Observed Decadal Sea-Level Variations Over the Tropical Indo-Pacific Basin: Association with & Indicators for Varying Walker Cells and Climate Modes

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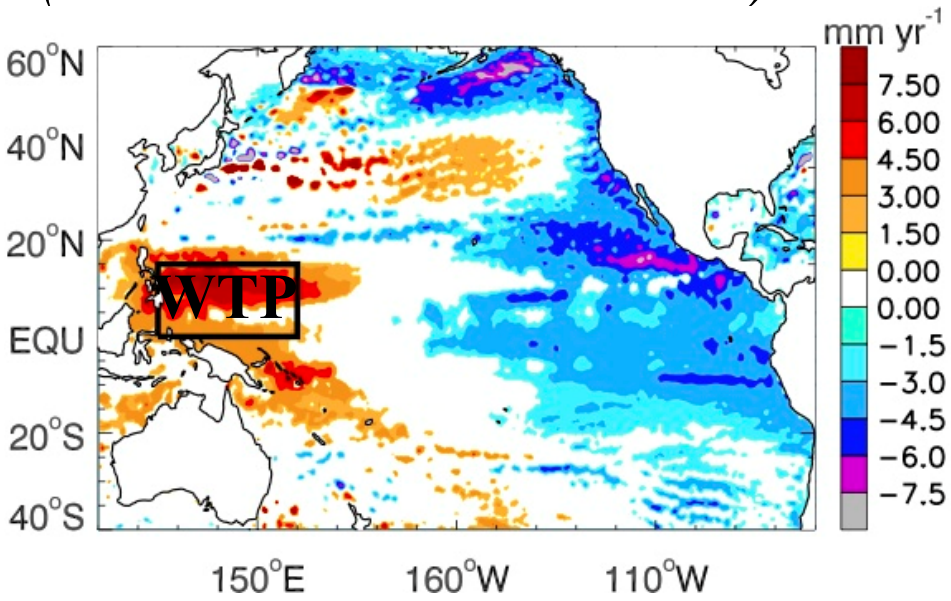
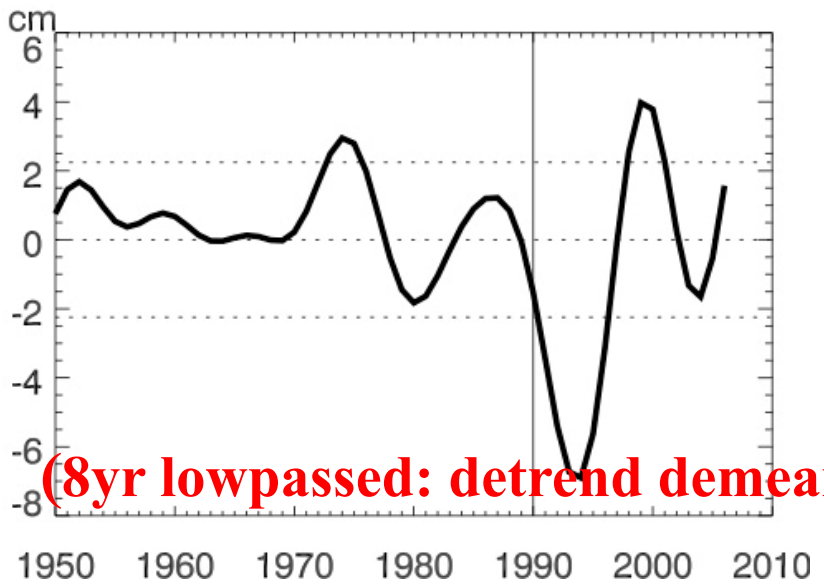
1. Background

Linear trends (1993-2010) of satellite (AVISO) SSH
(Global mean SLR removed)



Decadal thermosteric SLA 700m (Ishii & Kimoto 2009)



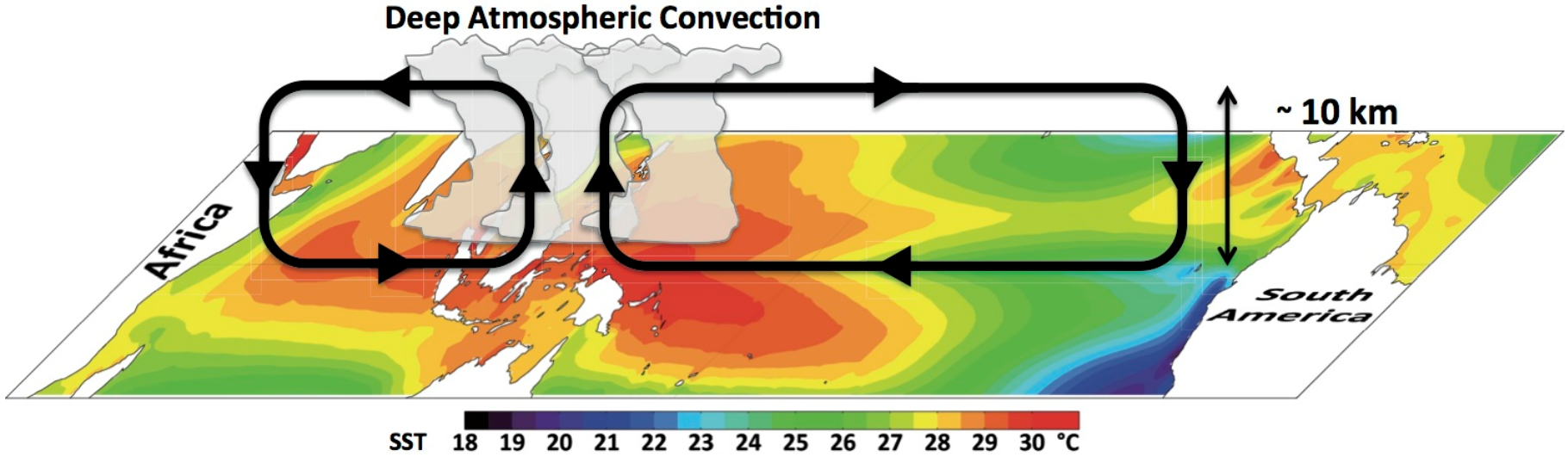
(8yr lowpassed: detrend demean)

Observations: ***intensified SLR in WTP > ~1990s, & large-amplitude decadal SLA - correlated with the decadal variability of ENSO (or PDO/IPO) indices;*** *(e.g., Merrifield et al. 2011, 2012; Zhang&Church 2012, Meyssignac et al. 2012)*

Modeling studies**: SLAs are driven mainly by decadal variability of zonal winds in EQ basin** *(e.g., Han et al. 2014; Hamlington et al. 2014)*

1. Background

Zonal surface winds - that drive the SLAs – are tied to variability of the Walker Cell (WC) ; the Indian & Pacific WCs driven by "tropical deep convection over the Indo-Pacific warm pool"



Science issues:

(1) Are the decadal variations of sea level over the EQ Indian & Pacific Oceans associated with variations of the WCs?

(2) What roles do climate modes play in causing the WCs' variability and therefore SLA?

Research goal: is to answer these science questions

2. Data and Approach

***Sea level data*:**

Satellite AVISO *SSH 1993-2014;*

In-situ products for upper 700m thermosteric sea level *(i.e., WOA13 from 1955-2013 , Ishii & Kimoto from 1945-2014);*

ORAS4 reanalysis sea level *(1958-2014)*

Data for WCs: surface branches

Indian WC: *zonal wind stress* $\boldsymbol{\tau^x}$ *averaged for* (70ºE-100ºE, 5ºS-5ºN)

Pacific WC: *zonal wind stress averaged for (150ºE-150ºW, 5ºS-5ºN) times -1 (i.e.* $\boldsymbol{-\tau^x}$*)*

Satellite CCMP v1 winds;

NCEP & JRA55 reanalysis

All data are 8yr lowpass filtered to obtain decadal signals

To exam relations between climate modes & WCs, we **use a relatively new approach, the Bayesian dynamical linear model (dlm), which consists of two EQNs:**

Observation equation:

$$Y(t) = b_0(t)+b_1(t)X_1(t)+ \ldots + b_M(t)X_M(t) + \varepsilon(t), \quad \varepsilon(t) \sim N(0,V(t)) \quad (1)$$

SLA **Predictors**

ENSO & IOD – dominant climate modes;
Off-EQ convection of Indian monsoon – can be affected by land/ocean factors–affect Indian WC

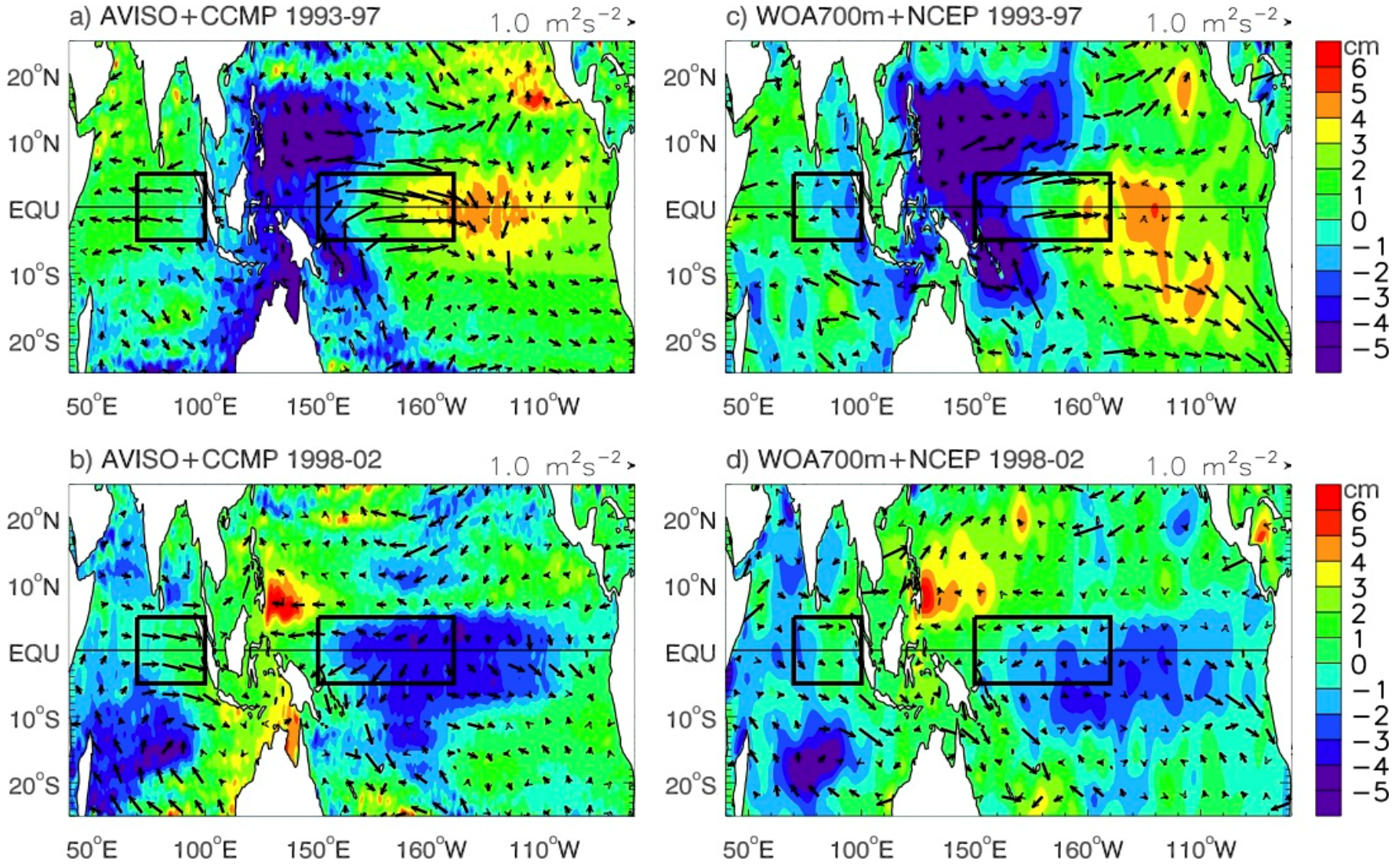
State equation:

$$b_i(t)= b_i(t\text{-}1)+w(t), \qquad w(t) \sim N(0,W(t)). \qquad (2)$$

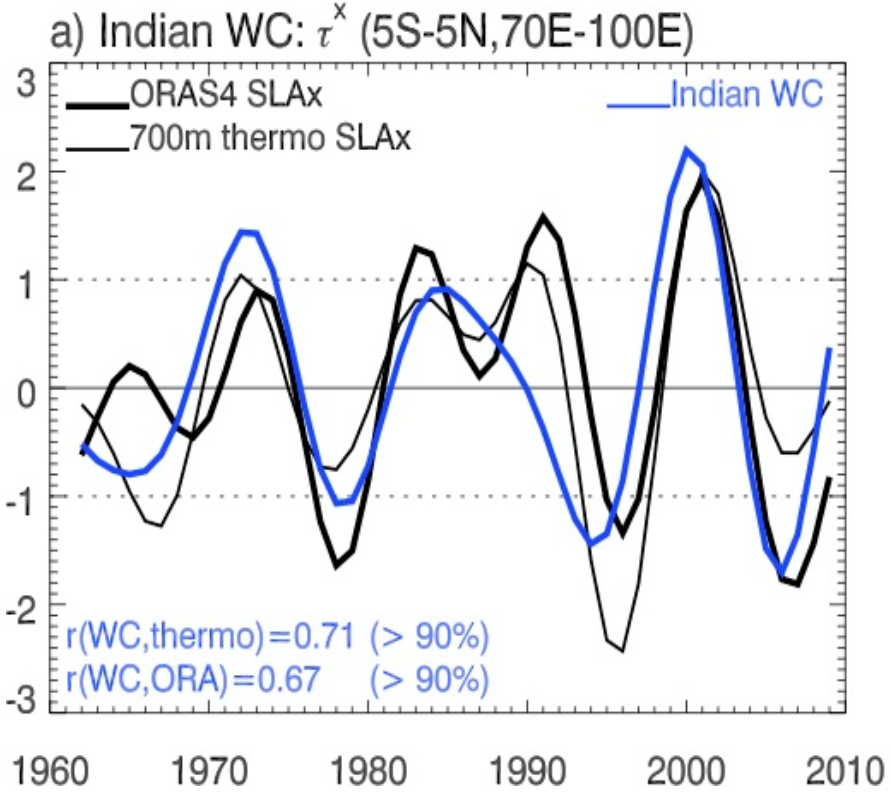
Using Kalman filtering and smoothing, Bayesian dlm allows b_i vary with time: measure **changing relation between *predictors*** X_i and ***response variable Y*** ("non-static" or "dynamical")

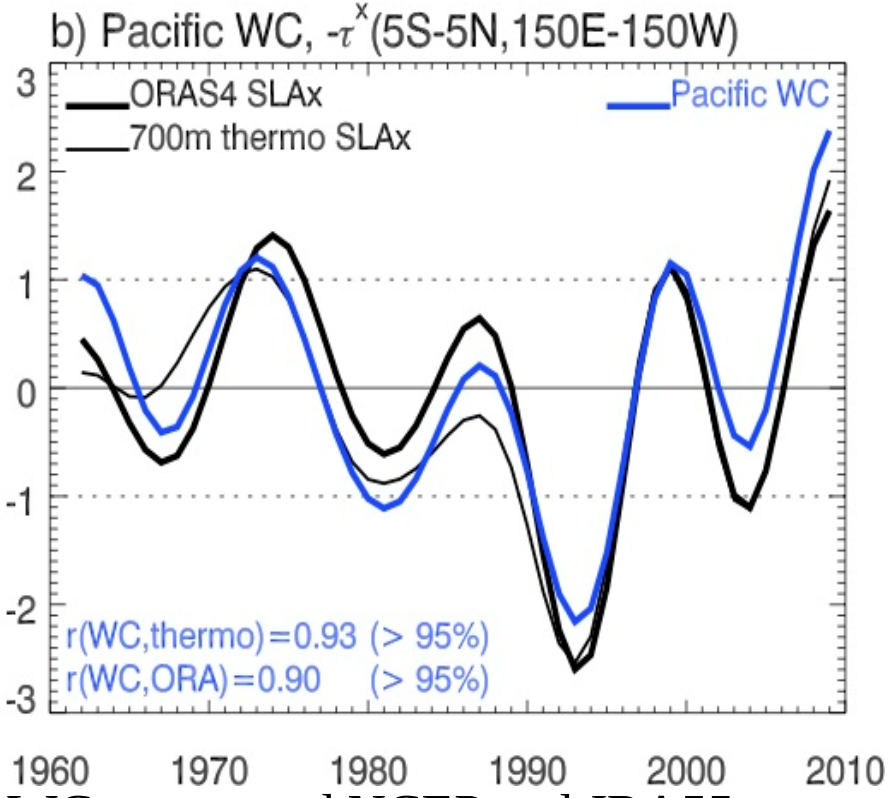
3. Results: (1) Decadal SSHa are associate with WCs variation

Observed SSHa (remove global & climatological mean): averaged for 1993-97 & 1998-02: decadal reversal



Decadal SLA_x along the EQ & variations of the WCs: 1962-2009





At the EQ, y=0:

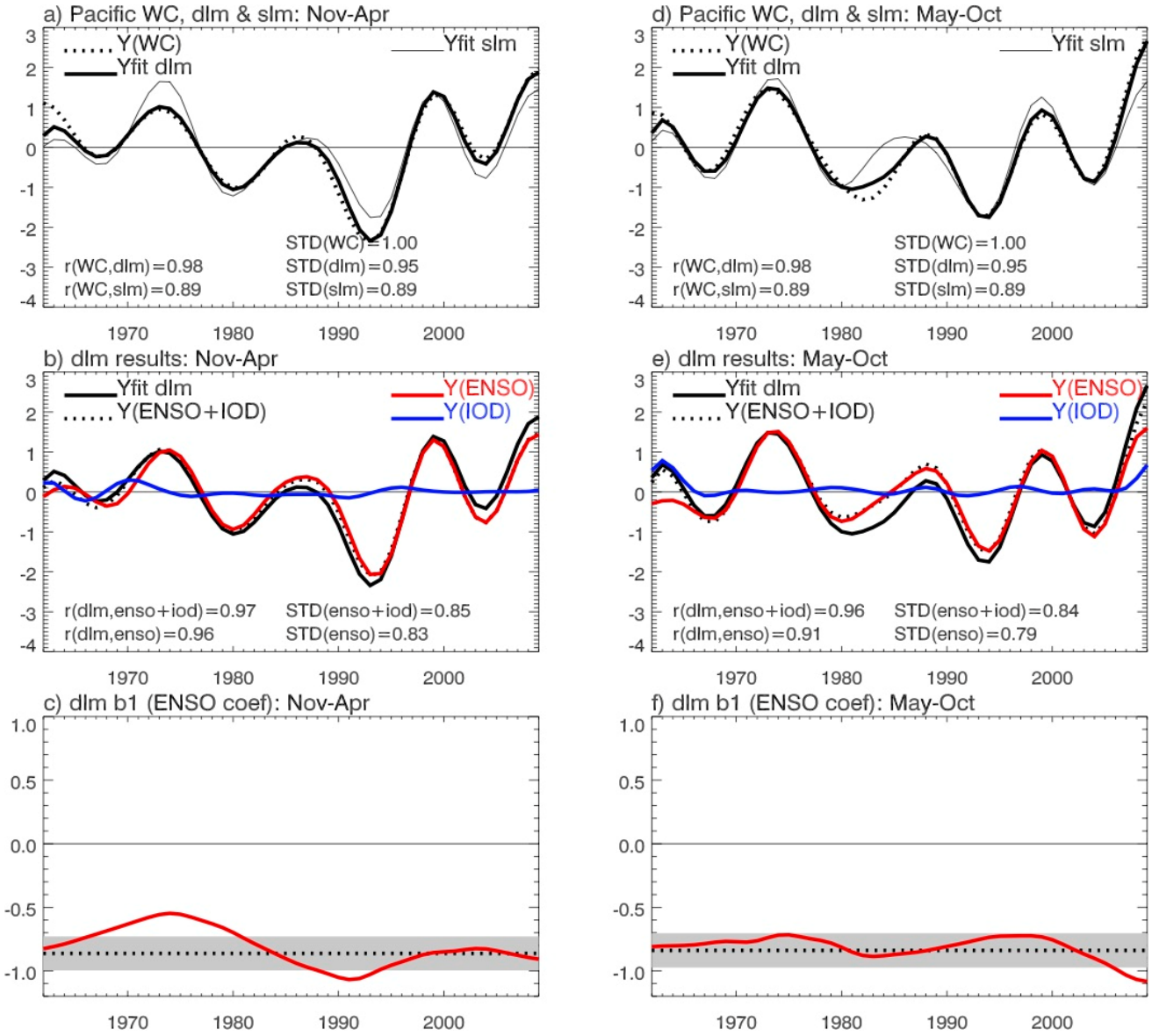
$$\frac{\partial u}{\partial t} - \beta y v + g' \frac{\partial \eta}{\partial x} = \frac{\tau^x}{\rho_0 H}$$

≈0 **=0**

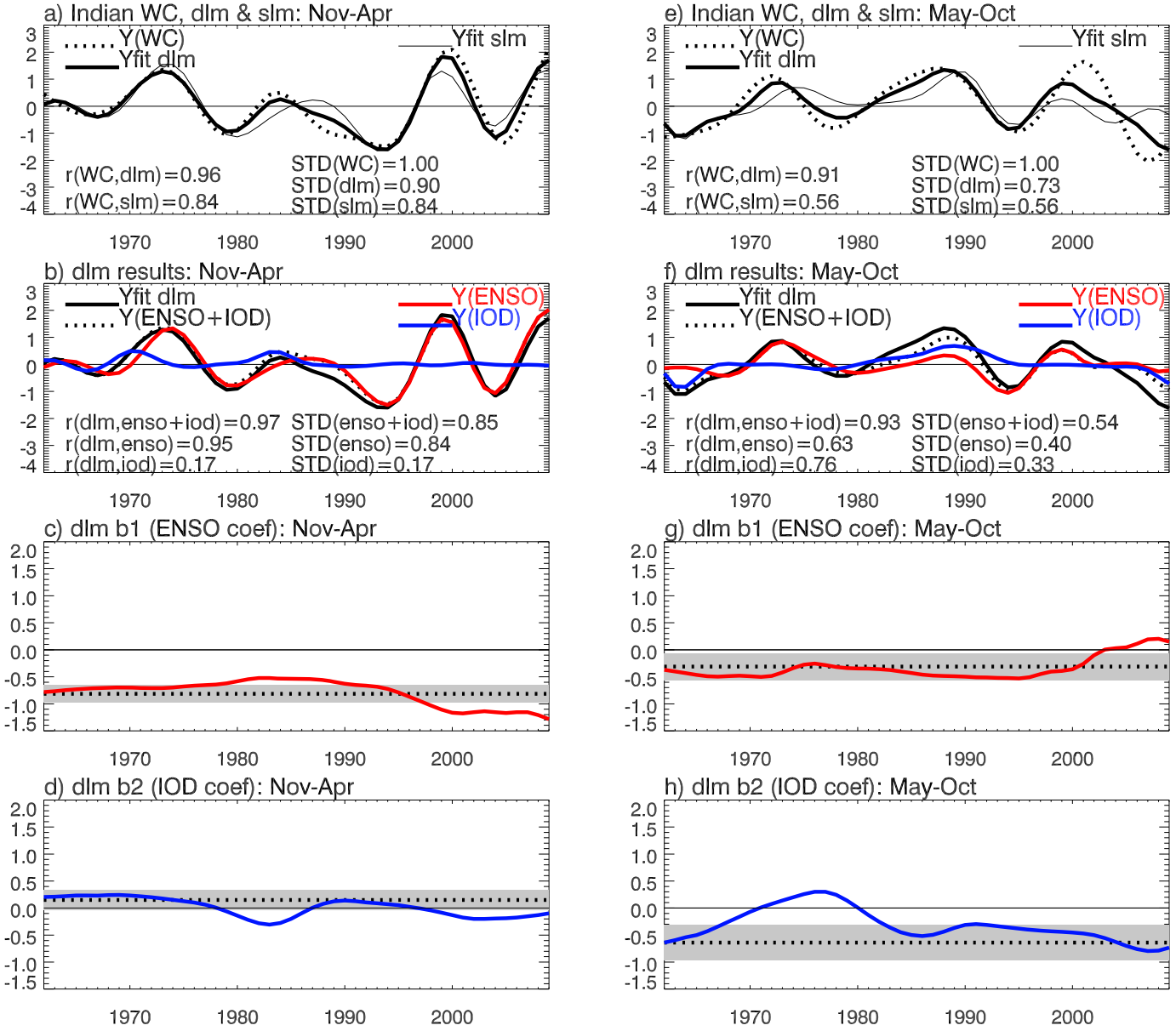
WCs: averaged NCEP and JRA55
700m thermal SLA: ave. WOA13+Ishii
ORAS4 total SLA

SLA_x: west-east for Pacific
east – west for Indian

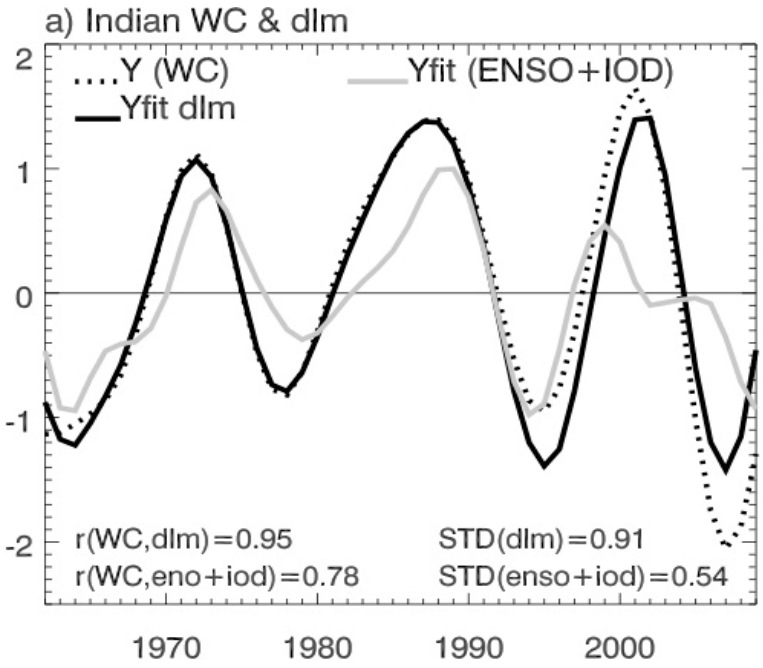
Results: (2) Climate modes effects: Pacific WC - ENSO dominates for both the winter and summer seasons

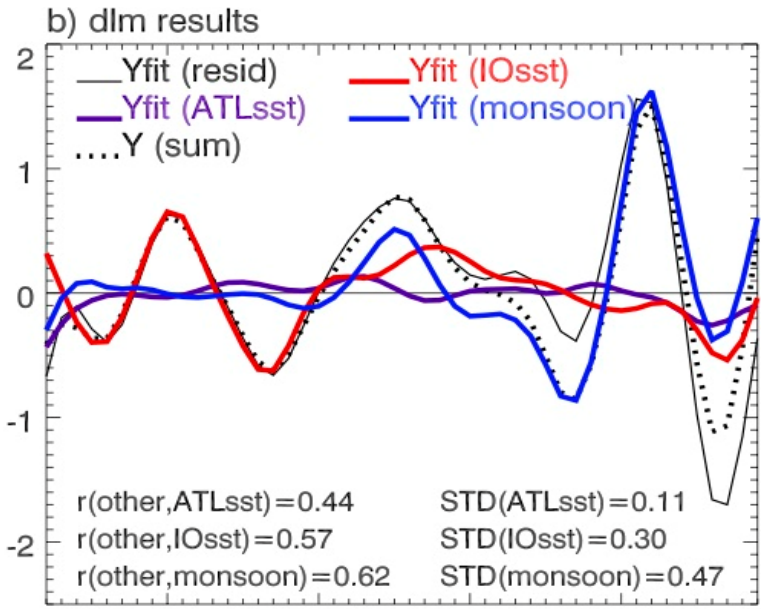


Results: (2) Climate modes effects: Indian WC - ENSO dominates in winter; summer – ENSO&IOD comparable

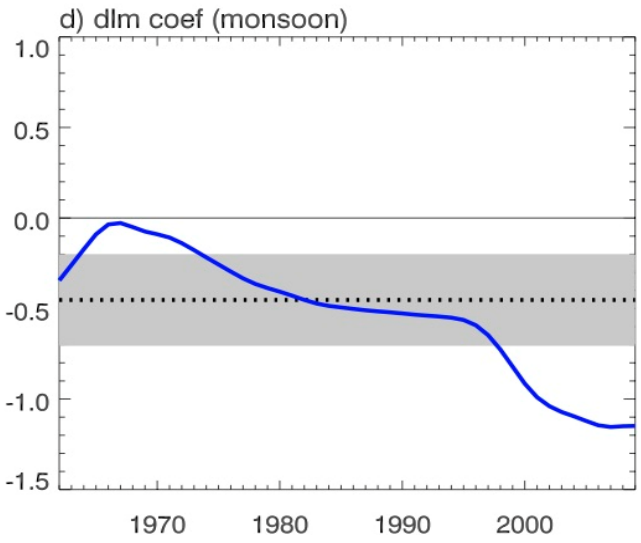


Summer season Indian WC





Off-EQ convection of Indian monsoon is as important as ENSO & IOD overall, & dominates in recent decades: after ~1990



Summary & Conclusions

•(1) Decadal variations of sea level over the EQ Indian & Pacific Oceans are highly associated with the WCs' variations, with intensified WCs driving intensified zonal SLA_x in the equatorial basin; thus, SLA may serve as an indicator for WCs' variability;

•(2) Over the Pacific, decadal variability of ENSO dominates WC variability for both winter and summer; Over the Indian Ocean, decadal variability of ENSO remains dominant in winter, but ENSO, IOD and off-EQ convection associated with Indian summer monsoon play comparable roles, with monsoon convection being the dominant cause in recent decades (since ~ 1990) – makes the Indian WC variability & SLA more difficult to predict in summer.

Thank you!

Acknowledgement

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Summer season Indian WC: Off-EQ convection of Indian monsoon as important as ENSO & IOD overall, & dominates after ~1990