A decadal shift towards an El Niño-like ocean state in the tropical Pacific and recent resumption of ocean warming

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1. Introduction

- Since the beginning of the 21th century, there has been tremendous public and scientific interest in a pause in global mean surface temperature warming, known as the recent "**hiatus**".
- It is linked to the negative phase of **IPO** and **PDO**, which manifests as a low-frequency La Nina-like pattern, with enhanced trade winds, warming of the western Pacific subsurface, strengthening of the Equatorial Undercurrent, and cooling of the eastern Pacific subsurface. [Meehl et al., 2011,2013; Maher et al., 2014, 2018; Nieves et al., 2015; England et al., 2014]
- However, in contrast to the "hiatus", global and central-to-eastern Pacific surface temperature was warming. At the same time, **IPO** and **PDO** shifted toward a positive phase.
- In this study, We
  1) analyzed sea levels and ocean data set to compare the recent shift in the tropical Pacific. **2)** used Ensemble Empirical Mode Decomposition to extract the intrinsic mode function from climate/ocean signal. **3)** used a global ocean circulation model to identify the dynamical ocean response to climate-related wind pattern.

2. Data and Methods

Data	Period	Source
SSH (Altimeters)	1993-2017(8) (monthly)	CSIRO
Temp. & Sal.	1993-2017(8) (monthly)	EN4, JAMSTEC
Wind	1993-2017(8) (monthly)	NCEP, ECMWF, CCMP
PDO, IPO index	1993-2017(8) (monthly)	JISAO, NOAA

Table 1. Used data set for study

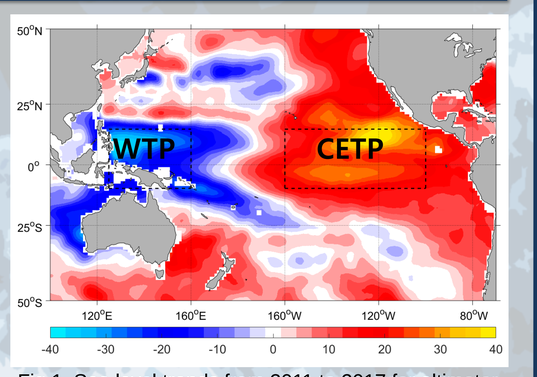

Fig 1. Sea level trends from 2011 to 2017 for altimeter.

Ensemble **E**mpirical **M**ode **D**ecomposition **(EEMD)** method

- Decompose the complex signal to finite intrinsic mode function
- Has the advantage of being available for **non-linear and non-stationary** climate signal
- We used EEMD to separate different climate signal from original timeseries

To identify the physical mechanism : Two model experiments are designed

1. Hindcast : Control run with original forcing data from 1950 to 2017
2. Experiment : Additional run with
   extracted climate-related low-frequency wind pattern over 1993-2017

3. Recent swing back towards an El Nino-like ocean state

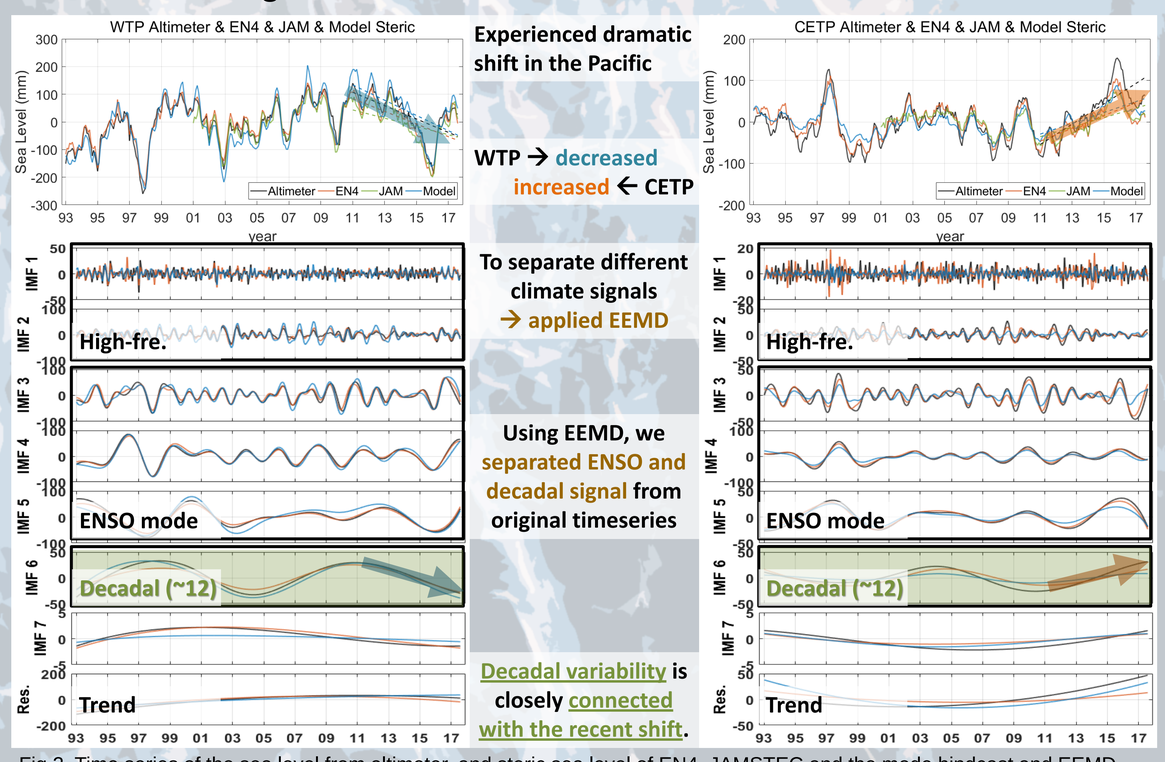

Fig 2. Time series of the sea level from altimeter, and steric sea level of EN4, JAMSTEC and the mode hindcast and EEMD decomposition of time series in WTP (left) and CETP (right).

Fig 3. Averaged equatorial ocean temperature trends between 5S and 5N.

Upper ocean temperature trends reflect recent shifts.

Ocean Heat Content also show this temperature trends.

OHC decadal mode also shifted since 2011, which is corresponded to decadal mode of sea level.

Cooling Warming

These results indicate a distinct decadal mode in the tropical Pacific

Fig 4. Ocean Heat Content (OHC) variability of EN4, JAMSTEC, and hindcast for WTP (left) and CETP (right).

4. Recent resumption of global ocean warming and Pacific decadal variability

La Nina-like cooling in CETP is the key point of global warming hiatus. [Kosaka and Xie 2013; England et al., 2014]

Global and CETP upper 100m OHC variability corresponded to the period of hiatus and acceleration.

Decadal modes in the global and CETP upward shifted over the acceleration period.

Decadal modes in the tropical Pacific is closely connected to the recent global warming acceleration.

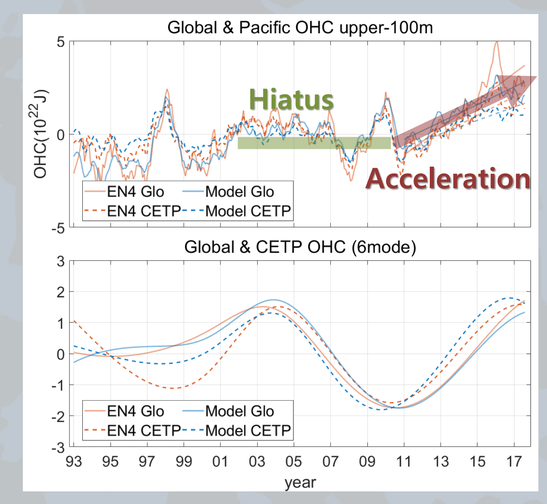

Fig 5. Upper 100m OHC variability in global and CETP from EN4, and hindcast and their normalized decadal modes derived from the EEMD decomposition.

Analyzed wind and climate indices, to identify a linkage between decadal shift and climate-related trade wind.

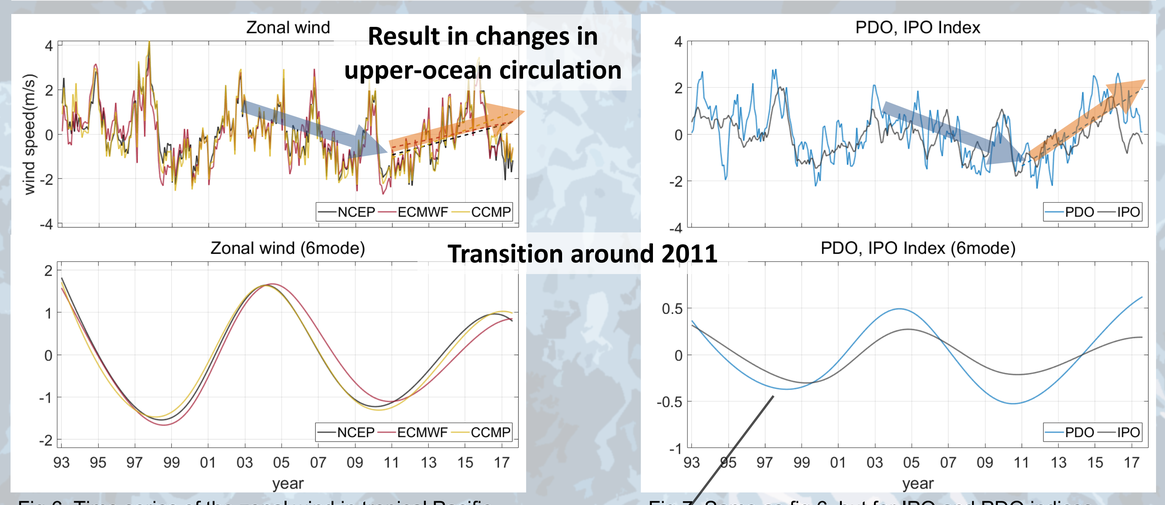

Fig 6. Time series of the zonal wind in tropical Pacific (140E-200E,10S-10N) from three products, and their decadal modes derived from EEMD decomposition.

Fig 7. Same as fig 6, but for IPO and PDO indices.

We applied regression analysis to identify the sea level and wind associated with decadal climate variability.

Sea level dipole pattern in the tropical Pacific is connected with trade wind weakening.

This pattern fluctuated with PDO decadal variability e.g. when the PDO is negative this pattern will be opposed

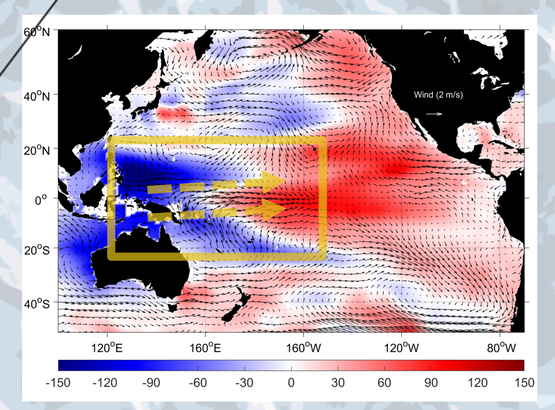

Fig 8. NCEP wind and altimetry-based sea level regressed on the PDO decadal mode (Fig 7).

5. Response of tropical Pacific ocean to climate-related trade winds

We used this pattern to conduct model experiment to identify the dynamical response to PDO-related wind.

"Hiatus" 2003-2010 | **"Acceleration" 2011-2017**

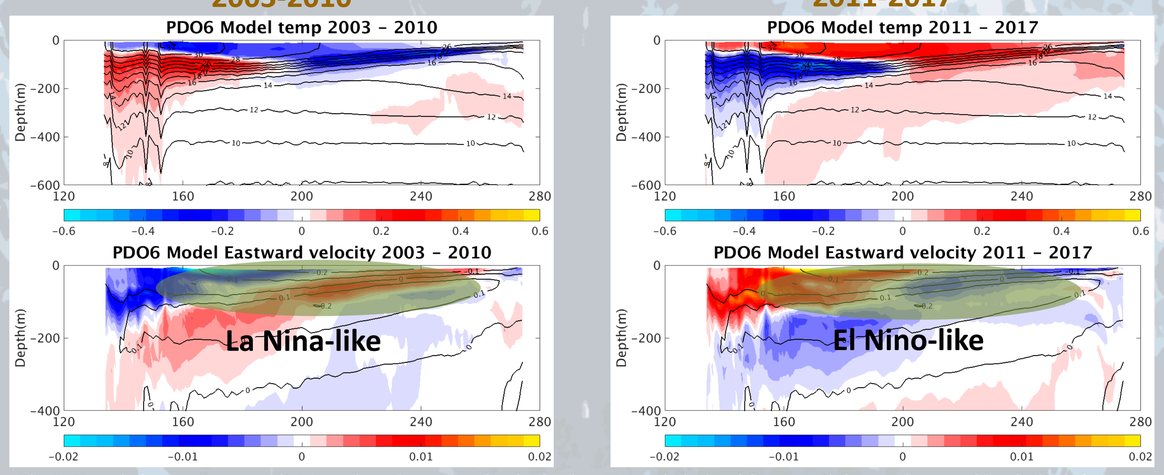

Fig 9. Trends in temperature ($°C/year$) and eastward velocity ($m/s/year$) derived from model experiment with wind forcing during the periods of 2003-2010 and 2011-2017, respectively.

Temperature and east ward velocity trends over the hiatus and acceleration period show opposite pattern.

Pacific Decadal Variability phase transition → **Trade wind weakening & upper ocean circulation change** → **Decadal shift towards an El Nino-like ocean state** → **Recent acceleration of global ocean warming**

6. Summary

- Since 2011, a dramatic shift towards an El Nino-like ocean states in the tropical Pacific has been detected.
- Using an EEMD analysis,
  we identified a distinct decadal mode in the tropical Pacific,
  which coincides with the recent acceleration of global ocean warming.
- Model experiments demonstrate that climate-related decadal oscillating wind pattern played an important role in the tropical Pacific Ocean.