

El Nino/Southern Oscillation (ENSO): Past, present and future

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1. Motivation

- What is ENSO and why do we care about it?

2. ENSO in the modern climate

- Observations, theory (the ENSO mode) and its implications

3. ENSO in the past

- Mid Holocene
- Last Glacial Maximum

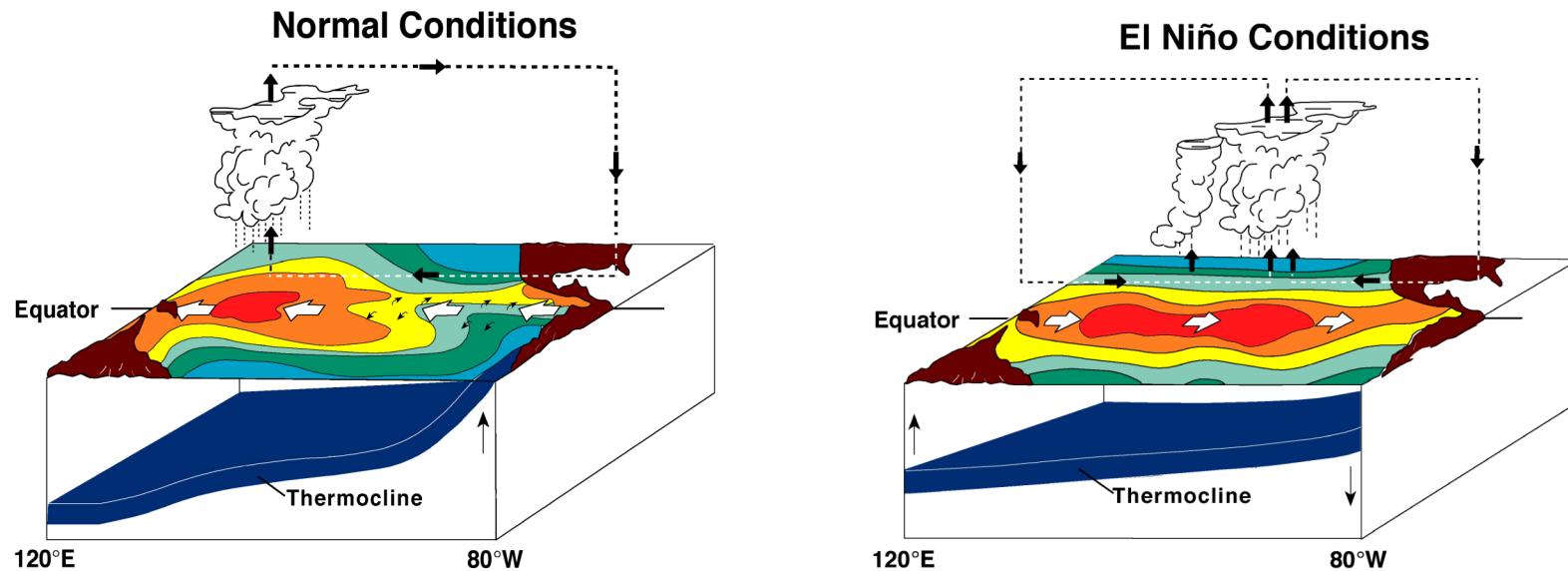
4. ENSO in the future

- How will ENSO change due to global warming?

5. Summary

1. What is ENSO and why do we care about it?

- El Niño/Southern Oscillation(ENSO) is the dominant pattern of climate variability on interannual time scales

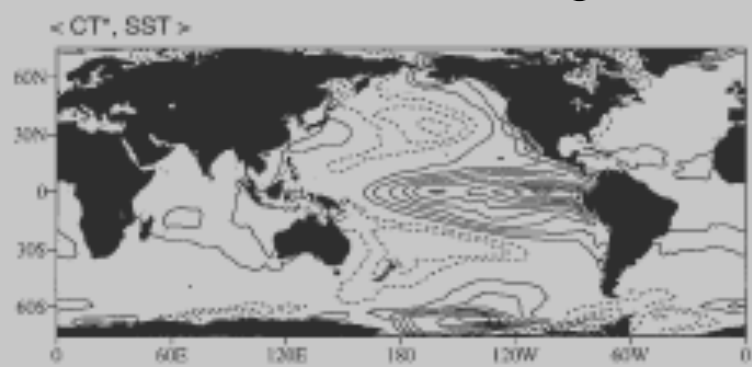


- Large scale changes in winds, precipitation and surface stress; sea surface temperature (SST), ocean currents and upwelling, sea level and thermocline depth.

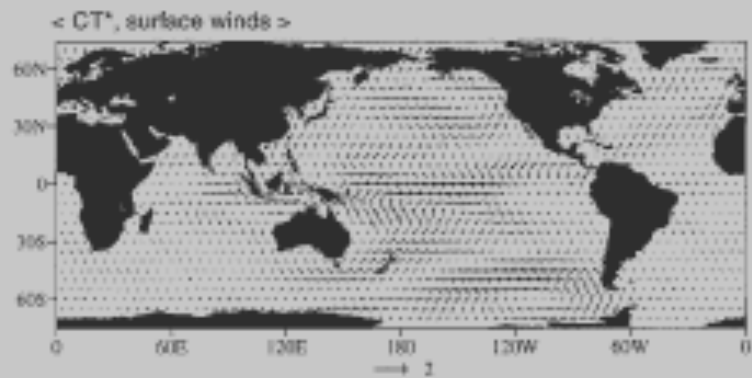
ENSO affects the global climate through atmosphere and ocean teleconnections

Anomalies during El Nino: the “warm phase” of ENSO

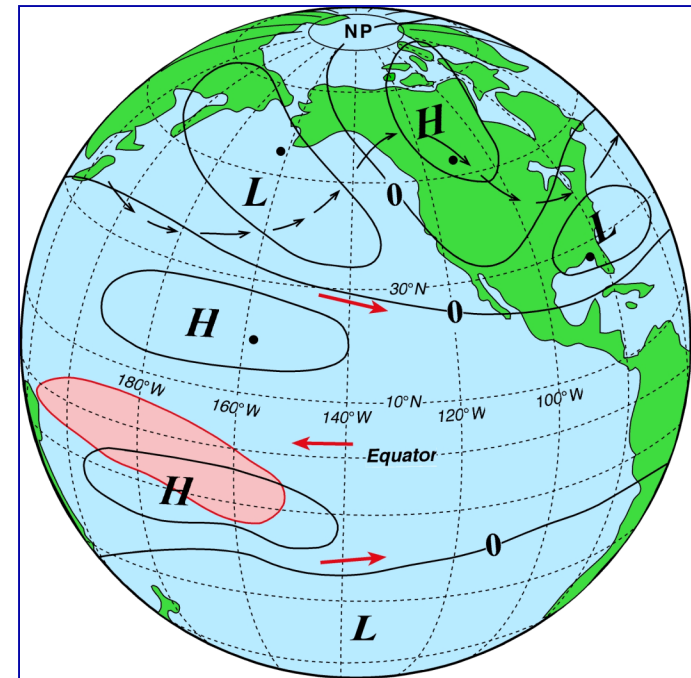
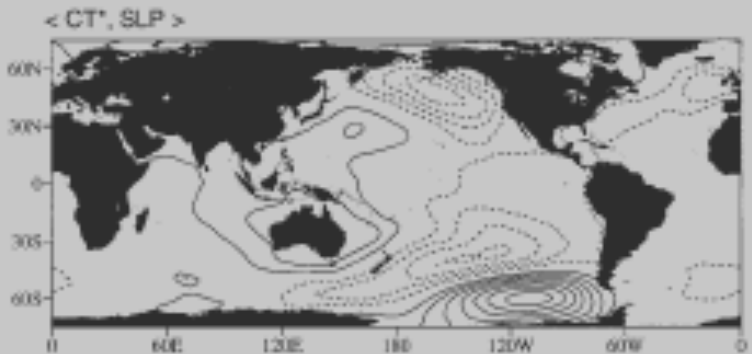
SST



Winds



SLP

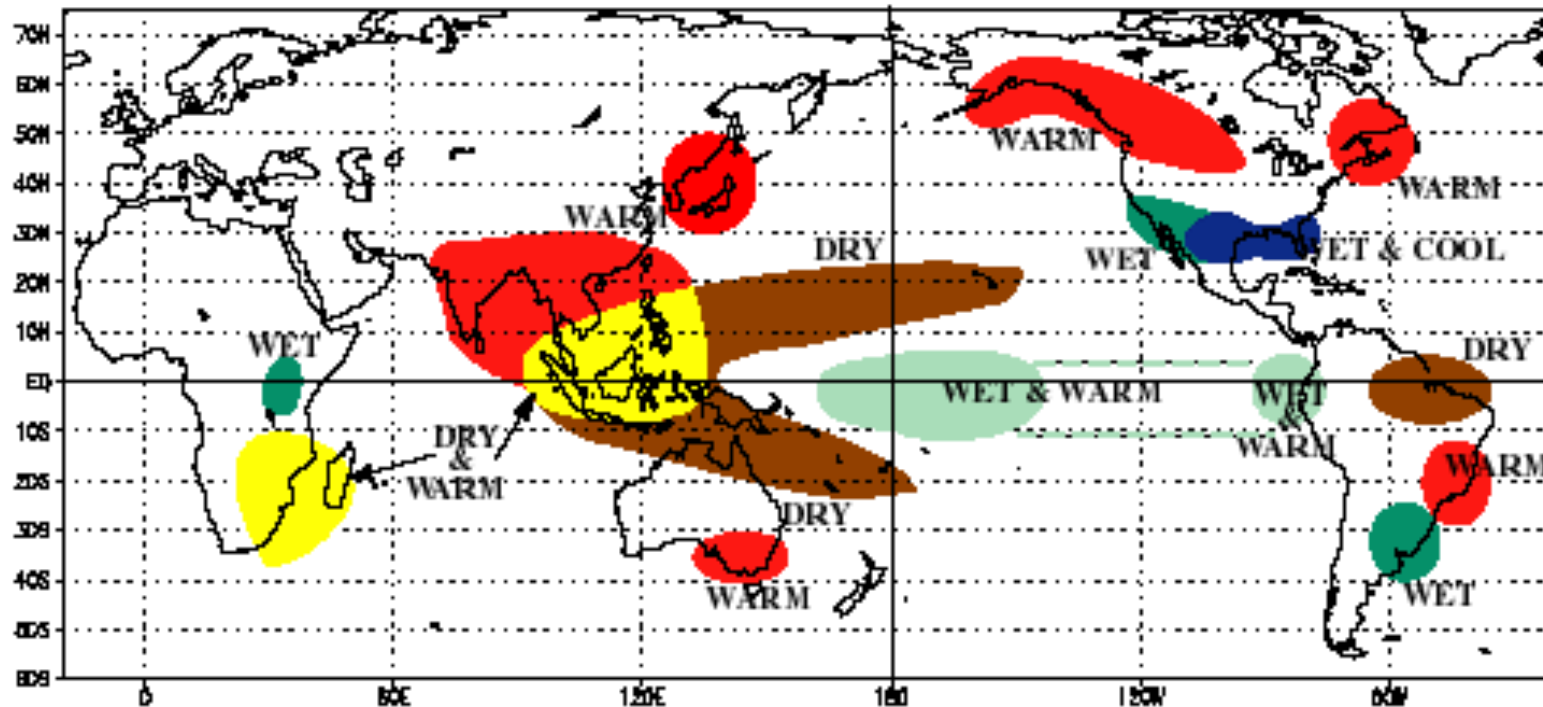


Upper level circulation

Zhang Battisi Wallace 1997

The impacts of ENSO

WARM EPISODE RELATIONSHIPS DECEMBER - FEBRUARY



- ENSO alters the Pacific storm tracks, and the probabilities of extreme weather events on a global scale.

2. ENSO: Past and Present

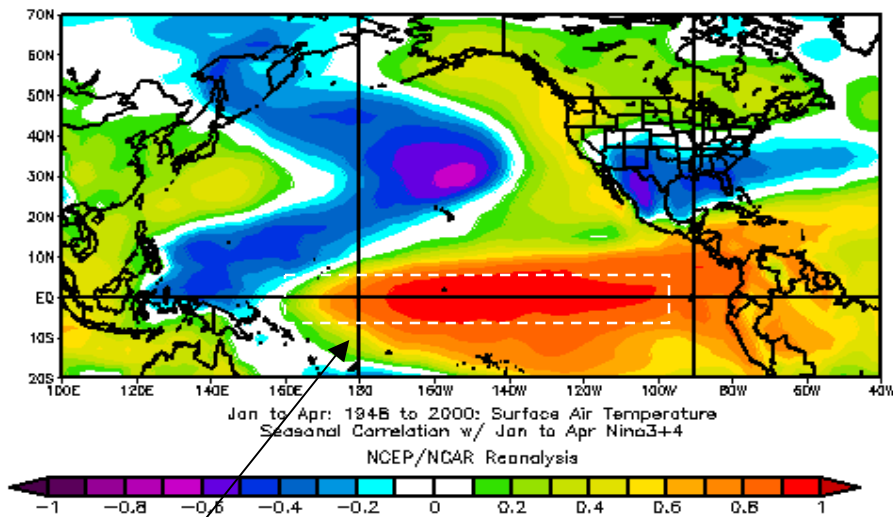
A. The 'Robust' Observations: present

- Spatial patterns of sea surface temperature, Sea Level Pressure and surface wind stress
- A coupled atmosphere-ocean phenomenon
- Temporal properties:
 - shows a broad spectral peak at 3-7 years
 - nearly Gaussian statistics (except in the eastern equatorial Pacific where warm events are more extreme than cold events)
- ENSO is coordinated with the annual cycle
 - events peak near the end of the calendar year
 - moderate warm and cold events last about one year.
 - the seasonality in the autolag correlation of “Nino3”
- Equatorial thermocline anomalies are coordinated with SST anomalies

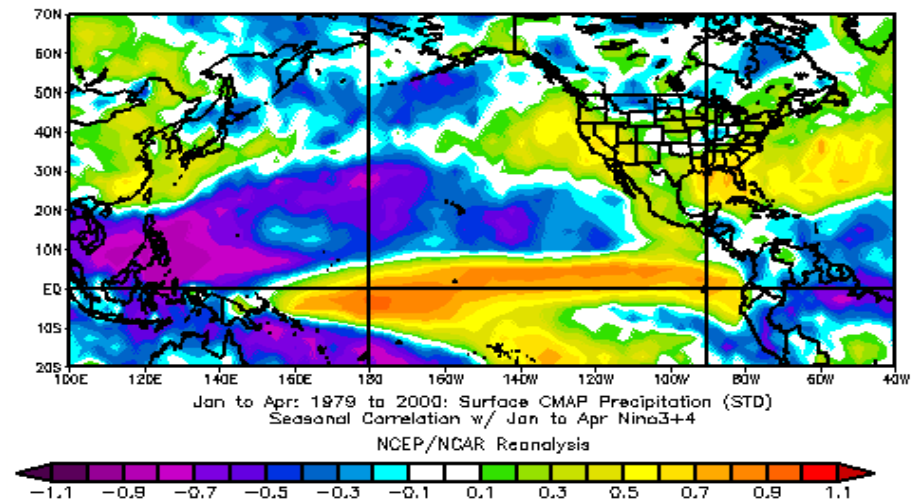
2A. The 'Robust Observations

Small changes in the distribution of sea surface temperature are coordinated with changes in atmospheric circulation and rainfall patterns;

Temperature Anomalies

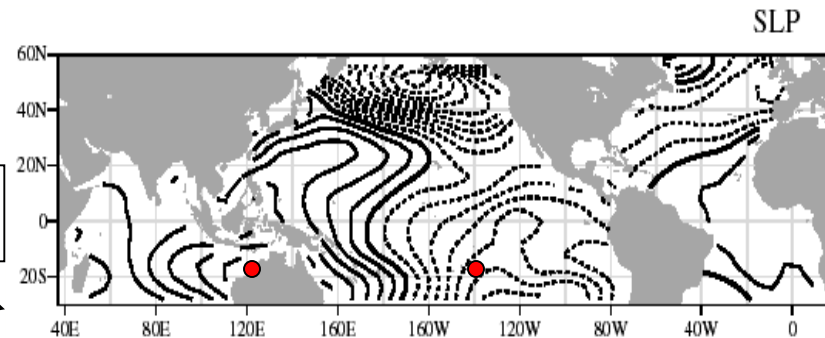


Precipitation Anomalies



Nino3.4 or CT

SOI (Tahiti -Darwin)

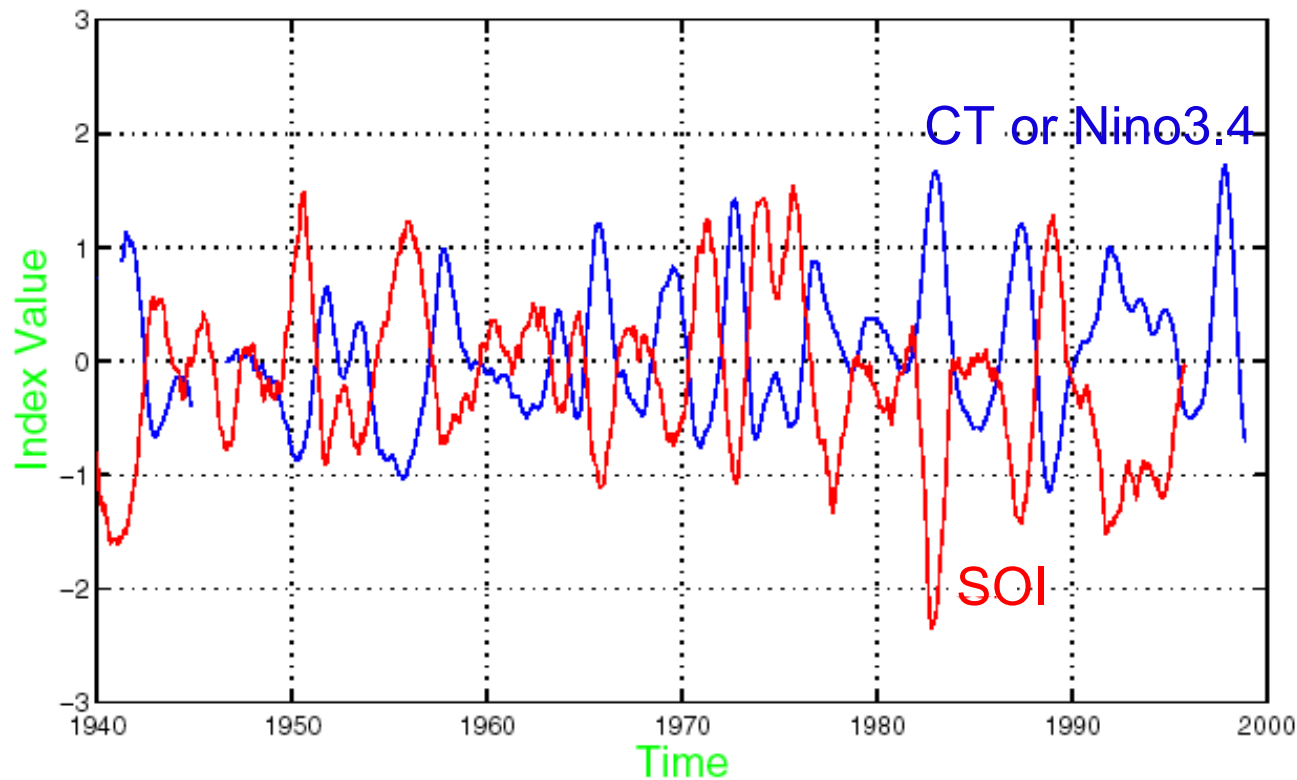


Sea Level Pressure

2A. The 'Robust' Observations

There is a tight coupling between the atmosphere & ocean

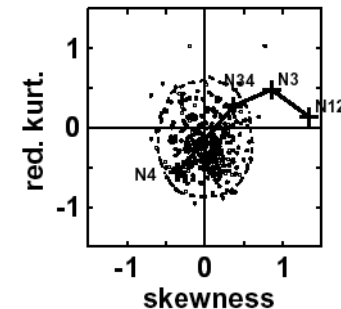
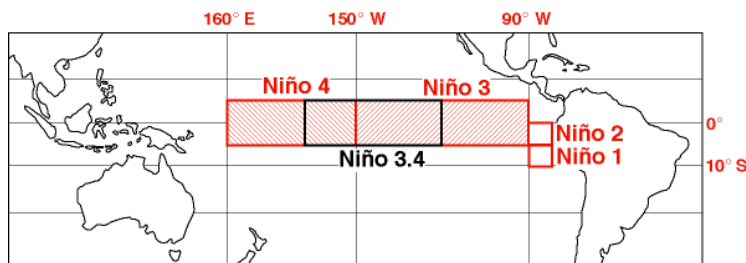
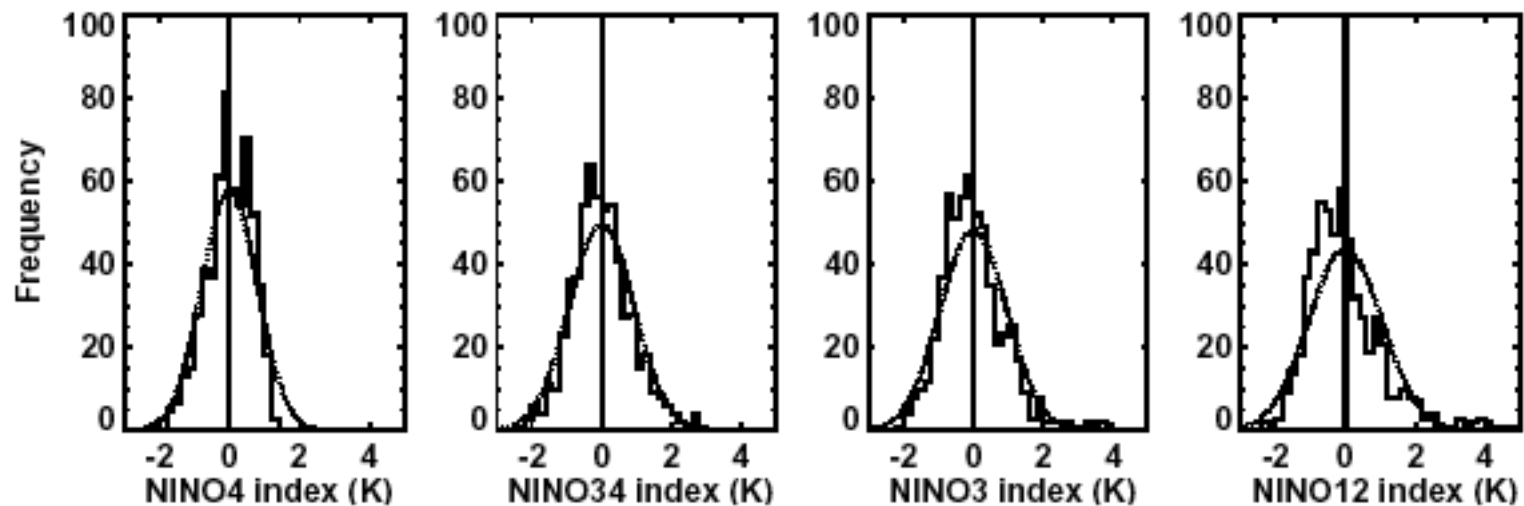
Sea Surface Temperature and Sea Level Pressure



$$r = 0.93$$

2A. The 'Robust Observations

The statistics of ENSO indices are mainly Gaussian --
except in the far eastern equatorial Pacific Ocean.



Burger and Stephenson 1999

2B. ENSO in the modern climate: the physics

(a summary of what comes next)

- **ENSO is the result of coupled atmosphere-ocean physics that is intrinsic to the tropical Pacific.**
 - Ocean models must be forced by Southern Oscillation to produce 'El Ninos';
 - Atmosphere models must be forced by 'El Nino' SST to produce the Southern Oscillation.
- **ENSO is a true mode of the coupled system**
 - ENSO is the leading eigenmode (Floquet mode) of the linearized equations for the tropical atmosphere and ocean.
- **The ENSO mode is strongly dependant on the climatological mean state.**
 - It strongly determines the amplitude, spatial and temporal character of ENSO
 - The mean state annual cycle causes the ENSO mode to peak at the end of the calendar year.
- **Stochastic forcing of the ENSO mode yields output that is consistent with the “robust observations” of ENSO (including the skewness in the eastern Pacific*)**
- Much of the energy for forcing ENSO comes from uncoupled atmospheric weather (wobbling of the jet in the NH winter)
- ENSO affects are teleconnected from the tropical Pacific by well-understood atmosphere and ocean dynamics:
 - Atmospheric impact is nearly global in extent.