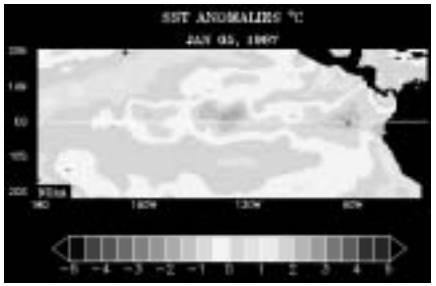
Lecture 8: El Nino-Southern Oscillation



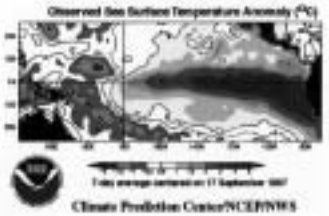
- The Southern Oscillation
- Ocean Adjustment
- Interaction Between Atmosphere and Ocean
- Predicting El Nino
- Modulation of El Nino

Global Impacts of El Nino

- Devastating floods in Ecuador and Peru
- Disappearing of the usually abundant fish along the South American coast
- Disastrous droughts in the Southeast Asia
- Disastrous droughts in northern Australia
- Poor monsoons over India
- Low rainfall over Southeastern Africa
- Unusual weather patterns over North and South America

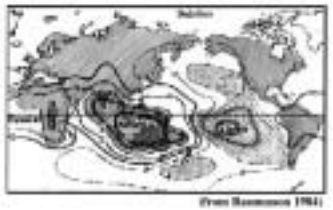
El Niño: originally, an oceanic phenomenon

- Every two to seven years, the waters warm up along the western-most shores of South America.
- Peruvian sailors who fished in this region, were the first to notice and to give a name to this phenomenon.
- Because the phenomenon would usually begin to peak around the Christian Christmas holiday, the sailors named the odd phenomenon "El Niño" meaning "the Christ Child."



Southern Oscillation: an atmospheric phenomenon

In 1910s, Walker found a connection between barometer readings at stations on the eastern and western sides of the Pacific (Tahiti and Darwin). He coined the term Southern Oscillation to dramatize the ups and downs in this east-west seesaw effect.



Sir Gilbert Walker

El Nino and Southern Oscillation

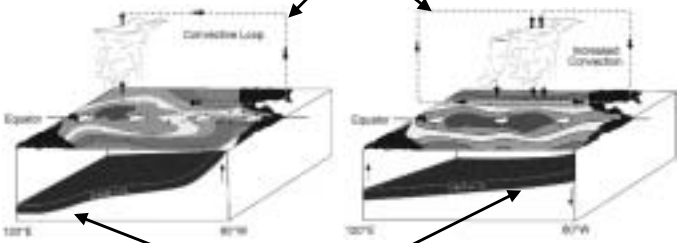
- Jacob Bjerknes was the first one to recognizes that El Nino is not just an oceanic phenomenon (in his 1969 paper).
- In stead, he hypothesized that the warm waters of El Nino and the pressure seasaw of Walker's Southern Oscillation are part and parcel of the same phenomenon: the ENSO.
- Bjerknes's hypothesis of coupled atmosphere-ocean instability laid the foundation for ENSO research.

Jacob Bjerknes

Coupled Atmosphere-Ocean System

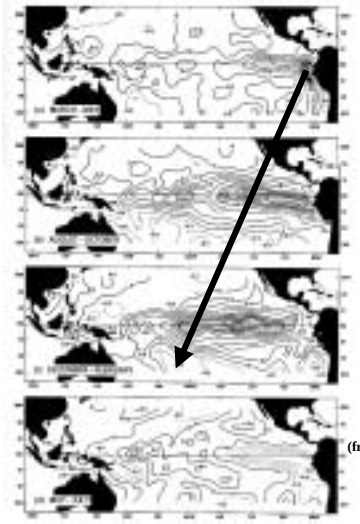
changes in atmospheric circulation over the Pacific

Normal Condition **El Nino Condition**



redistribution of warm upper ocean water along the equator

(from NOAA)



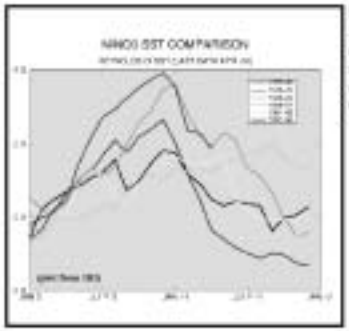
Onset Phase

Growing Phase

Mature Phase

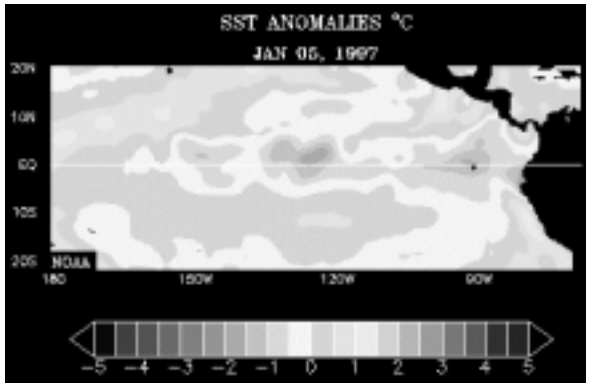
(from Rasmusson and Carpenter 1982)

ENSO's Phase-Lock to the Annual Cycle

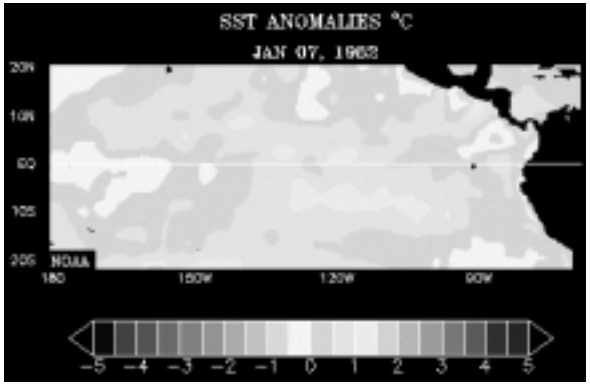


- Composition analyses have shown that ENSO events tend to onset, grow, and decay at certain seasons of the year (Rasmusson and Carpenter 1982).

1997-98 El Nino



1982-83 El Nino

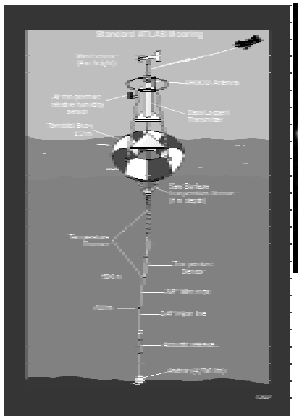


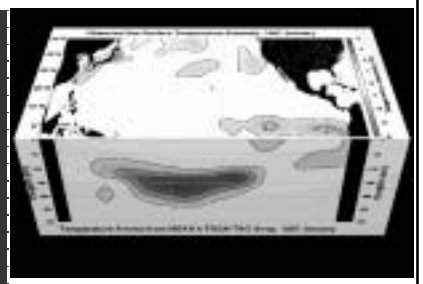
"Measuring" ENSO

Space-Based Observations

In-Situ Observations

Subsurface Ocean Observation

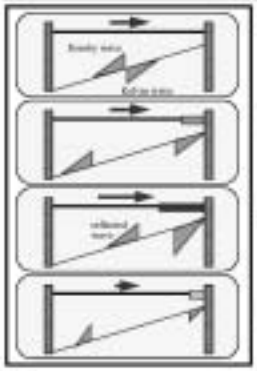




Ocean Memory

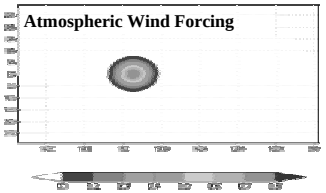
- The atmosphere responds to altered sea surface temperature patterns within a matter of days
  - ➔ little memory in the atmosphere
- The ocean has far more inertia and takes months to respond to the wind pattern changes in the atmosphere
  - ➔ Oceans have a long memory.
- The state of the ocean at any time is not simply determined by the winds at that time because the ocean is still adjusting to and has a memory of earlier winds.
- Ocean memory is carried by wave propagation along the thermocline.

Delayed Oscillator Theory

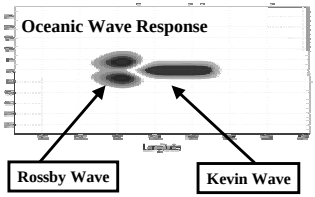


- Wind forcing at the central Pacific produces a downwelling Kevin wave propagating eastward and a upwelling Rossby wave propagating westward.
- wave propagation: the fast kelvin wave causes SST warming at the eastern basin, while slow Rossby wave is reflected at the western boundary.
- wave reflection: Rossby wave is reflected as a upwelling Kelvin wave and propagates back to the eastern basin to reverse the phase of the ENSO cycle.
- ENSO period is determined by the propagation time of the waves.

Delayed Oscillator: Wind Forcing

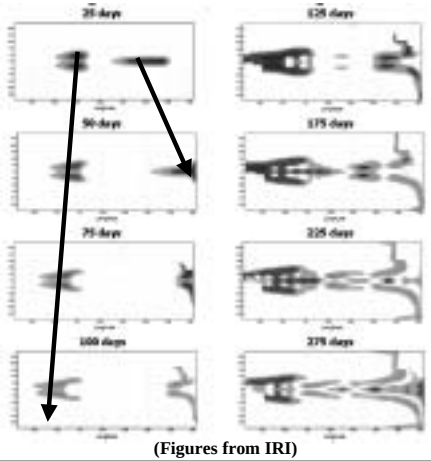


(Figures from IRI)



- The delayed oscillator suggested that oceanic Rossby and Kevin waves forced by atmospheric wind stress in the central Pacific provide the phase-transition mechanism (I.e. memory) for the ENSO cycle.
- The propagation and reflection of waves, together with local air-sea coupling, determine the period of the cycle.

Wave Propagation and Reflection



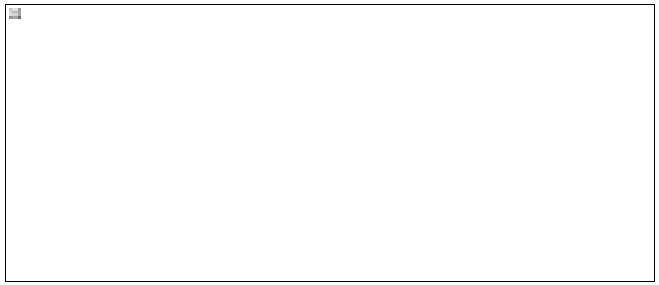
(Figures from IRI)

- It takes Kevin wave (phase speed = 2.9 m/s) about 70 days to cross the Pacific basin (17,760km).
- It takes Rossby wave about 200 days (phase speed = 0.93 m/s) to cross the Pacific basin.

Why Only Pacific Has ENSO?

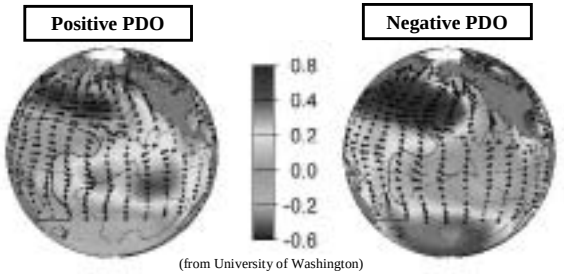
- Based on the delayed oscillator theory of ENSO, the ocean basin has to be big enough to produce the "delayed" from ocean wave propagation and reflection.
- It can be shown that only the Pacific Ocean is "big" (wide) enough to produce such delayed for the ENSO cycle.
- It is generally believed that the Atlantic Ocean may produce very weak and short-period ENSO-like oscillation.
- The Indian Ocean is considered too small to produce ENSO.

Decadal Changes of ENSO



(Figure from Fedorov and Philander 2000)

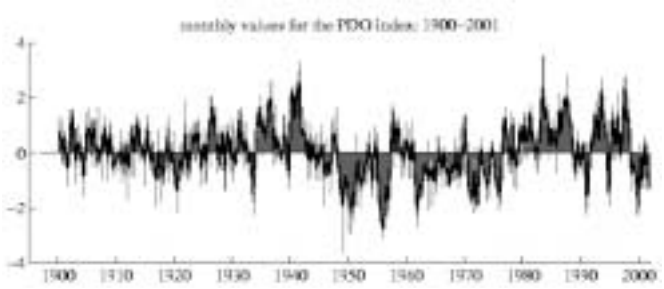
Pacific Decadal Oscillation



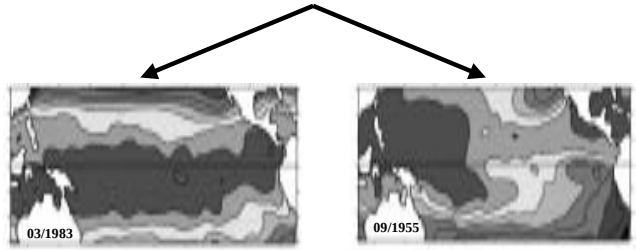
(from University of Washington)

- "Pacific Decadal Oscillation" (PDO) is a decadal-scale climate variability that describe an oscillation in northern Pacific sea surface temperatures (SSTs).
- PDO is found to link to the decadal variations of ENSO intensity.

PDO Index



How El Nino Changes When Climate Warms?



❑ **Hypothesis 1: Permanent El Nino**
(Philander 2003)
When global climate warms
➔ El Nino / La Nina alternations disappear
➔ El Nino forever.

❑ **Hypothesis 2: Stronger ENSO Activity**
(Huber and Gaballero 2003)
When global climate warms
➔ Stronger El Nino / La Nina lternations
➔ Stronger ENSO events.