GEOG 401
Climate Change

ENSO and PDO

El Niño-Southern Oscillation
Pacific Decadal Oscillation

Both ENSO and PDO are coupled ocean-atmosphere modes of variability focused in the Pacific Ocean
The Child

*El Niño* means “The (Boy) Child”, referring to the Christ Child, because of the annual Christmastime arrival of warm waters off the west coast of South America.

Mean Annual SST Cycle
Boys and Girls

- *El Niño* now refers to the much stronger, more persistent, more widespread warming of the eastern and central equatorial Pacific sea surface with recurs at irregular intervals of 2 to 7 years and lasts up to a year or more.
- *La Niña* “the (girl) child”, refers to an anomalous cooling of equatorial Pacific sea surface

Upwelling

- Coastal and equatorial upwelling occur along the South American coast and along the equator under normal conditions.
- In the presence of upwelling the thermocline moves closer to surface and SSTs are much lower
- If coastal and/or equatorial upwelling ceases, SSTs increase rapidly
Coastal Upwelling

Northern hemisphere

Ekman Spiral

Ekman transport perpendicular to surface wind direction

Coastal Upwelling

Formation of upwelling current

Sketch of Ekman transport
Equatorial Upwelling

COLD WATER

Upwelling

South Pacific Gyre

Normal Conditions

El Niño Conditions
La Niña Conditions

El Niño (Warm Event)
La Niña (Cold Event)

The Walker Circulation

The movement of air within along equatorial Pacific. Under normal conditions, controlled by low pressure in the west (Darwin, Australia) and high pressure in the east (Tahiti).
Southern Oscillation

The Walker Circulation is disrupted by El Niño, with higher than normal pressure in the western equatorial Pacific and unusually low pressure in the central and eastern equatorial Pacific.

Southern Oscillation

This shift in atmospheric pressure linked with changes in ocean surface temperature and currents is called the Southern Oscillation. It is thought of as a west-east shift in atmospheric mass accompanying changes in SST. The “centers of action” of this pressure oscillation are at Darwin in the west and Tahiti in the east.

SOI: Tahiti and Darwin as “centers of action”, useful correlations between two locations.
Southern Oscillation

The Southern Oscillation Index (SOI) provides an indication of the state of the El Niño-Southern Oscillation (ENSO) system. The SOI is calculated as the in sea level pressure at Tahiti minus the sea level pressure at Darwin, Australia (normalized by dividing by the standard deviation of the monthly differences. The SOI can be plotted as a time series to identify past El Niño and La Niña events.
SST Conditions for Early 2010

Sea Surface Temperature Anomaly (°C), Base Period 1971–2000
Week of 6 JAN 2010

SST Conditions for Late 2010

Sea Surface Temperature Anomaly (°C), Base Period 1971–2000
Week of 6 OCT 2010
SST Conditions for July 2012

Sea Surface Temperature Anomaly (°C), Base Period 1971-2000
Week of 4 JUL 2012

Current SST Conditions

NOAA/NESDIS 50 KM GLOBAL ANALYSIS: SST Anomaly (degrees C), 4/7/2014
2010-12 Equatorial SST Anomaly

Five-Day SST 3S to 2N Average

Multivariate ENSO Index (MEI)
El Niño Impacts

Teleconnections: Links between tropical (ENSO) fluctuations and mid-latitude weather anomalies.

El Niño Impacts

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY

WARM EPISODE RELATIONSHIPS JUNE - AUGUST
La Niña Impacts
Widespread Impacts of Exceptionally Strong 1982-83 El Niño

Hawaiian Rainfall and ENSO

Frazier et al. (in preparation)
Trigger for El Niño

- Westerly wind bursts in western equatorial Pacific
- Generation of equatorial Kelvin waves that propagate eastward across the Pacific
- Kelvin waves induce changes in ocean surface currents, halting upwelling, leading to rapid increase in SSTs
- Walker circulation responds to changes in SST distribution, strengthening the changes in ocean circulation
Monster El Nino Emerging From the Depths: Nose of Massive Kelvin Wave Breaks Surface in Eastern Pacific

(A monster Kelvin wave, possibly more powerful than the 1997-98 event, is now rushing toward the surface of the Eastern Pacific. Image source: NOAA/ESRL)
Current ENSO Status

SST Outlook: NCEP CFS.v2 Forecast (PDF corrected)
Issued: 7 April 2014

The CFS.v2 ensemble mean (black dashed line) predicts El Niño starting in April-June (AMJ) 2014

Current ENSO Status

Early-Mar CPC/IRI Consensus Probabilistic ENSO Forecast

ENSO state based on Niño3.4 SST Anomaly
Neutral ENSO: -0.5°C to 0.5°C

Climatological Probability:
- El Niño
- Neutral
- La Niña

Probability (%)
Pacific Decadal Oscillation (PDO)

- ENSO-like alternating pattern of SST changes in the Pacific
- Differs from ENSO in the locations of the SST changes (NW Pacific and Tropical Eastern North Pacific) and in the length of time between phases (20-30 years).
- PDO interacts with ENSO to reinforce or weaken ENSO events.
However, while land areas have warmed fastest at high latitudes, warming of the Pacific Ocean shows cyclical patterns with respect to latitude.
Hawai‘i Temperature Index


30-yr change = +0.5°C

HTI—PDO—SST

Hawaiian Rainfall and the PDO


ENSO and PDO Concluding Comments

- Both ENSO and PDO involve coupled ocean-atmosphere processes centered in the Pacific region
- ENSO phases (El Niño and La Niña) are correlated with worldwide weather anomalies called “teleconnections”
- Interannual- and multi-decadal-scale climate variability are associated with ENSO and PDO, respectively. This is especially true in the Pacific region.
- How global warming will affect ENSO is an important and unresolved scientific question
- Natural climate variability due to ENSO and PDO make detection of global-warming-related trends more difficult, especially in the Pacific region