

# Seasonally Stratified Analysis of Simulated ENSO Thermodynamics

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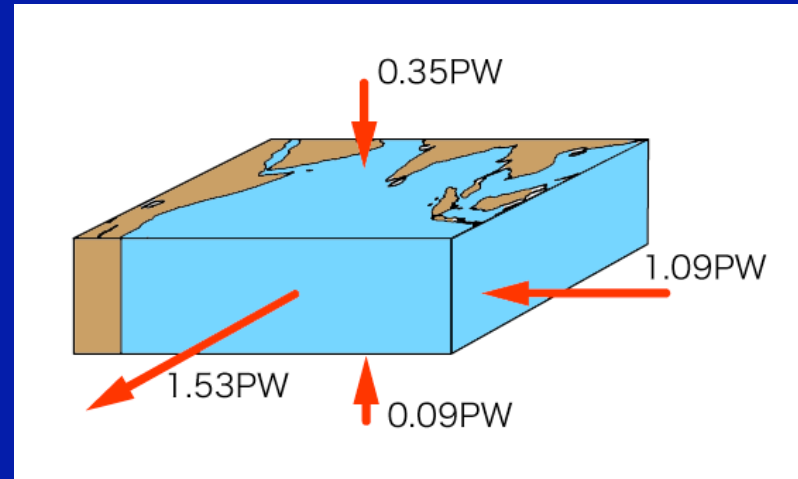
(J. Climate, in press)

## Tozuka et al. (2006)

The first law of thermodynamics is the basic principle in understanding variability of climate system.



Tozuka et al. (2006, J. Clim.): investigated the decadal variation of the tropical Indian Ocean through heat budget analysis.



## Tozuka et al. (2006)

The decadal modulation in the occurrence of the simulated Indian Ocean Dipole (IOD) is mainly induced by

- variations in the southward Ekman heat transport across  $15^{\circ}\text{S}$  associated with variations in the Mascarene High.
- variations in the Indonesian Throughflow heat transport related to ENSO.

As an extension, we have started examining origins of the decadal modulation of the ENSO based on the heat budget analysis to shed new light on this topic.

# Studies devoted to understanding of the ENSO based on thermodynamics

- ◆ **Wyrтки (1975, 1985)**: the warm water volume of the tropical Pacific (estimated from tide gauge data) tends to increase as a whole prior to El Niño event and then decreases during a course of the event.
- ◆ **Holland and Mitchum (2003)**: confirmed more precisely by using the TOPEX/POSEIDON altimetry data and OGCM results.
- ◆ **Jin (1997)**: formulated the recharge-discharge oscillator paradigm.

# Importance of the seasonal cycle to the ENSO

- ◆ **Rasmusson and Carpenter (1982)**
- ◆ **Tziperman et al. (1994), Jin et al. (1994):** seasonal cycle plays an important role in irregularity, chaotic nature, and phase-locking of ENSO events.
- ◆ **Tozuka and Yamagata (2003):** the ENSO may be interpreted as an interaction between the “interannual ENSO” mode and the “annual ENSO” mode.
- ◆ **Xu and Chan (2001), Horii and Hanawa (2004):**  
Relation between the onset and the evolution.
- ◆ **Harrison and Vecchi (1999), Lengaigne et al. (2006):**  
Relation between the termination and the seasonal cycle.

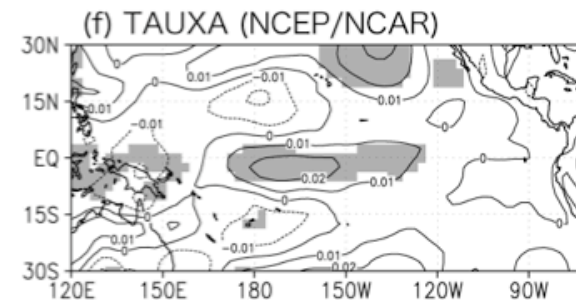
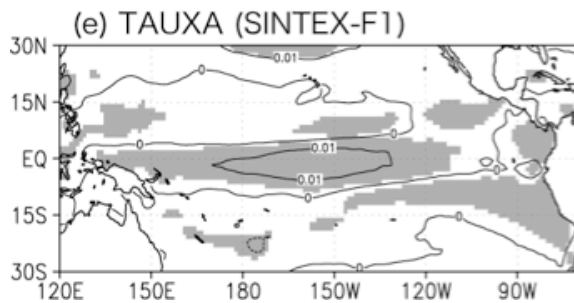
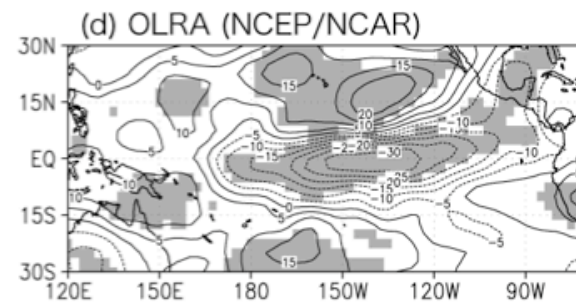
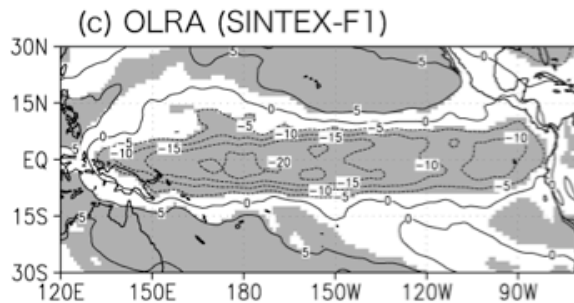
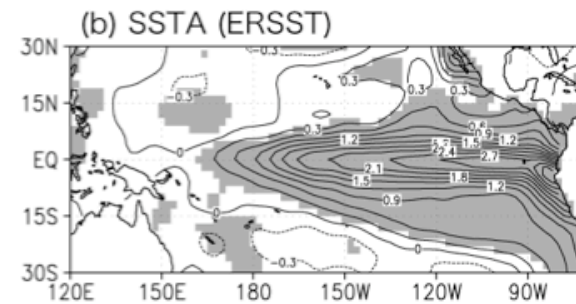
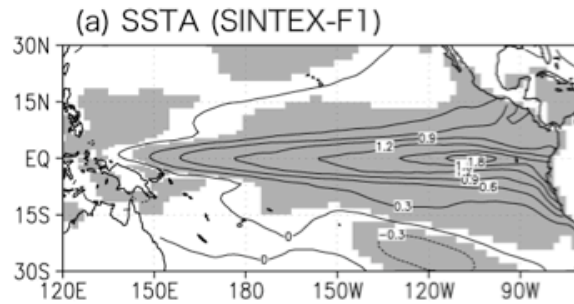
# Purpose

Using outputs from a 200-year integration of a high-resolution coupled GCM, we examine how the recharge-discharge process associated with ENSO events varies with season and why this variation occurs.

# Model description : SINTEX-F1

- ◆ AGCM: T106L19 ECHAM-4
- ◆ OGCM: OPA8.2
- ◆ Coupler: OASIS2.4
- ◆ Integration: 220 years (in Earth Simulator)
- ◆ Analyzed last 200 years of model outputs
- ◆ Good skill in reproducing variations in the tropics (Behera et al. 2003, Luo et al. 2003, Tozuka et al. 2005)

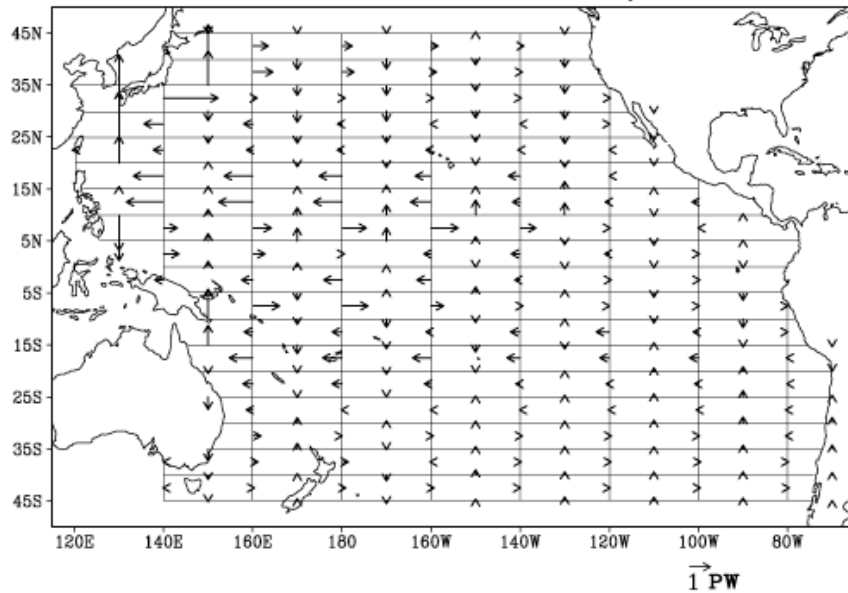
# El Niño composite (Peak phase)



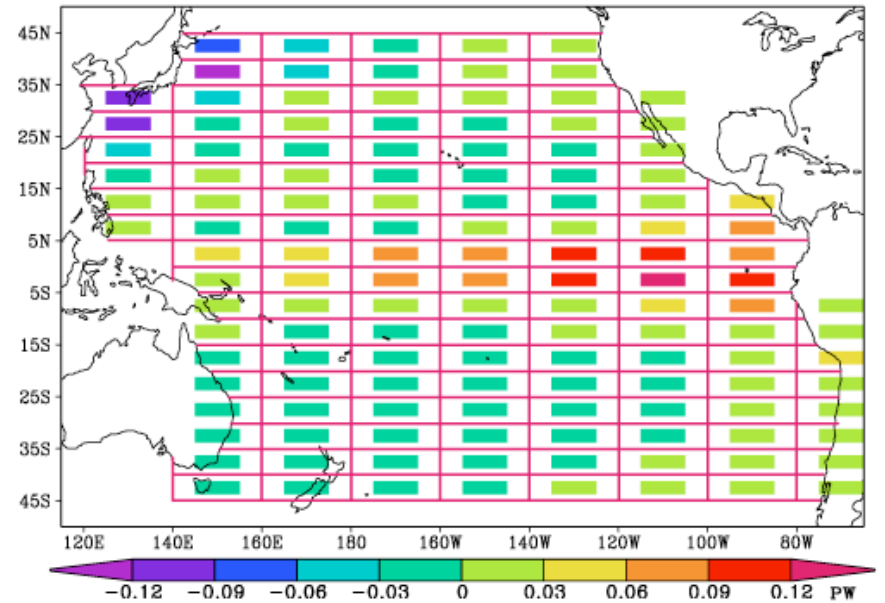
(shading : significant at 95%)

# Annual mean heat budget of the Pacific for upper 440m

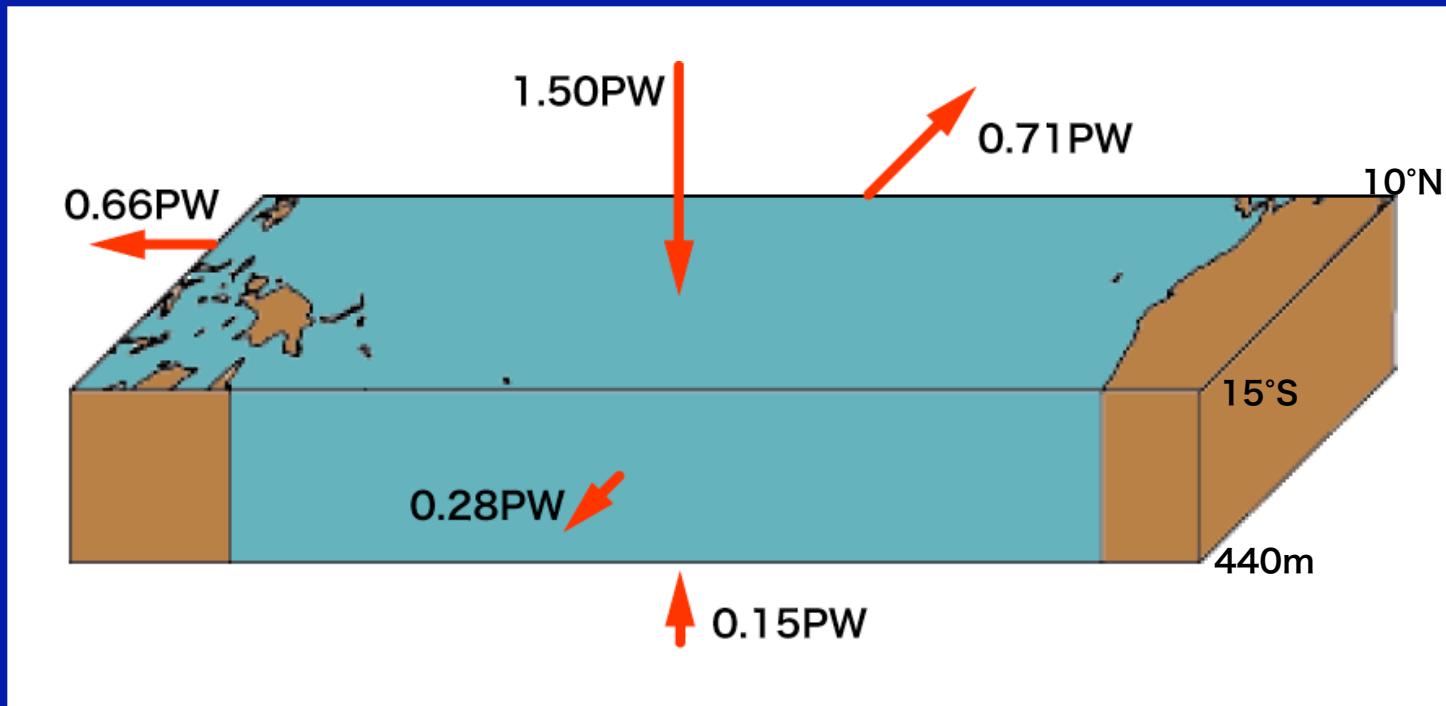
## Horizontal heat transport



## Surface heat flux



# Schematic diagram of the annual mean heat budget

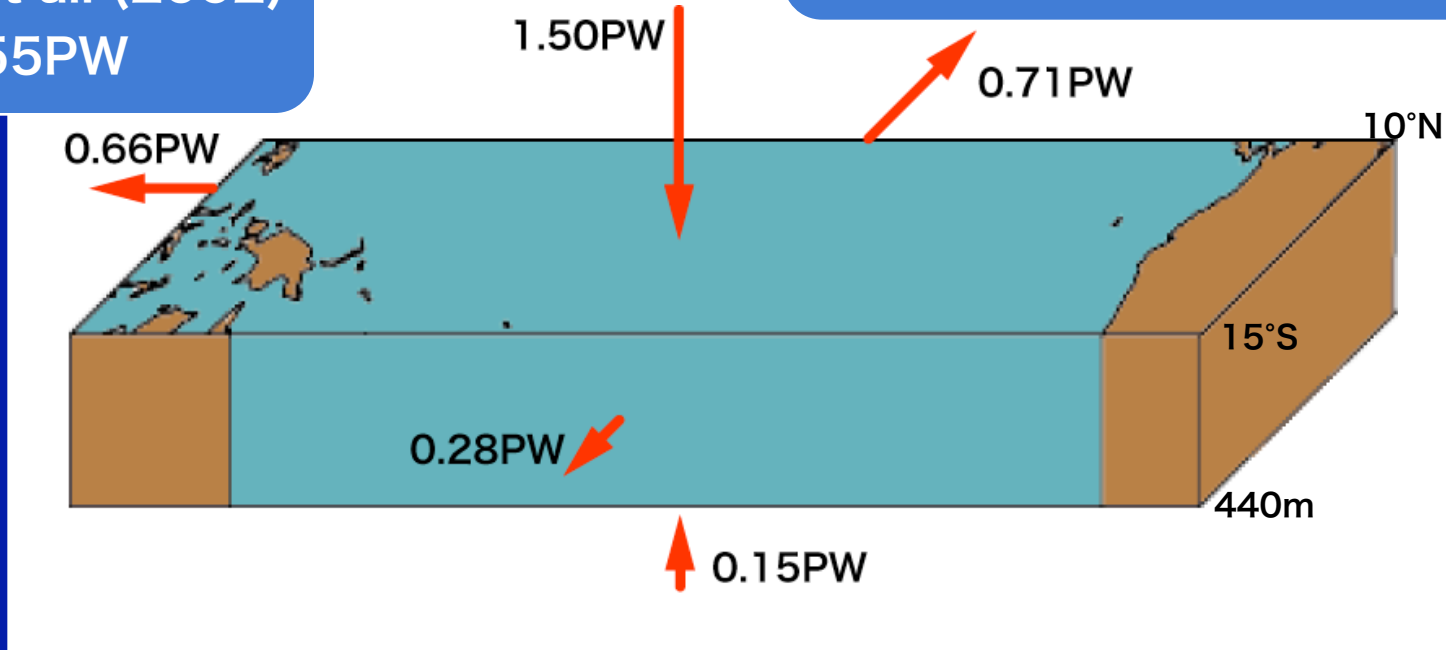


Ref. temp. = 0°C

# Schematic diagram of the annual mean heat budget

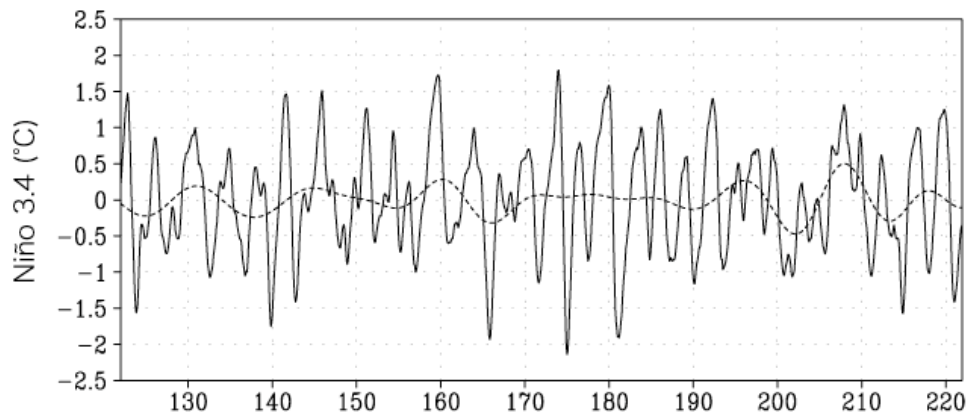
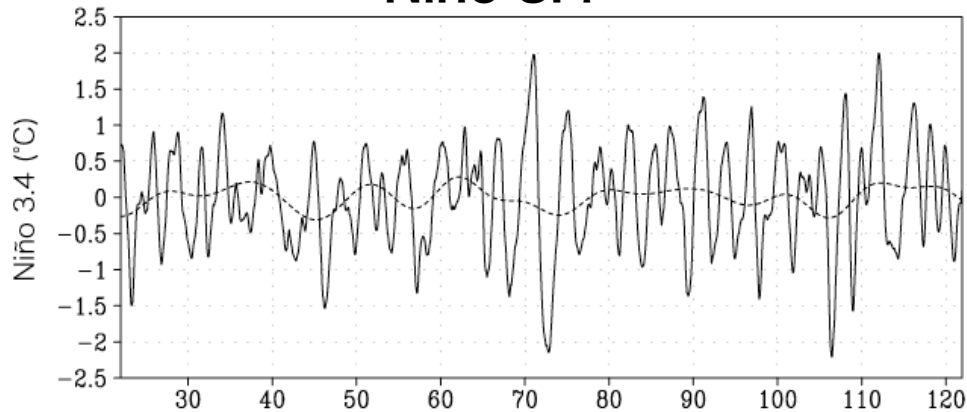
Vranes et al. (2002)  
0.55PW

Macdonald (1998)=0.44PW  
Wijffels et al. (1996)=0.7PW  
Talley (2003)=1.25PW



# Four types of El Niño based on a season in which Niño 3.4 reaches its peak

## Niño 3.4

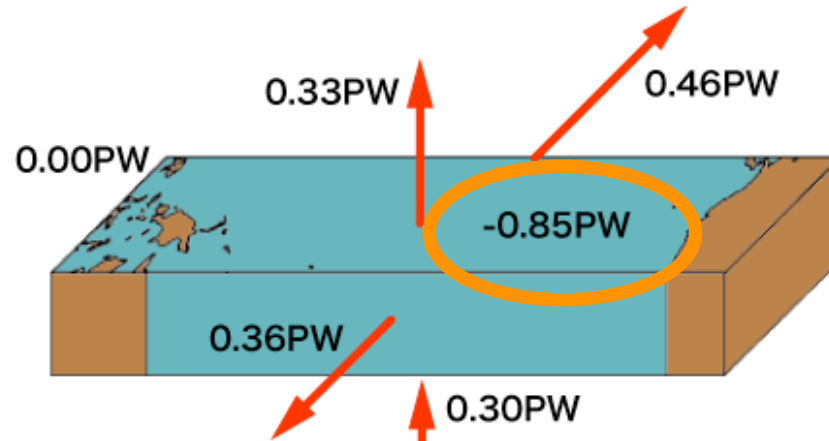


Season	#
DJF (winter)	17
MAM (spring)	8
JJA (summer)	8
SON (fall)	10

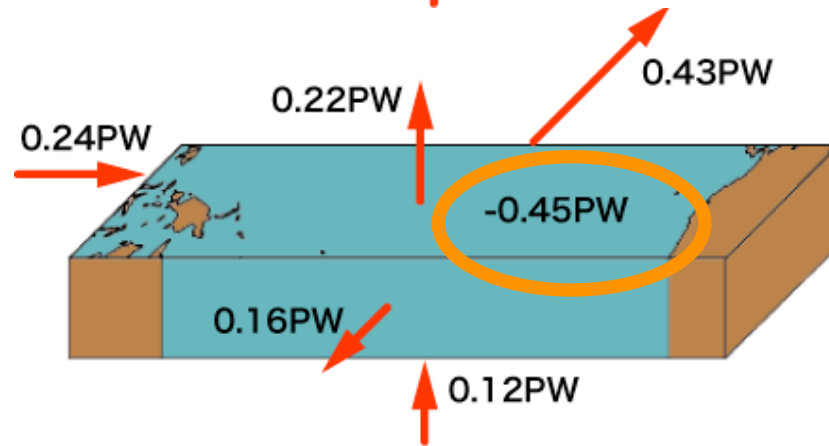
El Niño = Niño 3.4 with 5-month running mean exceeds 0.8°C.

# Composite diagrams of heat budget anomaly

Winter El Niño

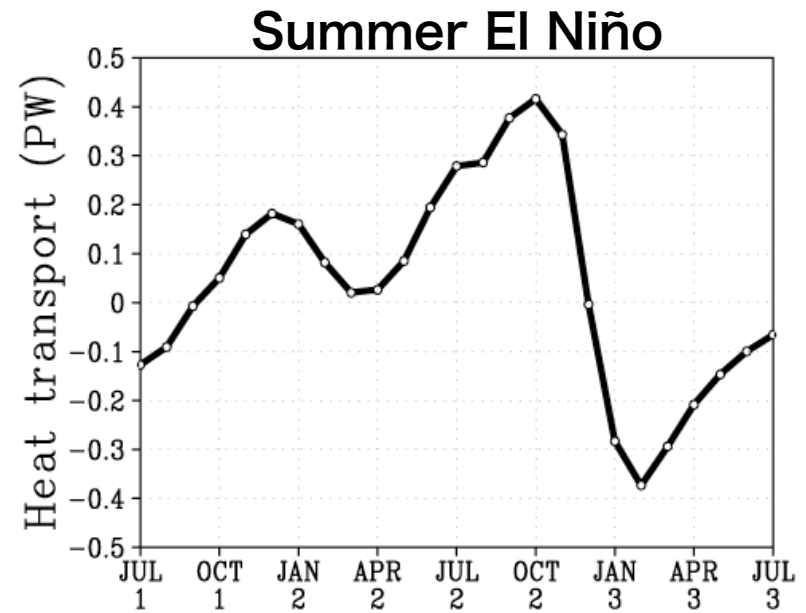
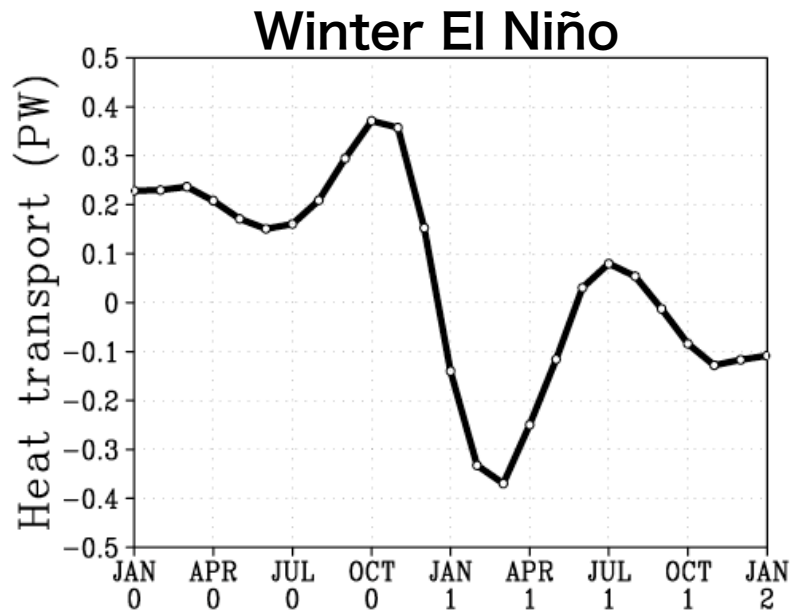


Summer El Niño



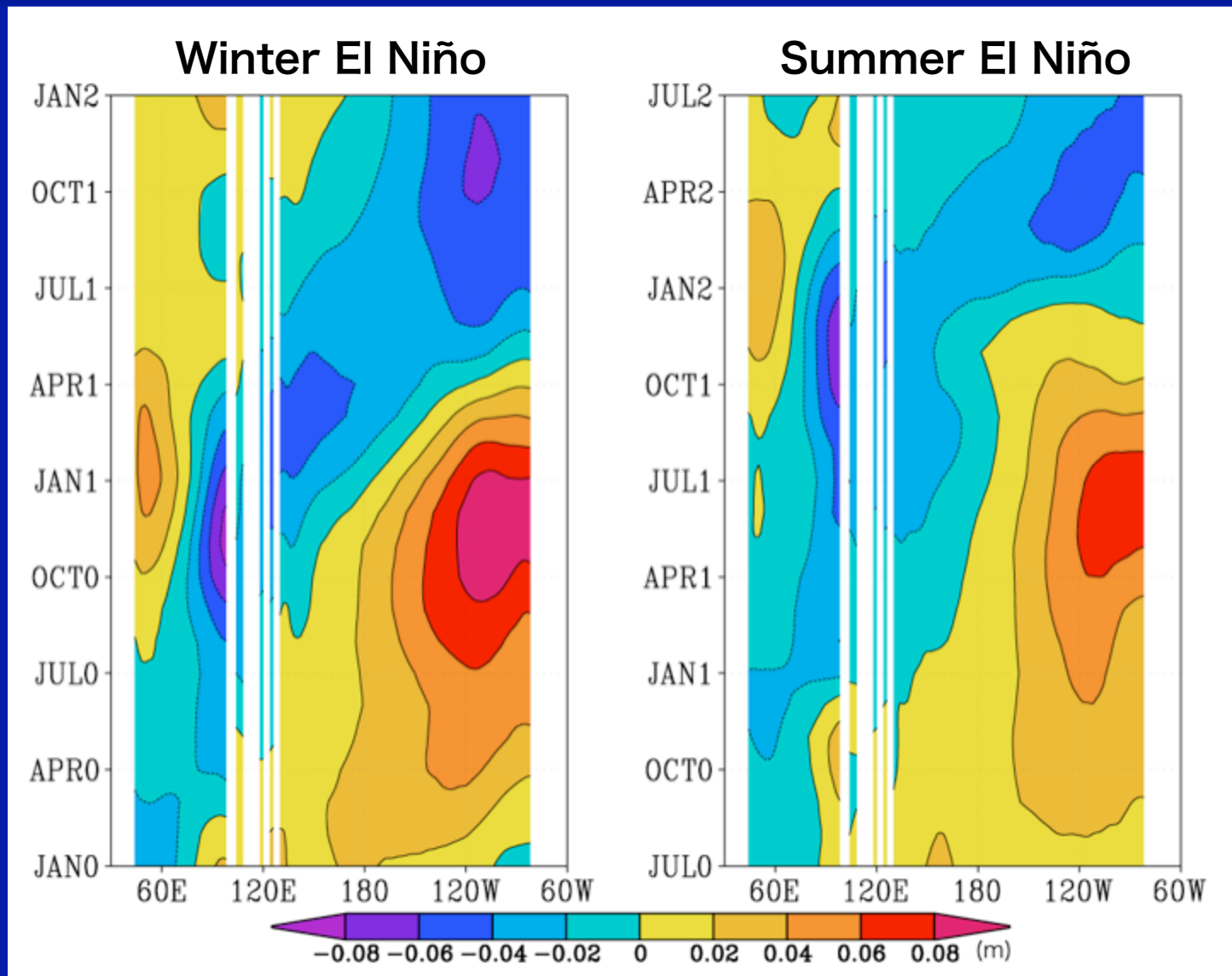
The heat loss during the winter El Niño is about two times larger than that of the summer El Niño.

# Indonesian Throughflow heat transport anomaly

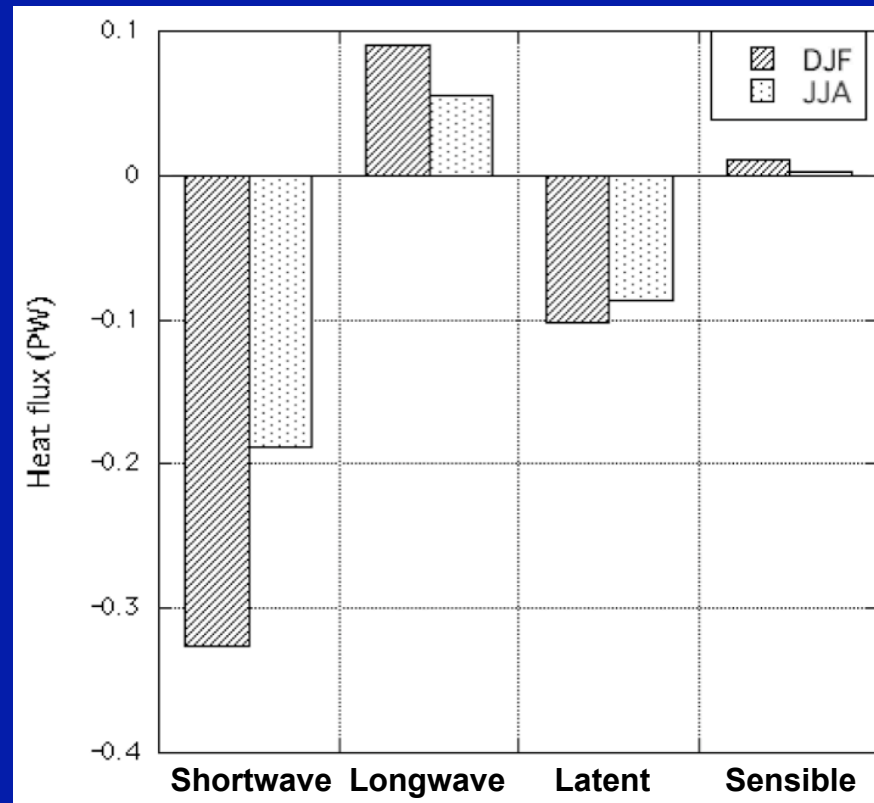


- ◆ The heat transport anomaly becomes negative just after the peak during the winter El Niño, while it remains positive over 4 months after the peak during the summer El Niño.
- ◆ The peak in the negative heat transport anomaly occurs in February after the peak in Niño 3.4 Index.

# Time-longitude diagrams of SSHA (Eq.)

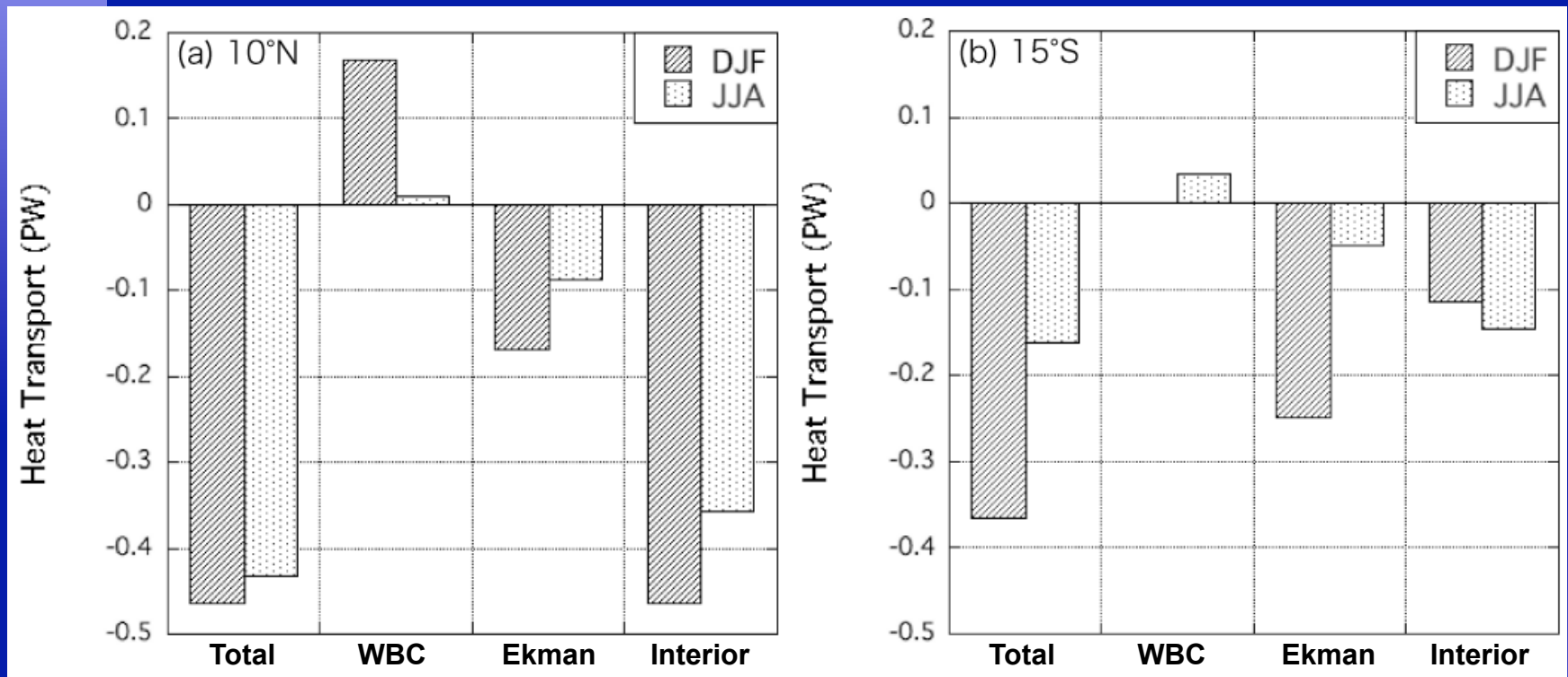


# Surface heat flux anomaly



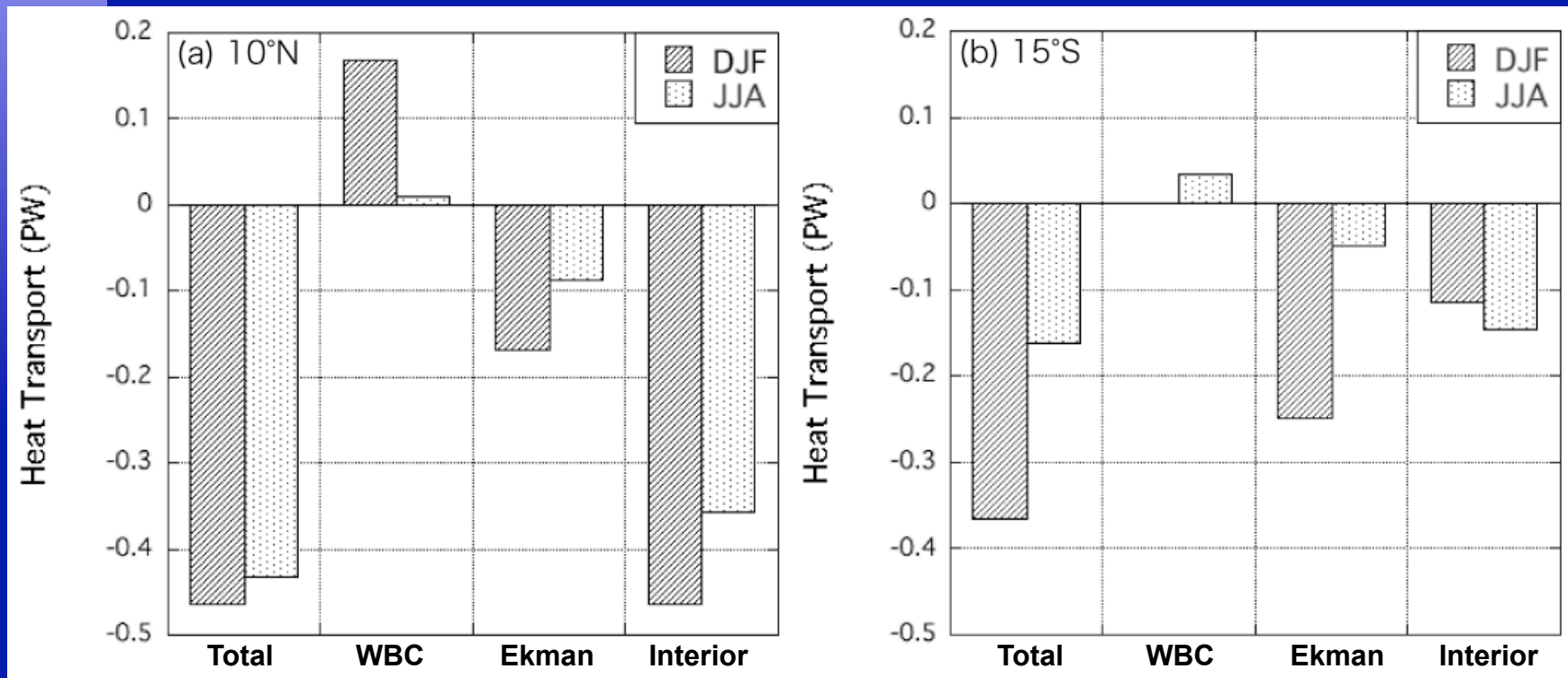
- ◆ The seasonal difference is related to the convective activity associated with warm events. The area averaged vertical velocity anomalies at 500 hPa in the equatorial band (5°S-5°N) is  $-0.016 \text{ Pa s}^{-1}$  for the winter El Niño and  $-0.010 \text{ Pa s}^{-1}$  for the summer El Niño.

# Meridional heat transport anomaly



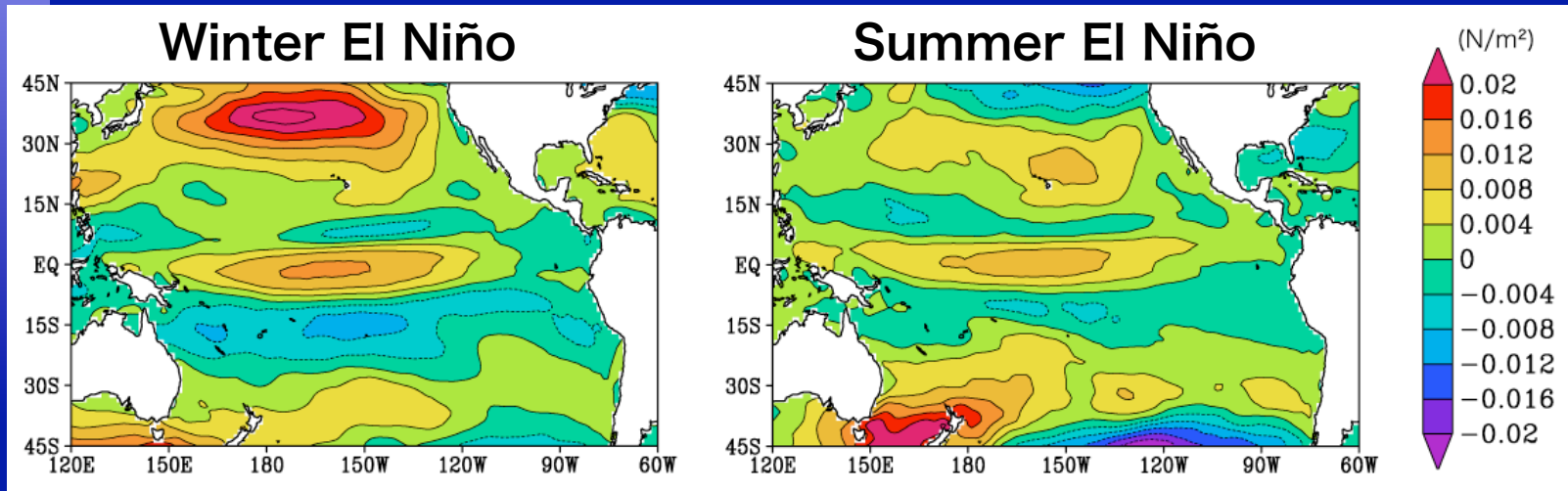
- ◆ The northward heat transport anomaly at 10°N is slightly stronger for the winter El Niño. The interior geostrophic and Ekman heat transport anomalies contribute constructively to the seasonal difference. However, the western boundary current contributes negatively to the discharge during El Niño events and it is larger during the winter El Niño.

# Meridional heat transport anomaly



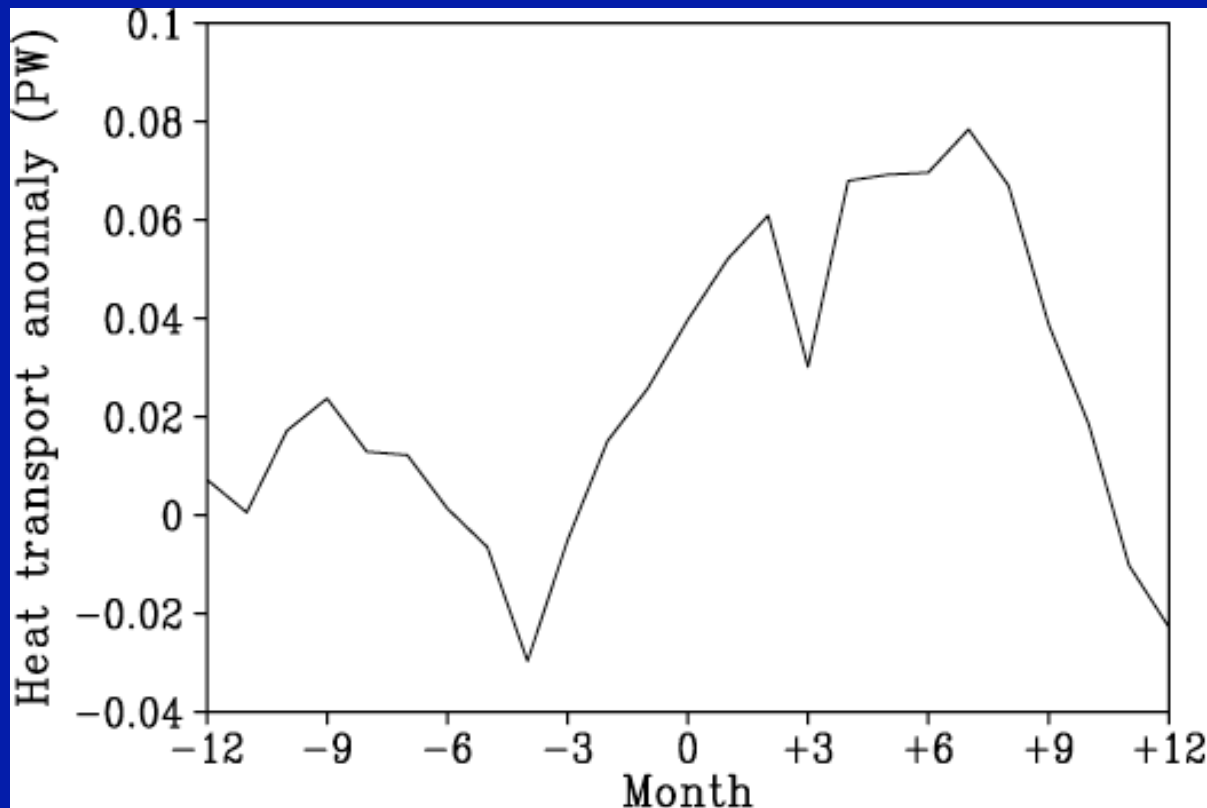
- ◆ The southward heat transport anomaly across 15°S is larger for the winter El Niño. This is mostly due to the 0.2 PW difference in the Ekman transport anomaly.

# Composites: zonal wind stress anomaly



- ◆ The magnitude of the zonal wind stress anomaly is larger for the winter El Niño, because the convective anomalies are stronger.
- ◆ This explains the larger poleward heat transport anomaly by the Ekman transport in both the Southern and Northern Hemispheres.

# Meridional heat transport by Kuroshio (25°N)



- ◆ The heat transported poleward from the tropical box influences oceanic conditions in mid-latitudes through the NEC and the Kuroshio. The heat transport anomaly by the Kuroshio at 25°N increases by a maximum of 0.08 PW, 7 months after the maximum in Niño3.4 Index.

# Conclusions

We have investigated thermodynamical aspects of ENSO events by classifying El Niño into four groups based on their peak season.

- ◆ The heat content of the tropical Pacific decreases for all four types, but it loses about twice as much of heat during the winter El Niño compared with the summer El Niño.
- ◆ The surface heat flux, the meridional heat transport, and the IT heat transport contribute constructively to this remarkable seasonal difference.

