Emerging signals of ENSO-driven precipitation anomalies under climate change

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World Meteorological Day 2025
"Closing the Early Warning Gap Together"

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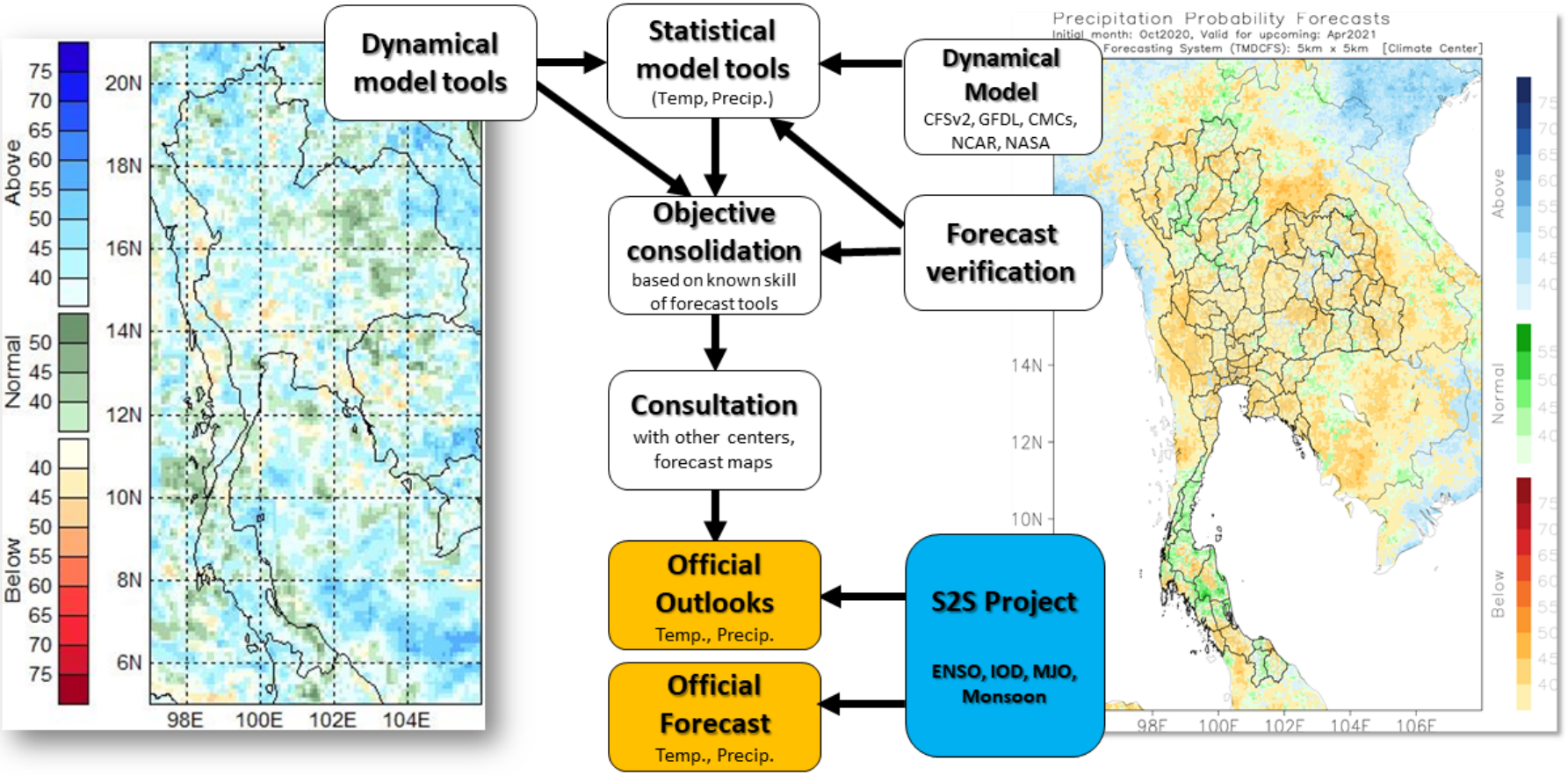
Early Warning and Planning of Climate Forecasting System

Schematic of TMD Climate Forecasting System



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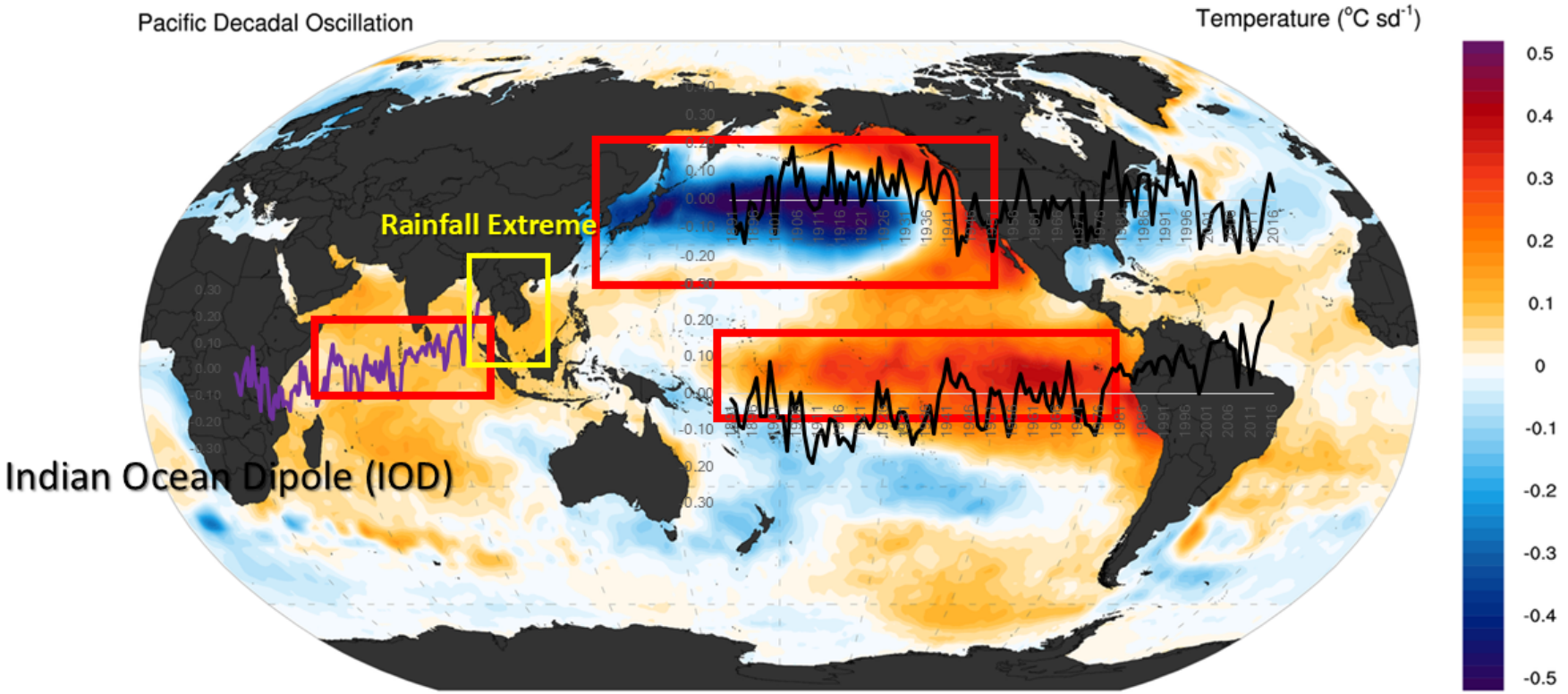
Global Impacts of Climate Phenomena

Pacific Decadal Oscillation (PDO)



El Niño Southern Oscillation (ENSO)

From Wikipedia

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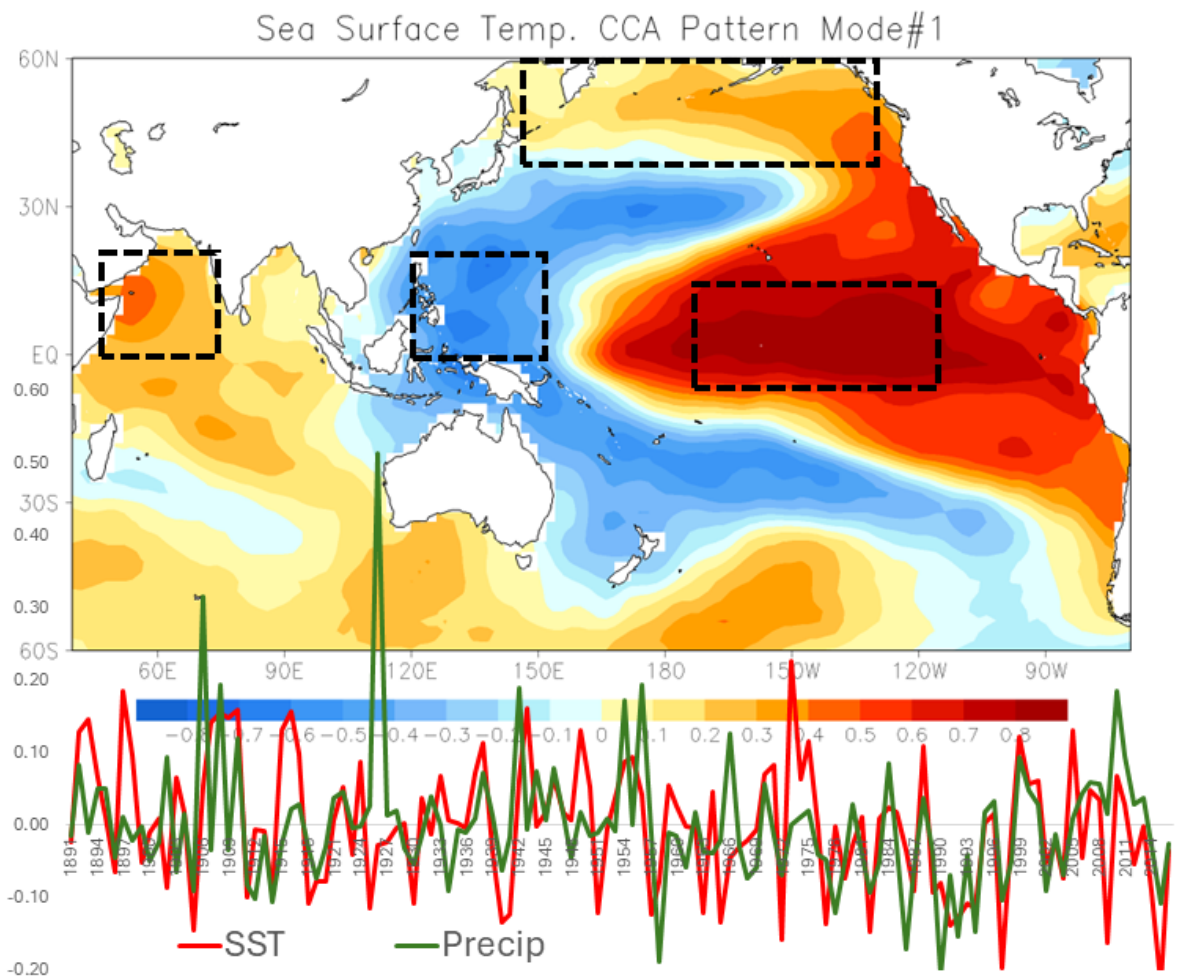
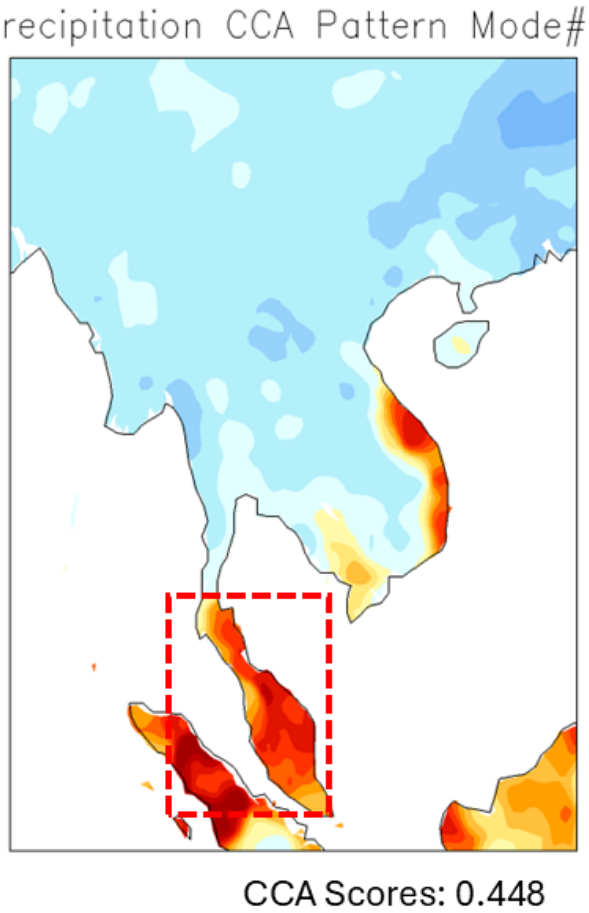
Eigenvector of Global SST and Precipitation

Preliminary results from CCA (Period: 1891-2016)





CCA Scores: 0.448

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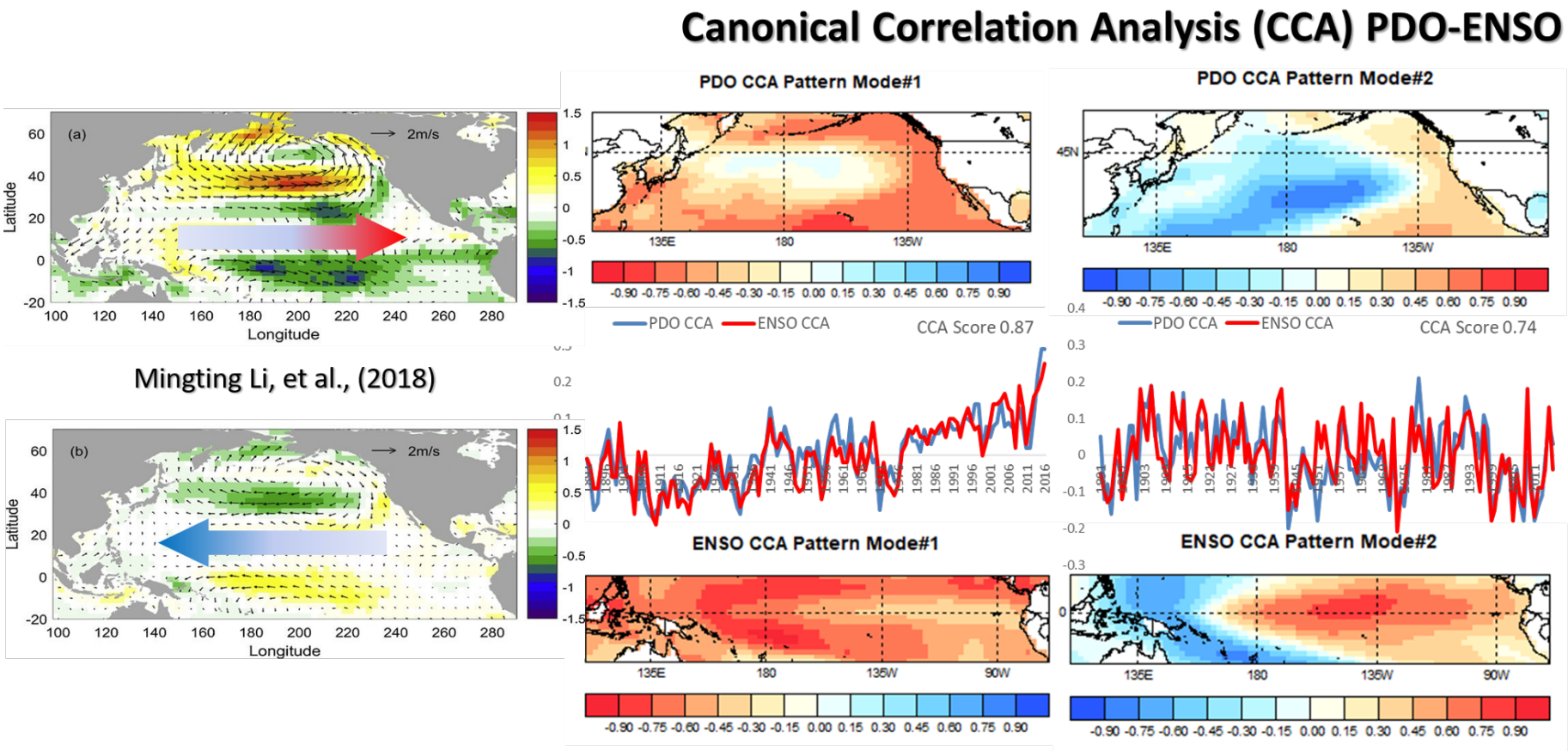
Intuitive view of Canonical Correlation Analysis

Two time series $X(t)$ and $Y(t)$. The correlation between $< X, Y >= corr$



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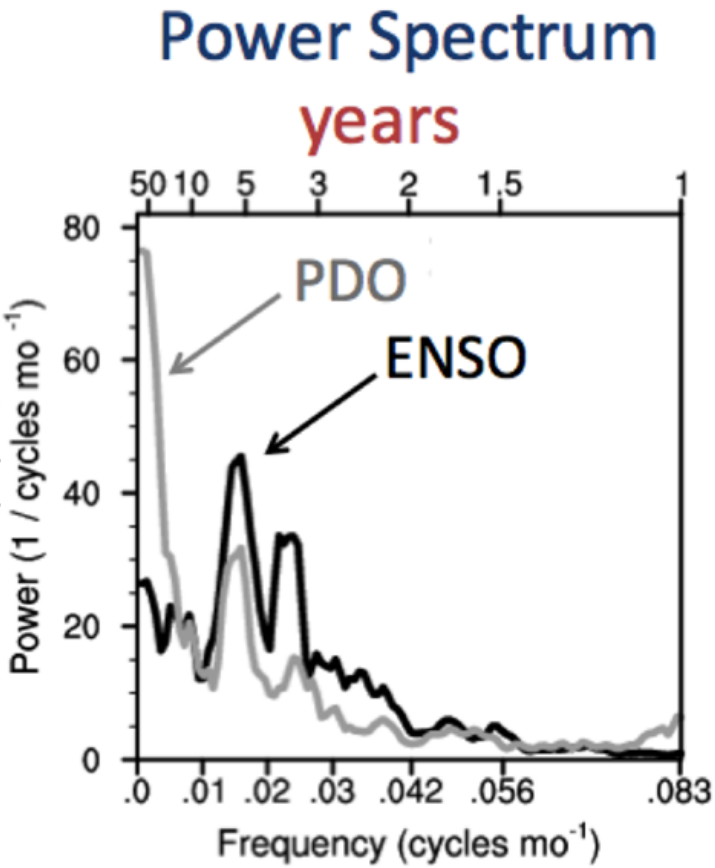
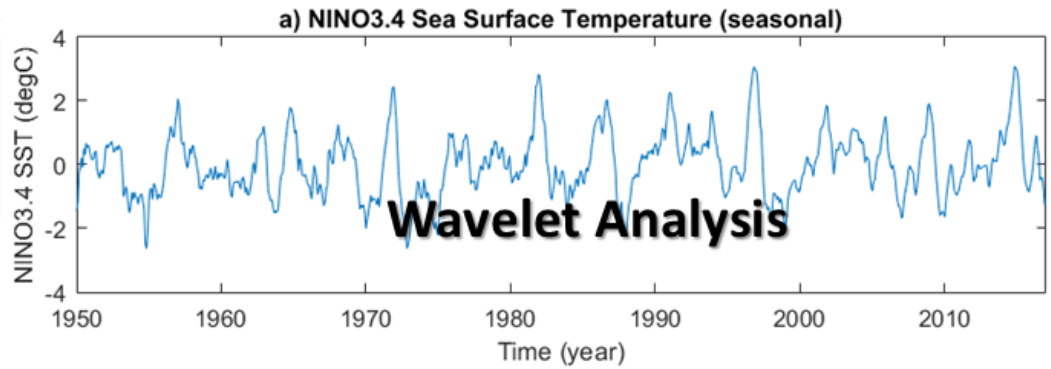
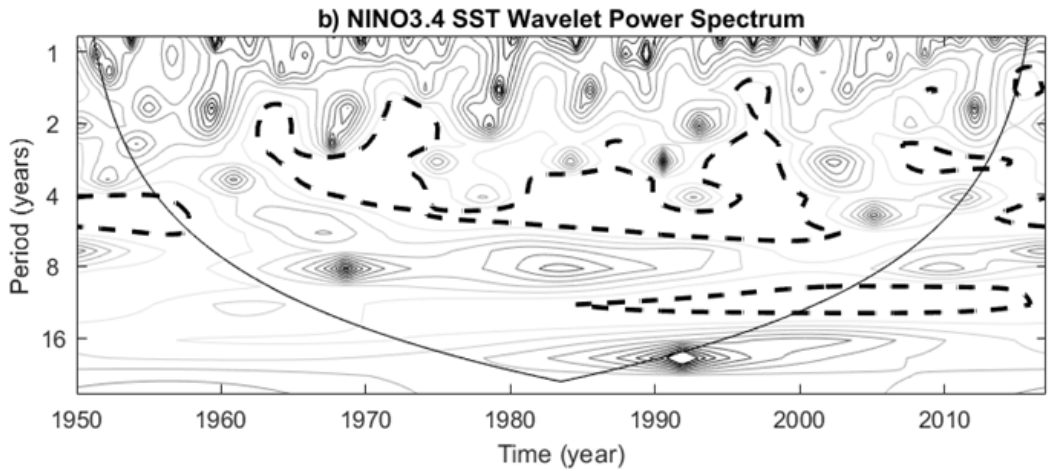
FFT and Wavelet Power Spectrum of PDO & ENSO

Warm(Cool) phase PDO keeps ENSO staying longer-live and more intense (Luiz Carlos B. 2013)







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Canonical Correlation Analysis as downscaling method

Index-based representation of observed fields

$$X(i,t) = \sum \alpha_k(t) p_k(i) = \alpha_1(t)p_1(i) + \alpha_2(t)p_2(i) + ...$$

$$Y(i,t) = \sum \beta_k(t) q_k(i) = \beta_1(t)q_1(i) + \beta_2(t)q_2(i) + ...$$

Linear Algebra

we have estimated p and q already.

By estimating the α and following the β

$$\beta_i = r_i \alpha_i$$

Linear methods and Error minimization

Linear methods: by minimizing the sum of squares

$$Error = \sum_{t,i} \left[X(i,t) - \sum_{k} \alpha_k(t) p_k(i) \right]^2$$

Zorita and Storch, 1998

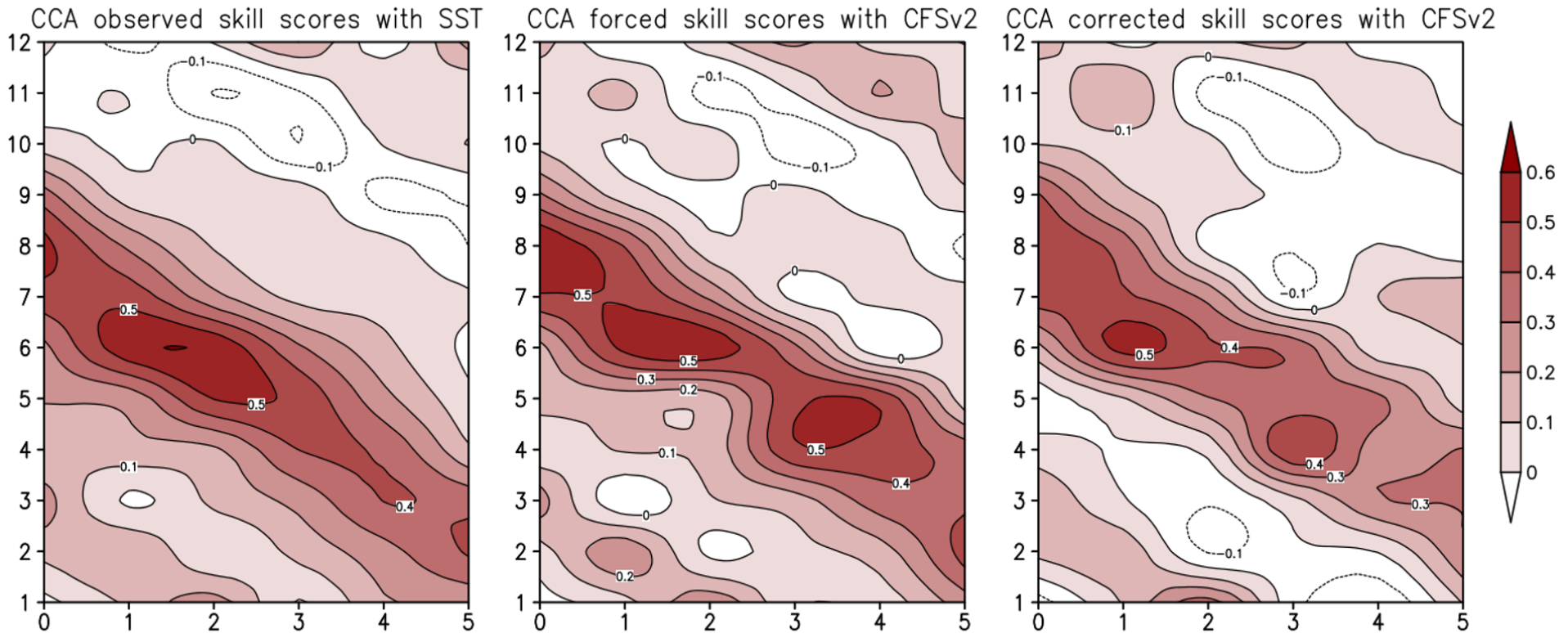
the solution become

Reconstruction Y

$$Y(i,t) = \sum \beta_k q_k = \beta_1(t) q_1(i) + \beta_2(t) q_2(i)$$

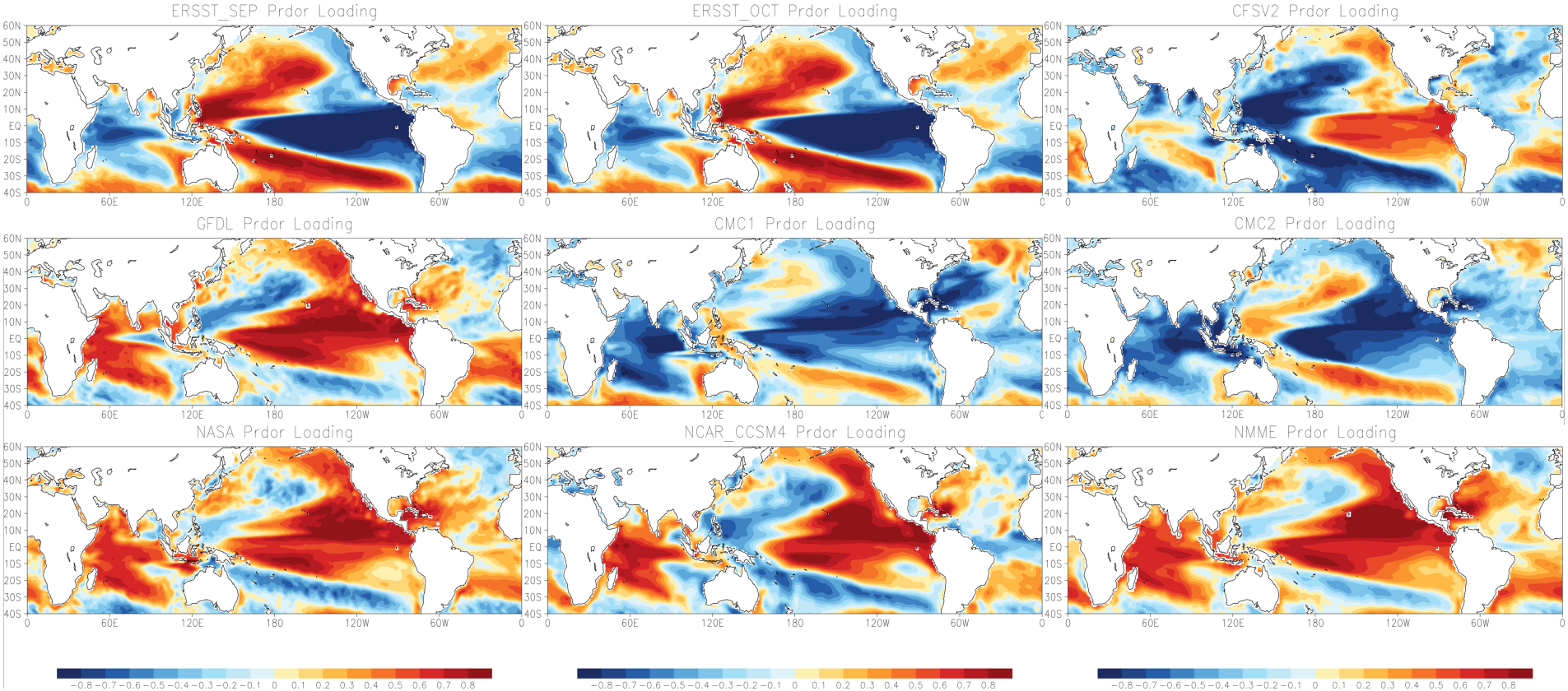
CCA Experiments for Calibration and Downscaling

Three Experiments performed the CCA Calibration and Downscaling



NMME 7+1 Models Sea Surface Temperature Patterns

Sea Surface Temperature Patterns



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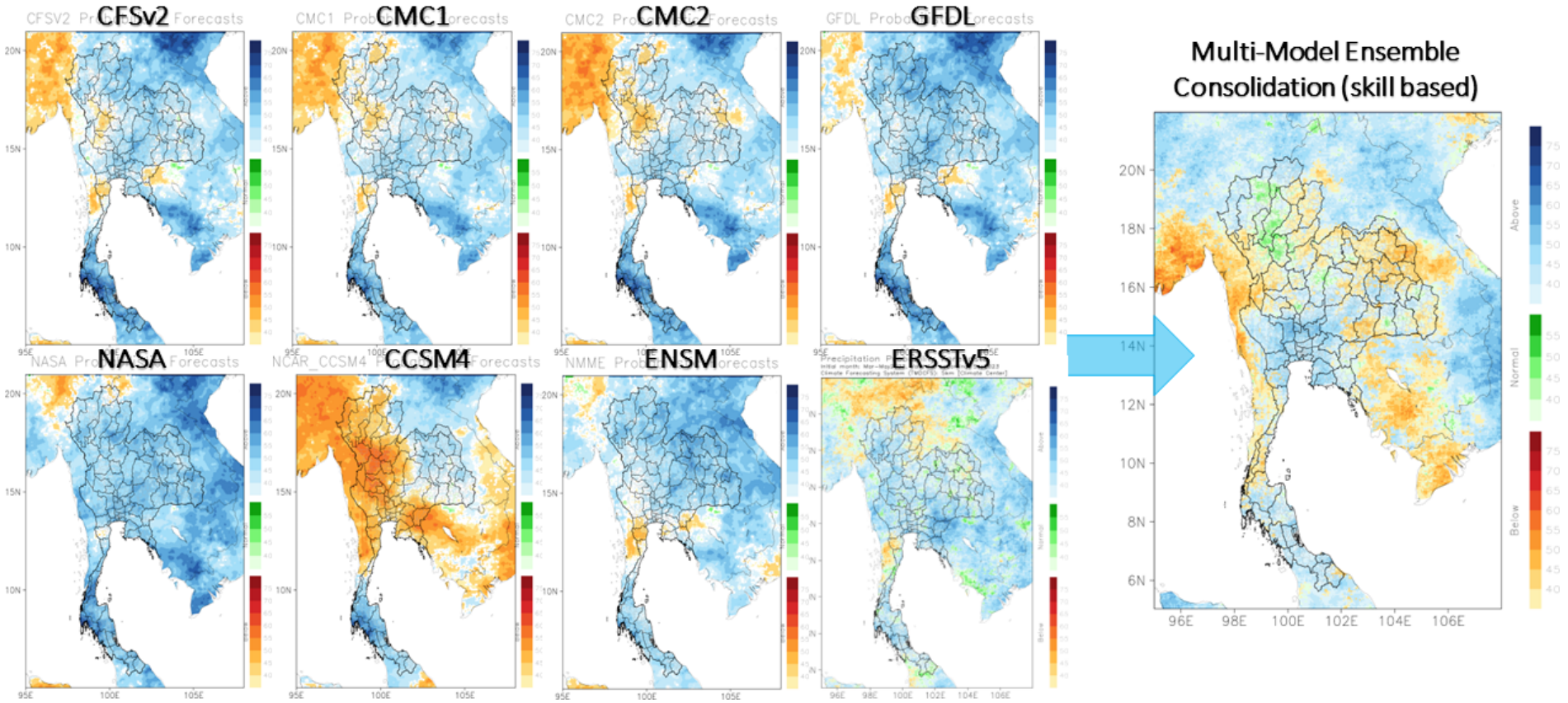
Multi-Model Ensemble on the Probabilistic Forecast

TMDCFS MME(7+1)using Model Output Statistic (MOS)
Probabilistic Forecast for September 2023



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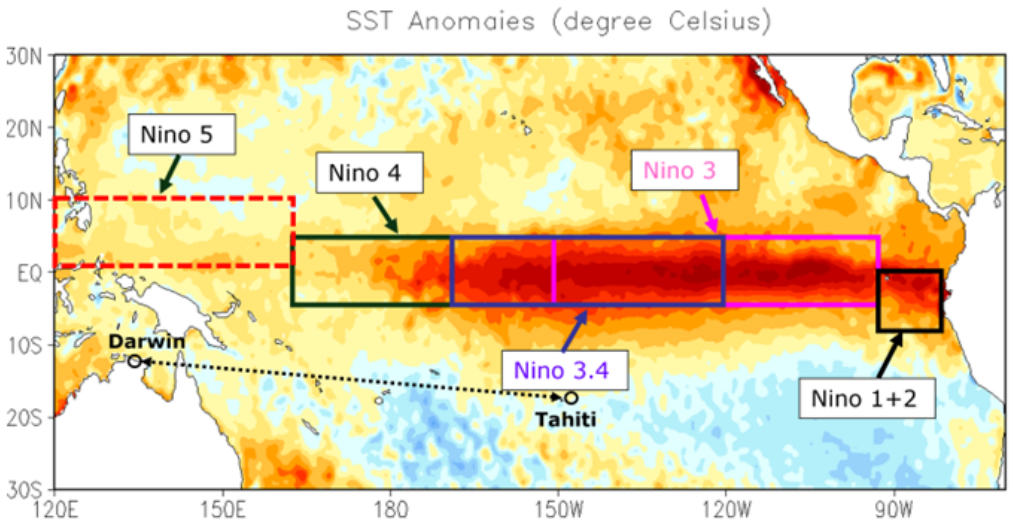
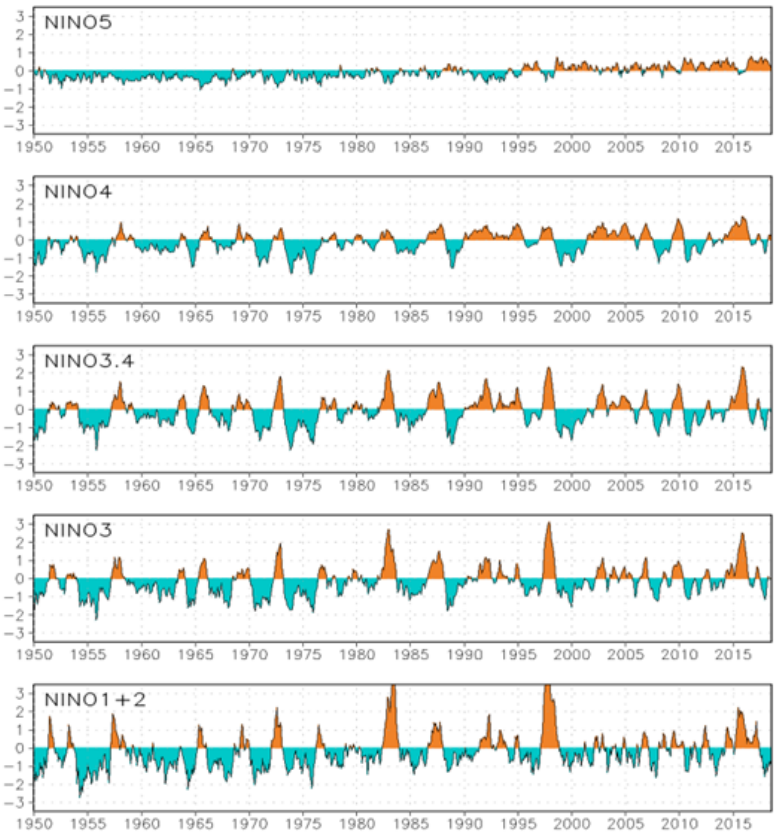
Emerging signals of Climate Change to SST Evolution

Evolution of weekly SSTA patterns



ENSO Indices

- Based on observed SST anomalies (difference from the long-term mean) in the equatorial Pacific in **four** regions (observation from TAO moored buoys)
- Based on surface pressure differences between Tahiti and (minus) Darwin, called the Southern Oscillation Index (SOI)
- Nino 5 index reveals a global warming signal and changing of ENSO impact



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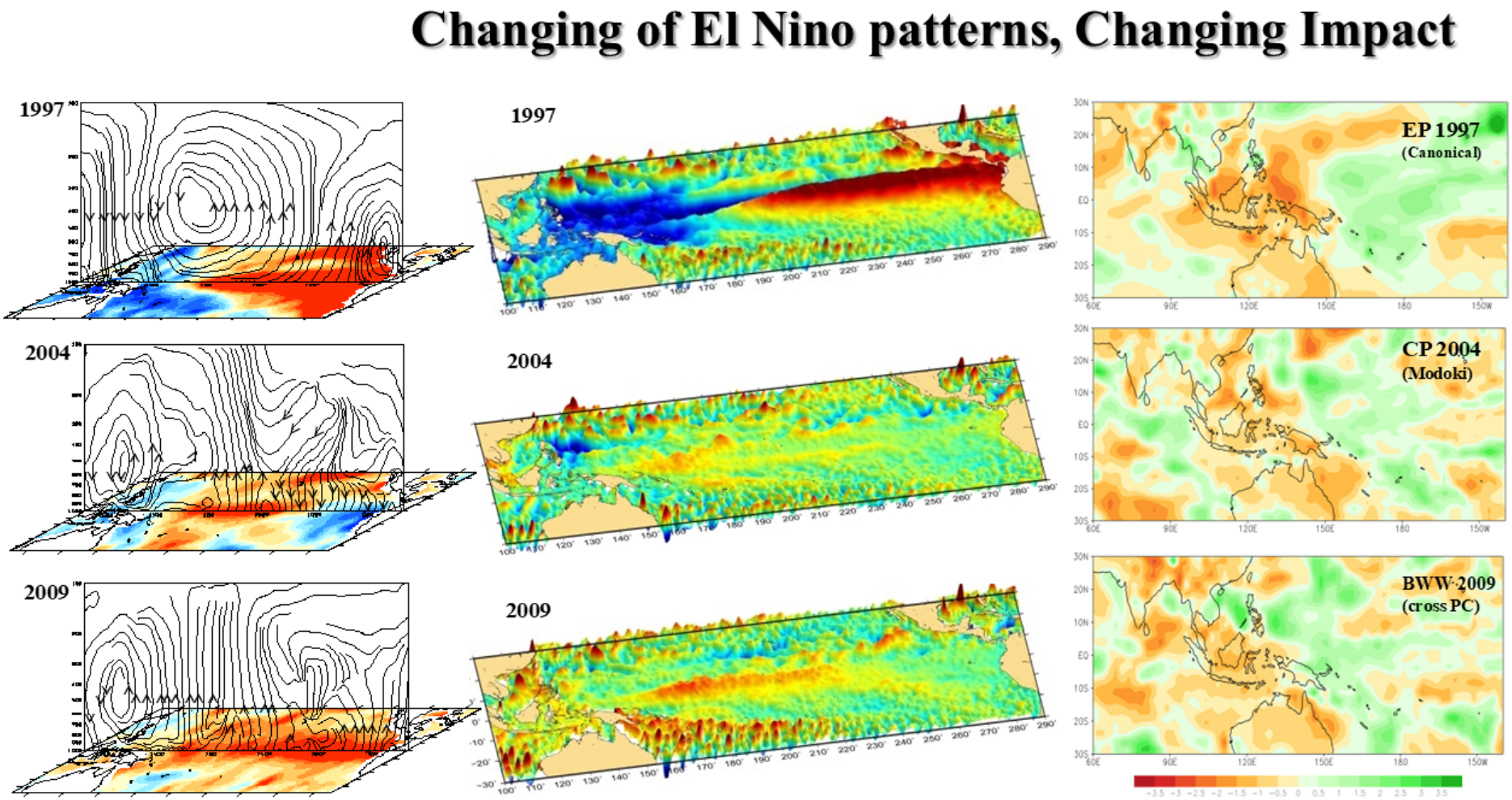
Changing of El Nino Patterns, Changing Impact



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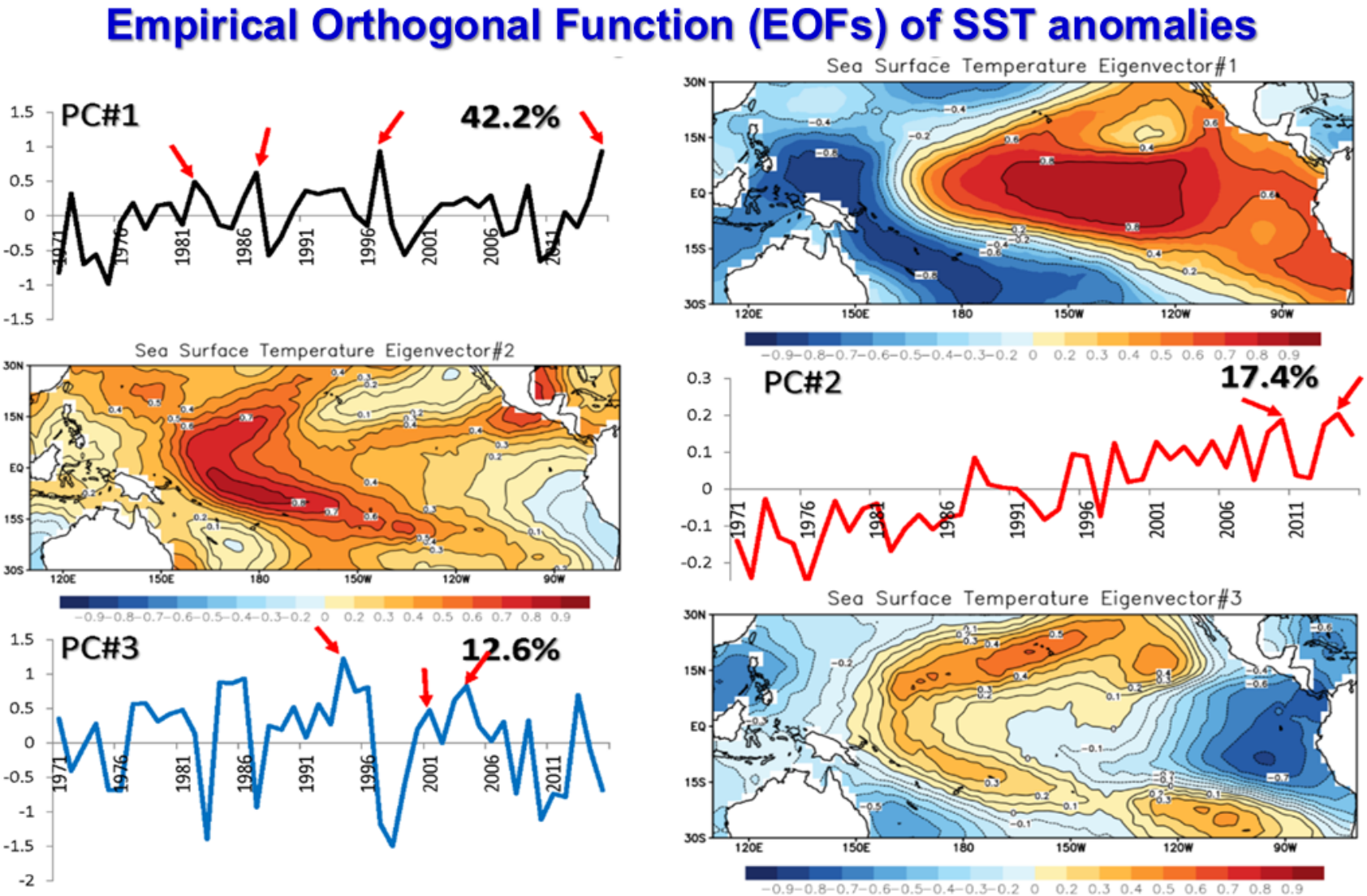

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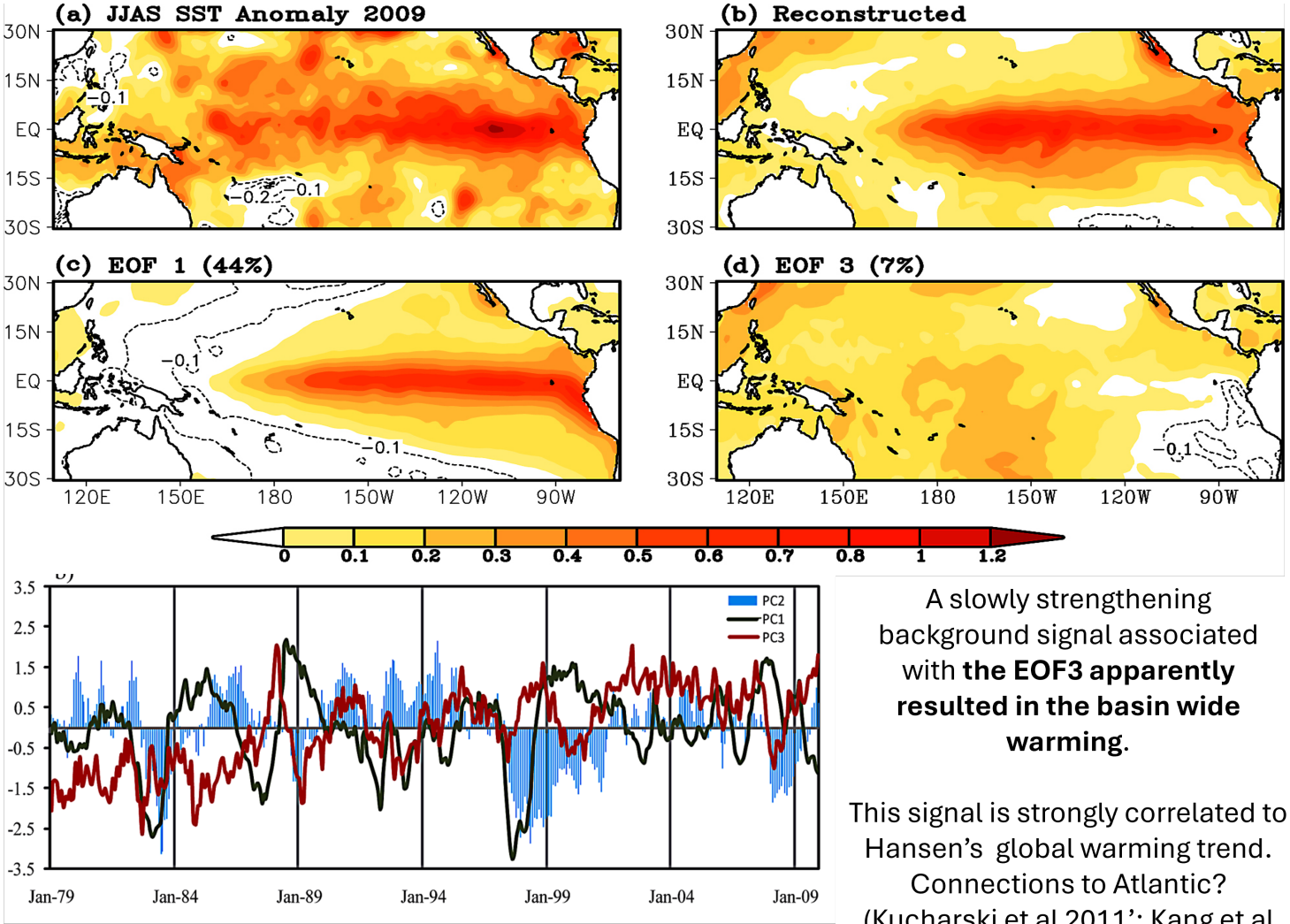
Emerging of Basin Wide Warming



EOF analysis of the observed tropical Pacific interannual SSTA (1979–2009). ** The sign of PC1 has been inadvertently changed **

A slowly strengthening background signal associated with **the EOF3 apparently resulted in the basin wide warming.**

This signal is strongly correlated to Hansen's global warming trend. Connections to Atlantic? (Kucharski et al 2011'; Kang et al 2014).

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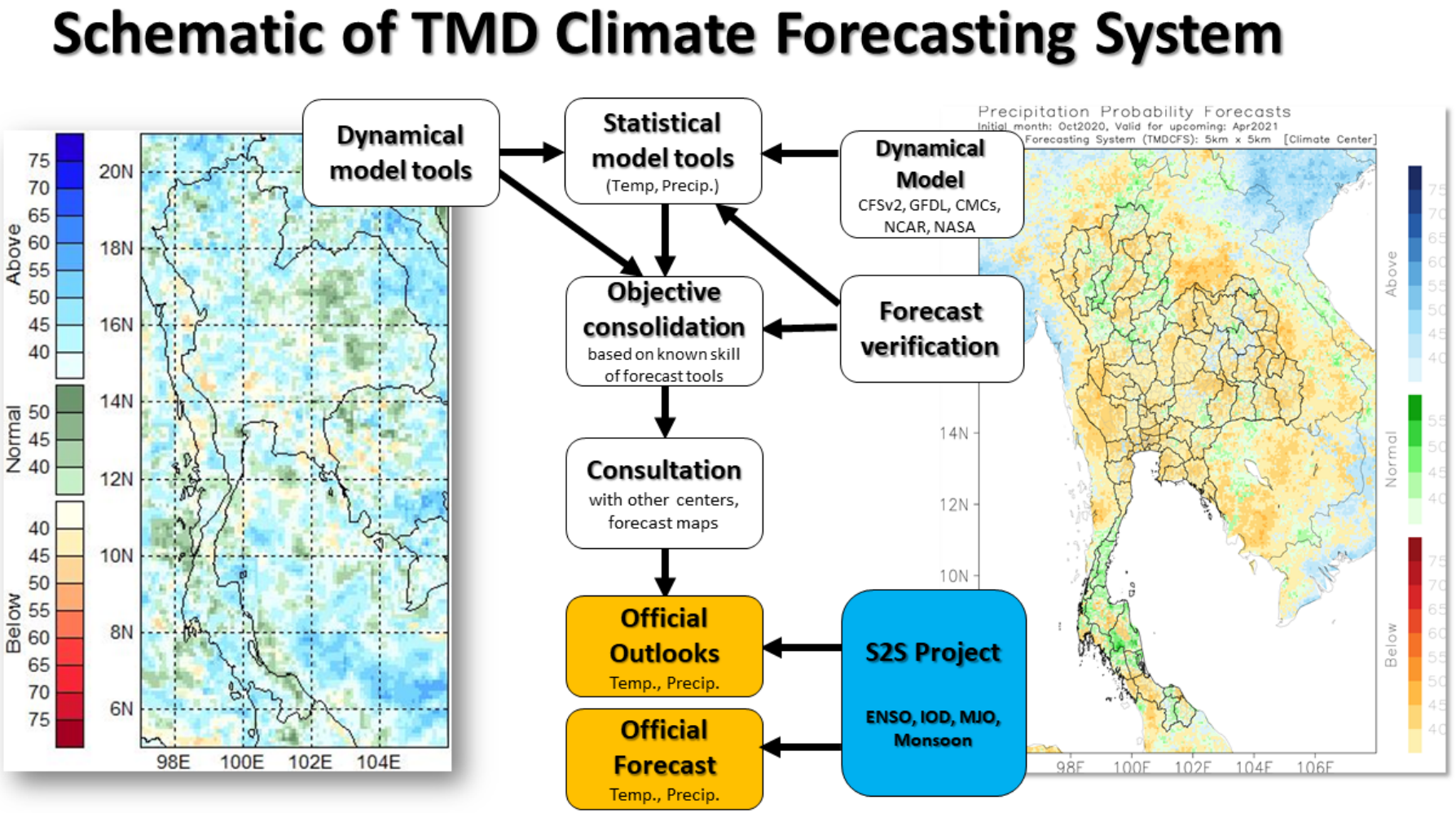
Discussions

1. The EOF analysis reveals that a few leading modes captured about 72% of the first EOF depicts east Pacific SST anomalies (42.2%), the second mode depicts across Pacific SST anomalies (17.4%), and the third mode depicts central Pacific SST anomalies.
2. The Niño5 region reveals a signal of west Pacific SST anomalies triggering an across-Pacific El Niño type under global warming.
3. Both tropical basins and extra-tropical teleconnections have contributed to producing drought/deficit rainfall over the Indochina Peninsula region.
4. The SST anomalies over the tropical Pacific have modulated the Walker cell and, in turn, the Hadley cell, leading to tropical interconnections that impact the Asian monsoon season.

Schematic of Climate Forecasting System



Thanks for your attention !