El Niño, La Niña
The Southern Oscillation (ENSO)
Equatorial South America Normal Conditions

- Strong Trade Winds blow from east to west.
- Trade winds drive equatorial current
- West flowing “Equatorial” Current pushes water to the west
- Movement of water to the west causes deep water to raise up just offshore Ecuador and Peru.
- Deep water carries nutrients for phytoplankton
- Thriving phytoplankton attract zooplankton, fish and fisherman.
Trade Winds are constant easterly winds (blows from the east). These are normally confined to 0 and 15 degrees latitude North and South.
Productivity – Nutrients and sunlight

http://www.soc.soton.ac.uk/CHD/education/posters/productivity.html
The Peruvian upwelling is a 300 x 300 mile area adjacent to the coast and is the most biologically productive coastal upwelling system on Earth. High oceanic productivity occurs in areas of upwelling in the ocean, particularly along continental shelves (red areas on map below). The coastal upwelling in these regions is the result of deep oceanic currents colliding with sharp coastal shelves, forcing nutrient-rich cool water to the surface.
Over fishing and el Niño

The rapid development of the Peruvian fishing industry coincided with a severe El Niño and nearly destroyed the fishery.

http://www.soc.soton.ac.uk/CHD/education/posters/productivity.html
What is El Niño?

- When the trade winds weaken or stop, the equatorial current weakens or stops. Deep water and nutrients can no longer rise to the surface. Phytoplankton, zooplankton, and fish die or move away.

- El Niño was the name given by Peruvian fishermen to a period of warm waters and poor fishing that often coincided with the Christmas season.

- El Niño typically persists for 12 to 18 months and recurs approximately every two to seven years.
El Niño conditions (December 1997)

Deviation from normal surface water temperature in degrees centigrades during El Niño (Note Eastern Pacific is 4 °C warmer than normal)
Introduction

- Terms and definitions
  - ENSO and all its members
  - El Niño
  - La Niña
  - ENSO Neutral
- History of El Niño
- Impacts on the weather
- Impacts on history and prehistory
- Impacts on health
El Niño, the Southern Oscillation, ENSO, and La Niña

- The Southern Oscillation (SO) is a variation in air pressure between the central and western tropical Pacific. These pressure changes alter the strength of the trade winds, affect surface ocean currents, and are related to El Niño.

- Scientists often combine the terms, El Niño and the Southern Oscillation, ENSO.

- Normal conditions are sometimes called La Niña.
SST (Sea Surface Temperatures) and Anomalies Maps during southern summer

http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensocycle/ensocycle.html
Southern Oscillation and Southern Oscillation Index

- **SO**: Southern Oscillation: a change in pressure measured between Tahiti and Darwin that is related to Trade Winds strength.
- **SOI**: index measuring the pressure which in turn gives a feel for the Trade Wind direction and power over the Pacific basin.
Map of wind blowing related to pressure

Southern Oscillation Pressure Anomalies

During El Niño, air pressure in the western Pacific is higher than normal and lower than normal in the Eastern Pacific (Tahiti). During La Niña, those conditions reverse.
What does the SOI have to do with El Niño?

- SOI measures difference in air pressure between (Tahiti minus Darwin air pressure) W. Pacific (Darwin) and E. Pacific (Tahiti).
- Winds blow from areas of high pressure to areas of low pressure.
- When high pressure is in the Eastern Pacific (SOI > 0), strong Trade Winds blow: La Niña.
- When high pressure is in the Western Pacific (SOI < 0), Trade Winds stop: El Niño.
Hadley Circulation, Walker Circulation, and ENSO.

- **Hadley circulation:**
  Latitudinal (N-S) convective circulation. Warm air rises over equatorial regions, which draws air in to replace it. Hadley circulation – coupled with Earth’s rotation - is the main reason for the trade winds.

- **Walker Circulation:**
  Longitudinal (E-W) convective circulation modulated by the SST anomalies.
Hadley Circulation

Warm air rises over the Equator and moves North and South. Air moves at the surface towards the Equator. Deflection of surface winds by Coriolis effect causes the Trade Winds.
Normal Walker circulation sees warm air rising over the warmer waters of the Western Pacific and descending over the cooler Eastern Pacific.
Walker circulation during El Niño breaks down because warm air rises over the entire equatorial Pacific.
How we monitor El Niño?

- Sea Surface Temperature SST
  - Already discussed
- Southern Oscillation Index SOI
  - Already discussed
- Trade Winds Intensity
  - Already discussed
- Sea Surface Elevation
- Depth of the Thermocline
Sea Surface Elevation and Depth of the Thermocline during the ENSO Cycle

- In the tropical eastern Pacific during La Niña, strong Trade Winds move water westward, resulting in lower sea level, a rise in the thermocline, and a drop in sea-surface temperature.

- In the tropical eastern Pacific during El Niño, weakened Trade Winds results in higher sea level, a deeper thermocline, and warmer sea-surface temperature.
Variation of SST and Sea Level during El Niño La Niña Cycle
Changes in SST, Thermocline and Sea Level during El Niño – La Niña Cycle
Vertical profile from the previous animation
How SST, and other variables are measured

- SST can be measured from space.
- Wind velocity and water temperature from below sea surface must be collected using tethered buoys (TAO/Triton array).
- Data may be retrieved over the internet at http://www.pmel.noaa.gov/tao/disdel/

NIÑO#: areas of equatorial Pacific where data is collected by buoys.

http://www.pmel.noaa.gov/tao/proj_over/mooring.shtml
NIÑO SST regions to monitor
Niño SST Regions

- **NIÑO 1 and 2**: Along the coast of South America. Sensitive to local impacts and upwelling. No longer used as indication of El Niño/La Niña.
- **NIÑO3**: Region runs from 5°N-5°S, and from 90°W-150°E.
- **NIÑO4**: 160°E to 150°W, is known as the warm pool, where Pacific SST’s are typically the warmest.
- **NIÑO3.4**: overlaps regions 3 and 4 and seems to be the best region to monitor for predicting ENSO.
# Occurrence of ENSO – 20th Century

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SOI and ENSO

Ocean Temperature Departures (°C) for Niño 3.4
(5°N-5°S, 170°W-120°W)

Tahiti - Darwin SOI (3 month-running mean)
Everyone Blames El Niño, but how does it really affect us?
La Niña (Normal phase)

December - February La Niña Conditions

Colder water in E. Pacific evaporates less and leads to less rainfall in this region and adjacent regions of S. America.
El Niño (Warm Phase)

Warmer water in E. Pacific evaporates and there is more rain in this region and in adjacent areas of S. America.
Weather Impacts: El Niño
Weather Impacts: La Niña
Recent ENSO Events and Impacts

- 1972-73 El Niño Event
  - Was big but not a record, but global food problems occurred.
  - Russian wheat crisis brought El Niño to forefront. US sold wheat to Russia.
  - Understanding of relationship between abnormal weather and El Niño grows.

- 1982-83 Event: The big anomaly
  - Thought to have been the El Niño of the Century until 1998.
  - Big global impacts on food and weather.
    - Floods and droughts in tropics blamed on El Niño.
      - Flooding in Peru.
      - Droughts in Indonesia, Australia, north and south Africa.
    - Eastern US warmest winter in 25 years.
  - Value of ENSO forecasting grew in importance.
More El Niños

- 1986-87 First successful El Niño Forecast
- 1990-95 A long El Niño Event
  - Long slow El Niño
  - may be one of the longest events documented
  - was not an intense event
  - showed up consistently in NIÑO3.4 data
- 1997-98 El Niño
  - the strongest on record in terms of amplitude
  - followed closely by a strong La Niña
  - was forecast but not as well as we might think!

When will the next El Niño be?
ENSO 1997-1998
Drought in Pacific Islands
ENSO 1997-1998

Drought in Pacific Islands

- More skin disease in Micronesia
- Poor air quality from wildfires in Guam, Pohnpei, Yap, Palau
- Relief food shipments
- Many diseases under study (dengue, ... )
El Niño in the Prehistory

- Geologists identified in coastal Peru El Niño–like episodes around AD 1450, 1300, 1100, 600, and 500 (Thompson, Mosley-Thompson, Thompson 1992).

- Moving the time sequence back even farther, geologists studying sedimentation in a mountain lake in southern Ecuador (Rodbell et al. 1999) claim that El Niños occurred as long ago as 10,500 years b.p., while sedimentological studies from ponds on the Galapagos Islands—near the center of the prime El Niño region—detected traces of La Niña–like episodes from 6170 and 5070 b.p. (Steinitz-Kannan et al. 1998).

- Geologists believe that the interval of recurrences before 5000 BC was fifteen years and that for this reason the traces of prehistoric El Niños are more discernable.

- On this point, there is significant disagreement: while some claim that El Niños are traceable only after 5000 BC (Sandweiss et al. 1996) others claim that ENSO events occurred as far back as 8000 and even 40,000 years b.p.
ENSO perturbations in the Middle Moche Valley, Peru

Figure 4. Stratigraphic column for the Quebrada Chinos Stratigraphic Locality with associated ceramic and 14C ages.

Flooding associated with El Niño events are recorded in the archaeological record.

Archaeological sites and surficial geology of the distal portion of Quebrada de los Chinos.
El Niño Prehistory

- Around AD 800, the Moche were assimilated by the Chimú, whose capital was Chan Chan, located near the mouth of the Moche River not far from the present city of Trujillo. The capital of the Chimú kingdom counted some 30,000 inhabitants.
- Around 1100AD, a powerful El Niño occurred. The northern Chimú center at Batán Grande on the upper La Leche River was heavily flooded and became uninhabitable. Irrigation systems all along the Moche River and in the city of Chan Chan were severely damaged.
- The magnitude of the AD 1100 mega-Niño in the circum-Pacific rimlands is reflected in a major cultural change on Easter Island around that time, probably associated with the arrival of a new wave of Polynesian settlers (Weakened trade winds allowed them to sail east?).
The El Niño cycle is associated with increased risks of some of the diseases transmitted by mosquitoes, such as malaria, dengue and Rift Valley fever.

Malaria transmission is particularly sensitive to weather conditions.

Deserts don’t have mosquitoes, but areas that are normally dry that are affected by heavy rainfall (El Nino in Peru) can create puddles that provide good breeding conditions for mosquitoes.

In some highland regions higher temperatures linked to El Niño may increase malaria transmission by allowing mosquitoes to live where they normally cannot. In very humid climates, droughts may turn rivers into strings of pools, preferred breeding sites of other types of mosquito.

In Venezuela, Colombia and Brazil, malaria cases increase by more than one third following dry conditions associated with El Niño.
Brazil Landsat Image for Castanhal, Pará
1982-'83 El Niño. Encephalitis (West Nile) outbreaks occurred on the east coast of the U.S. attributed to a warm, wet spring fostering mosquitoes.
Conclusions

- ENSO is a cyclic phenomenon that affects both the atmospheric and the oceanic circulation.

- ENSO has has 2 phases
  - El Niño
  - La Niña

- The phases impact climate
  - this impacts global circulation patterns, which affects climate around the world.
Final Question

- What affect will Global Warming have on ENSO?
References

Web resources

- http://www.atmos.washington.edu/~mantua/abst.PDO.html
Nasa Team NSIPP (NASA’s Seasonal-to-Interannual Prediction Project) developed the [NSIPP forecast animation](http://nsipp.gsfc.nasa.gov/) (10.1 MB), which shows predicted conditions from September 2004 through August 2005.

It is interesting to note that while the NSIPP model doesn’t predict any significant El Niño conditions for this year, it does forecast the onset of an El Niño in the summer of 2005.

However, NASA oceanographer and climate modeler David Adamec cautions us to take that forecast with a grain of skepticism—the accuracy of the NSIPP model is not very accurate more than 6 months into the future.

http://nsipp.gsfc.nasa.gov/
Volcanic glass

shards: pieces of volcanic glass viewed microscopically have characteristic shapes, vesicles and stretched bubbles More common: flat with round bubbles, ragged edges

St. Helens, 1980

**Volume of ash:** 0.26 cubic miles (1.4 billion cubic yards)

**Ash fall area:** Detectable amounts of ash covered 22,000 square miles

**Ash fall depth:** 10 inches at 10 miles downwind (ash and pumice); 1 inch at 60 miles downwind; 1/2 inch at 300 miles downwind
El Niño and La Niña Consequences

- Changes in oceanic and atmospheric circulation in the tropical Pacific impact weather and climate in the tropics and well beyond.
- Temperature governs the rate at which water molecules escape a water surface and enter the atmosphere; that is, warm water evaporates more readily than cool water. Regions of relatively warm surface waters heat the atmosphere and add moisture to the atmosphere. Thunderstorms more readily develop in this warm, humid air. Towering thunderstorms help shape the planetary-scale atmospheric circulation, altering the course of jet streams and moisture transport at higher latitudes.
- Changes in the planetary-scale atmospheric circulation during El Niño and La Niña often give rise to weather extremes, including drought and excessive rainfall, in many areas of the globe outside the tropics.
- No two El Niño or La Niña events are exactly the same, so that in some areas weather extremes may or may not accompany a particular El Niño or La Niña.