Global Ocean Tripole and Climate Variability

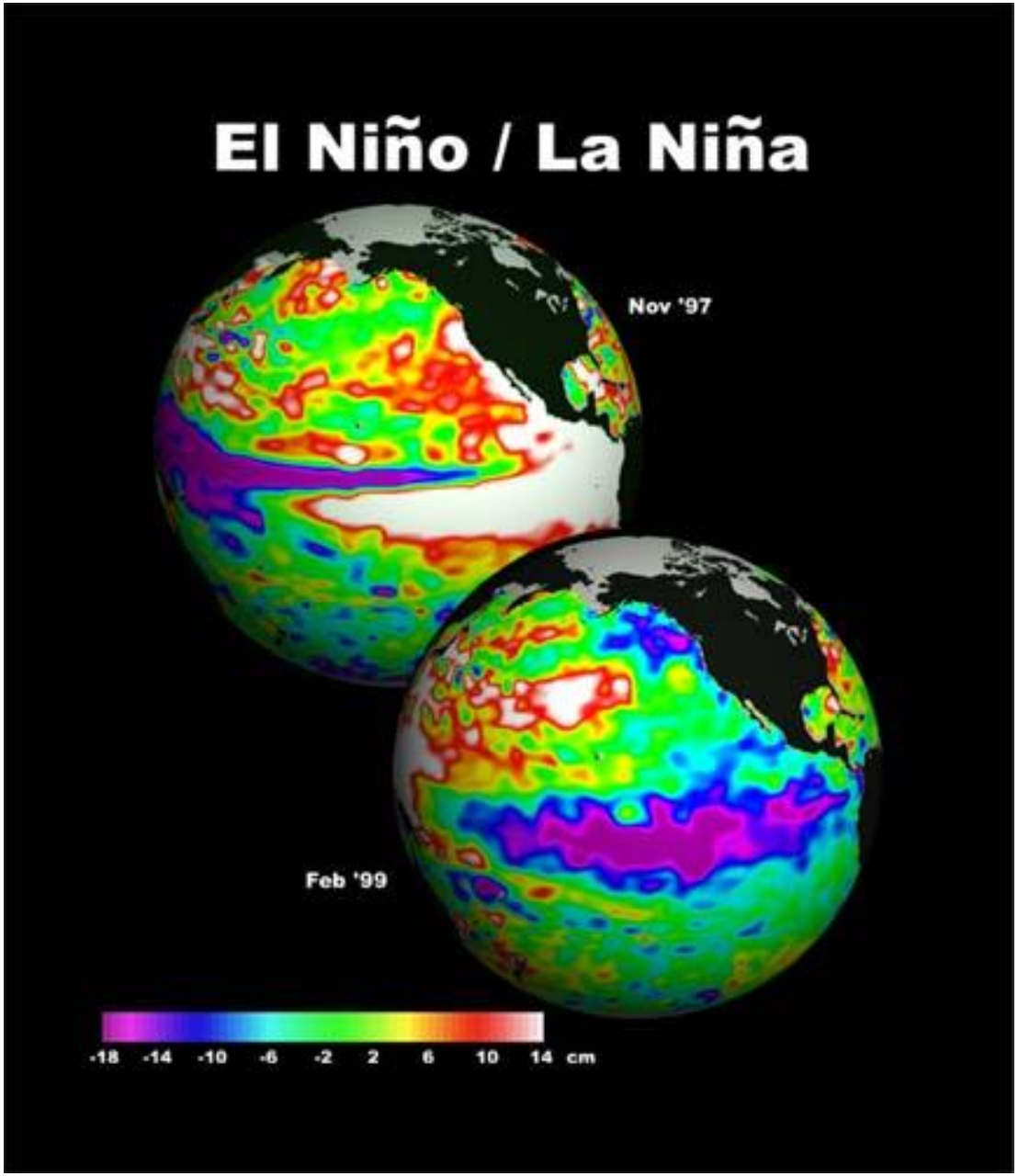
Peter C. Chu

Naval Postgraduate School

Institute of Applied Marine Physics and Undersea Technology, National Sun Yat-Sen University, Kaohsiung, Taiwan, 24 December 2010.

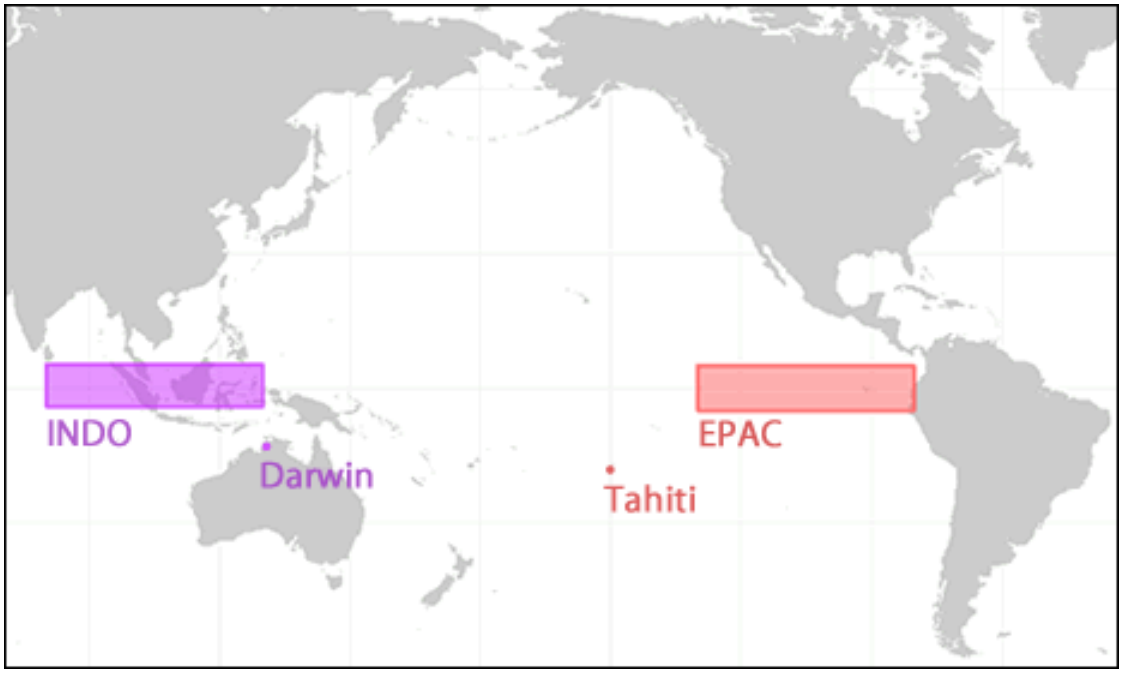
Outline

- (1) New Discoveries in Short-term Climate Variability
- (2) Data Analysis: (T, S) Profiles → Synoptic Gridded Data with Monthly Increment
- (3) Synoptic Upper Ocean (0-300 m) Heat Content
- (4) Global Tripole → Canonical El Nino, El Nino Modoki, Indian Ocean Dipole, …


El Niño / La Niña
Nov '97
Feb '99
-18 -14 -10 -6 -2 2 6 10 14 cm

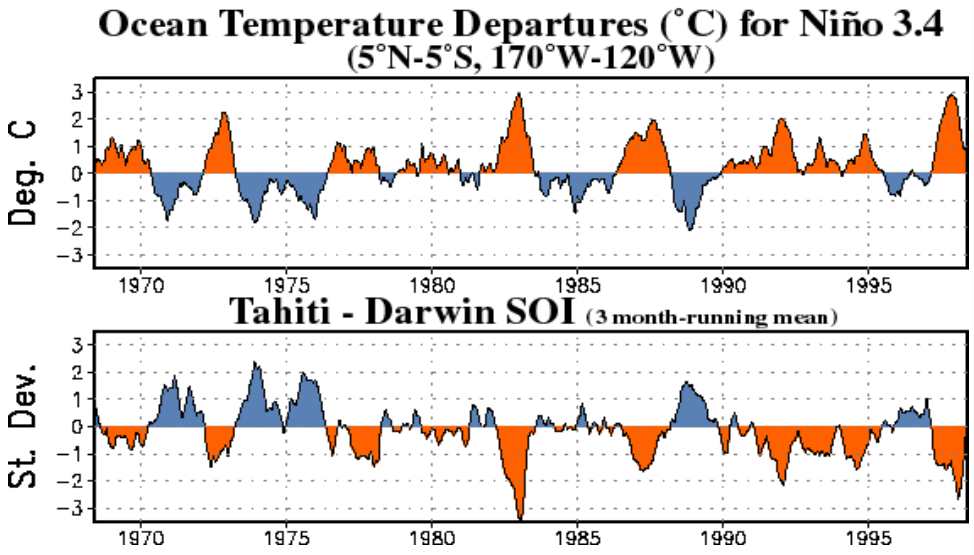
The Southern Oscillation Index (SOI)

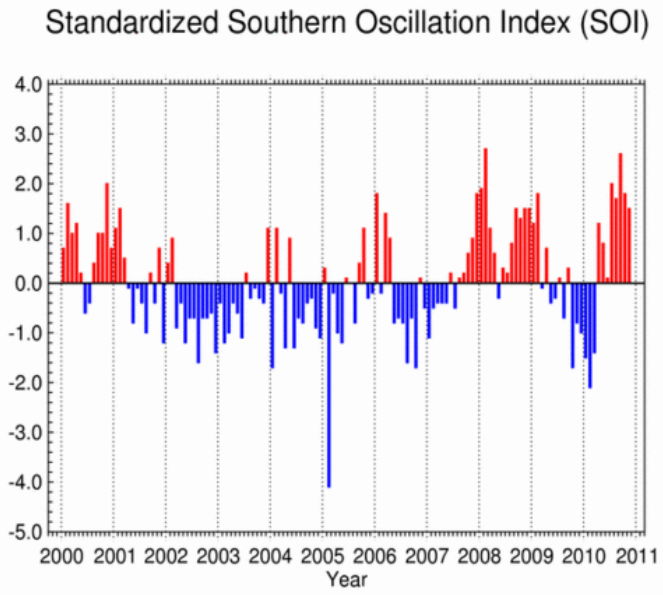
One measure of the large-scale fluctuations in air pressure occurring between the western and eastern tropical Pacific



The Southern Oscillation Index (SOI)

Negative SOI → EL Nino

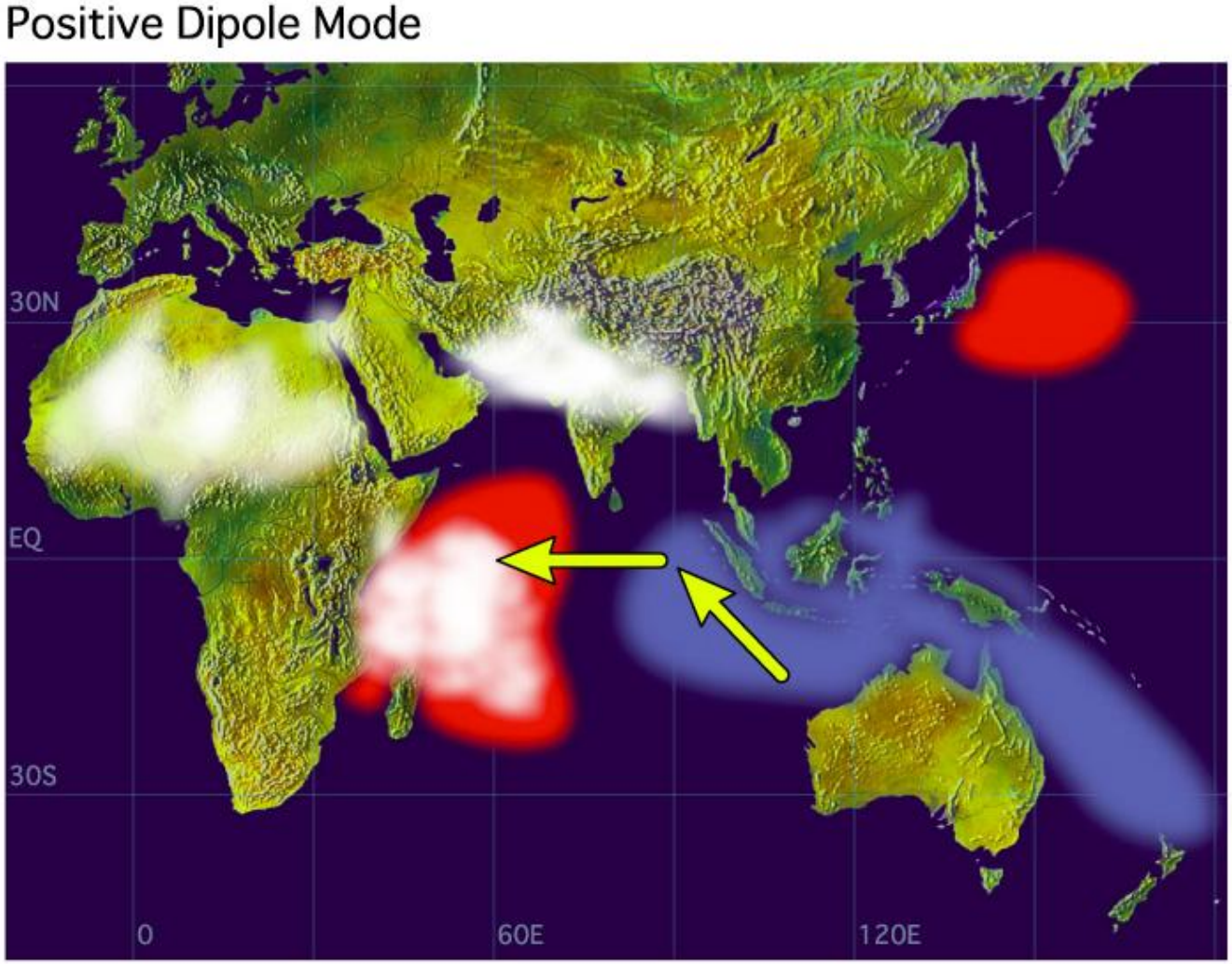




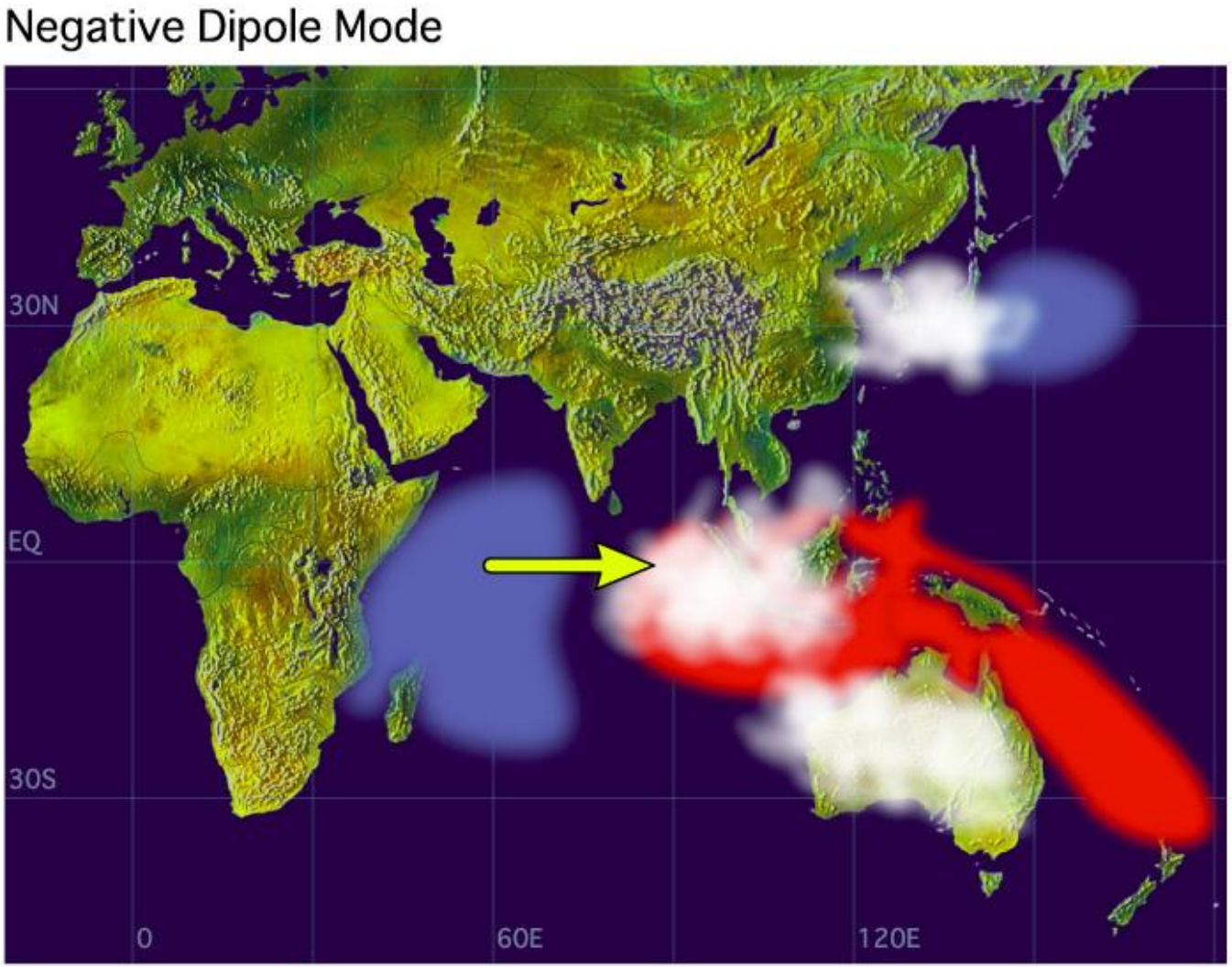
(1) New Discoveries in Climate Variability

Indian Ocean Dipole
El Nino Modoki

Indian Ocean Dipole (Saji et al. 1999)

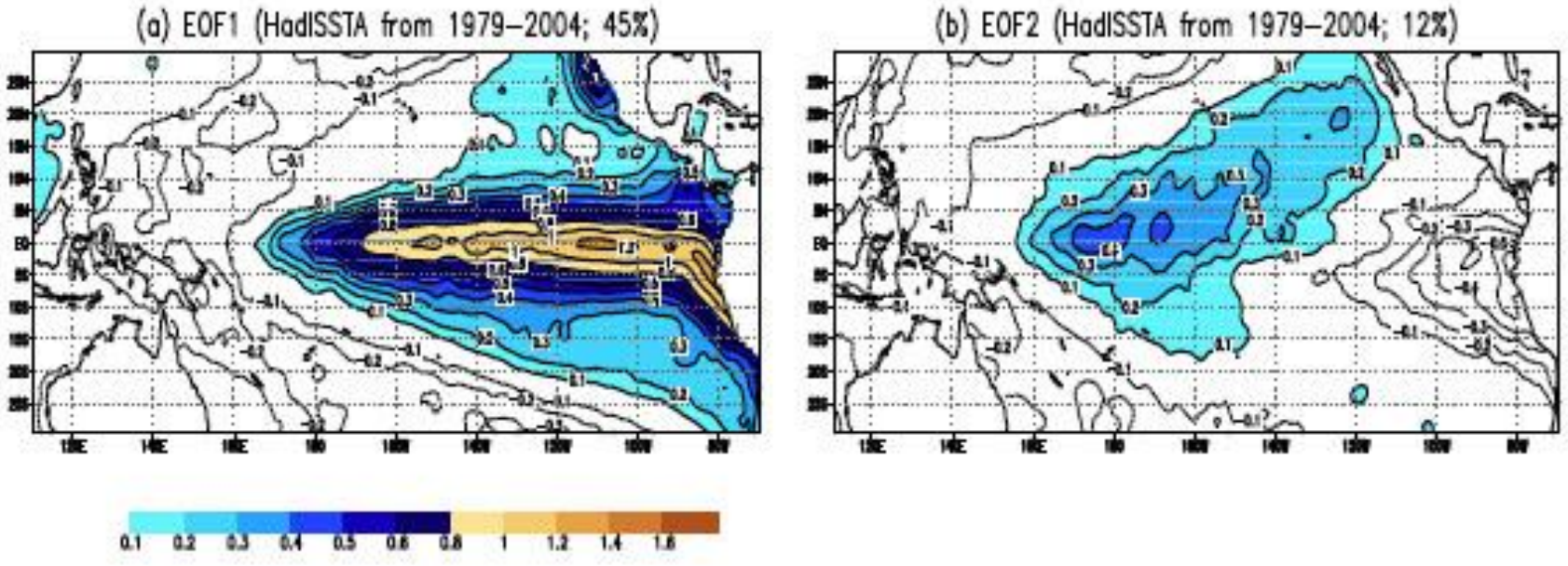


Indian Ocean Dipole (Saji et al. 1999)



El Nino and El Nino Modoki

(Weng et al. 2007, Ashok et al. 2007)



(Images coutesy Karumuri Ashok, APEC Climate Center)

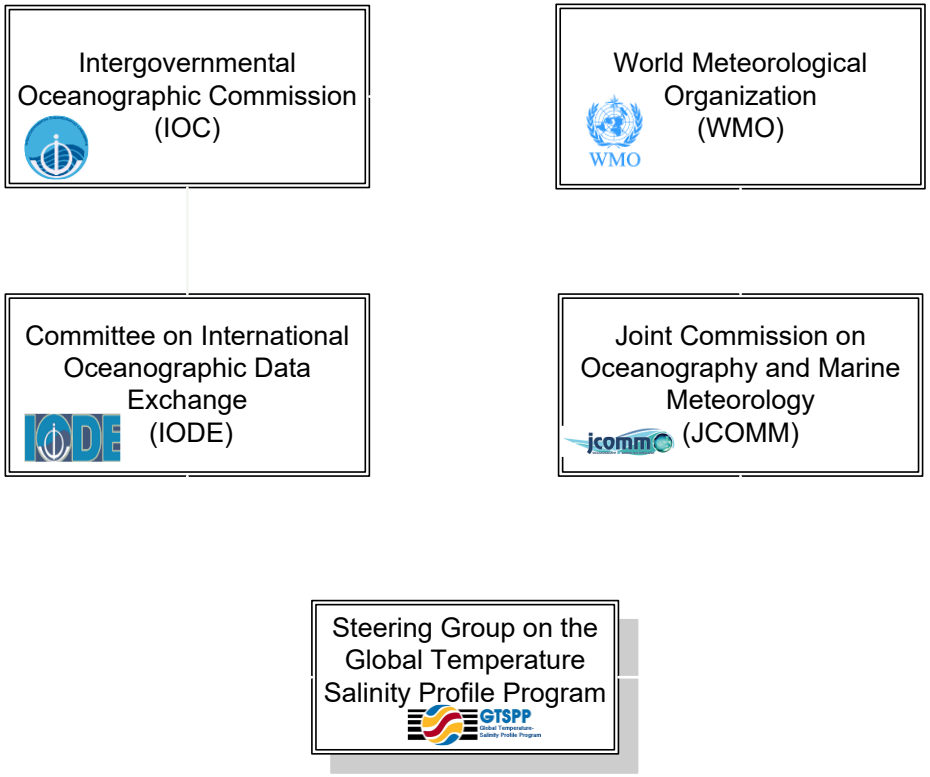
(2). Data Analysis

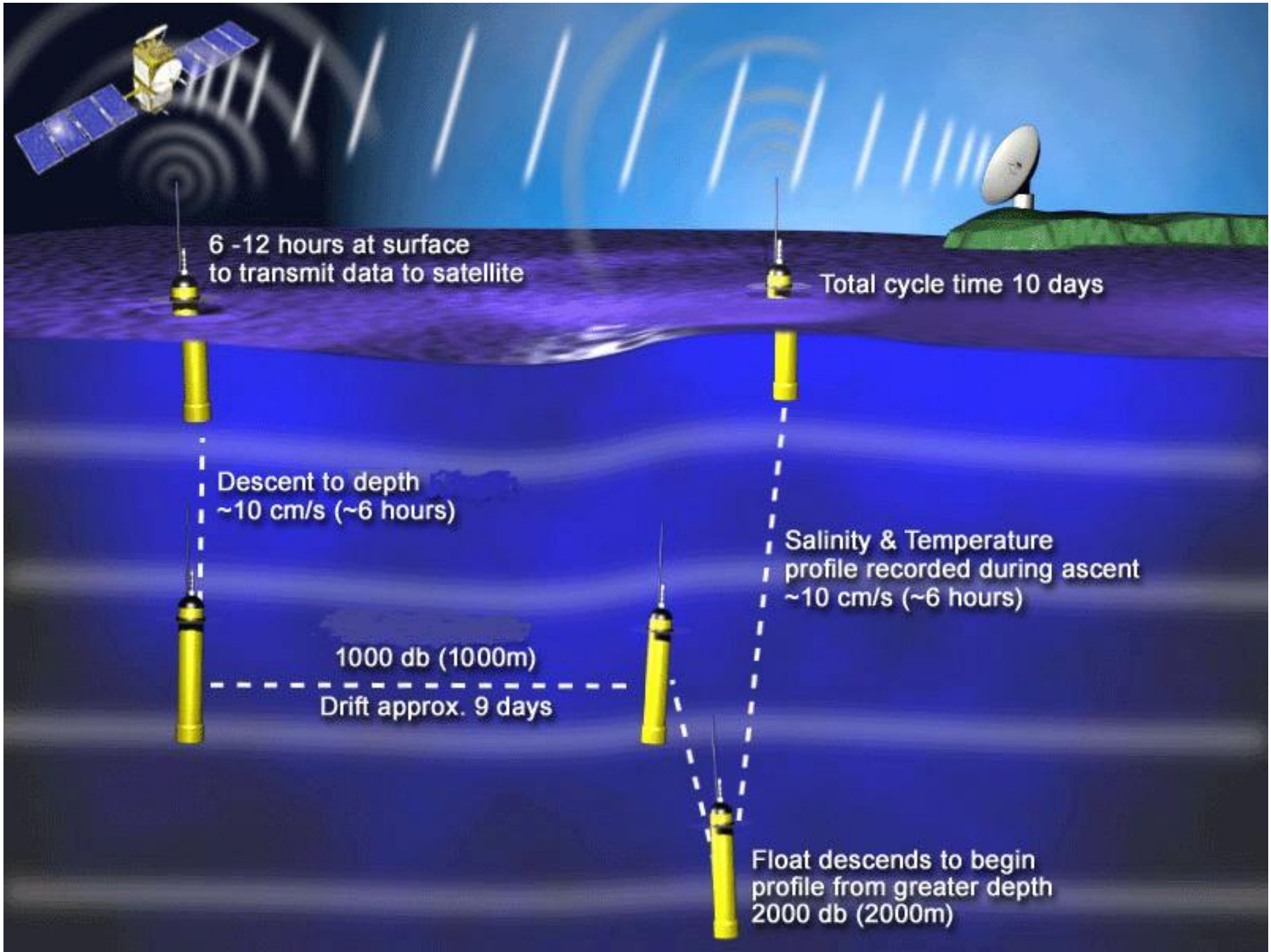
Global Temperature and Salinity Profile Program (GTSPP)

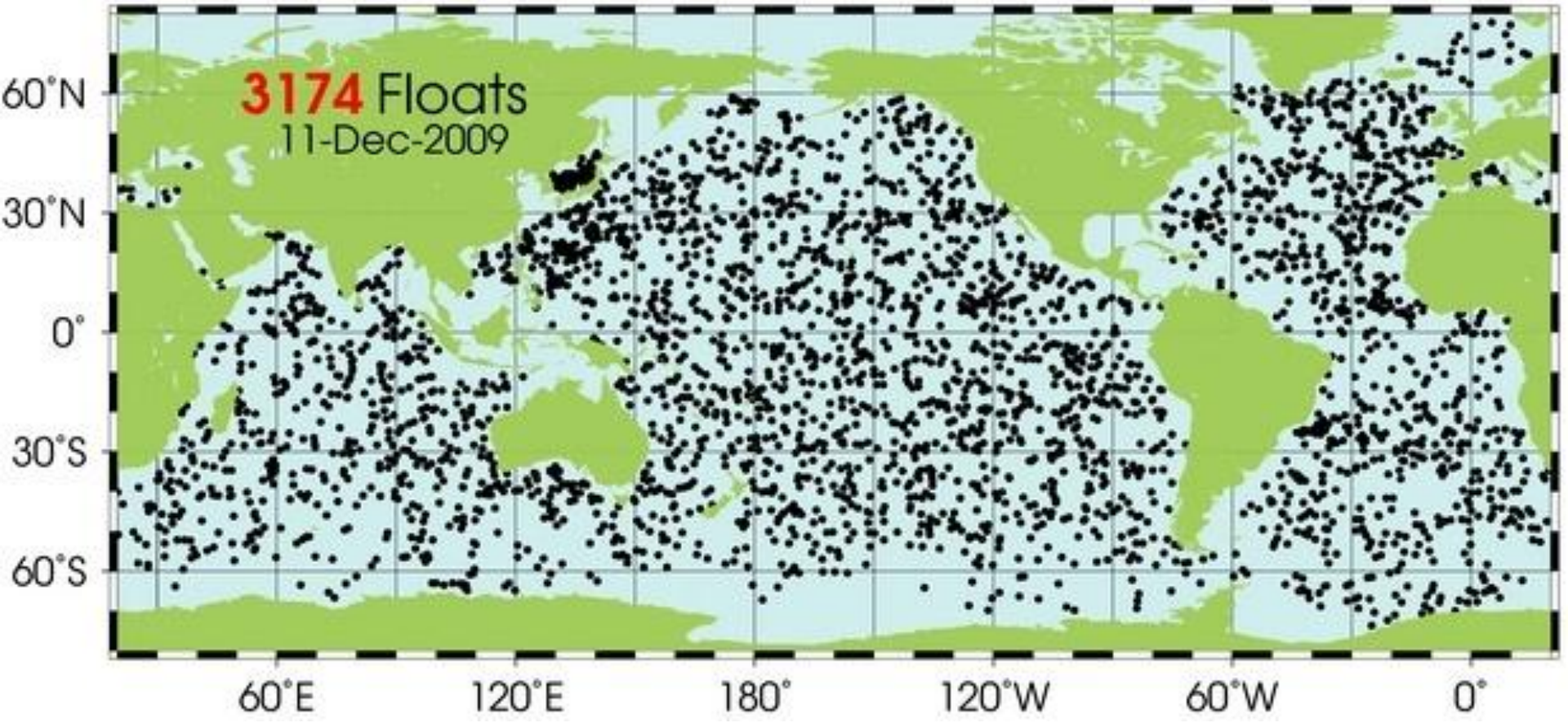
GTSPP

GTSPP = Global Temperature Salinity Profile Program

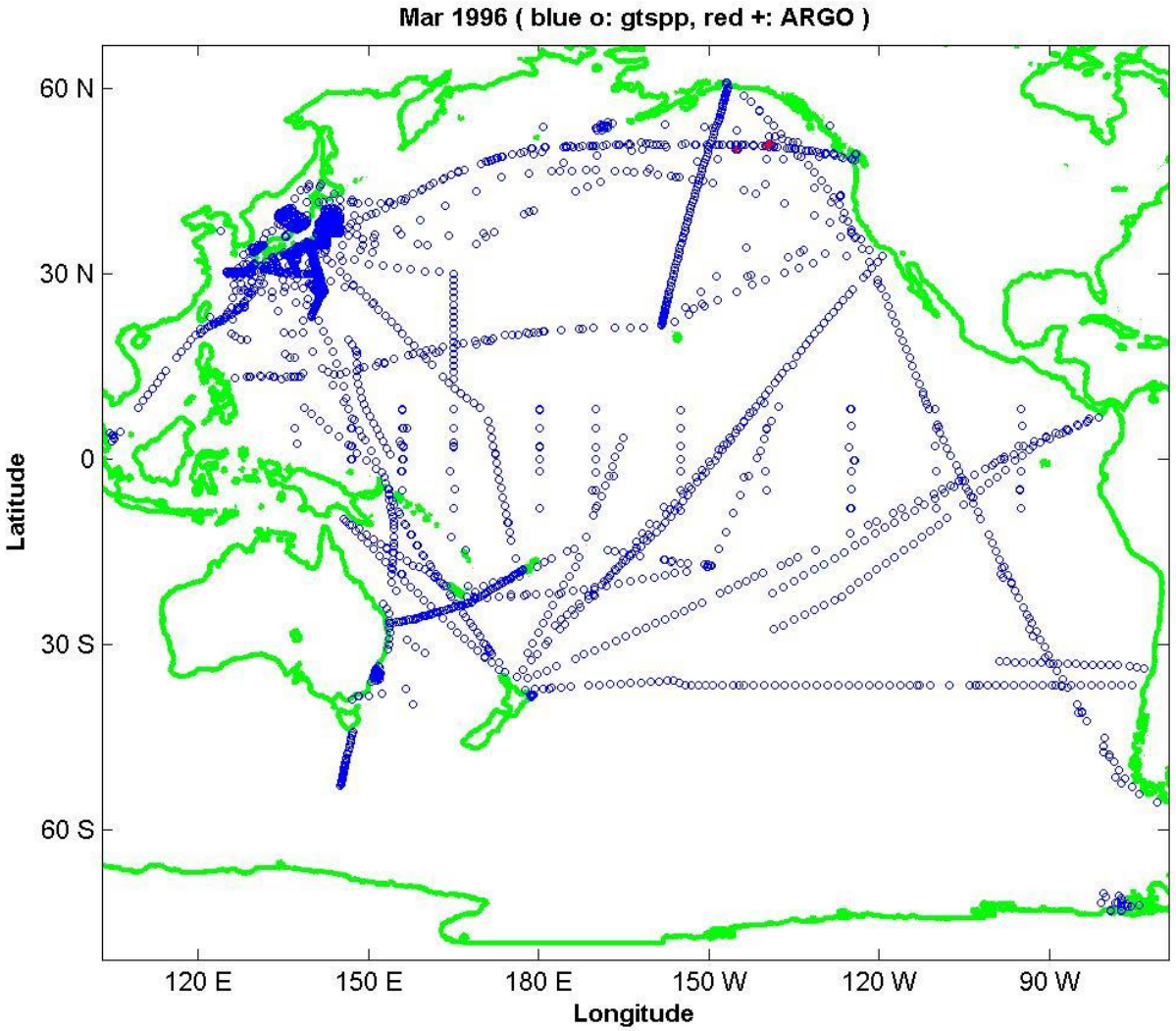
- GTSPP is a joint WMO-IOC program designed to provide improved access to the highest resolution, highest quality data as quickly as possible.
- GTSPP began as an official IODE pilot project in 1989.
- It went into operation in November 1990.



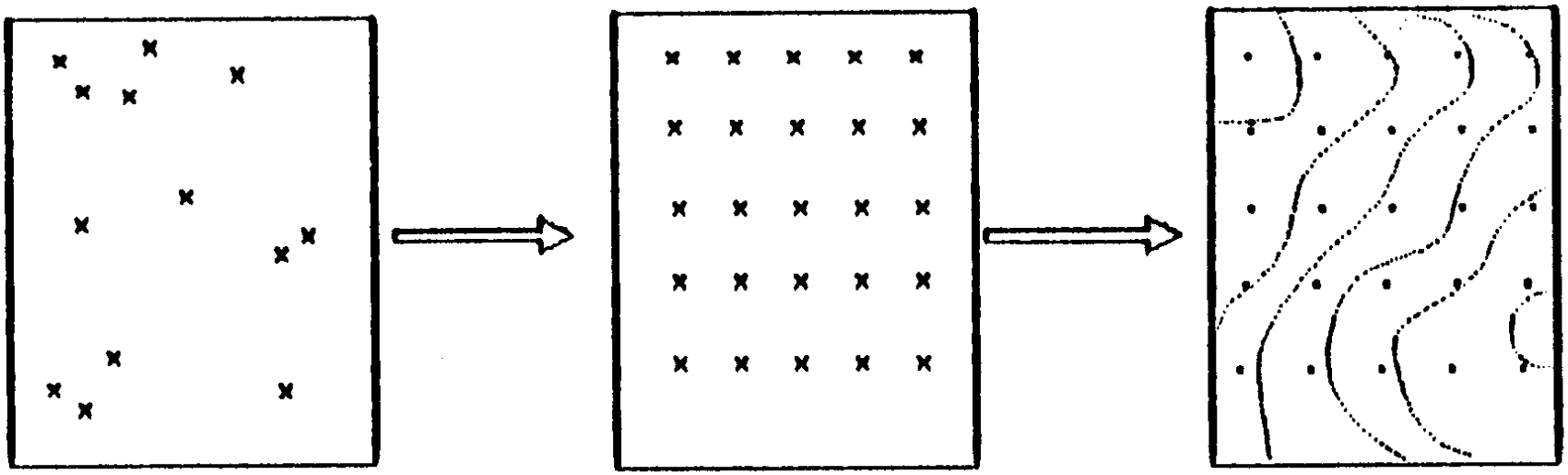

6 -12 hours at surface
to transmit data to satellite
Total cycle time 10 days
Descent to depth
~10 cm/s (~6 hours)
Salinity & Temperature
profile recorded during ascent
~10 cm/s (~6 hours)
1000 db (1000m)
Drift approx. 9 days
Float descends to begin
profile from greater depth
2000 db (2000m)


3174 Floats
11-Dec-2009
60°N
30°N
0°
30°S
60°S
60°E
120°E
180°
120°W
60°W
0°

Example → GTSPP Data



Ocean Data Analysis



Fourier Series Expansion

→ Optimal Spectral Decomposition

Joseph Fourier 1768-1830



Fourier was obsessed with the physics of heat and developed the Fourier series and transform to model heat-flow problems.

(3) Upper Ocean Heat Content

Upper Ocean (0-300 m) Heat Content

$$HC = \int_{-h}^{0} \rho c T dz$$

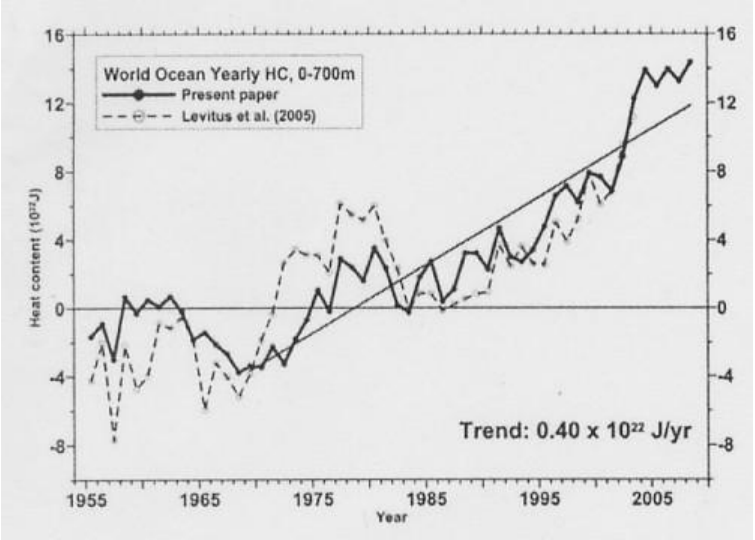
$HC = HC_{\text{mean}} + HC_{\text{seasonal}} + HC_{\text{anomaly}}$

EOF Analysis → HC_{anomaly}

→ Global Ocean Dipole Modes

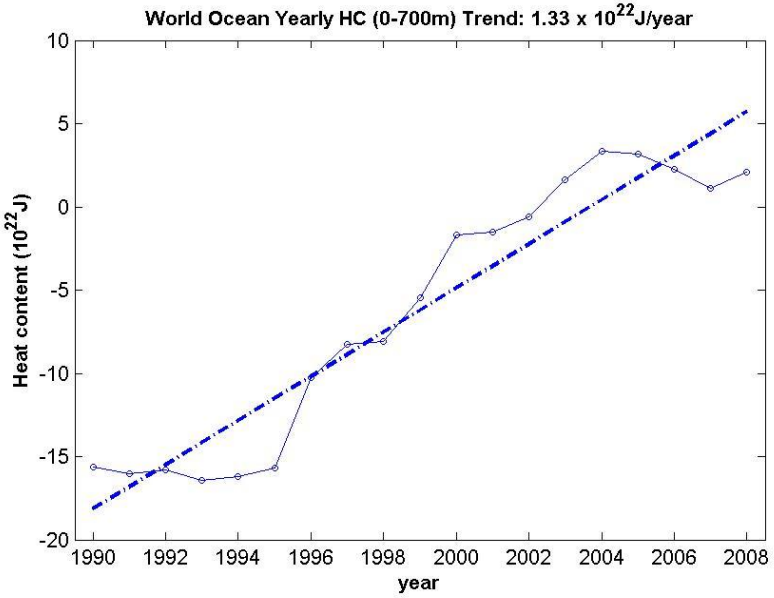
Trend of Upper Ocean (0-700 m) Heat Content

0.4 X 10^{22} J/yr
(1958-2008)
(Levitus et al.,GRL, 2009)
Without Argo data

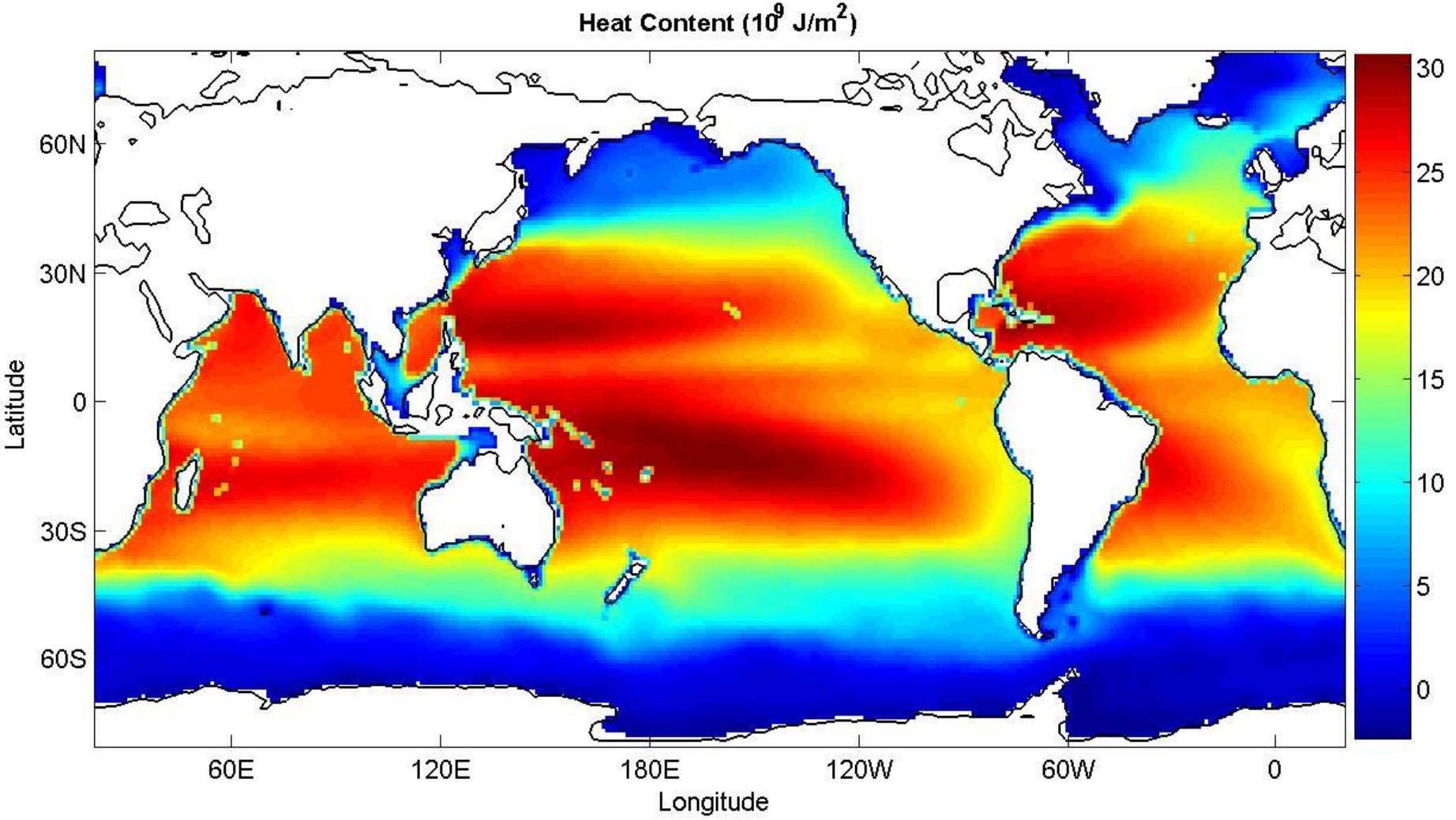


1.3 X 10^{22} J/yr
(1990-2008)

With Argo data

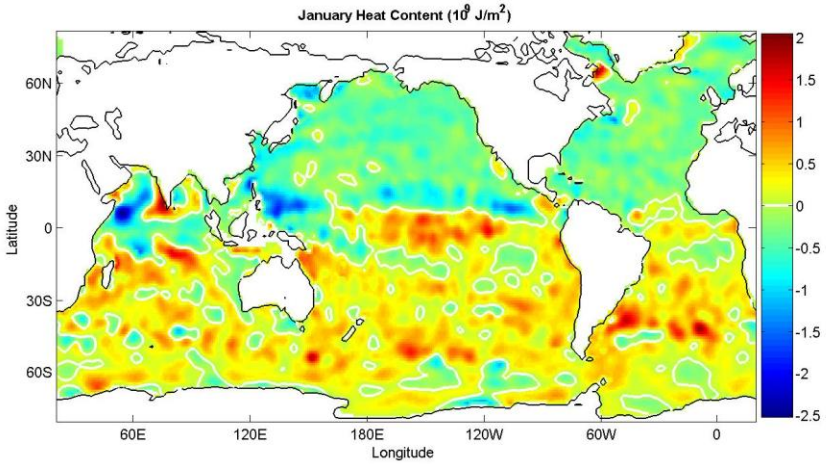


Upper Ocean (0-300 m) Mean Heat Content (J/m^2) (1990-2009)

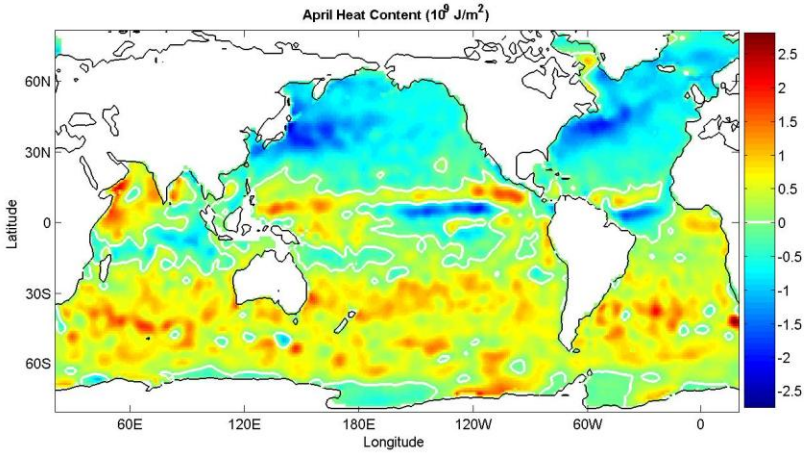


Seasonal Variability of Upper Ocean (0-300 m) Heat Content (J/m^2) (1990-2009)

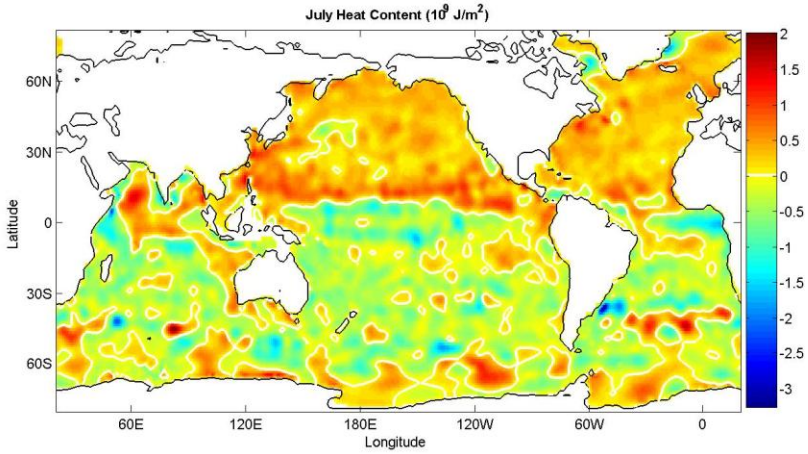
January



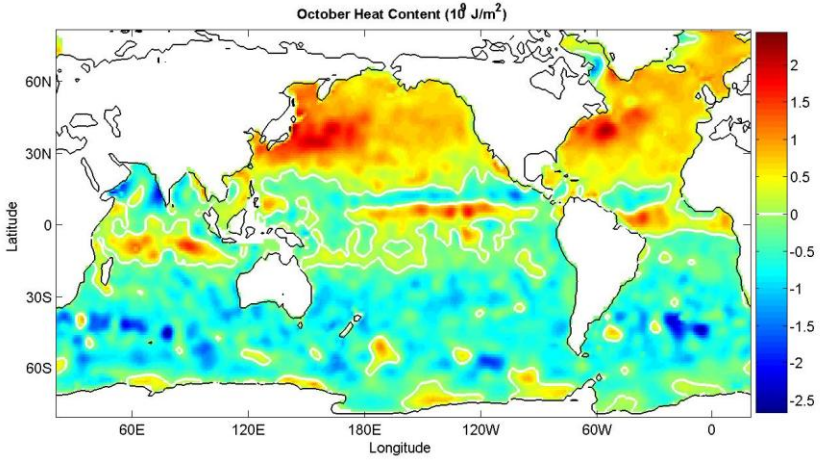
April



July



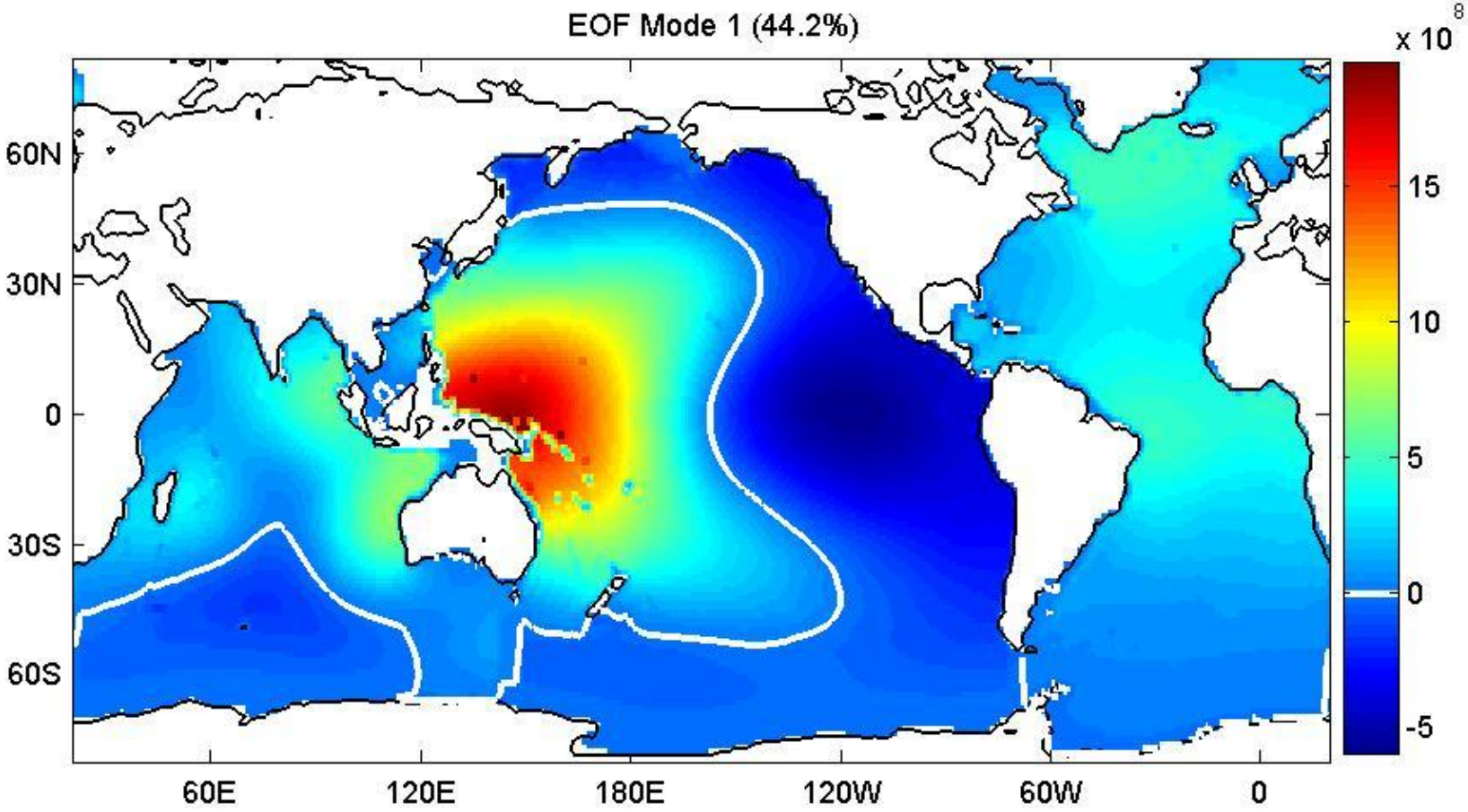
October



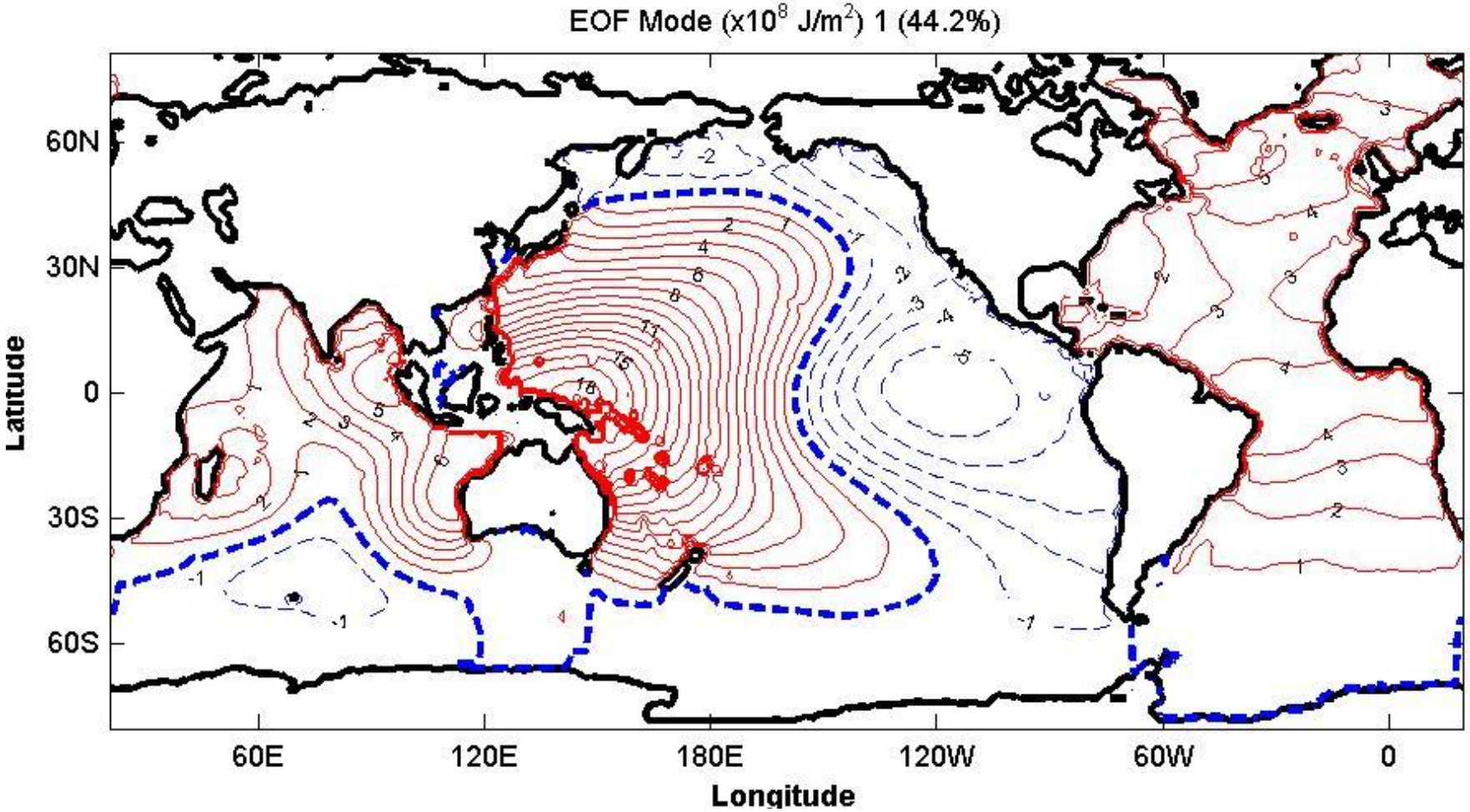
EOF Analysis →

Heat Content Anomaly Relative to Seasonal Variation

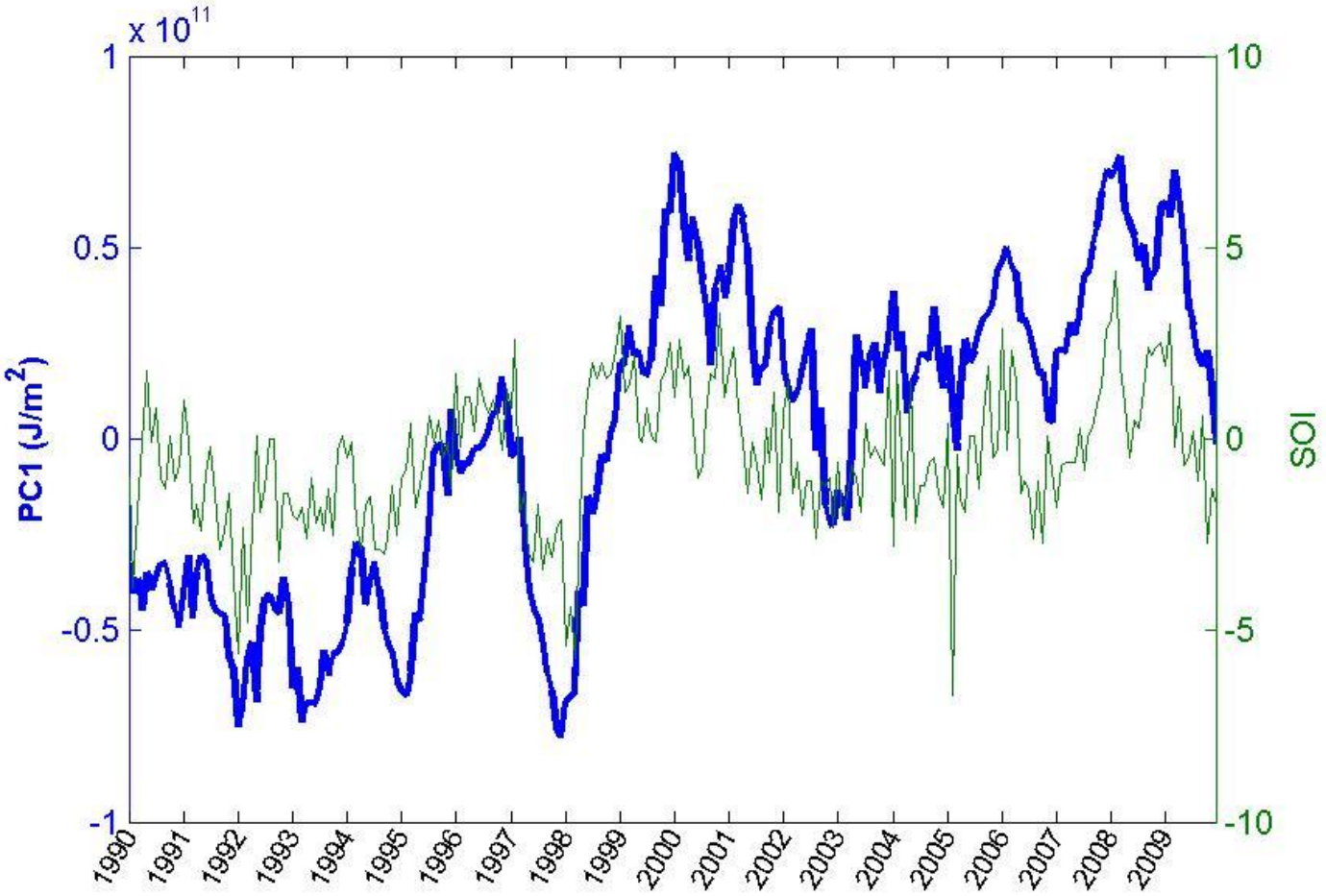
EOF-1 (in 10^8 J/m^2)



EOF-1 (in 10^8 J/m^2)

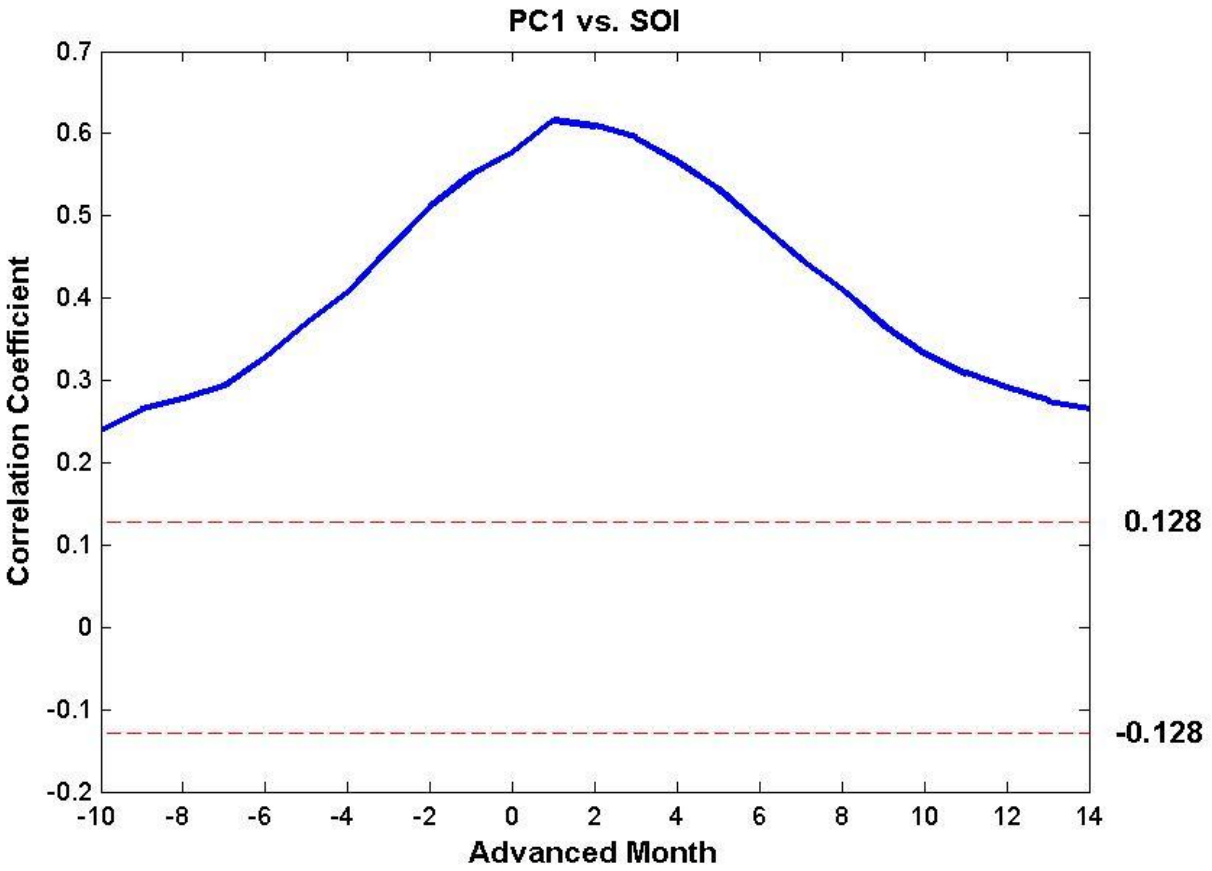


SOI and PC_1



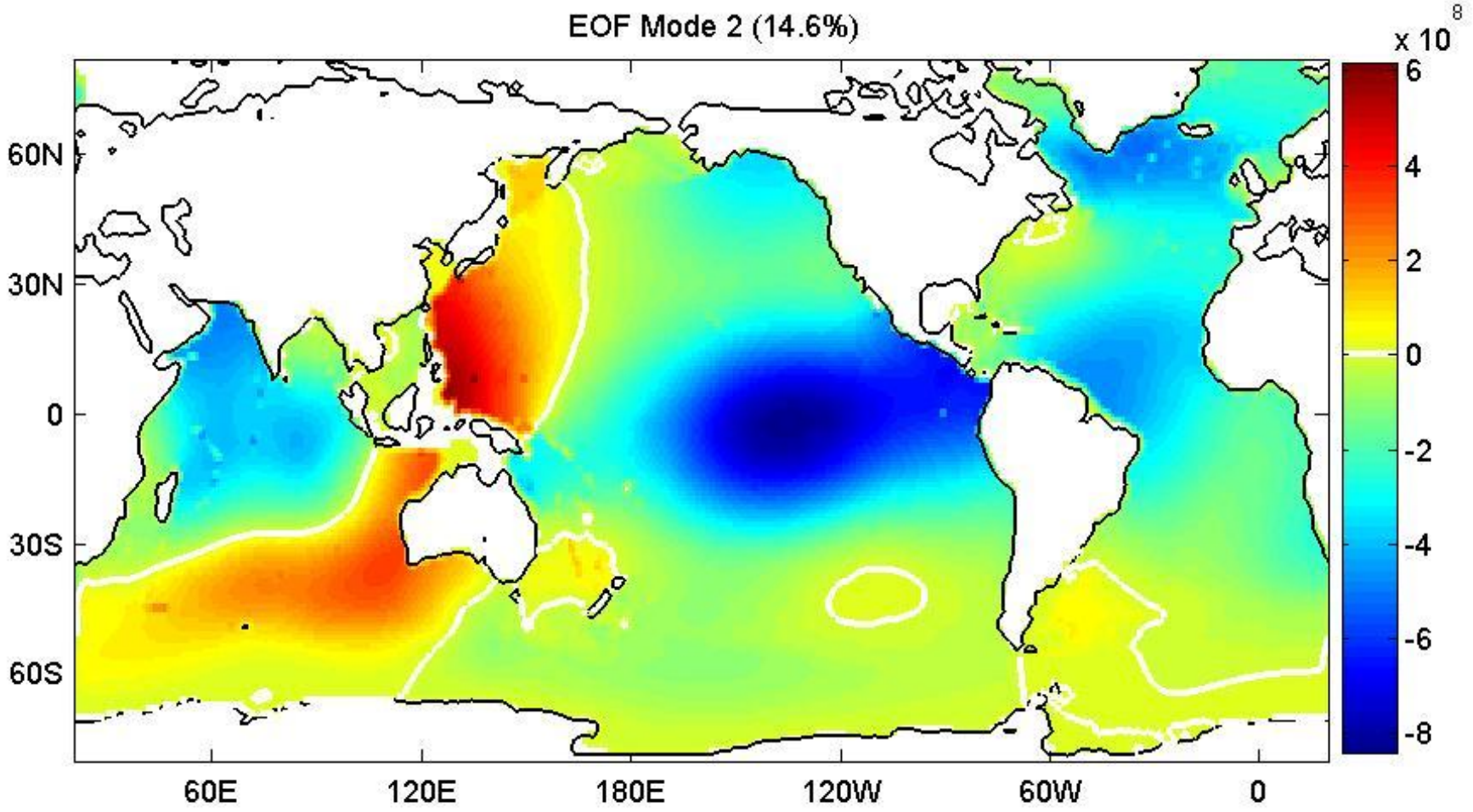
Negative SOI → El Nino

Lag Correlation between PC_1 and SOI

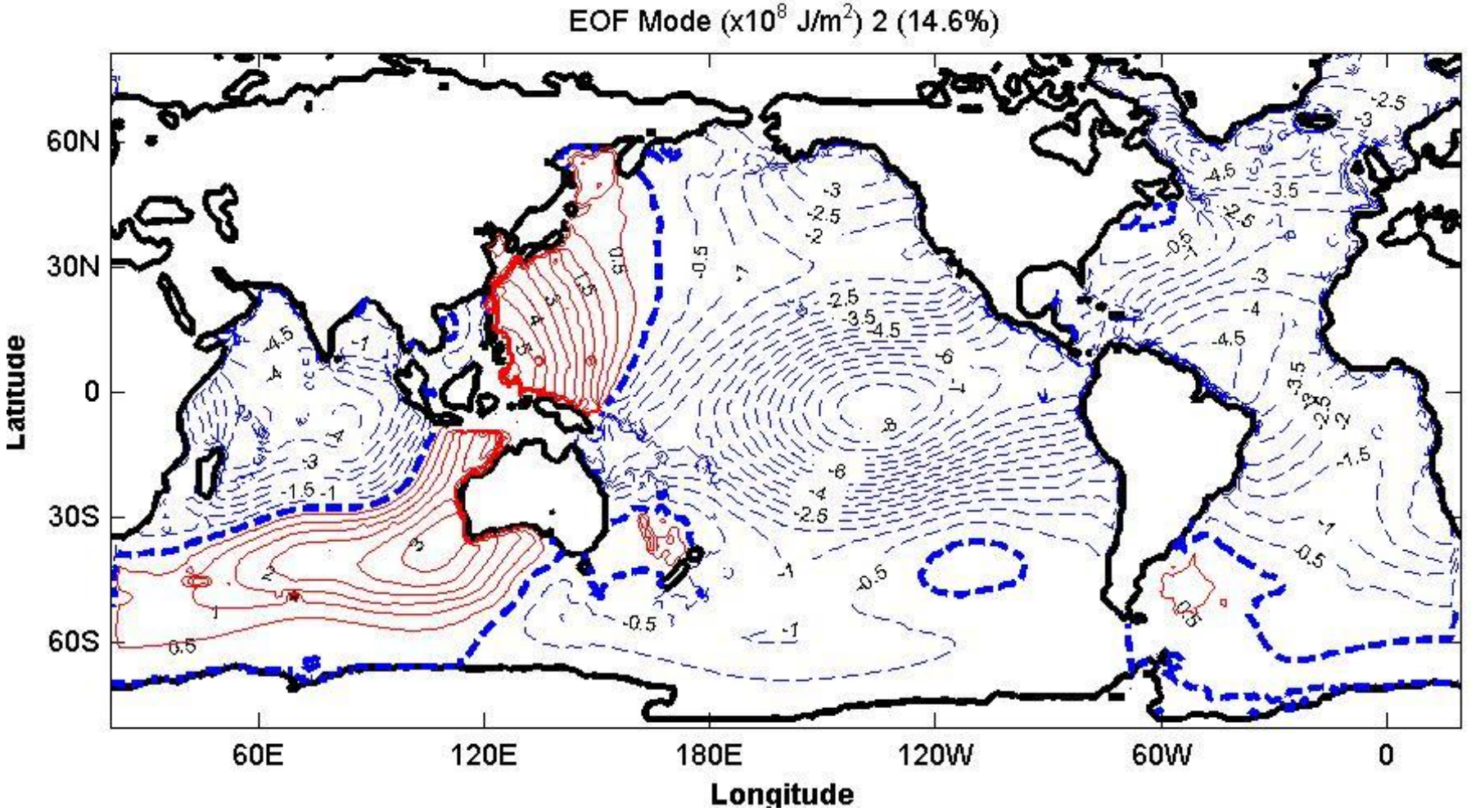


Positive Month → PC_1 advancing SOI

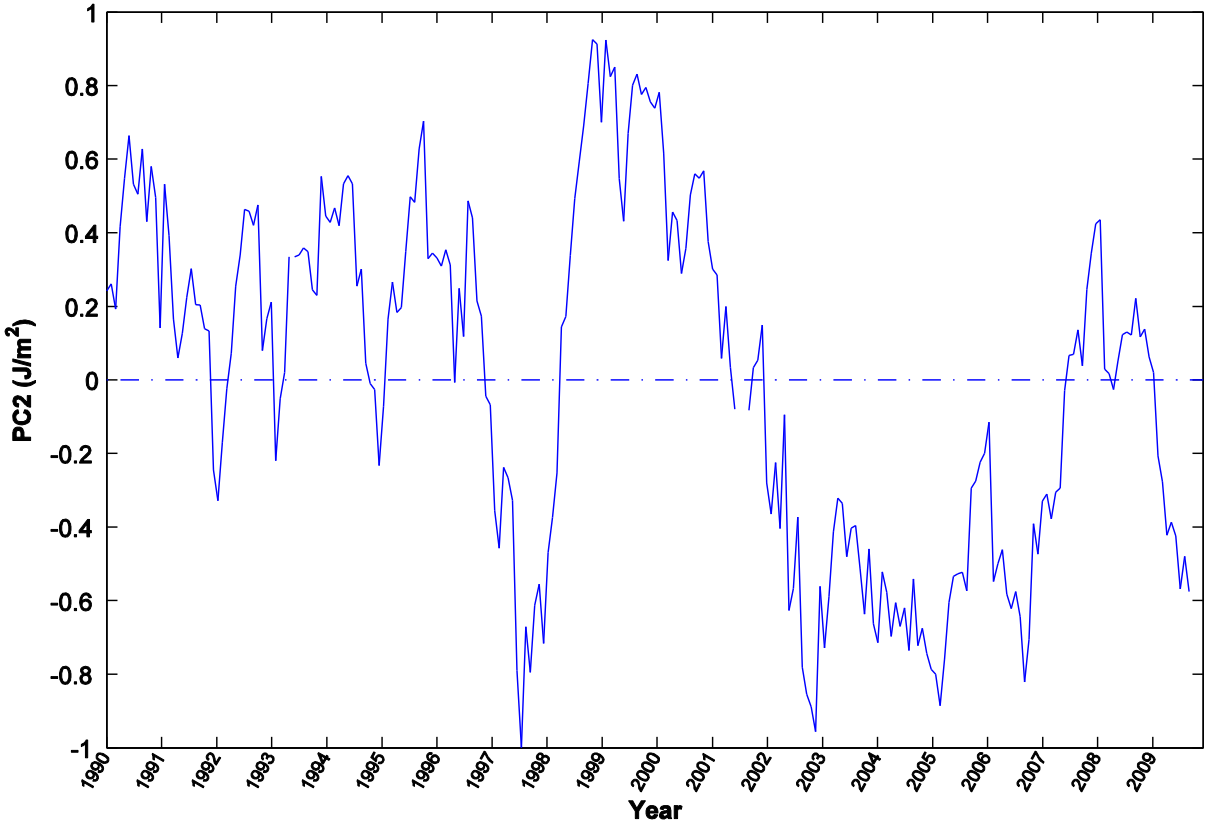
EOF-2 (in 10^8 J/m^2)



EOF-2 (in 10^8 J/m^2)

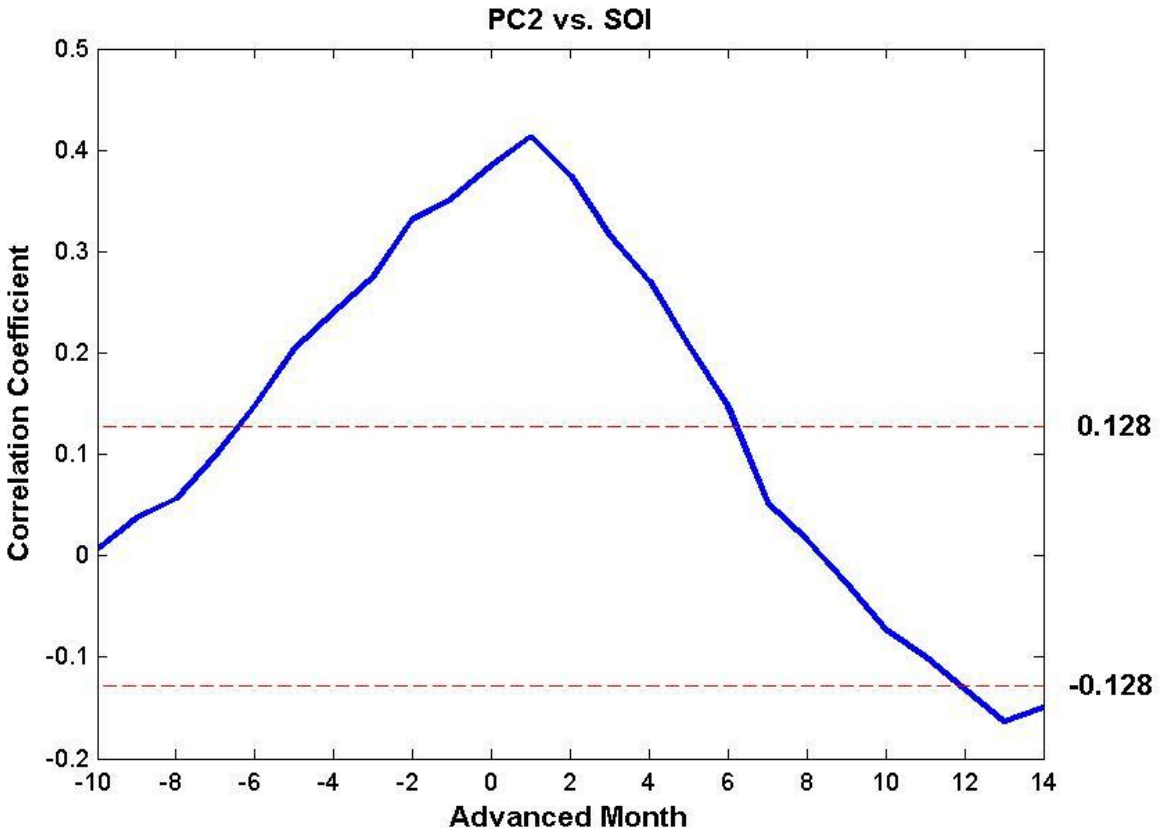


PC_2



Negative SOI → El Nino Modoki

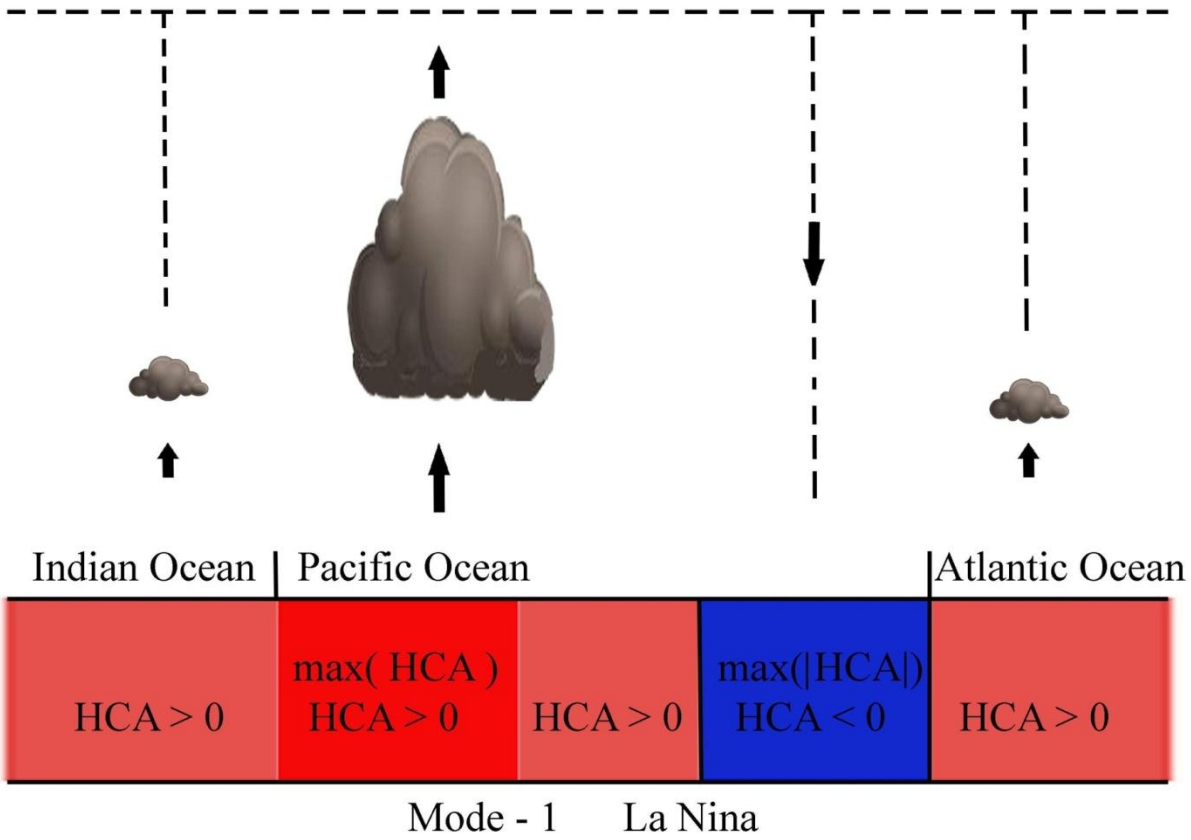
Lag Correlation between PC_2 and SOI



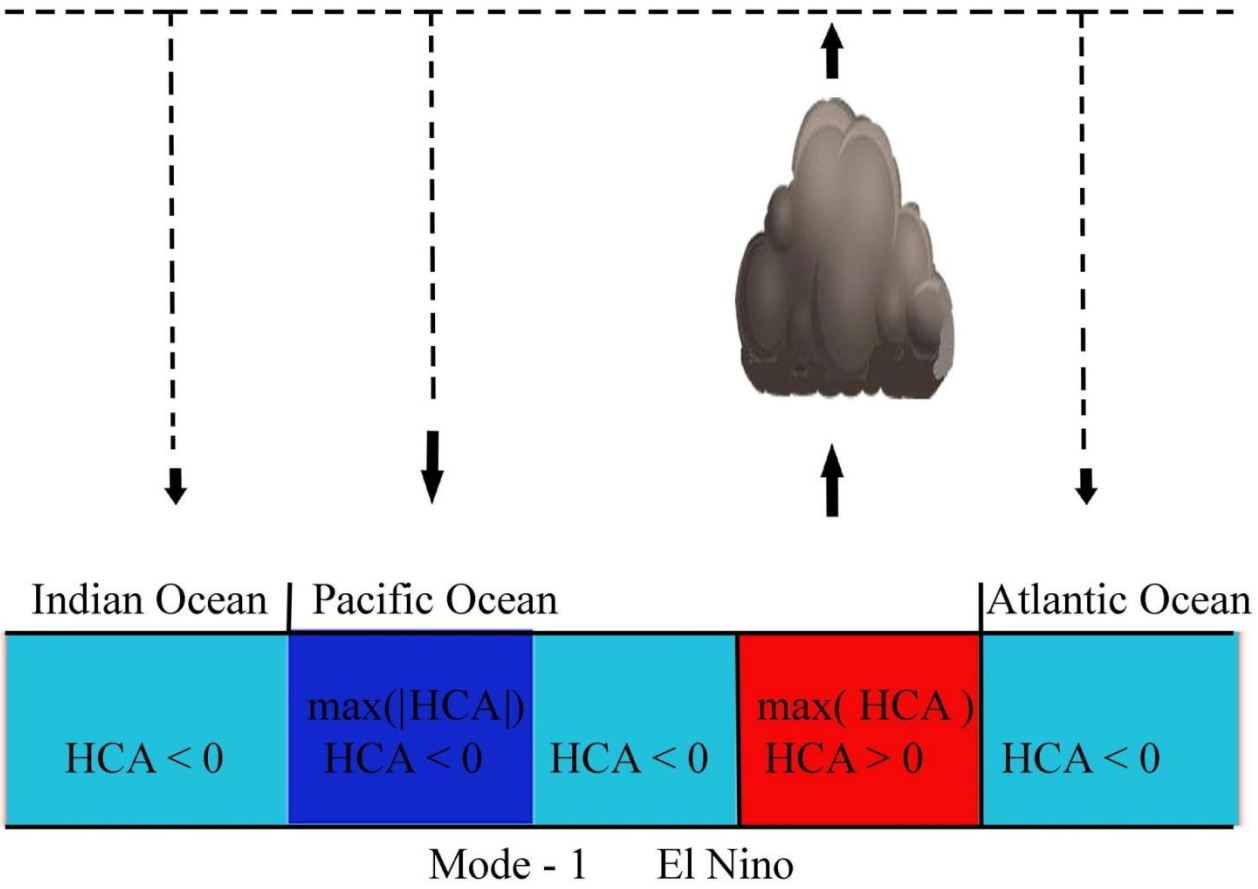
Positive Month → PC_2 advancing SOI

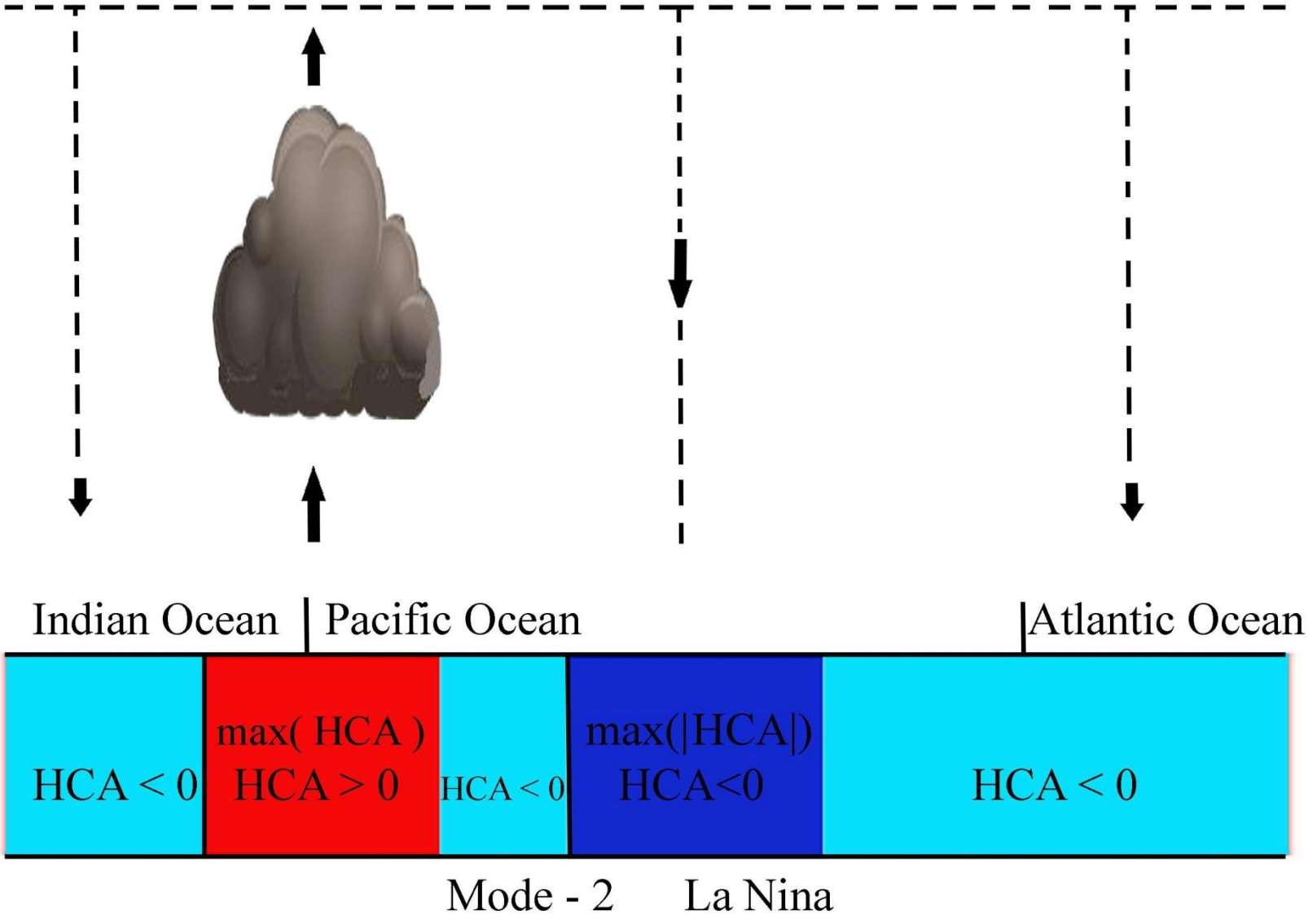
(4) Global Ocean Tripole

Canonical La Nina →
More and Stronger Hurricanes in Atlantic (Pielke and Landsea, 1999 BAMS)



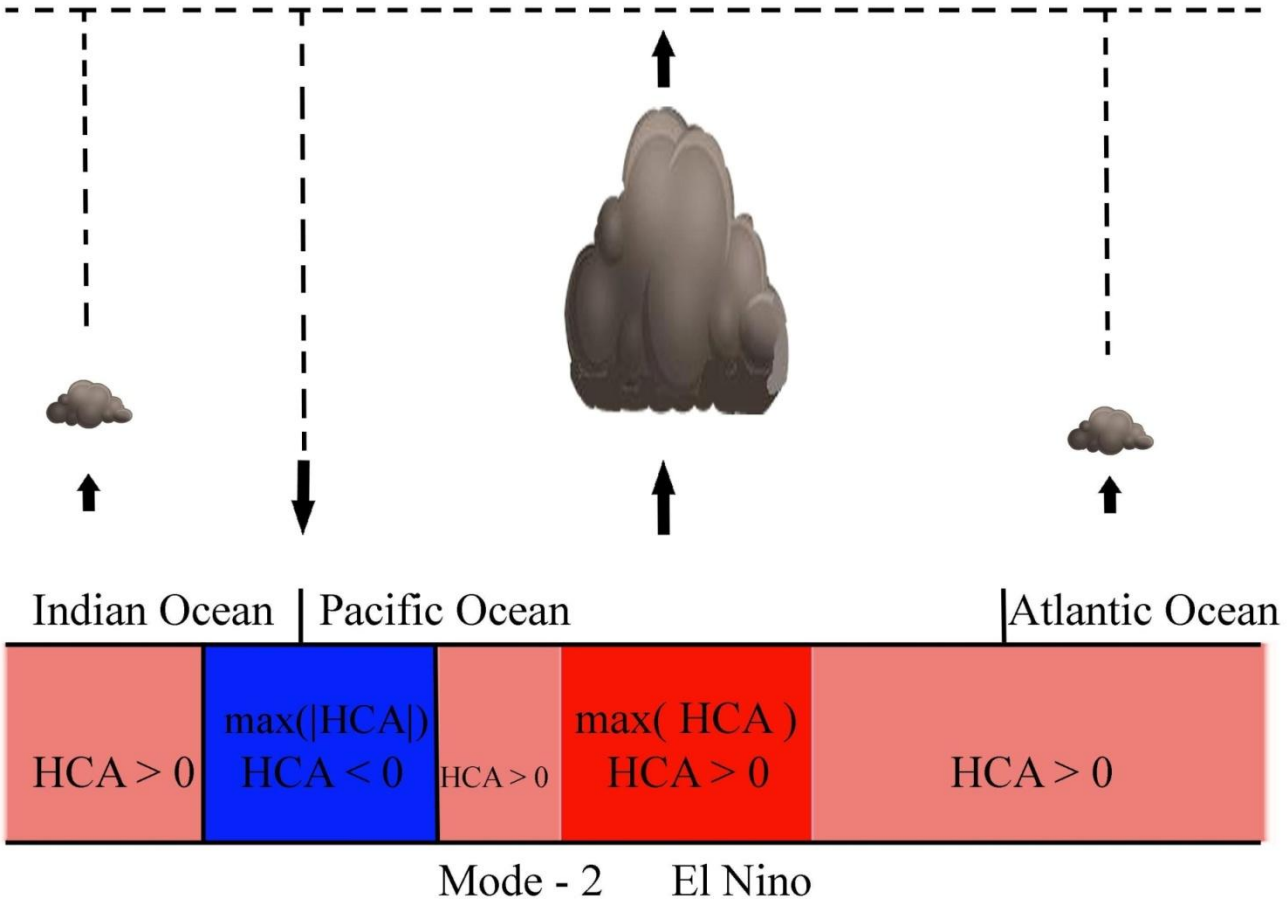
Canonical El Nino




Indian Ocean
Pacific Ocean
Atlantic Ocean
HCA < 0
max(HCA)
HCA > 0
HCA < 0
max(|HCA|)
HCA<0
HCA < 0
Mode - 2
La Nina

El Nino Modoki

More and Stronger Hurricanes in Atlantic



Trajectory in Phase Space (PC_1, PC_2)

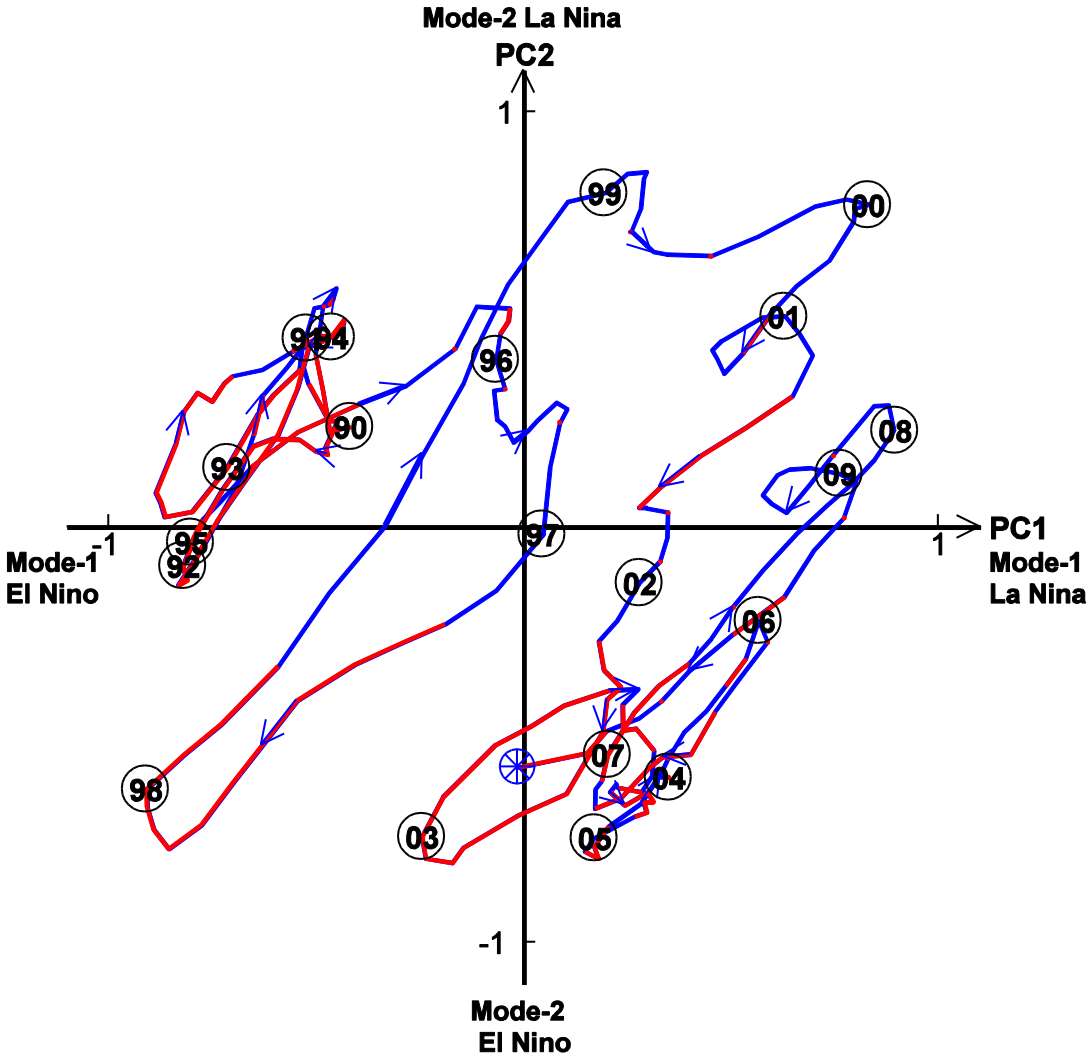
- Blue Curve →

  La Nina

- Red Curve →

  Two Types of

  El Nino



Conclusions

- (1) Upper ocean heat content contains the signal for climate change (interannual) → Global Ocean Tripole.

- (2) El Nino, El Nino Modoki, and Indian Ocean Dipole can be unified by Global Ocean Tripole.