# Reconciling disparate 20th Century Indo-Pacific ocean temperature trends in the instrumental record and in CMIP5

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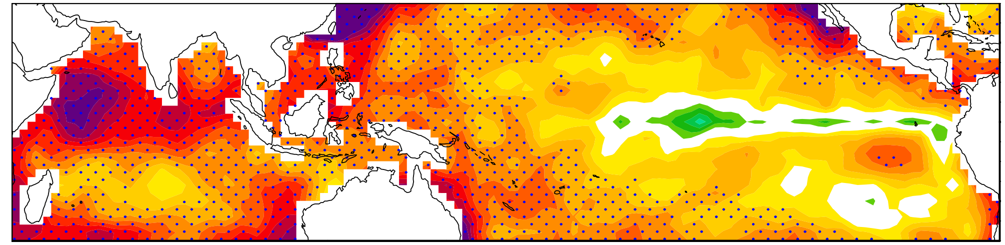
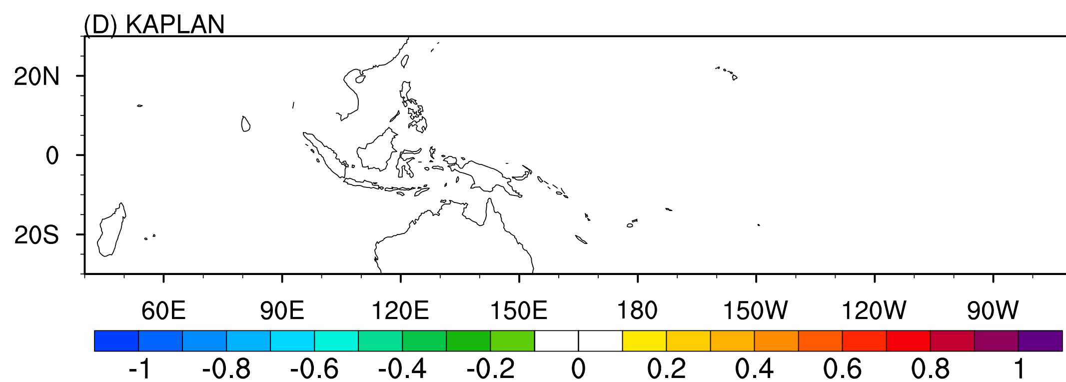
Solomon, A. and M. Newman, 2012 : Reconciling disparate 20th Century Indo-Pacific ocean temperature trends in the instrumental record.
*Nature Climate Change.*, in review.

Large differences exist between 20th century (1900-2010) tropical Indo-Pacific sea surface temperature trends estimated from current reconstructions



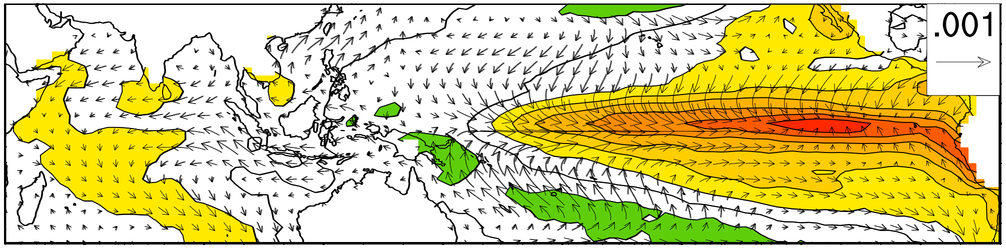


Is this disagreement due to sparseness of data, especially in the earlier part of the record (Deser et al. 2011)?

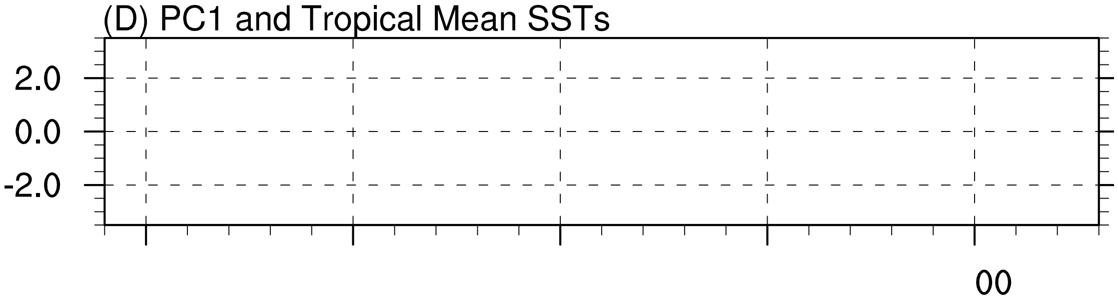
Is this disagreement due to different “analysis” techniques? (There is some disagreement in recent decades as well.)

**We suggest that differences are largely due to different ENSO characteristics in each SST reconstruction.**

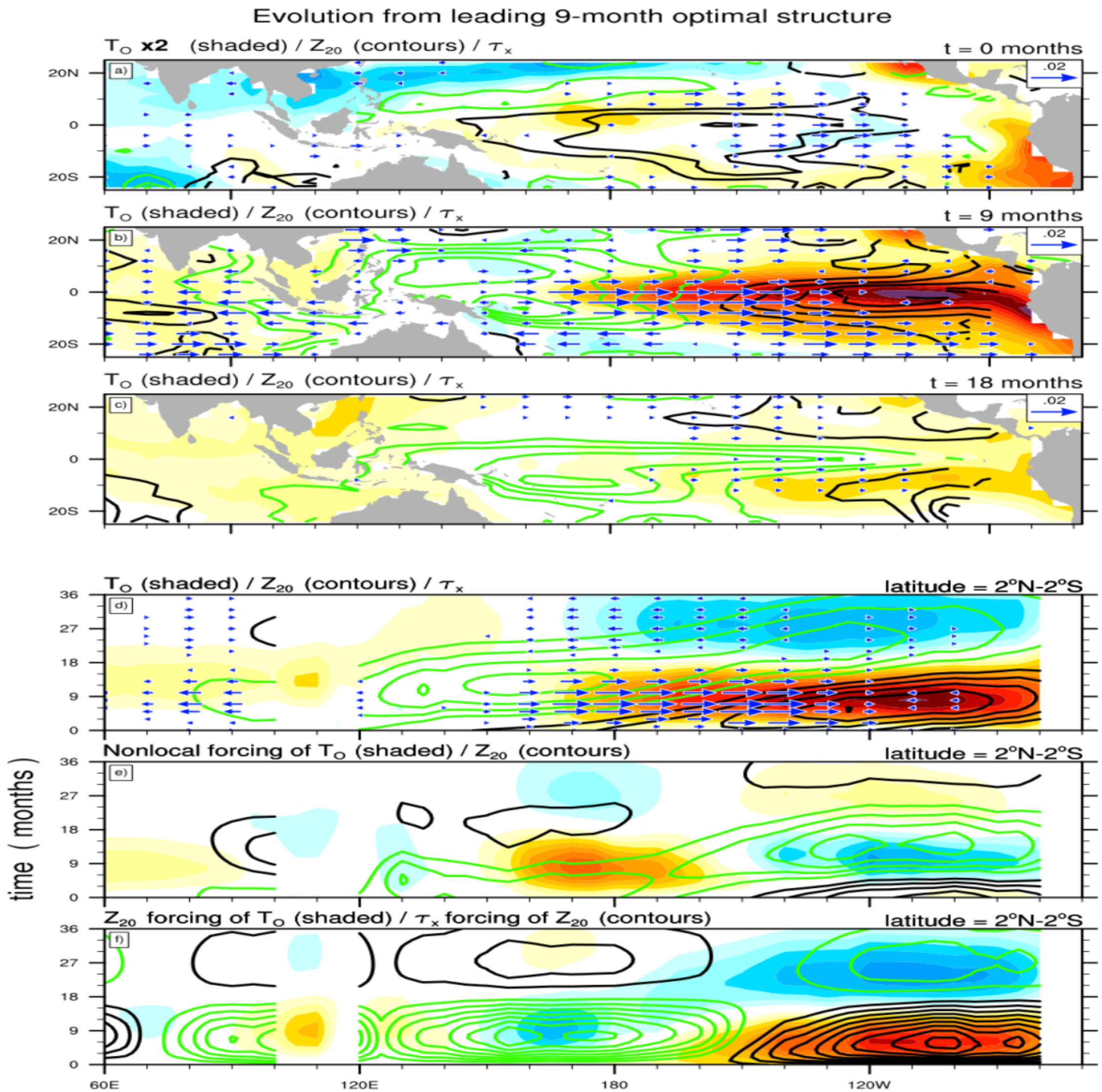
ENSO variability complicates tropical SST trend determination




Can we “remove” ENSO from SSTs to determine background trend?



# ENSO is a dynamical phenomenon



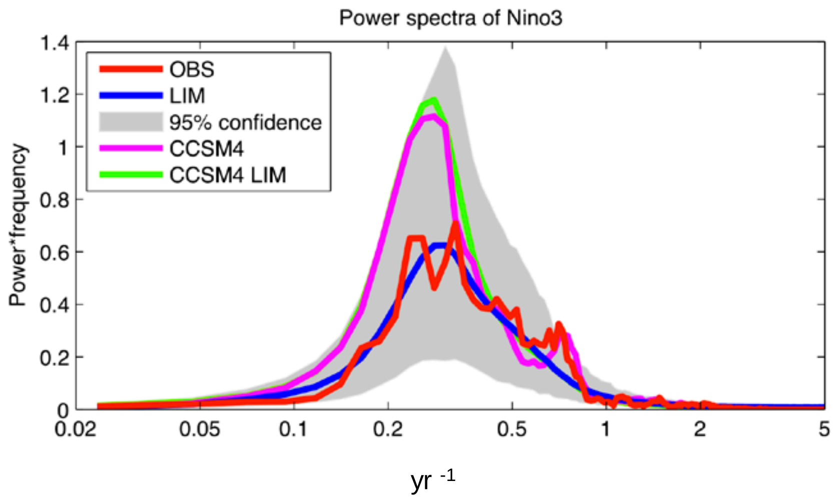
# "Multivariate Red Noise"

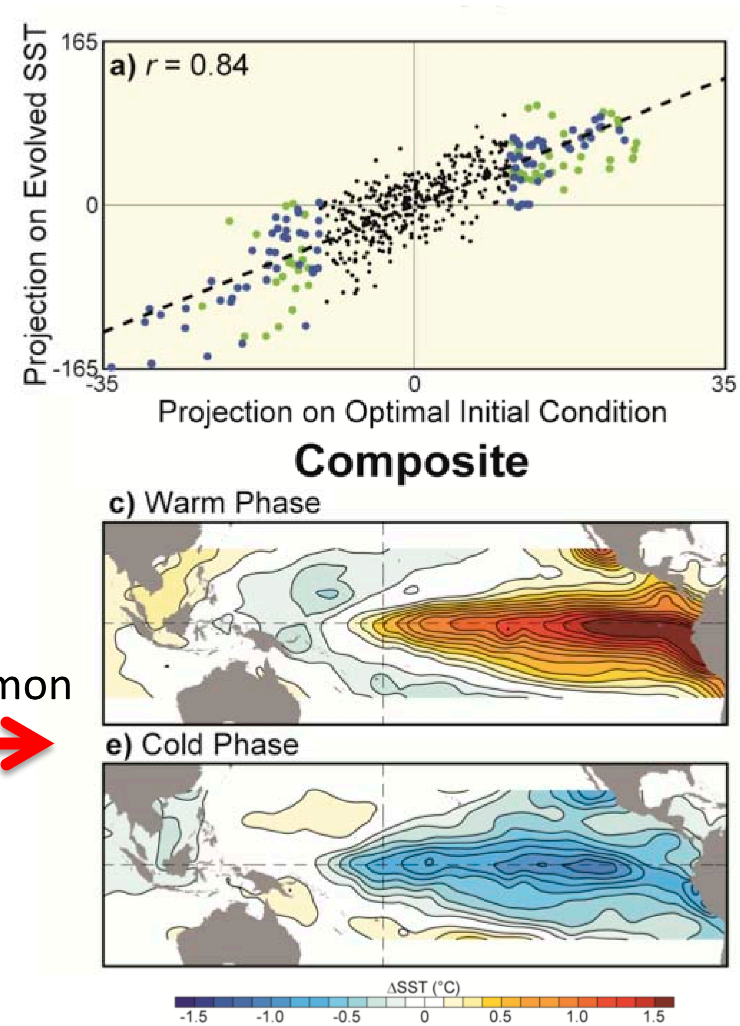
- Noise/response is non-local: patterns matter
  - For example, SST sensitive to atmospheric gradient
  - use multivariate ("patterns-based") red noise:

    $$d\mathbf{x}/dt = \mathbf{B}\mathbf{x} + \mathbf{F}_s$$

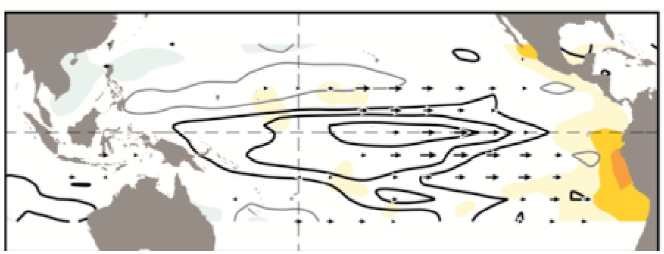
    where $\mathbf{x}(t)$ is a series of maps, **B** is stable, and $\mathbf{F}_s$ is white noise (maps)
  - Analogous to "univariate red noise"
- Determine **B** and $\mathbf{F}_s$ using "Linear Inverse Model" (LIM)
  - $\boldsymbol{x}$ is Tropical IndoPacific seasonal SST anomalies
  - LIM determined from fixed lag (3 months) as in AR1 model
- "Optimal perturbation" $\mathbf{v_1}$ : initial condition leading to greatest possible SST anomaly over time $[t, t+\tau]$
  - Determined from propagator matrix $exp(\mathbf{B}\tau)$

# Multivariate red noise captures ENSO evolution




Initial
(t = 0)



after 6 mon

SST: shading
Thermocline depth: contours
Zonal wind stress: vectors

Composite: Six months ***after*** a > ± 1 sigma projection on the optimal initial condition, constructed separately for warm and cold events

# “Optimal perturbation filter”

- Iteratively remove evolving ENSO, from optimal perturbation through peak ENSO through decay (here, over 21 months)

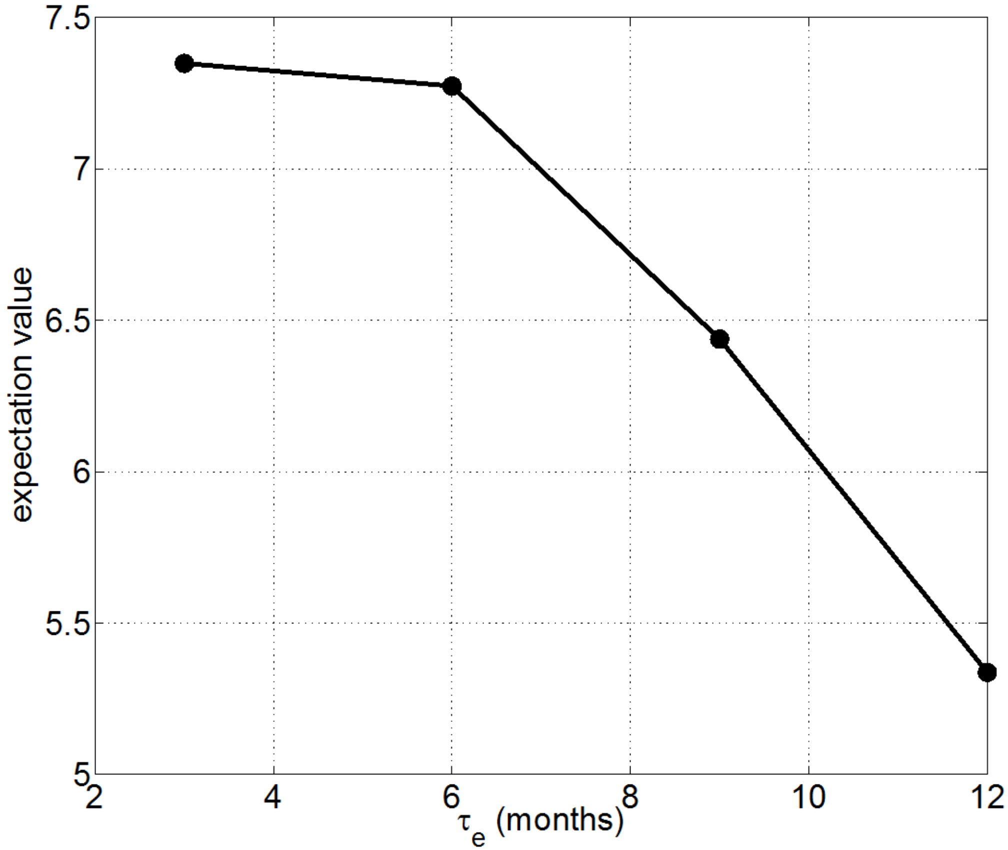
$$\mathbf{r}(t) = \mathbf{x}(t) - \hat{\mathbf{x}}(t)$$

$$\hat{\mathbf{x}}(t) = \exp(\mathbf{B}t)\mathbf{v}_1$$

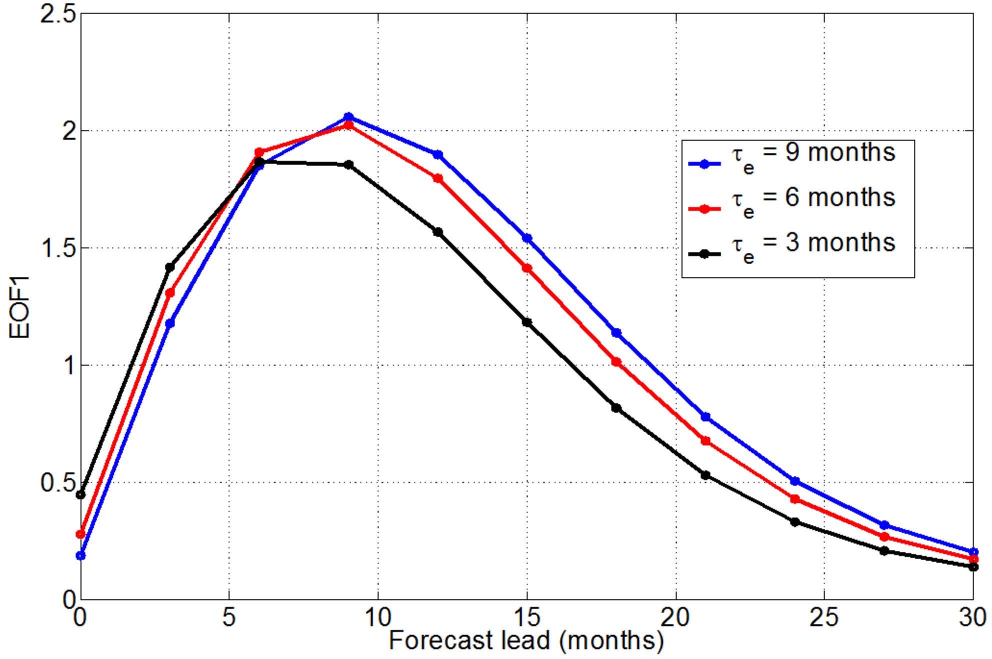
$t = 0$ $t = \tau_e$

# Parameter choice: what time interval to choose for “optimal”

Projection of noise on optimal initial conditions, 1891-2010



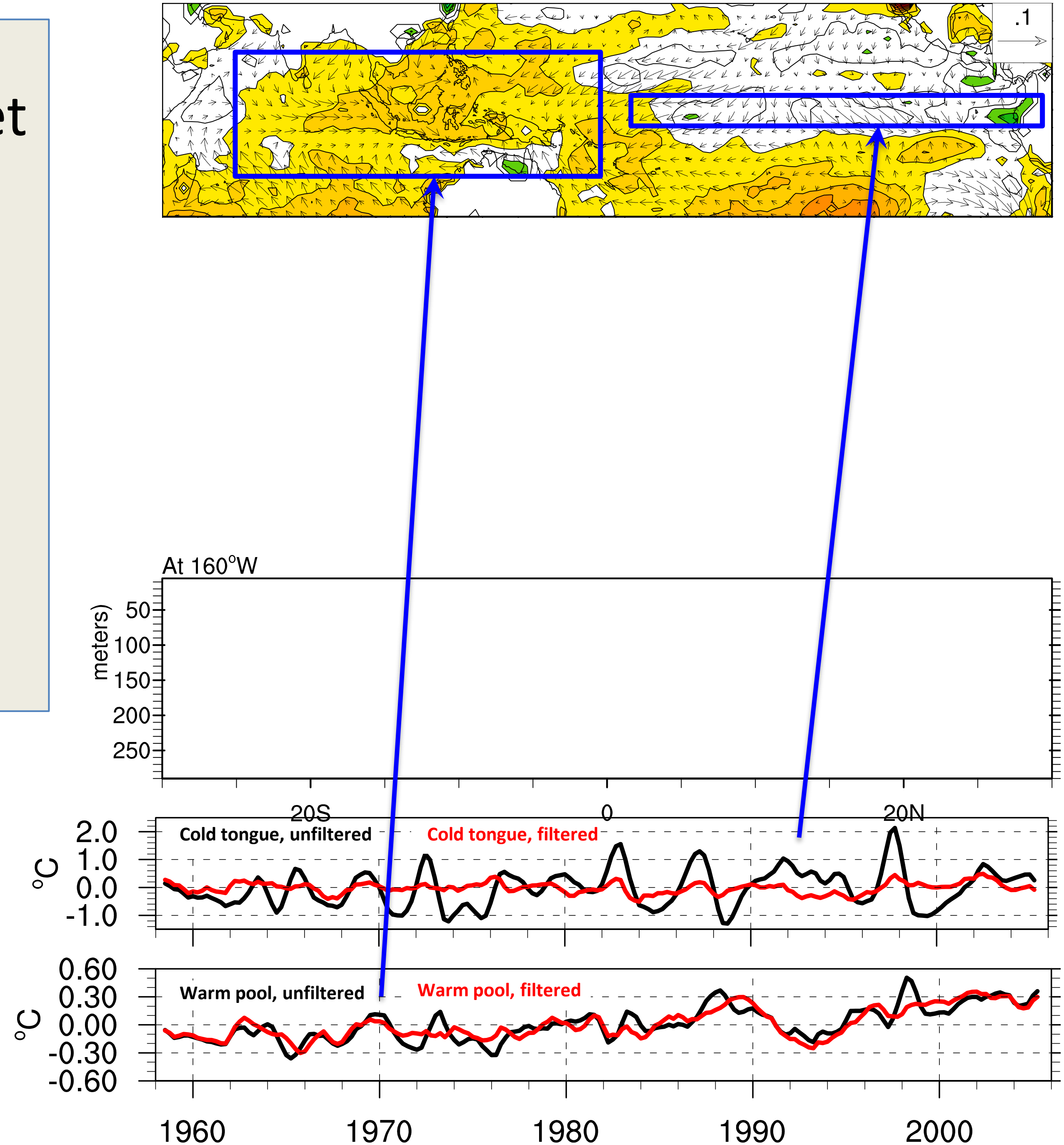
# Growth curves for different optimization times



# Removing ENSO from SODA dataset

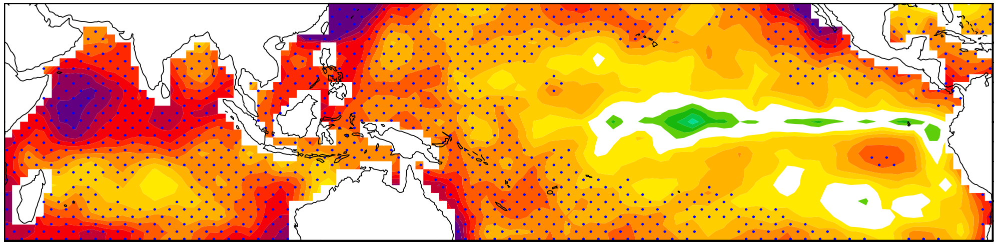
Warming warm pool, near constant cold tongue

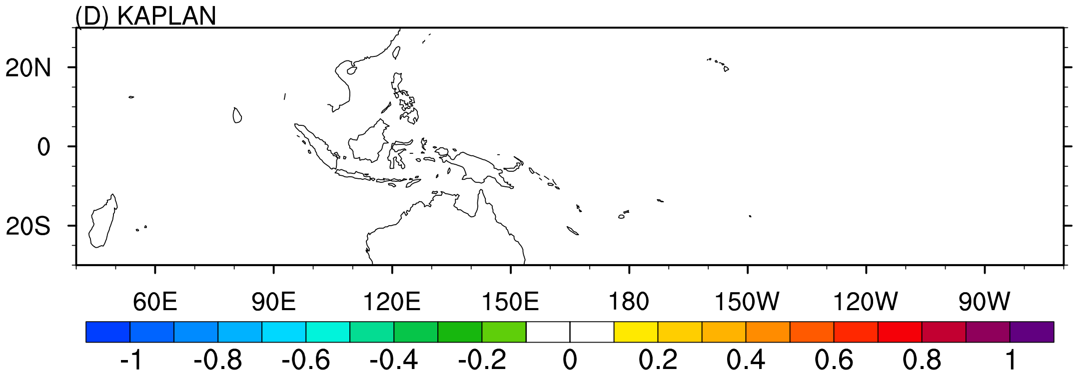
Also: slightly *stronger* equatorial easterlies




1960-2000 trend of filtered SODA SSTs, regressed to ocean temperature and wind stress anomalies

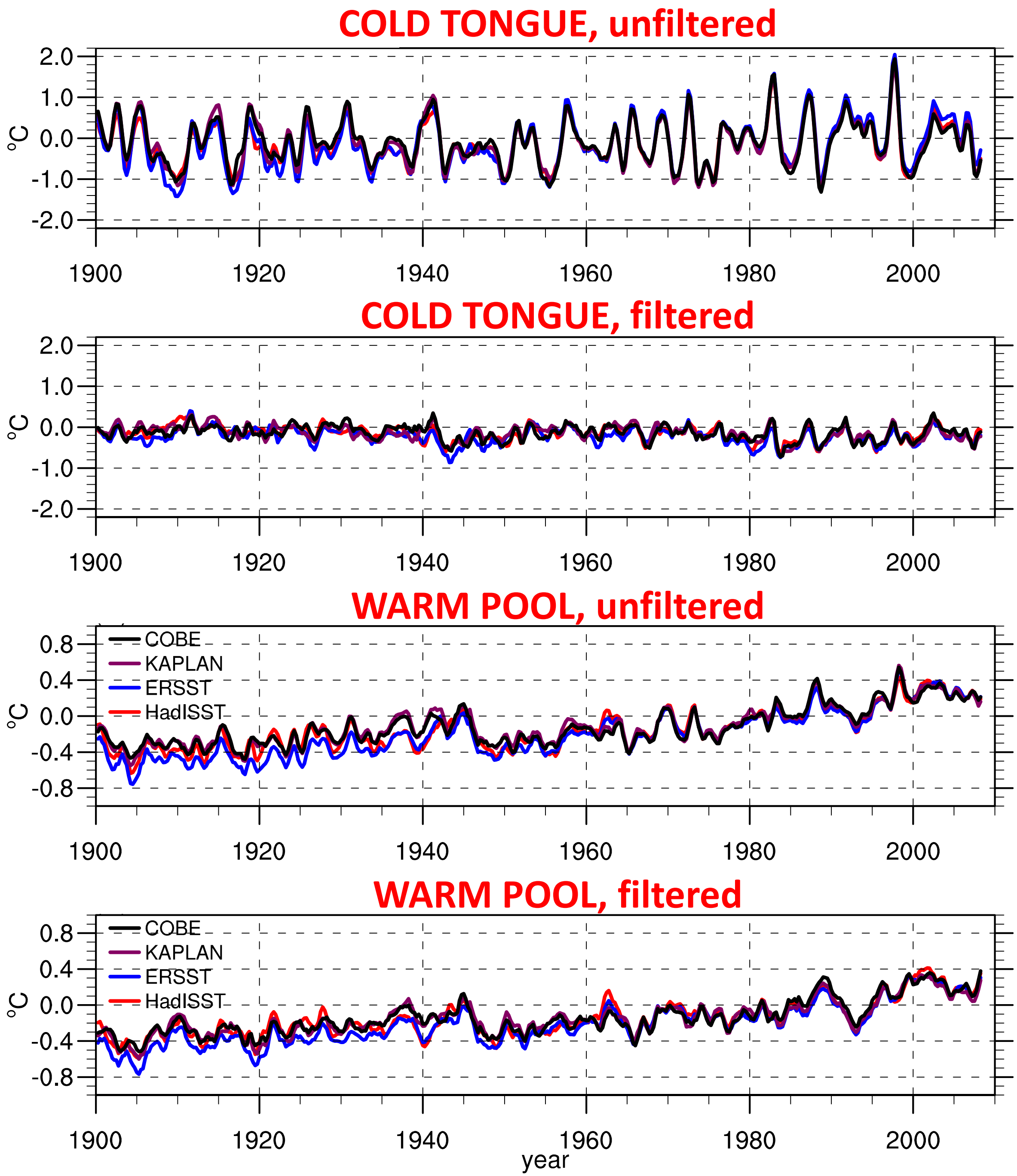
Significance of (full)trends is determined by local comparison to multivariate red noise (LIM)



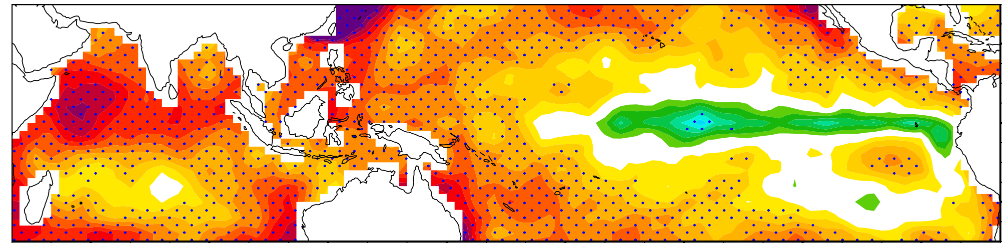


Removing ENSO from 20th century SST datasets

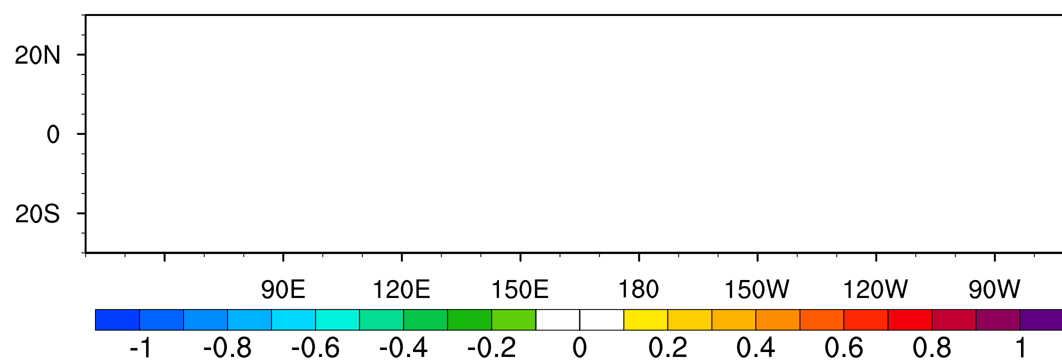
Warming warm pool, slightly cooling cold tongue

# Removing ENSO yields robust SST trend pattern



20th century (1900-2010) tropical Indo-Pacific sea surface temperature trends from filtered SST reconstructions



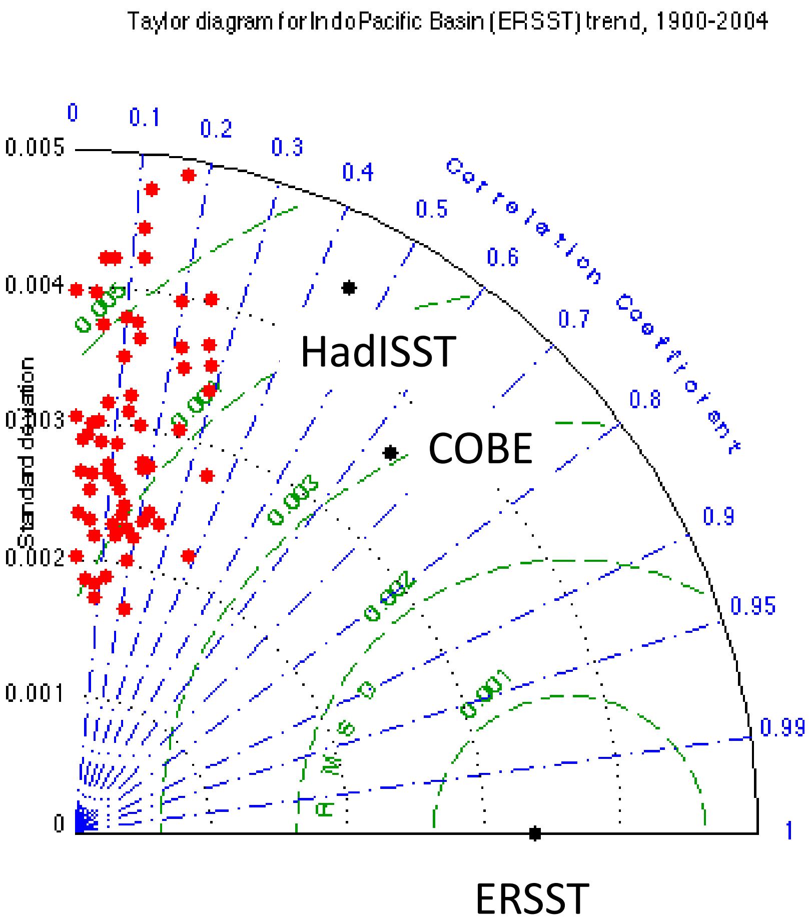
# Conclusion

- Filtering ENSO from each SST dataset shows that **trend disagreement is largely due to different estimates of ENSO variability**.
- The resulting robust trend pattern represents a **post-1900 strengthening of the equatorial Pacific temperature gradient**, due to a warming trend in the warm pool and weak cooling/ negligible warming in the cold tongue.
- A similar analysis is needed to validate climate model hindcasts of the 20$^{th}$ Century and assess climate model projections of the 21$^{st}$ Century.

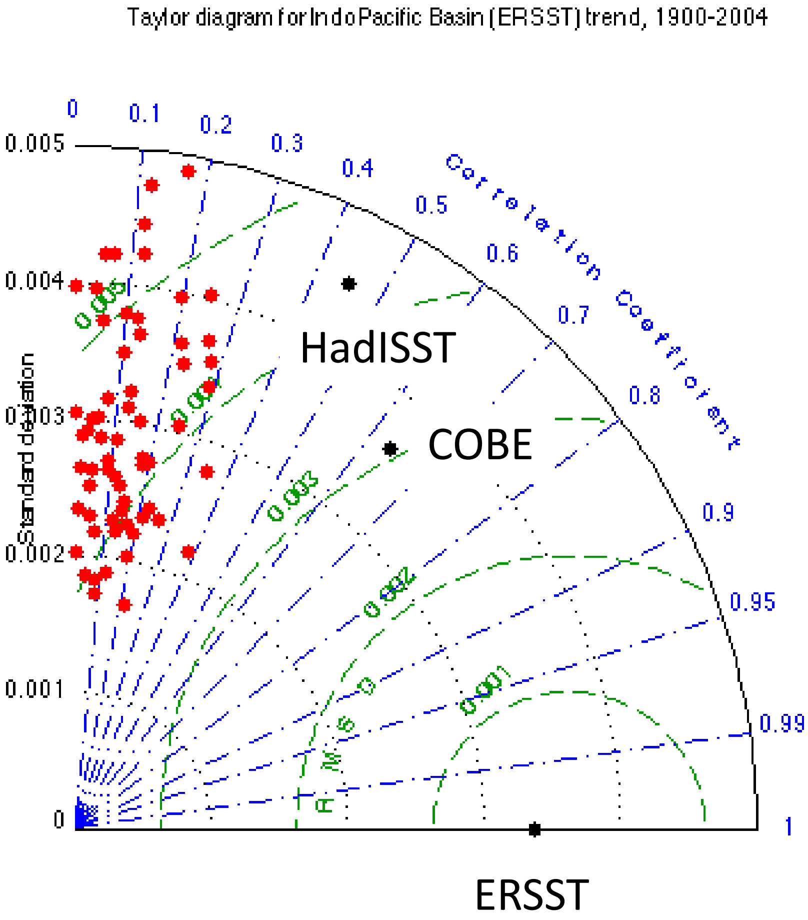
# A similar analysis to validate climate model hindcasts of the 20th Century (preliminary)

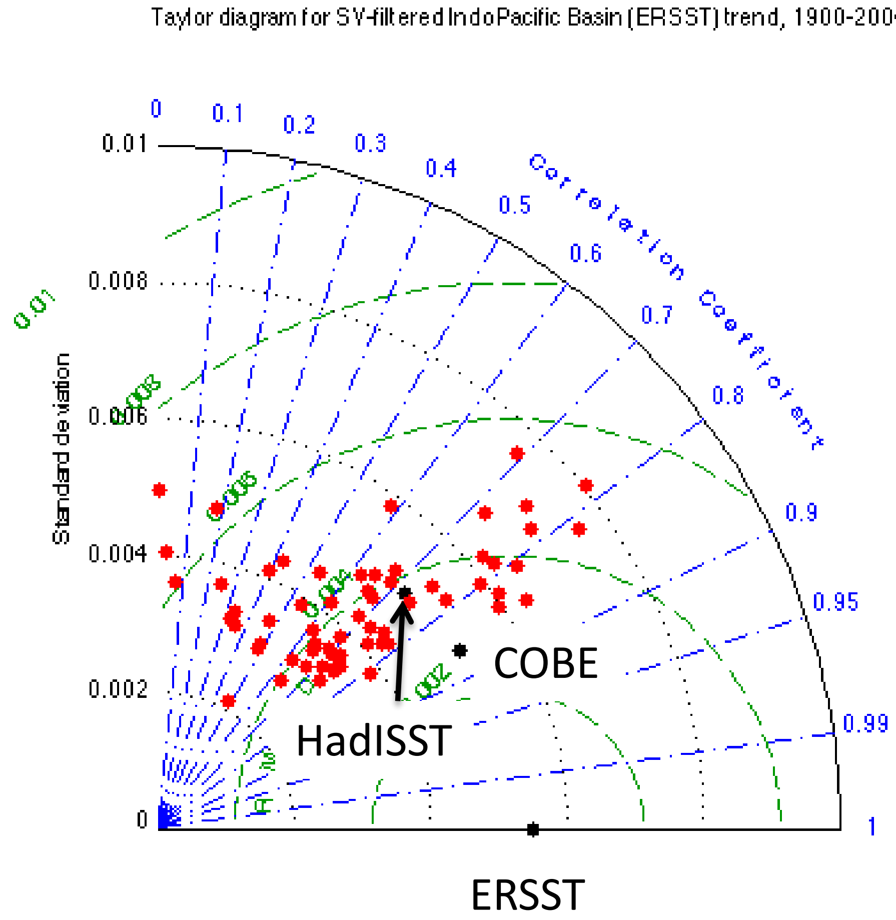
- 15 CMIP5 model "historical forcing" simulations totaling 74 realizations (so far)
- Constructing a separate LIM from each realization, using same parameters as observed

# CMIP5 trends compare poorly to SST reconstructions



# Filtered CMIP5 trends compare much better to filtered SST reconstructions



# CCSM4 example