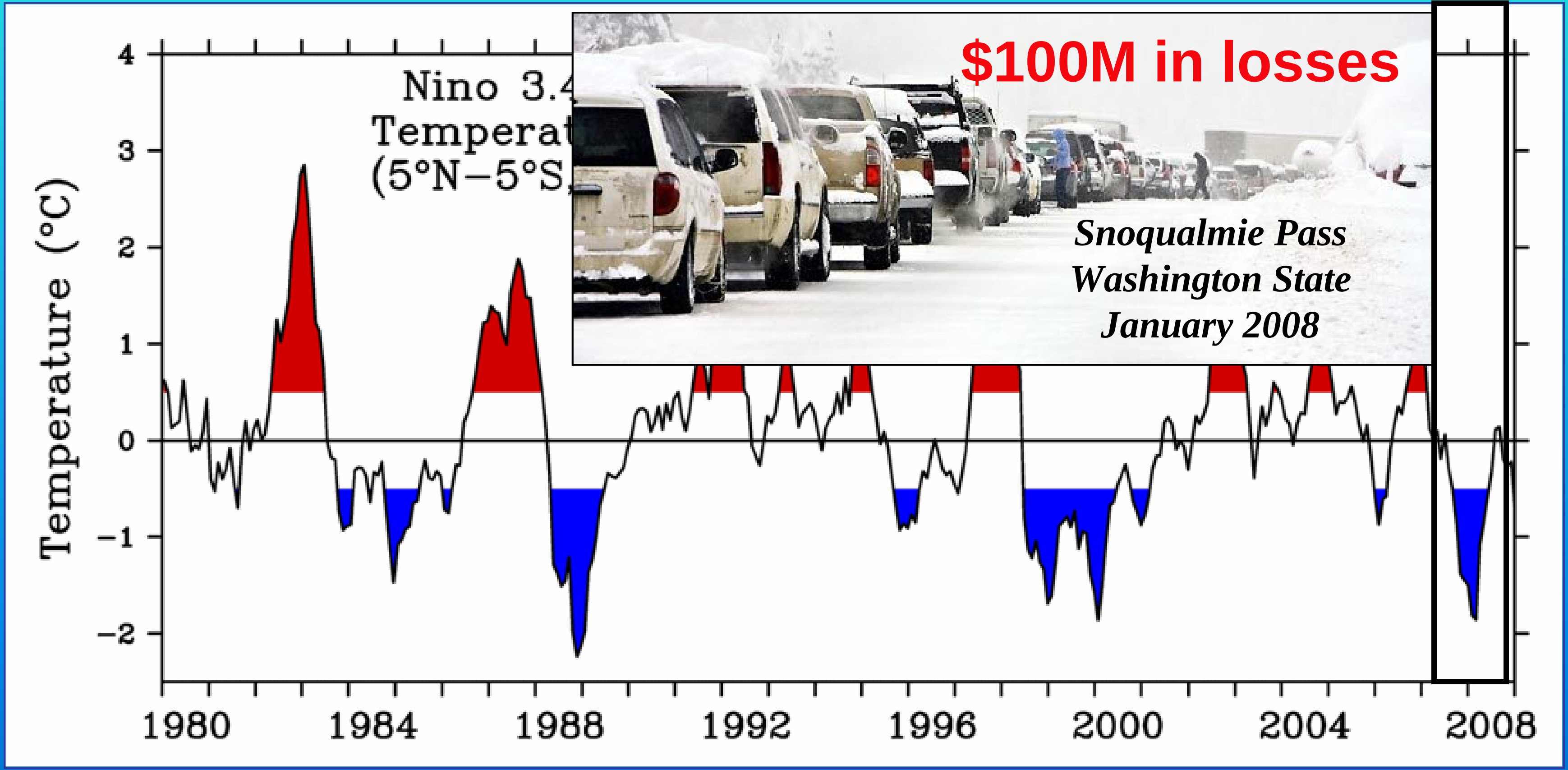
Impacts on Tropical Storms



- **El Niño tends to suppress formation of Atlantic hurricanes**
- **El Niño tends to increase intensity and geographic range of Pacific hurricanes**
- **Opposite tendencies occur during La Niña**

El Niño & La Niña Index





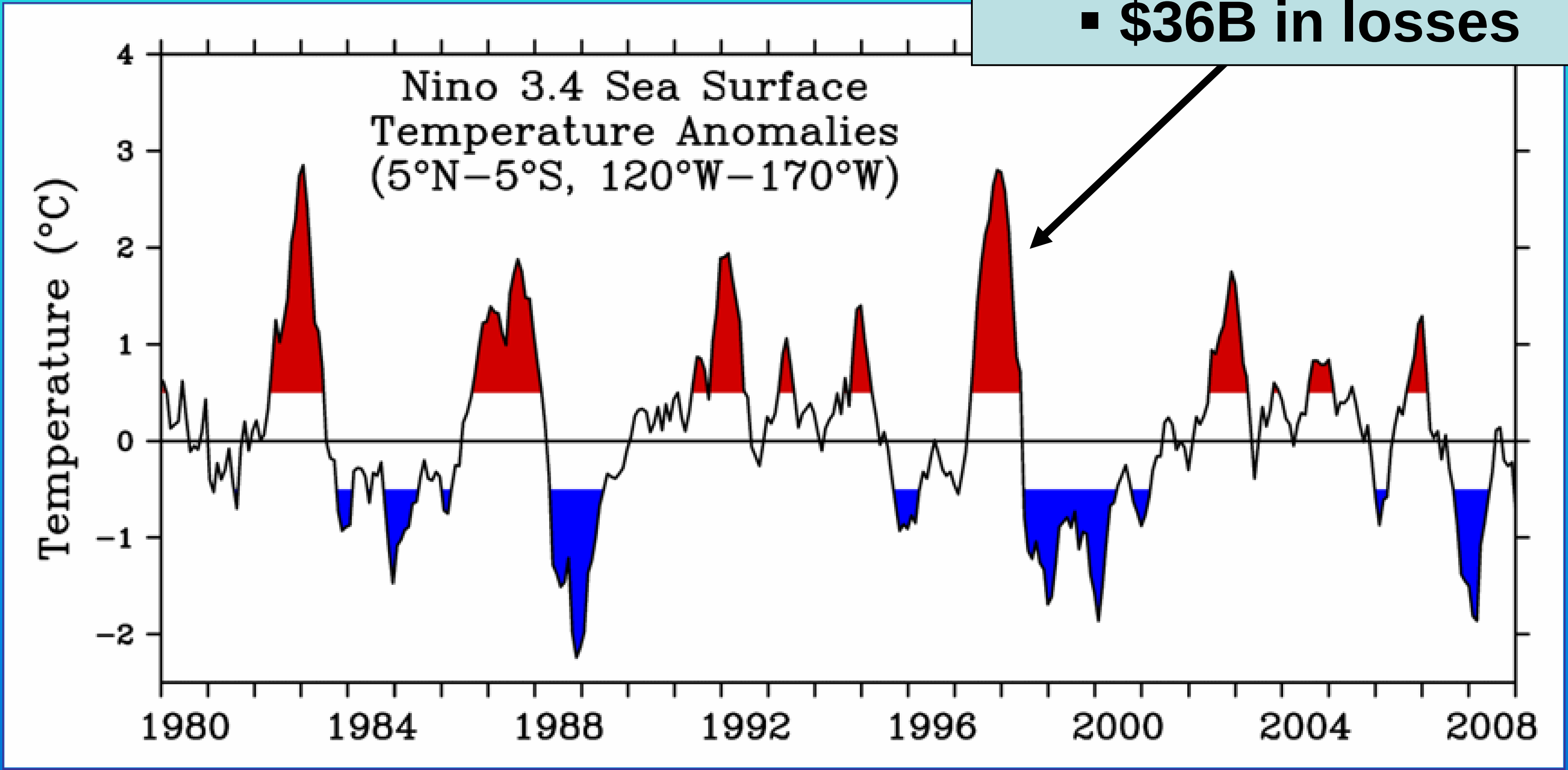
NINO3.4 ≥ 0.5°C for 5 months= El Niño

NINO3.4 ≤ -0.5°C for 5 months= La Niña

El Niño & La Niña Index

1997-98 El Niño Global Impacts:

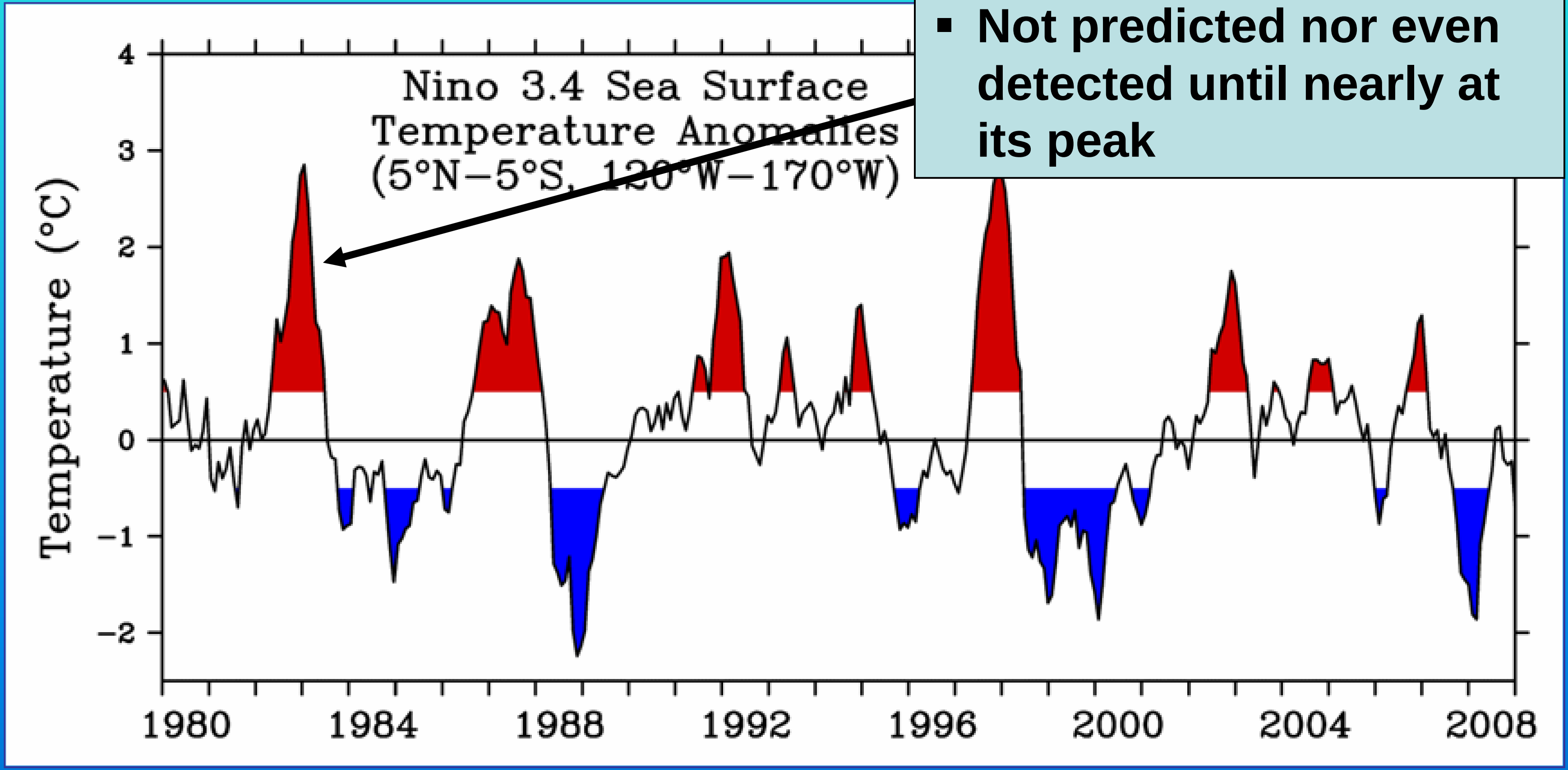
- **23,000 fatalities**
- **$36B in losses**



NINO3.4 ≥ 0.5°C for 5 months= El Niño

NINO3.4 ≤ -0.5°C for 5 months= La Niña

El Niño & La Niña Index

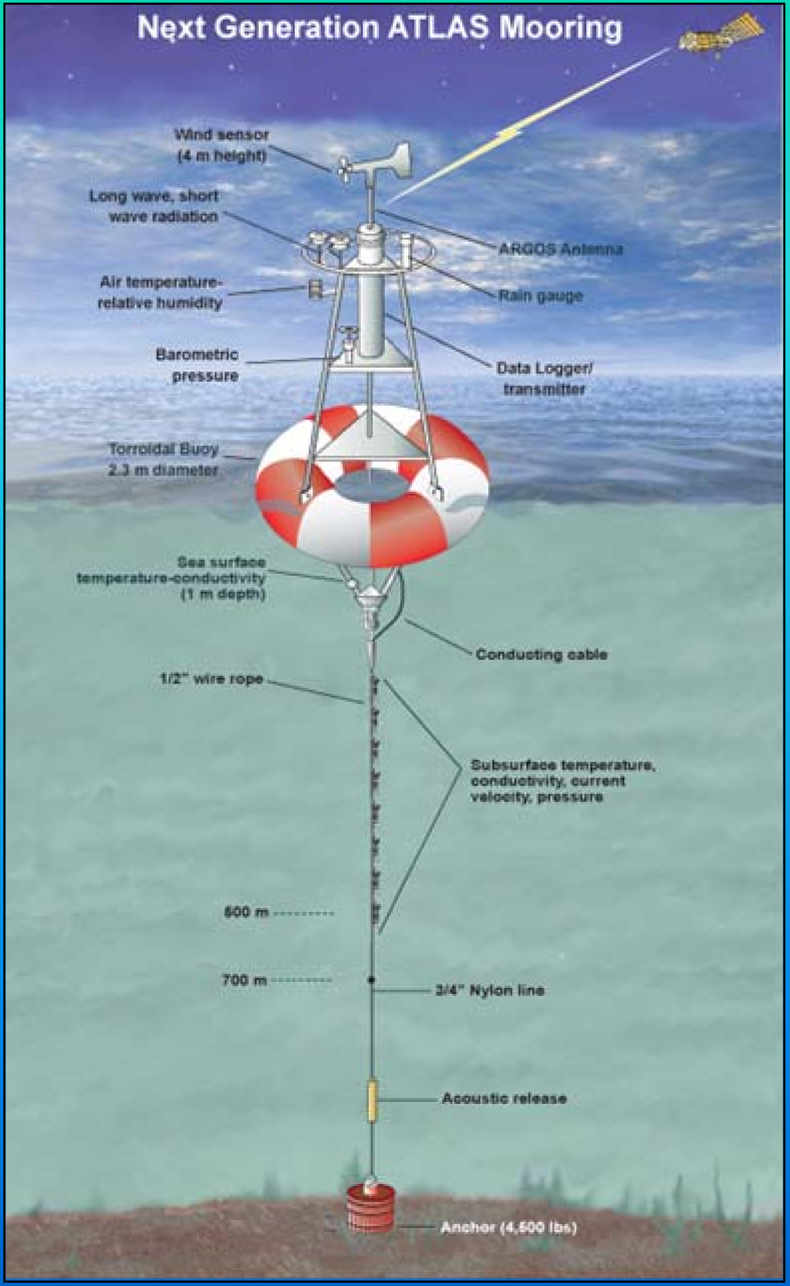


1982-83 El Niño:

- **Strongest of the 20th century up to that time**
- **Not predicted nor even detected until nearly at its peak**

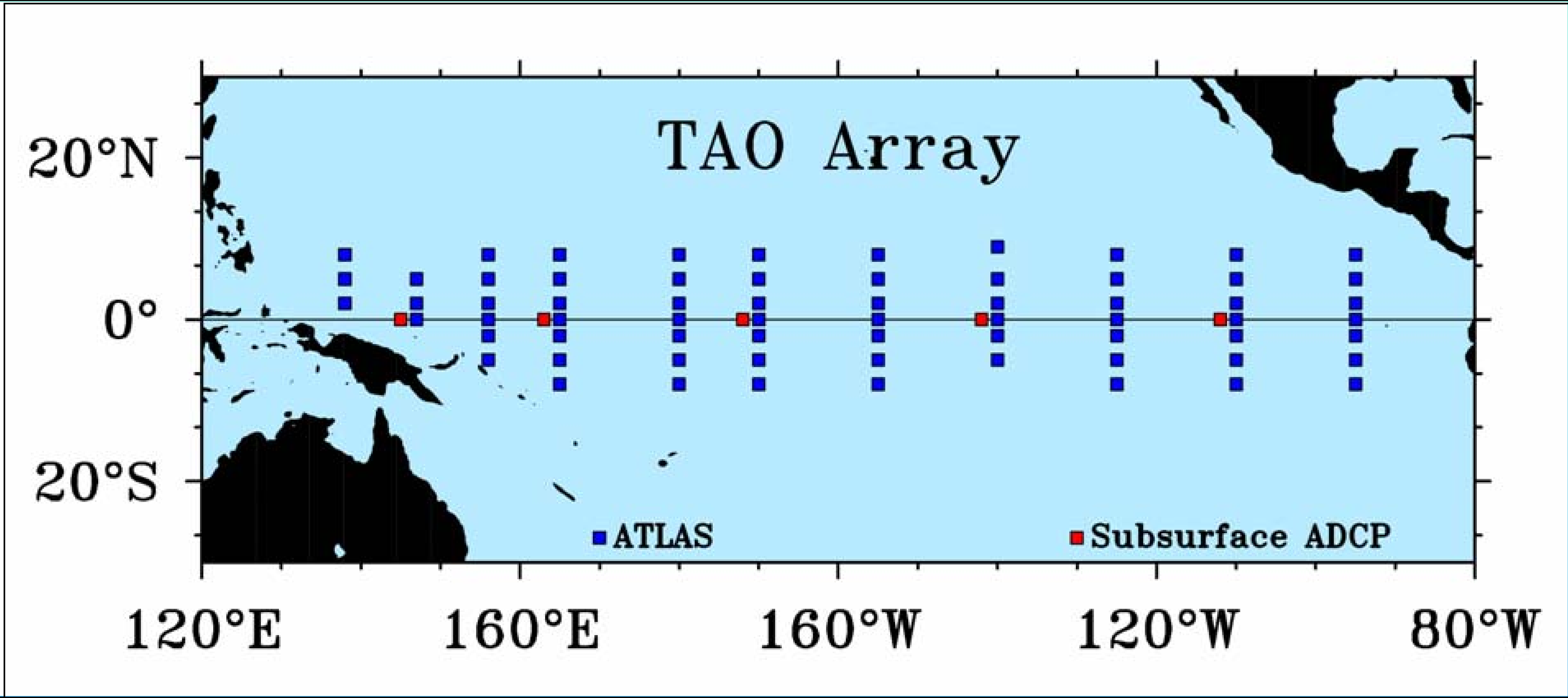
NINO3.4 ≥ 0.5°C for 5 months= El Niño

NINO3.4 ≤ -0.5°C for 5 months= La Niña



ATLAS Mooring

- ✓ **Low cost**
- ✓ **Real-time data**
- ✓ **Ocean and atmosphere**
- ✓ **Rapid sampling in time**

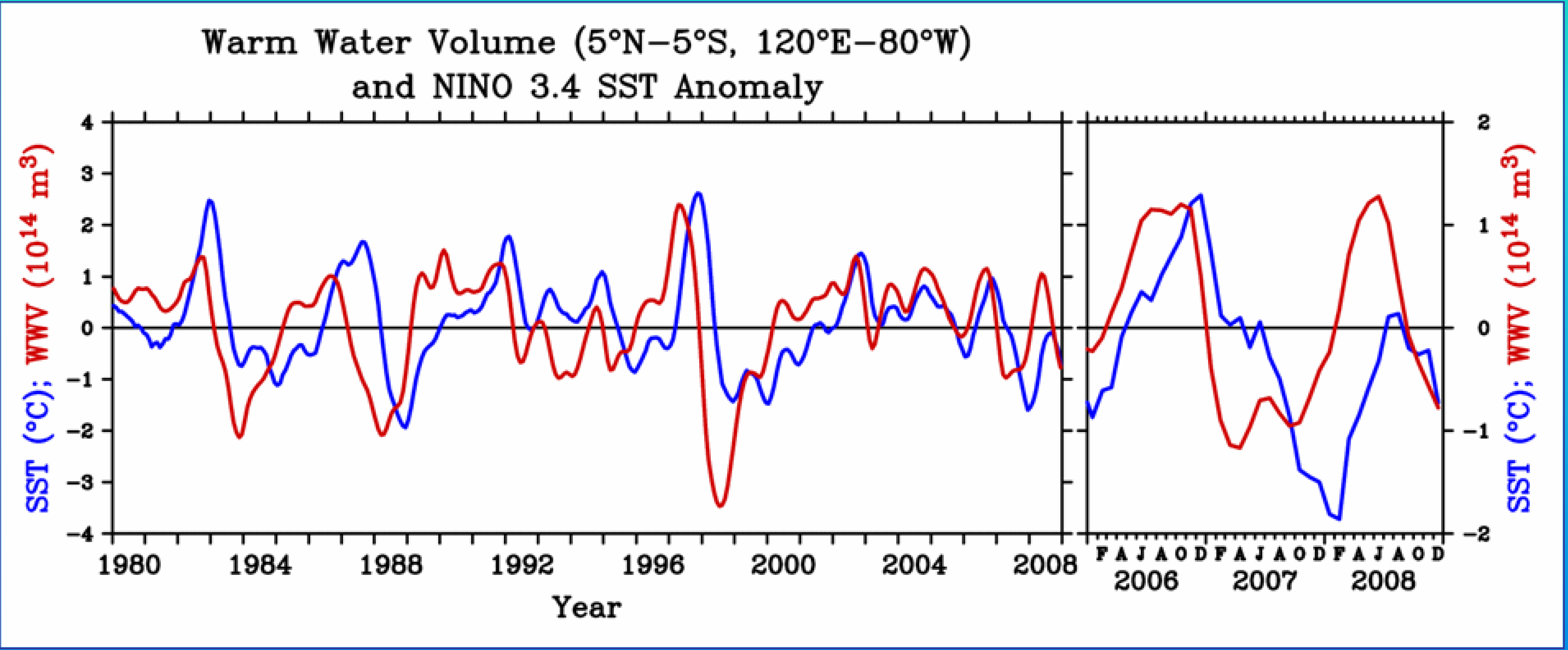


- Tropical Atmosphere Ocean (TAO) array built up over 10 years (1985-94)
- Presently a U.S./Japan collaboration (as of 2000)
- Transition to operations underway (since 2005)

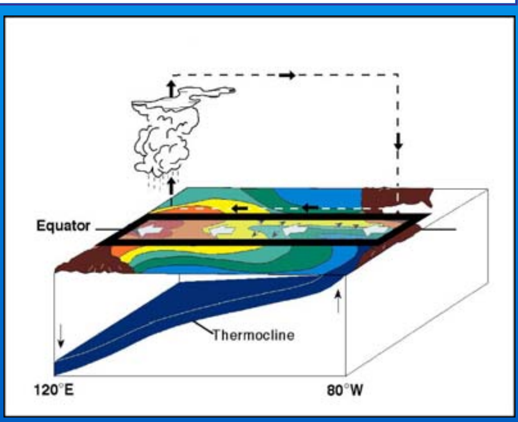
Processes Governing ENSO Evolution

- **Low frequency (seasonal) deterministic dynamics**
  - ✓ **Coupled feedbacks between ocean and atmosphere**
  - ✓ **Wind forced changes in ocean circulation that redistribute heat in the upper ocean**
- **High frequency (days to weeks) wind forcing**
  - ✓ **Weather noise**
  - ✓ **Introduces irregularity (timing, duration, amplitude)**

Upper Ocean Heat Content and ENSO

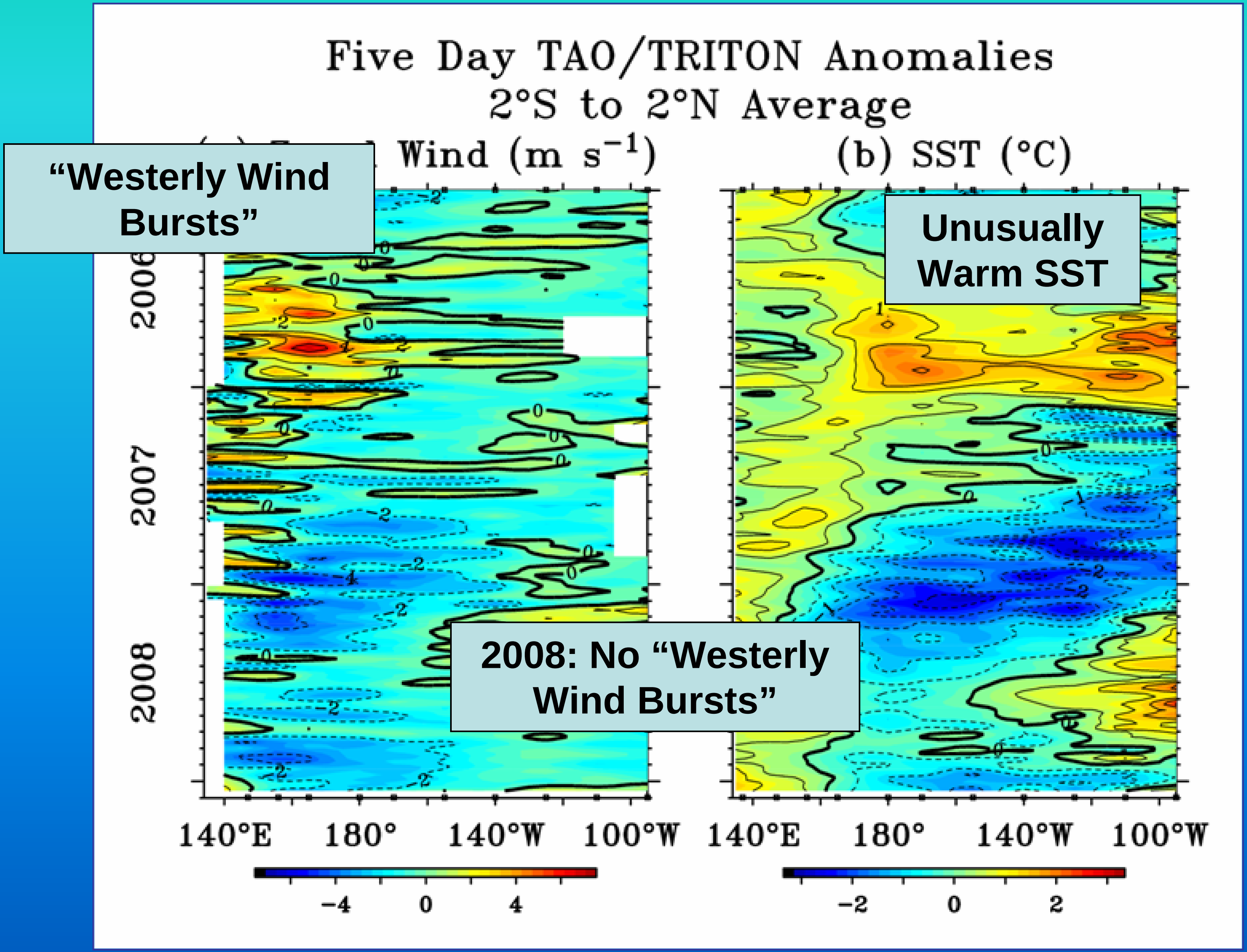


WWV index for heat content based TAO/TRITON, XBT and Argo data



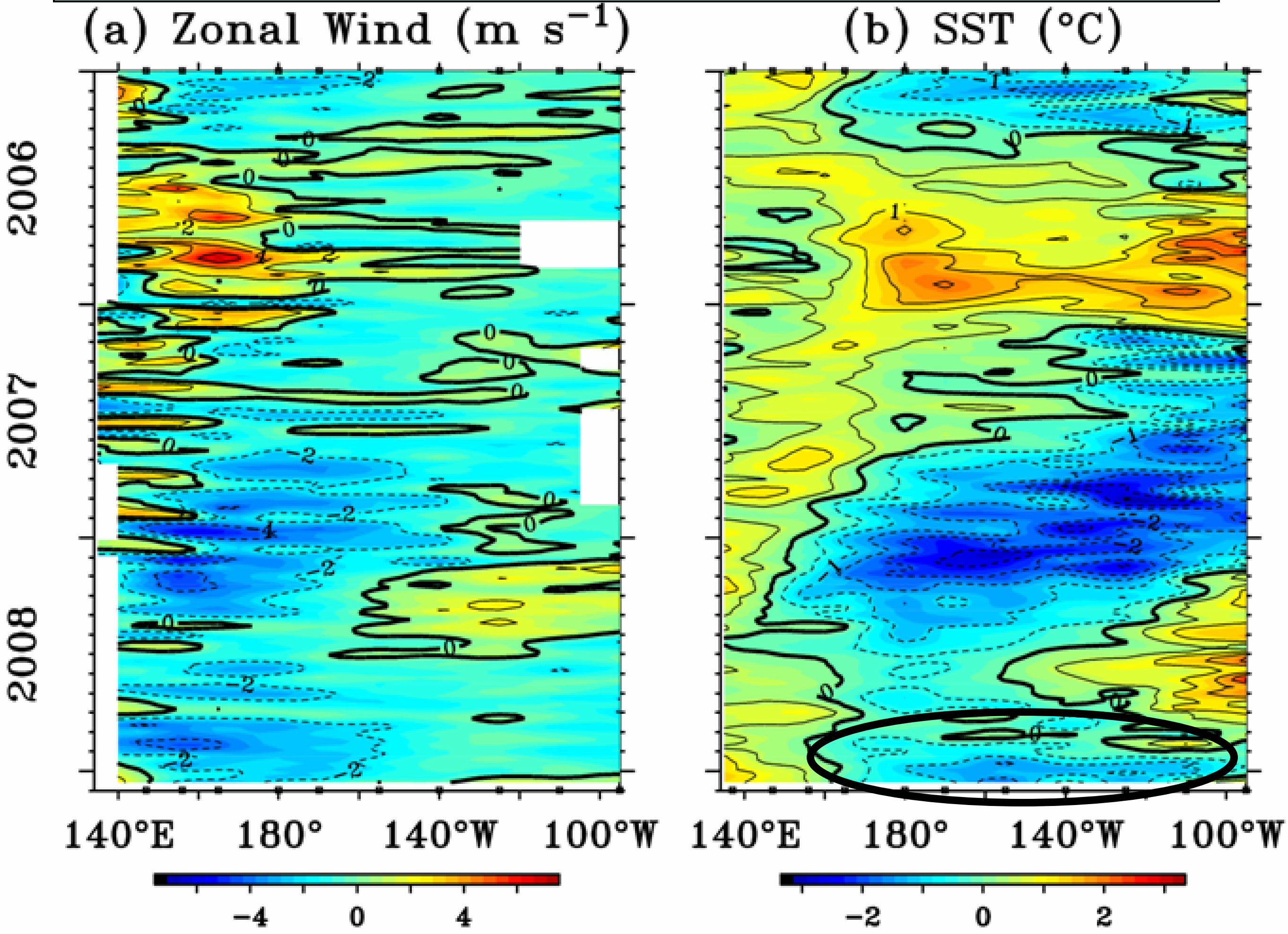
Upper ocean heat content provides basin scale preconditioning for ENSO cycle variations.

ENSO Cycle, 2006-08



ENSO Cycle, 2006-08

High frequency wind forcing affects the evolution of ENSO events

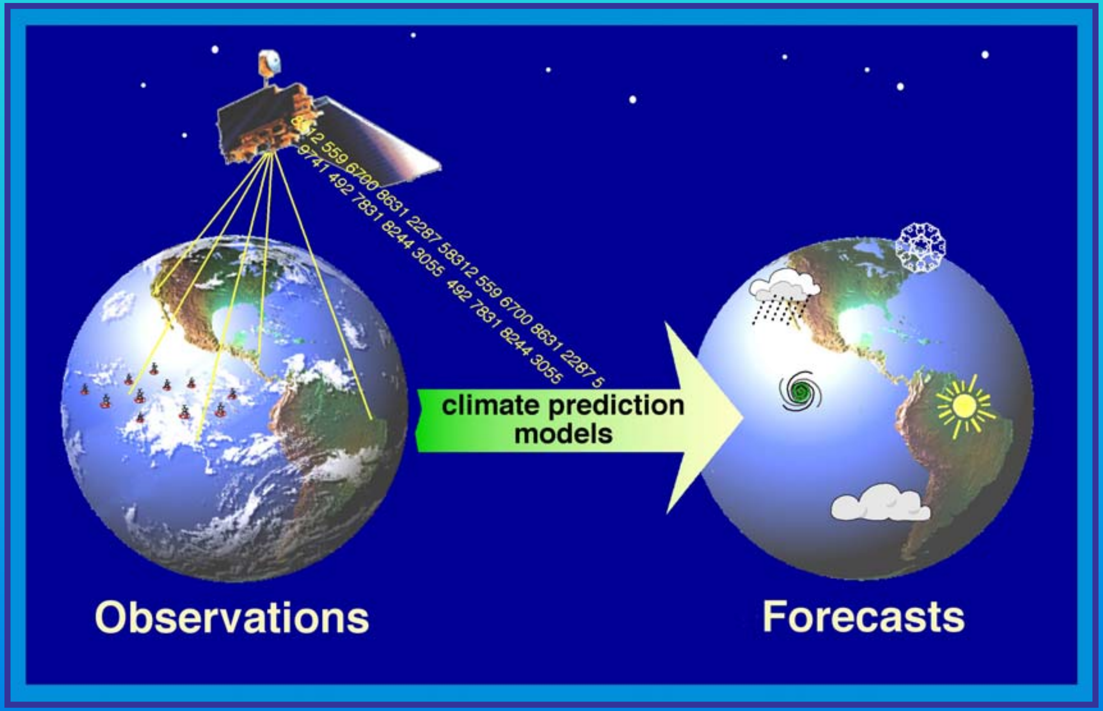


Current Conditions (Developing La Niña)

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

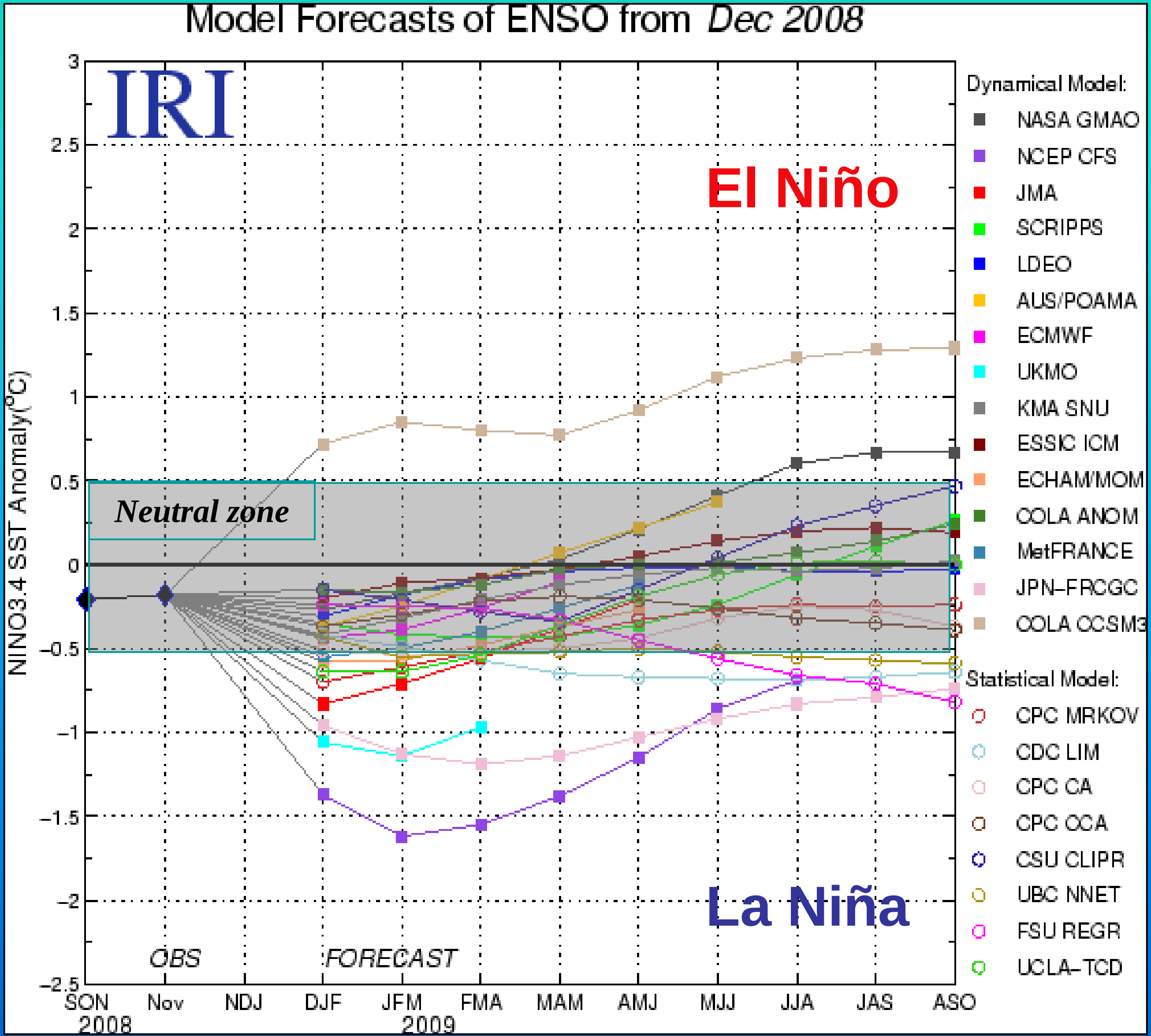
http://www.pmel.noaa.gov/tao/

ENSO is Predictable



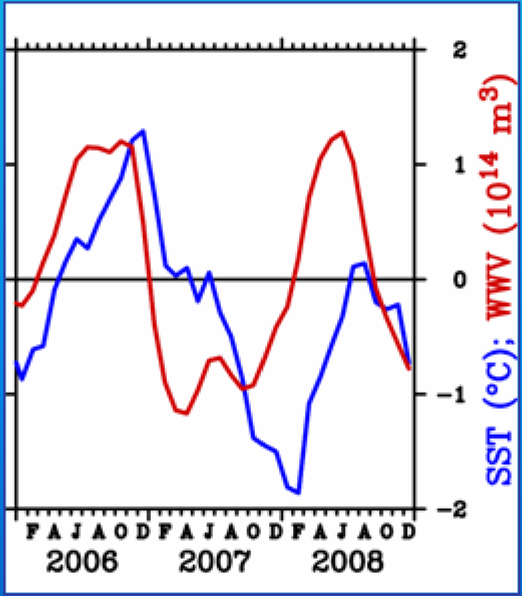
- ***First successful El Niño prediction in 1986***
- ***Models show skill at 1-3 season lead***
- ***Predictability based on slow evolution of upper ocean heat content***
- ***Predictability limited by model bias, initial error, weather noise***

Niño-3.4 Predictions From Dec 2008



"Developing La Niña conditions are likely to continue into Northern Hemisphere Spring 2009"

NOAA/NCEP
8 Jan 2009



Compiled by the International Research Institute for Climate and Society (IRI)

Atlantic Ocean

PIRATA

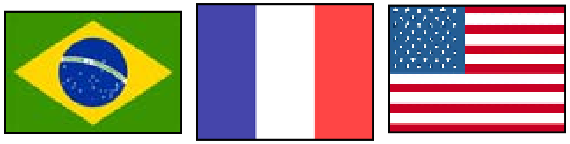
PIRATA=Predication and Research Moored Array in the Tropical Atlantic

PIRATA

Goals:

1) **Describe, understand and predict processes controlling SST variability**
2) **Understand the role of SST in ocean-atmosphere interactions that affect the West African Monsoon, Brazil rainfall, and the statistics of Atlantic hurricane activity**
3) **Identify internal vs remote climate influences in the tropical Atlantic**

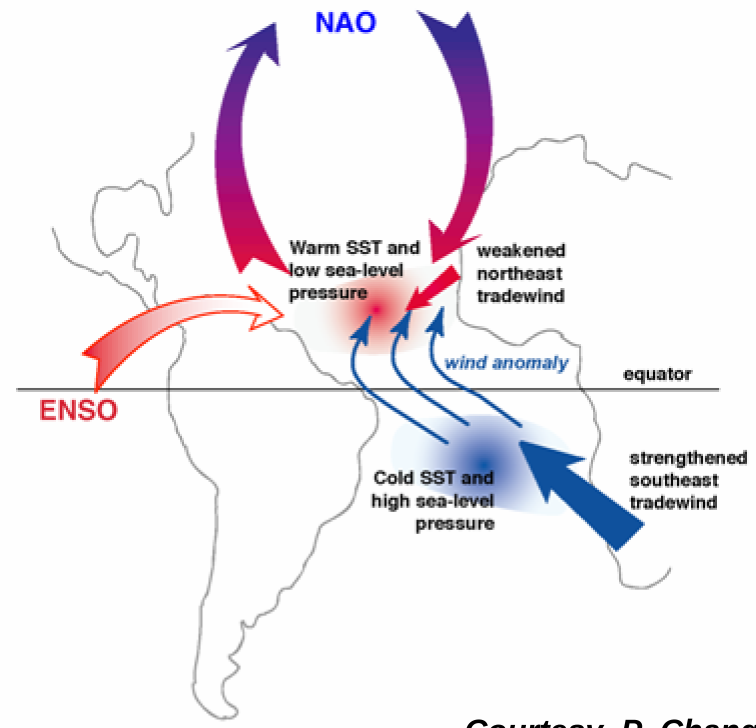
Partners:



✓**Brazil (INPE & DHN) & France (IRD & Meteo-France) provide logistic support & most ship time (~300 sea days during 2004-08)**

✓**USA (NOAA) provides most mooring equipment & data processing**

Mechanisms of Tropical Atlantic Variability



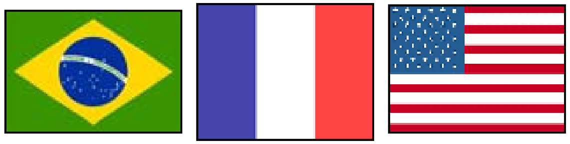
Courtesy, P. Chang

PIRATA

Goals:

1) Describe, understand and predict processes controlling SST variability
2) Understand the role of SST in ocean-atmosphere interactions that affect the West African Monsoon, Brazil rainfall, and the statistics of Atlantic hurricane activity
3) Identify internal vs remote climate influences in the tropical Atlantic

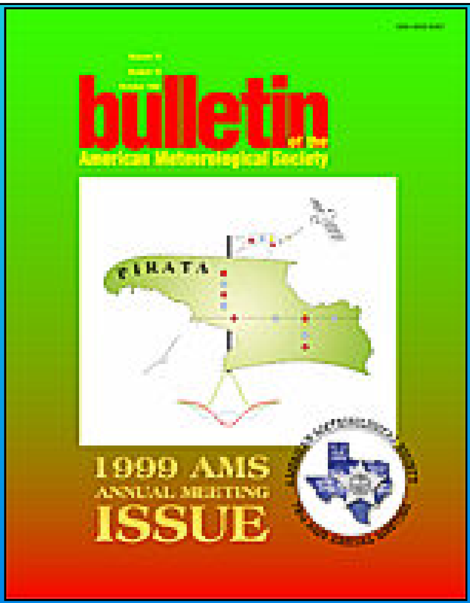
Partners:

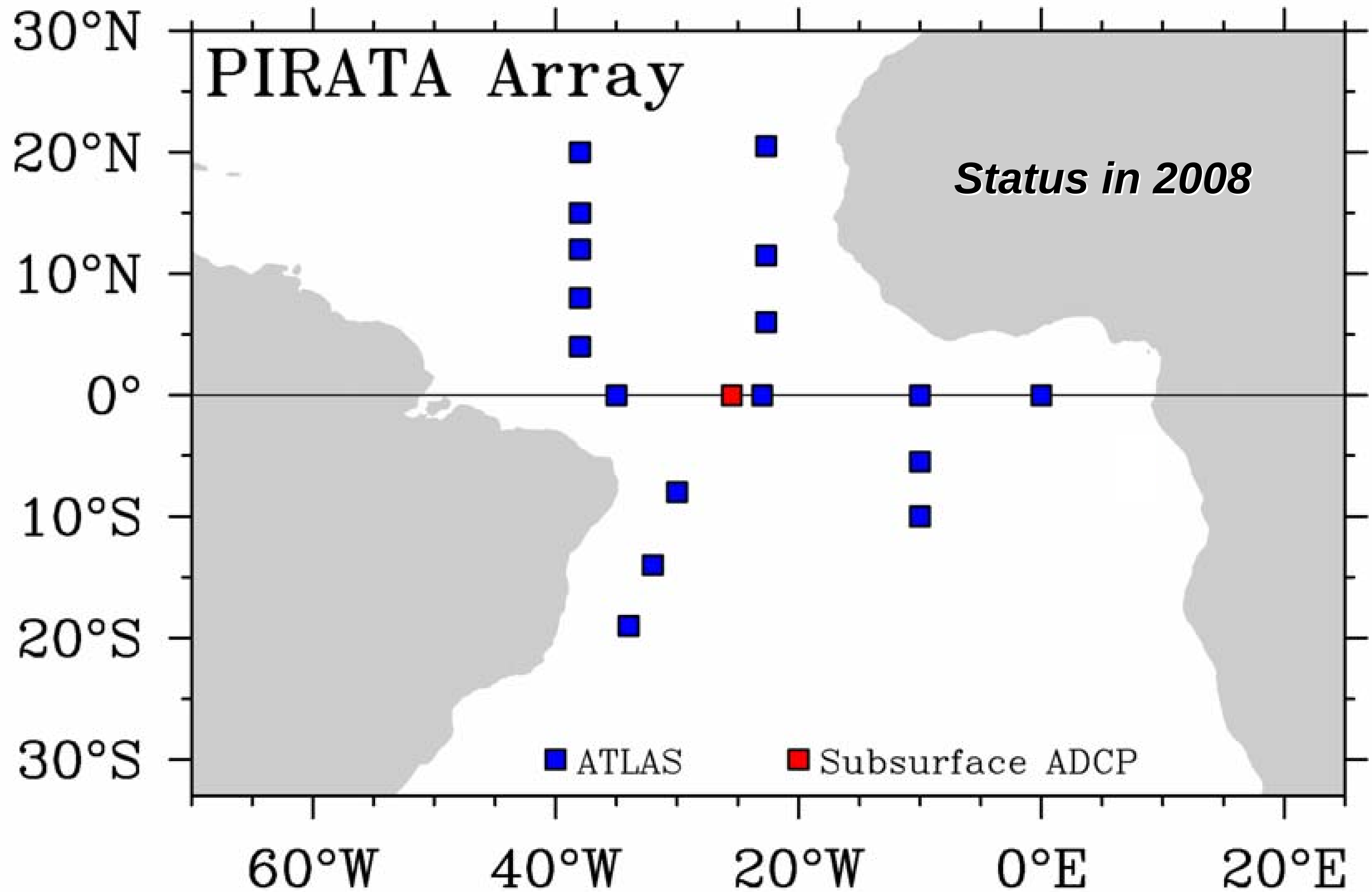


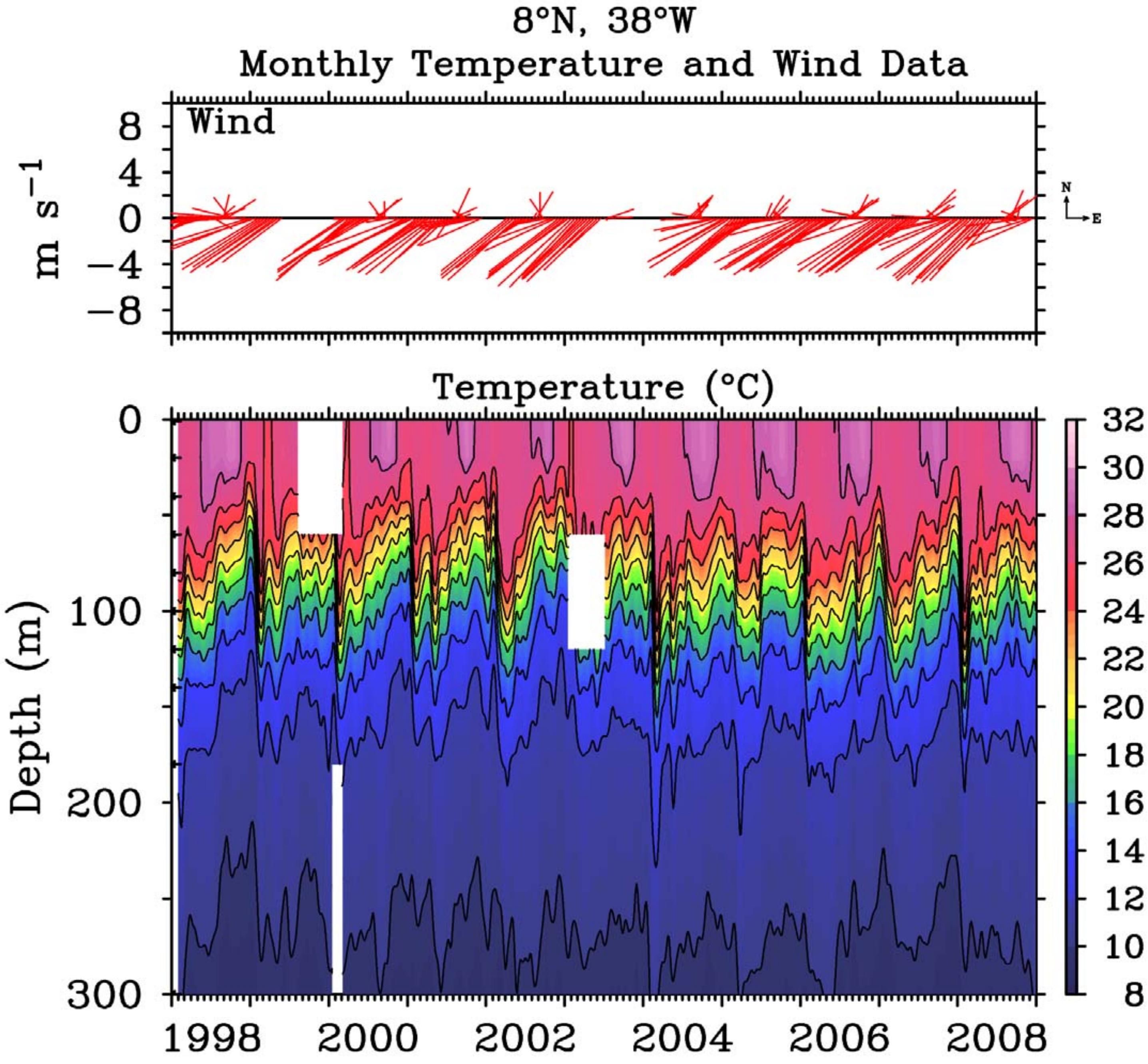
✓Brazil (INPE & DHN) & France (IRD & Meteo-France) provide logistic support & most ship time (~300 sea days during 2004-08)

✓USA (NOAA) provides most mooring equipment & data processing

PIRATA Introduced October 1998




PIRATA Array
Status in 2008
ATLAS
Subsurface ADCP
30°N
20°N
10°N
0°
10°S
20°S
30°S
60°W
40°W
20°W
0°E
20°E



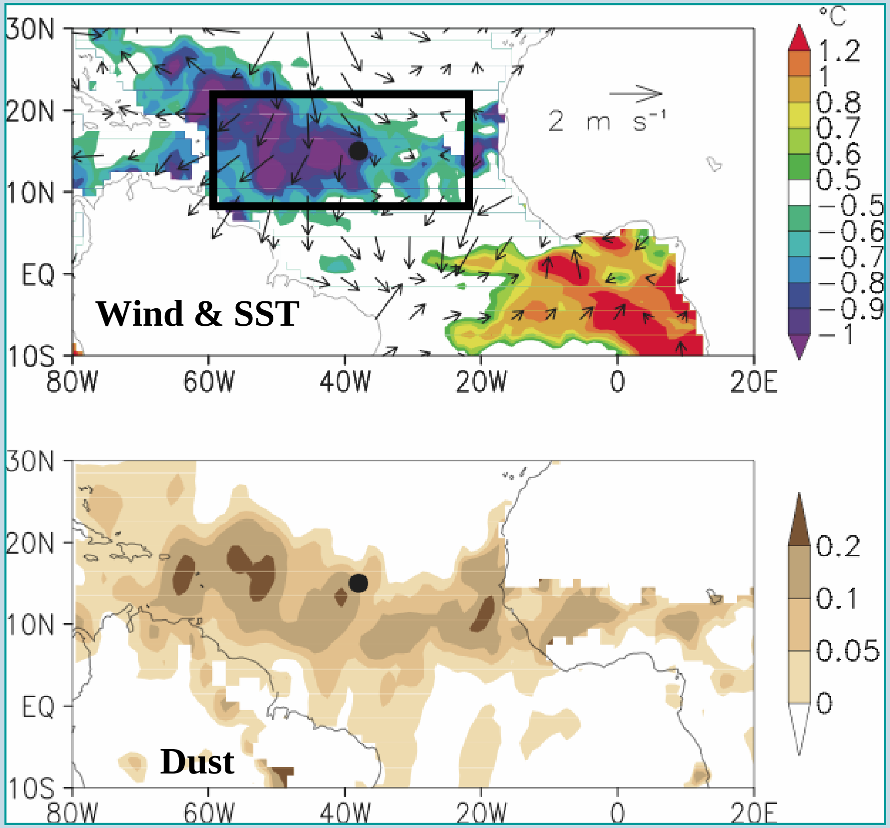
8°N, 38°W
Monthly Temperature and Wind Data
Wind
m s⁻¹
8
4
0
−4
−8
N
E
Temperature (°C)
0
100
200
300
Depth (m)
1998
2000
2002
2004
2006
2008
32
30
28
26
24
22
20
18
16
14
12
10
8

A Tale of Two Atlantic Hurricane Seasons

	2005	2006
Named storms (Hurricanes)	27 (15)	9 (5)
Pacific Conditions	Normal	El Niño
Atlantic SST	Record high	Normal

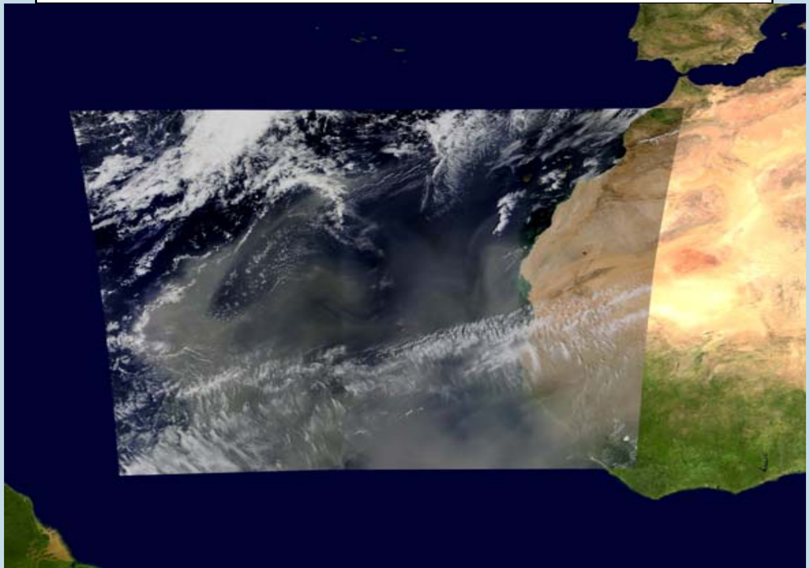
Hurricanes & North Atlantic SST

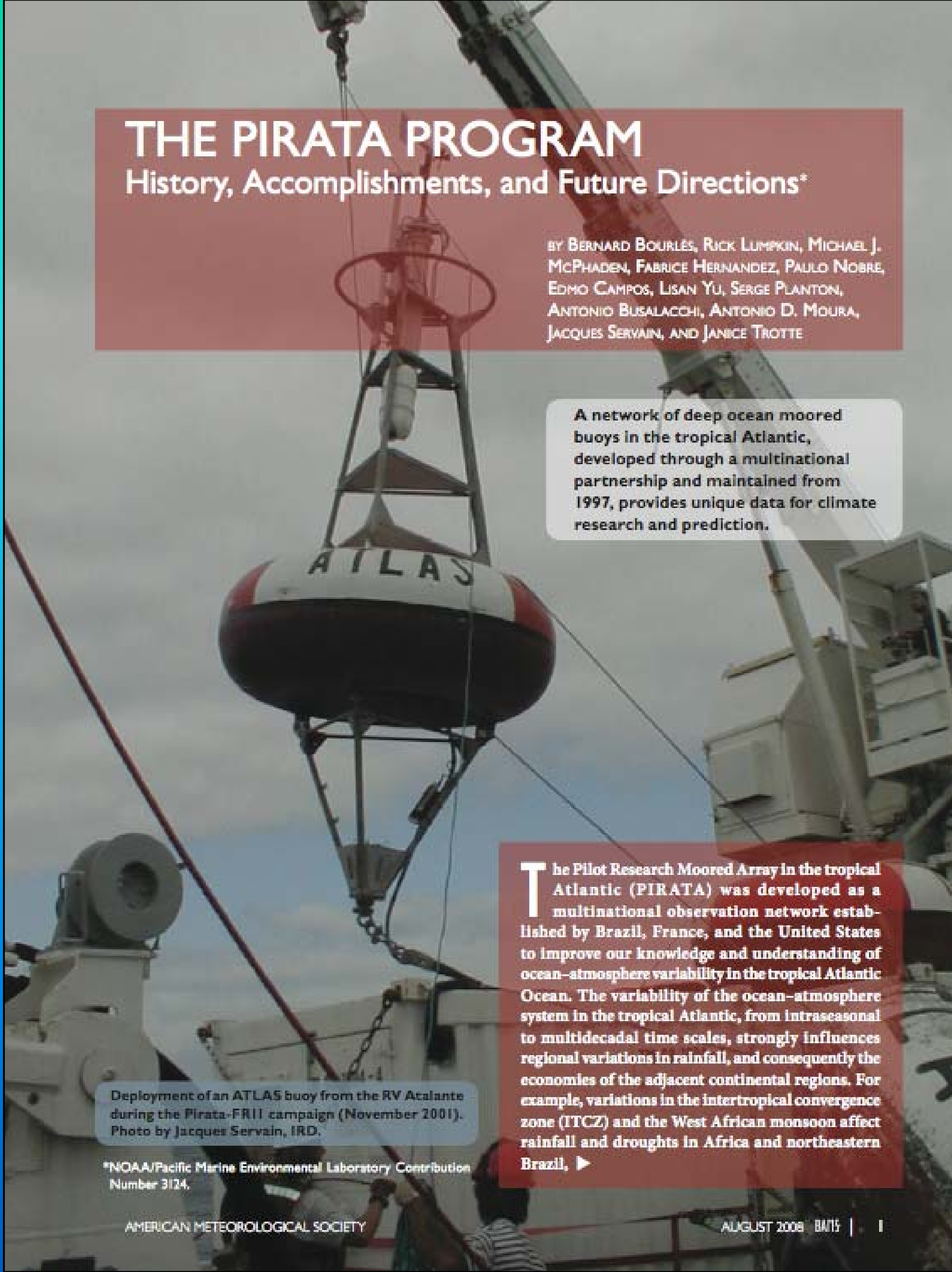
JJA Differences, 2006-2005



"…most of the anomalous cooling in 2006 occurred prior to the period of enhanced dustiness and was driven primarily by wind-induced latent heat loss…dust did not play a major direct role in the cooling… "

Foltz & McPhaden GRL, 2008





THE PIRATA PROGRAM
History, Accomplishments, and Future Directions*

BY BERNARD BOURLÈS, RICK LUMPKIN, MICHAEL J. MCPHADEN, FABRICE HERNANDEZ, PAULO NOBRE, EDMO CAMPOS, LISAN YU, SERGE PLANTON, ANTONIO BUSALACCHI, ANTONIO D. MOURA, JACQUES SERVAIN, AND JANICE TROTTE

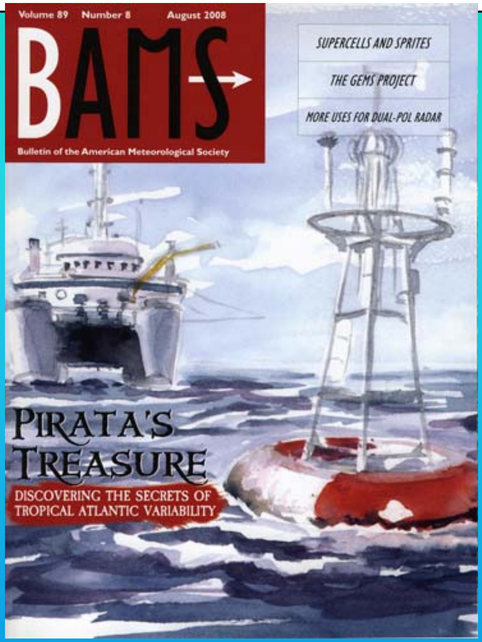
A network of deep ocean moored buoys in the tropical Atlantic, developed through a multinational partnership and maintained from 1997, provides unique data for climate research and prediction.

The Pilot Research Moored Array in the tropical Atlantic (PIRATA) was developed as a multinational observation network established by Brazil, France, and the United States to improve our knowledge and understanding of ocean–atmosphere variability in the tropical Atlantic Ocean. The variability of the ocean–atmosphere system in the tropical Atlantic, from intraseasonal to multidecadal time scales, strongly influences regional variations in rainfall, and consequently the economies of the adjacent continental regions. For example, variations in the intertropical convergence zone (ITCZ) and the West African monsoon affect rainfall and droughts in Africa and northeastern Brazil, ▶

Deployment of an ATLAS buoy from the RV Atalante during the Pirata-FRII campaign (November 2001). Photo by Jacques Servain, IRD.

*NOAA/Pacific Marine Environmental Laboratory Contribution Number 3124.

PIRATA Reviewed August 2008



Highlights:

1) Advances in understanding SST

2) New discoveries (e.g. role of ocean salinity in tropical Atlantic climate variability)

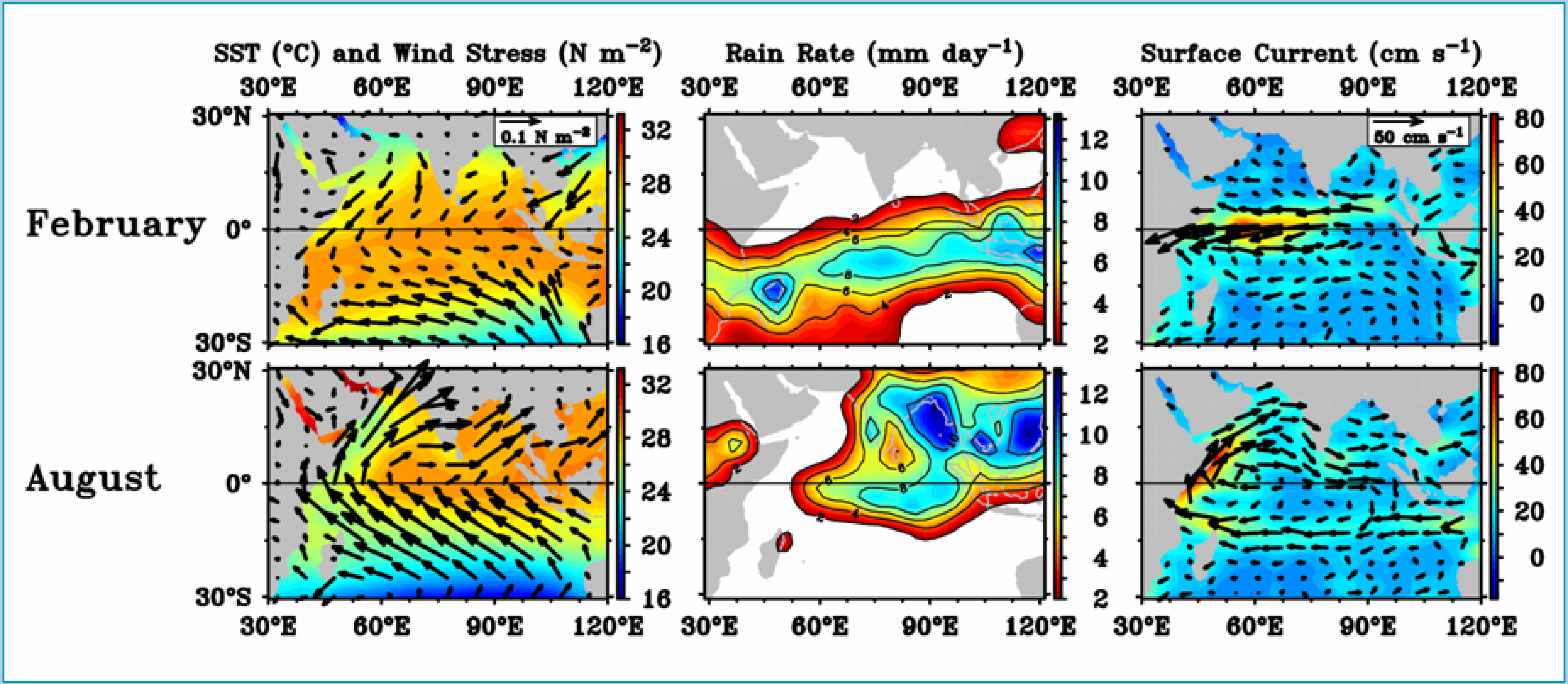
3) Development of new ocean and climate analysis and forecasts systems for the Atlantic

Indian Ocean

RAMA

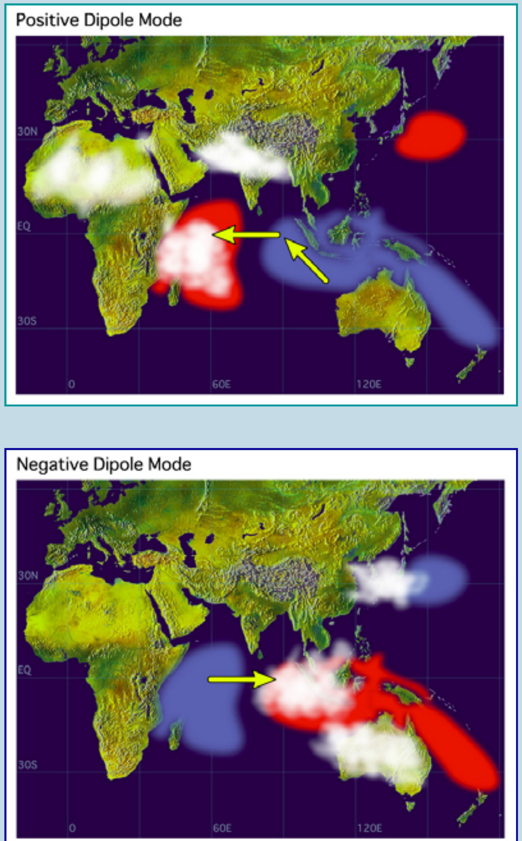
RAMA=Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction

The Monsoons



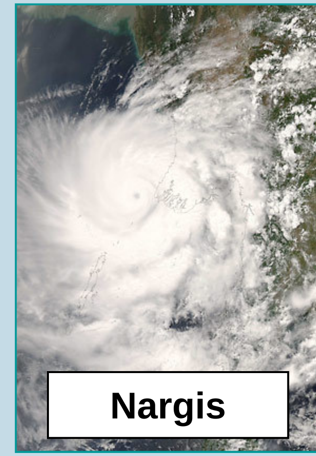
One third of the world's population depends on monsoon rainfall

Indian Ocean Science Drivers

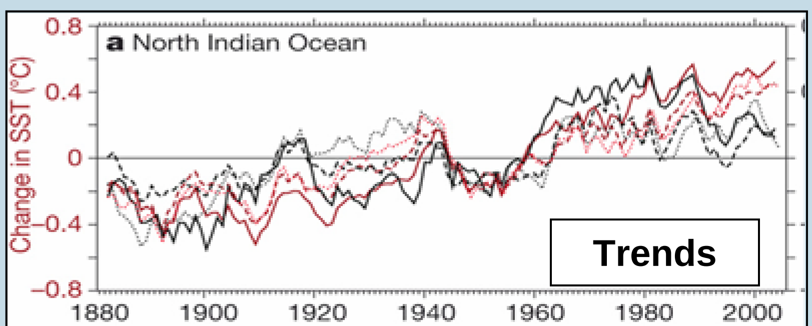


Indian Ocean Dipole

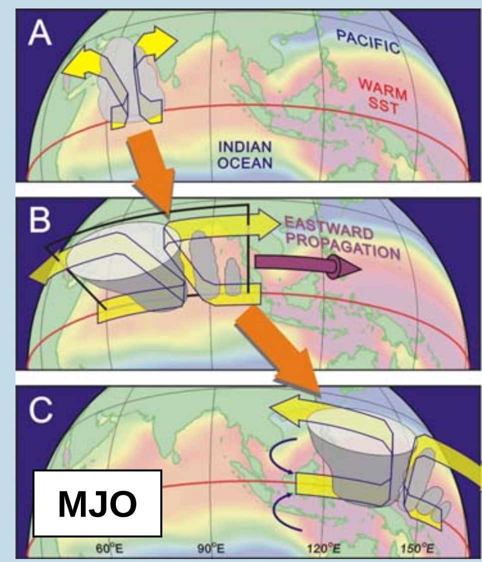
- **Seasonal monsoons**
- **Severe weather events & cyclones**
- **Intraseasonal (30-60 day) Madden Julian Oscillation (affects ENSO, west coast US weather, hurricanes)**
- **Interannual variations: the Indian Ocean Dipole**
- **Decadal variability and warming trends (affects North American temperature and precipitation)**



Nargis

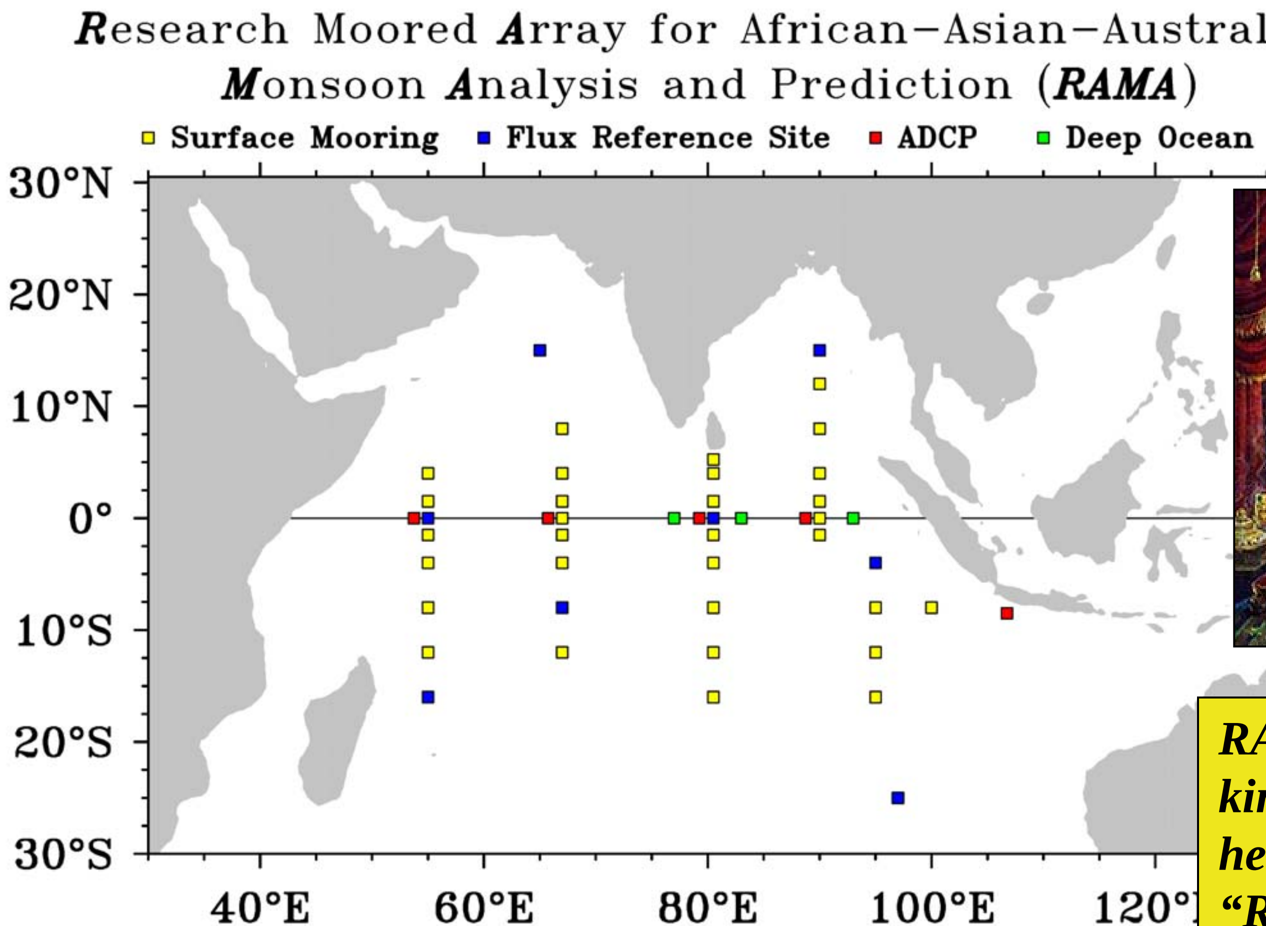


Trends



MJO

RAMA

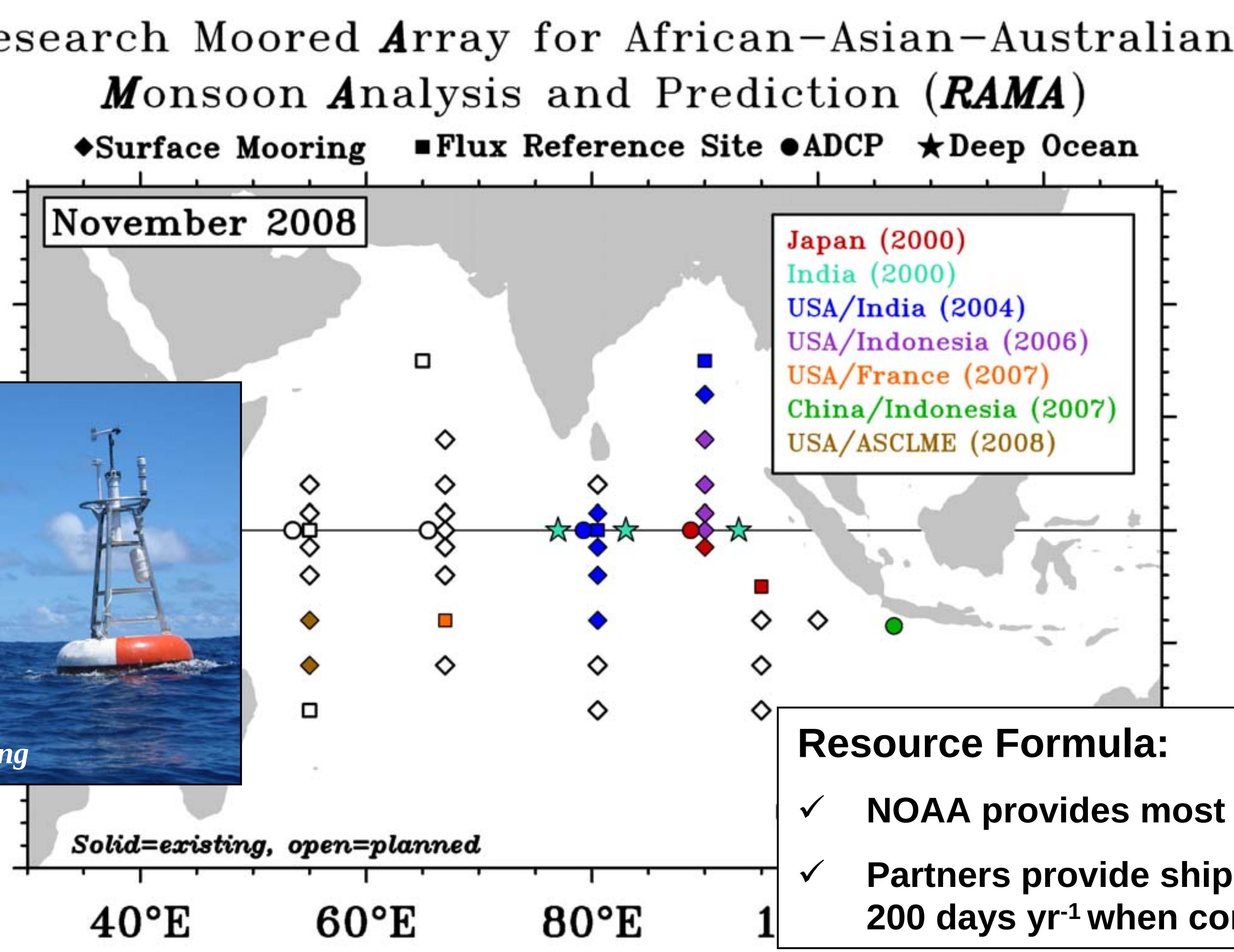


RAMA

RAMA: Ancient king of India and hero of the epic "Ramayana".

McPhaden et al, 2009: RAMA. Bull. Am. Met. Soc., in press

RAMA: Present Status



ORV Sagar Kanya deploys ATLAS mooring

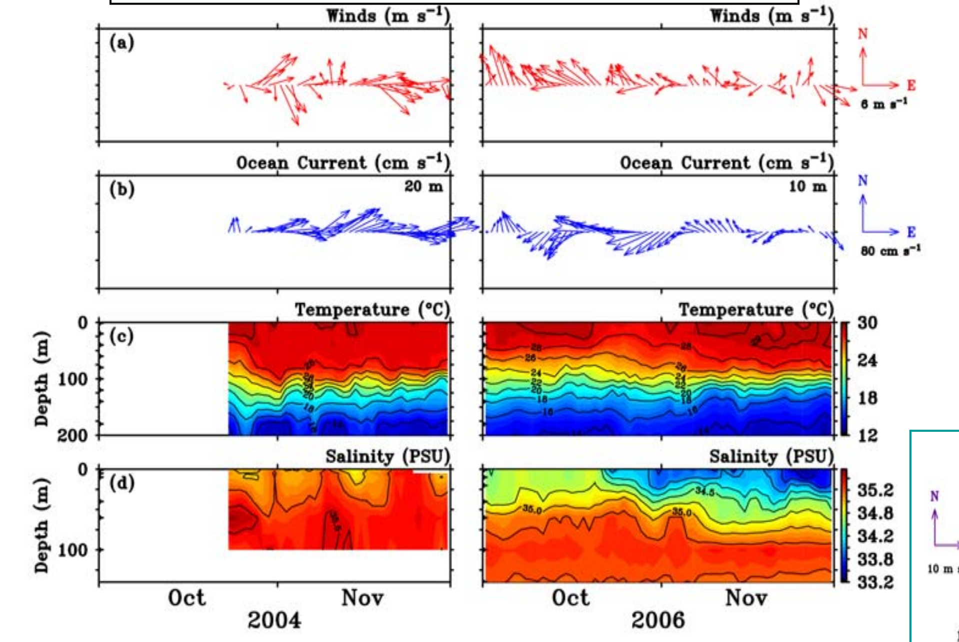
Resource Formula:

- ✓ NOAA provides most equipment
- ✓ Partners provide ship time (~150-200 days yr^{-1} when complete)

47% of sites occupied at present (22 of 46)

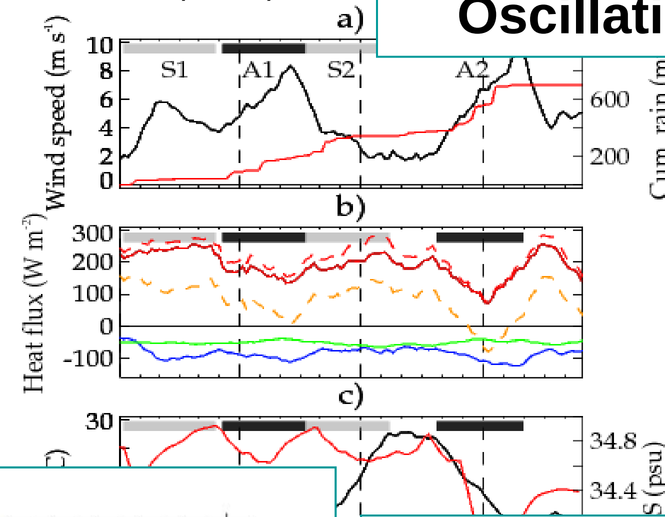
Scientific Progress

Indian Ocean Dipole

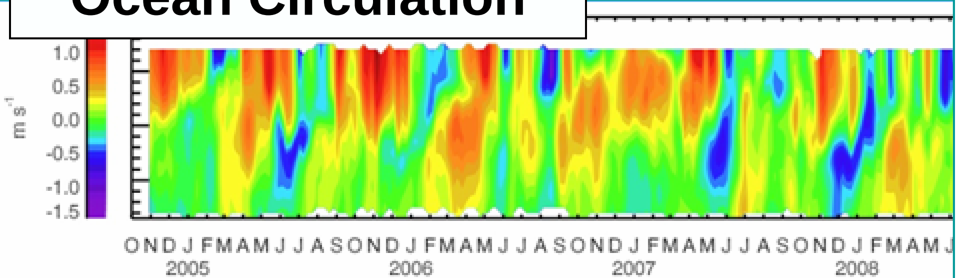


Madden-Julian Oscillation

Vialard et al, GRL, 2008

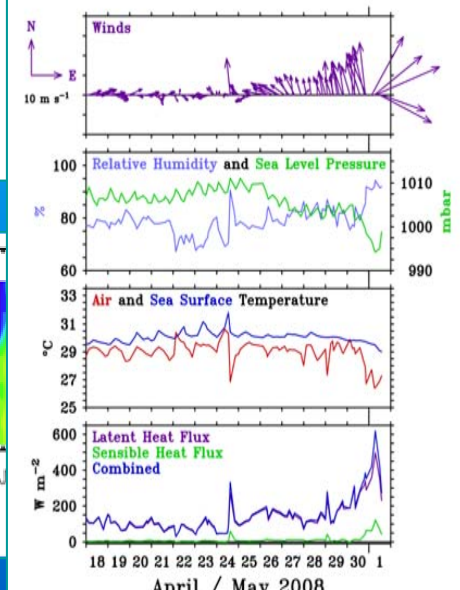


Ocean Circulation

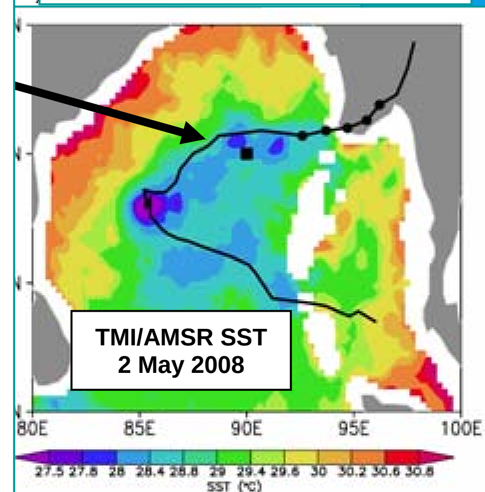


Nagura & McPhaden, GRL, 2008

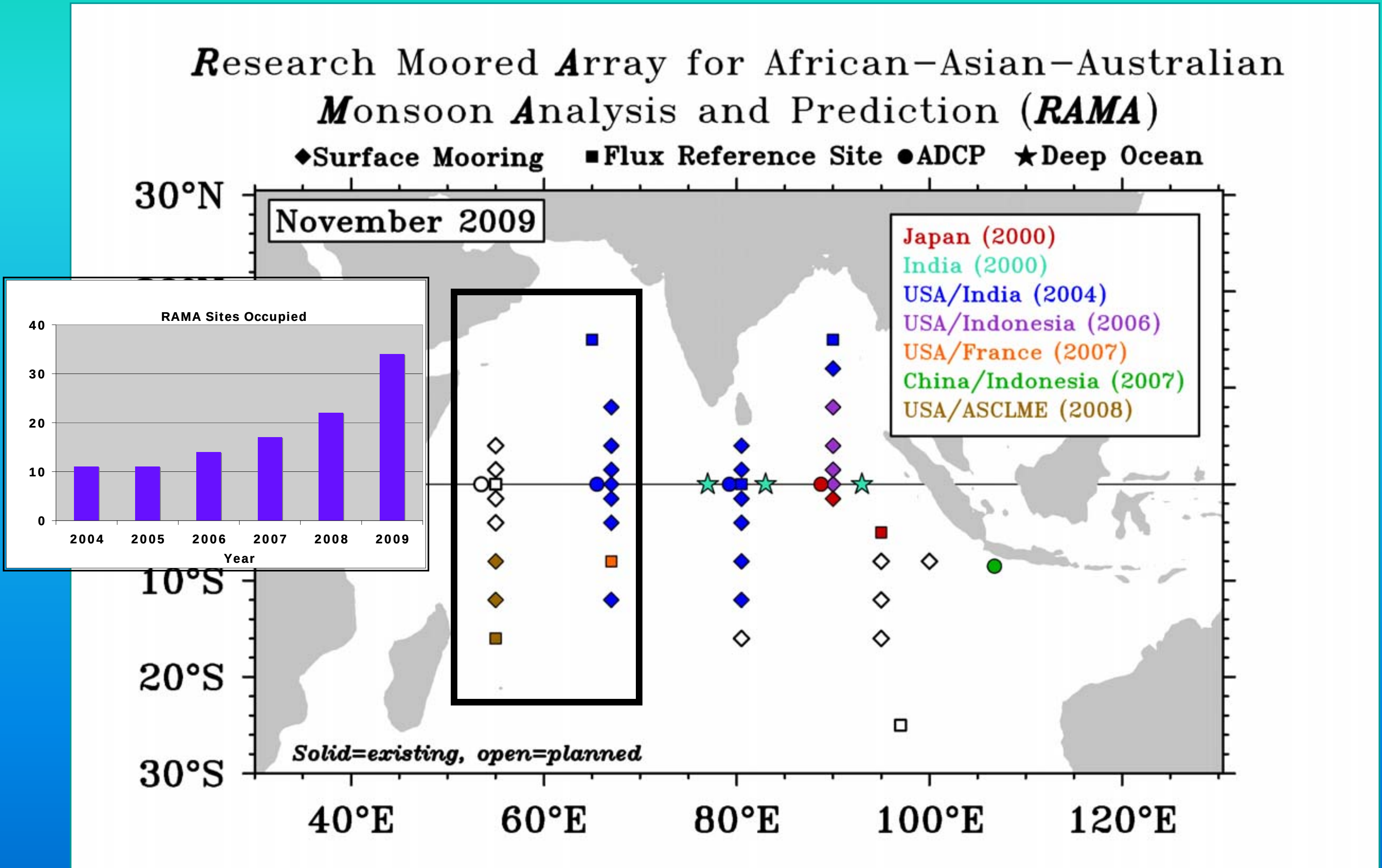
Cyclone Nargis



McPhaden et al, EOS, 2008



RAMA: Plans for 2009



74% of sites occupied by November 2009 (34 of 46)

International Cooperation

Formal bilateral agreements between NOAA and agencies in:

- **Indonesia--signed in 2007**
- **India--signed in 2008**
- **Japan--signed in 2008**
- **France--planned in 2009**
- **ASCLME (9 East African countries)--planned in 2009**


Perspectives


"In the future, we can visualize…a worldwide service of…monitoring buoys reporting by way of communication satellites…such data which enter into…electronic computers…for global long-range dynamical predictions of…the coupled circulations of the atmosphere and ocean."
--Jacob Bjerknes
1969

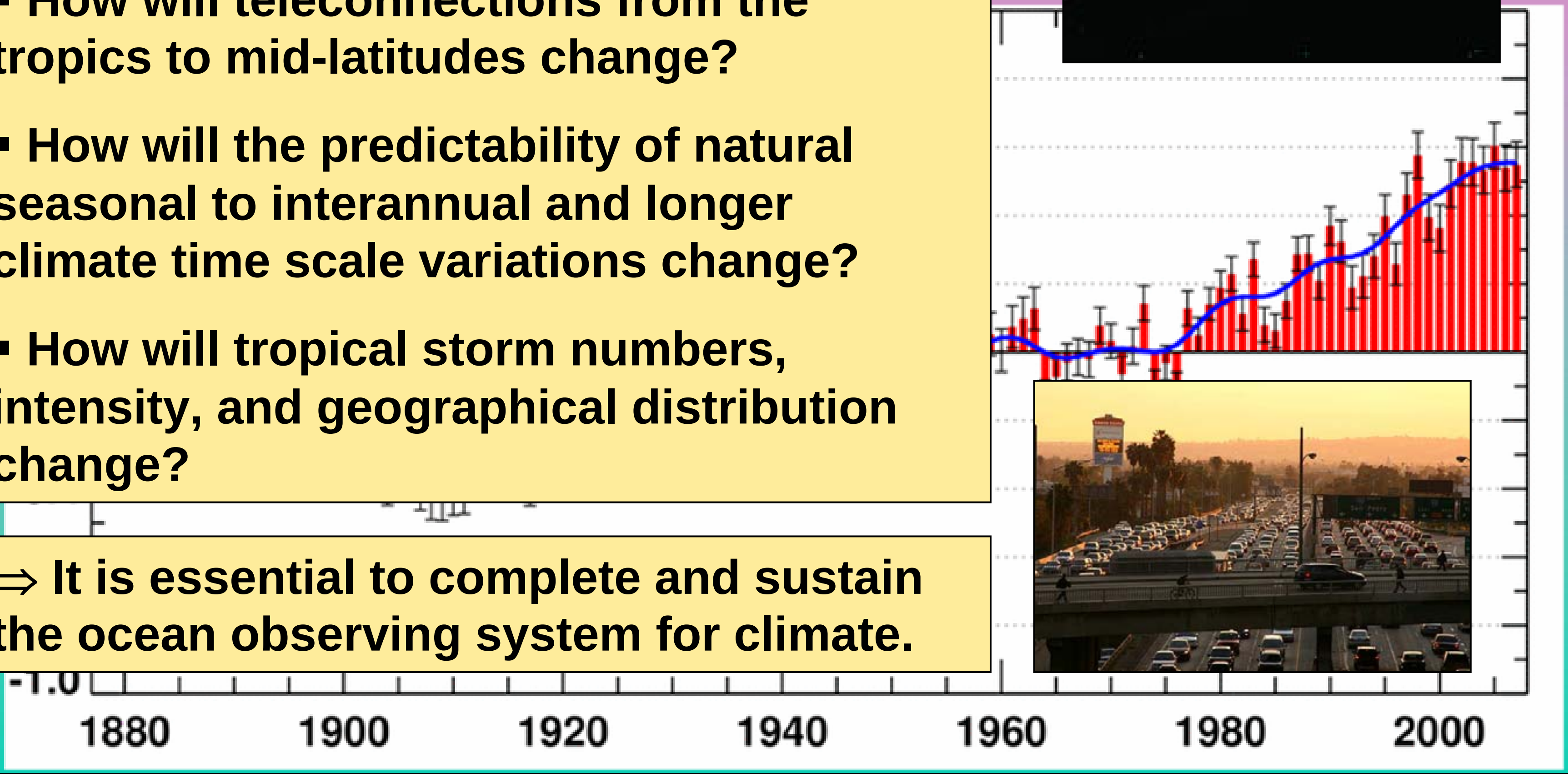
A NOAA Success Story

- **Mission: environmental assessment and prediction**
- **Talent: scientists, engineers, technicians**
- **Infrastructure: ships, laboratories, programs**
- **Commitment: build and sustain**

The Climate is Changing

- **How will ENSO, Tropical Atlantic Climate Variability, the monsoons, and their interactions change?**
- **How will teleconnections from the tropics to mid-latitudes change?**
- **How will the predictability of natural seasonal to interannual and longer climate time scale variations change?**
- **How will tropical storm numbers, intensity, and geographical distribution change?**

⇒ It is essential to complete and sustain the ocean observing system for climate.



Thank You!