

Diagnosing subseasonal predictability of tropical atmospheric anomalies

Matt Newman

CIRES, University of Colorado and NOAA/ESRL/PSD

MAPP Webinar: Intraseasonal to Interannual Prediction
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“Multivariate Red Noise” null hypothesis

$$dx/dt = \mathbf{L}x + \mathbf{F}_s$$

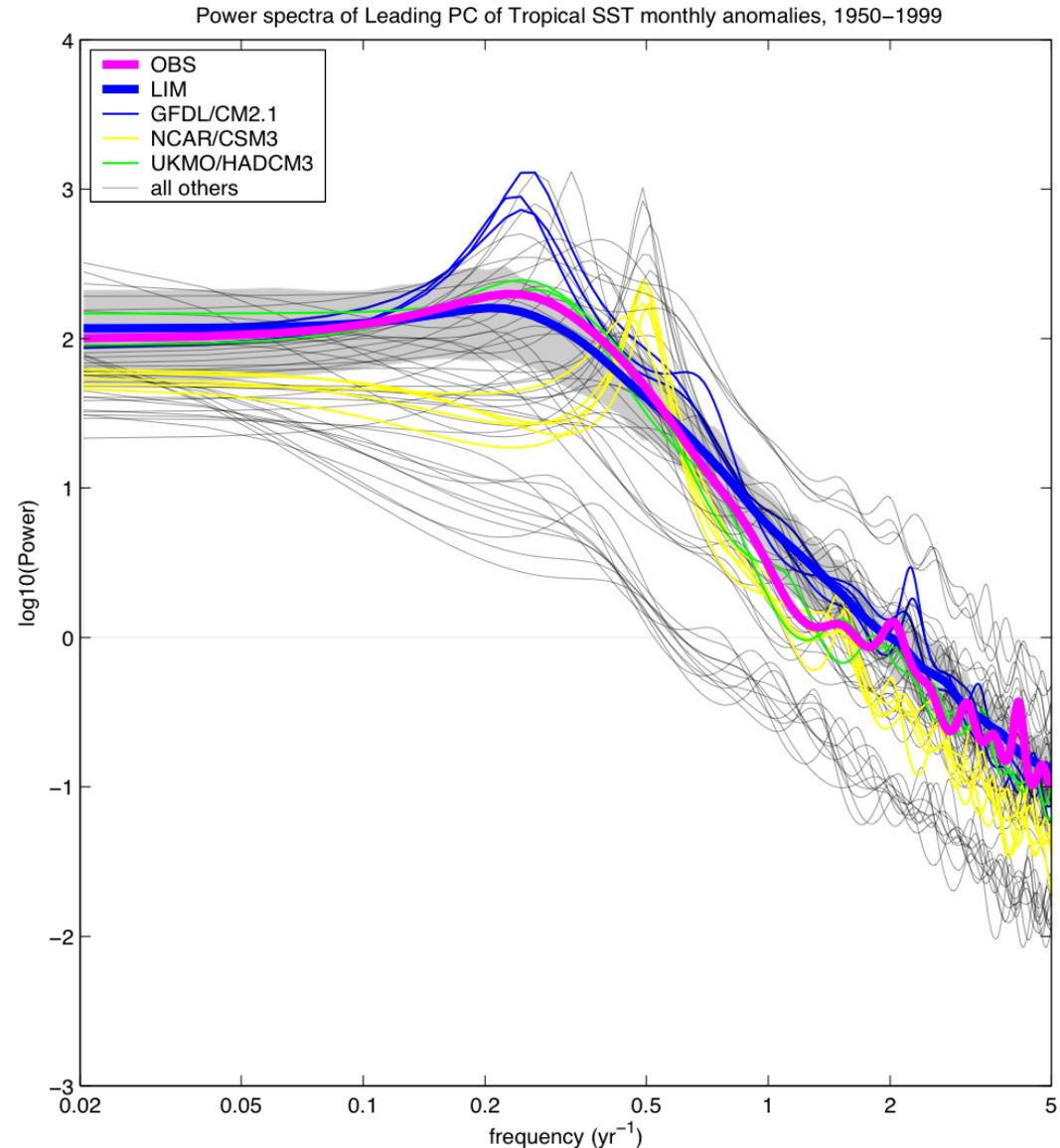
where $\mathbf{x}(t)$ is a series of maps, \mathbf{L} is stable, and \mathbf{F}_s is white noise (maps)

- Determine \mathbf{L} and \mathbf{F}_s using “Linear Inverse Model” (LIM)
 - \mathbf{x} is **SST/OLR/200 and 850 mb wind** 5-day running mean anomalies in Tropics, 1982-2009 (similar to Newman, Sardeshmukh, and Penland 2009, *J. Climate*)
 - prefiltered in reduced EOF space
 - LIM determined from specified lag $\tau_0=5$ (e.g., the data averaging interval) as in AR1 model, using τ_0 and zero-lag covariance of \mathbf{x}
 - Then test the LIM over much longer time intervals

ENSO in C-LIM and IPCC AR4 “20th-century” CGCMs compared to observations, 1950-1999

C-LIM simulation of observed evolution of variability is as good as in coupled GCMs, so we can use it to quantify predictability.

Newman, Sardeshmukh, and Penland 2009



Using LIM to estimate predictability

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

\mathbf{L} = constant, \mathbf{F}_s = additive (state-independent) noise.

$$\mathbf{x}(t + \tau) = \exp(\mathbf{L}\tau) \mathbf{x}(t) + \boldsymbol{\varepsilon} = \mathbf{G}(\tau) \mathbf{x}(t) + \boldsymbol{\varepsilon}$$

“signal”

“noise”

Expected forecast error covariance

(assuming no initial error) :

$$\mathbf{E}(\tau) = \langle \boldsymbol{\varepsilon} \boldsymbol{\varepsilon}^T \rangle = \mathbf{C}(0) - \mathbf{G} \mathbf{C}(0) \mathbf{G}^T$$

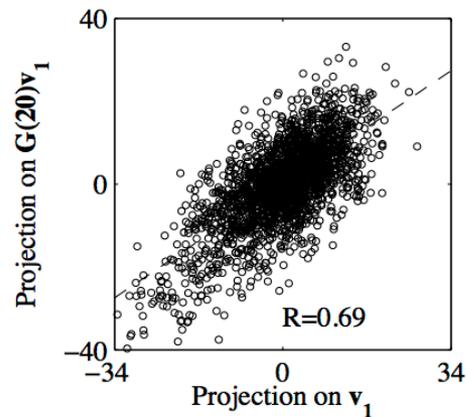
Expected forecast anomaly correlation

$$\rho_\infty = \frac{s}{\sqrt{1+s^2}}, \text{ where } s^2 = \frac{[\mathbf{G} \mathbf{C}(0) \mathbf{G}^T]_{ii}}{[\mathbf{E}(\tau)]_{ii}}$$

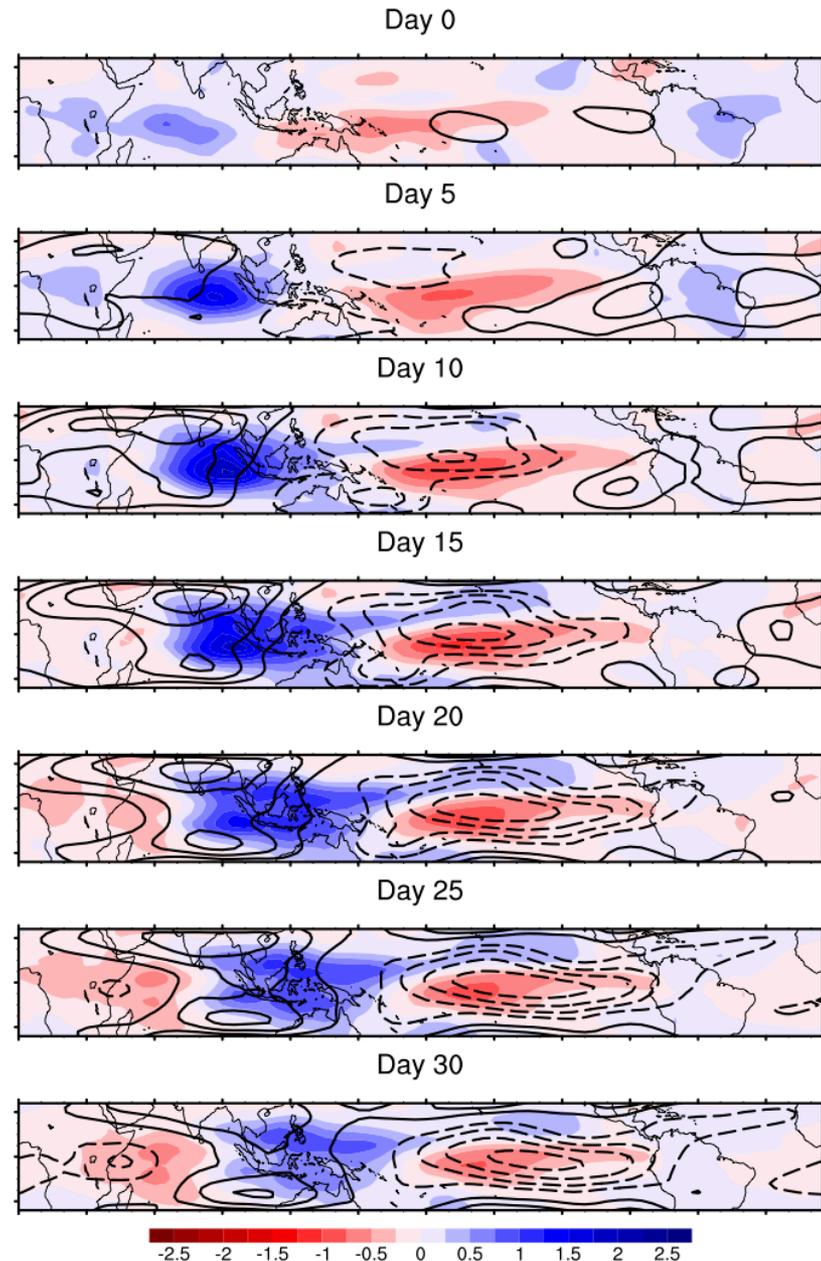
Larger signal related to leading singular vector of $\mathbf{G}(\tau)$

Structure leading to greatest OLR anomaly amplification over 20-day interval

Shading: OLR anomalies
Contours: 200 mb zonal wind anomalies



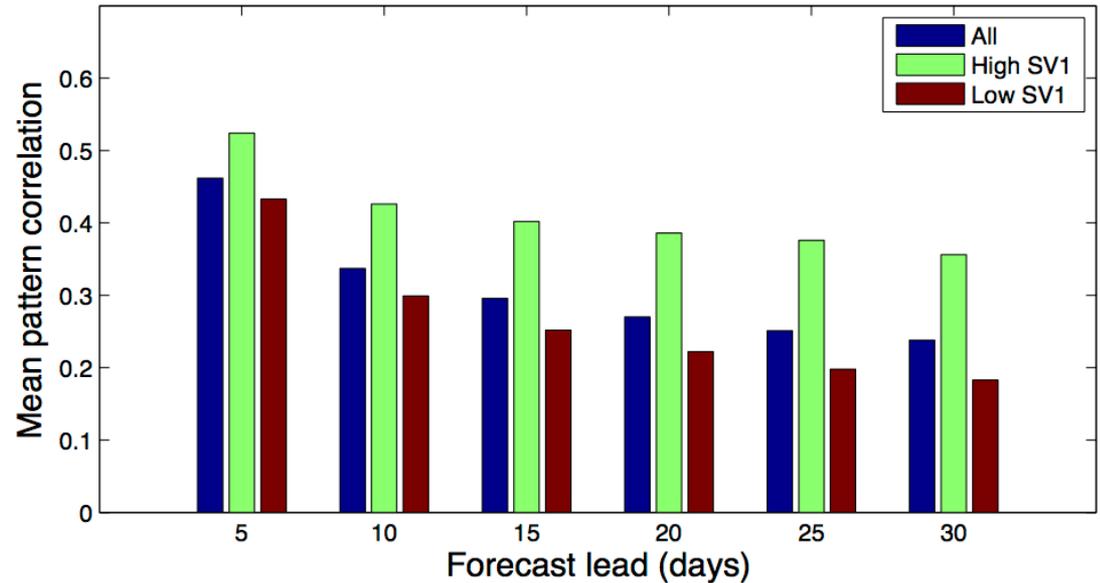
Leading singular vector, OLR norm, for 20 day interval



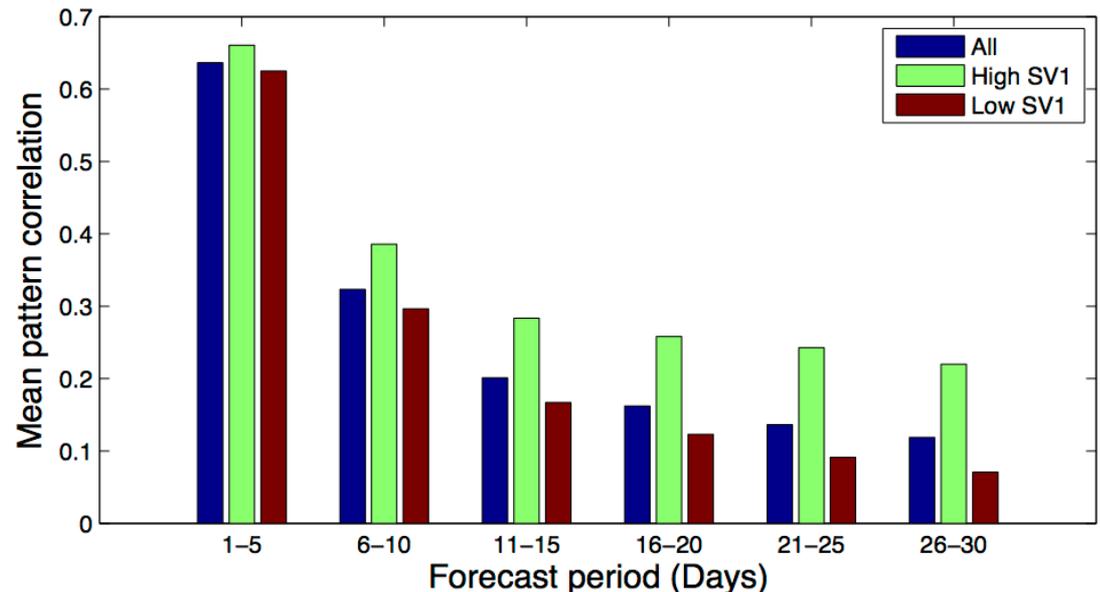
Using LIM to identify relatively more skillful forecast cases *a priori* from forecast signal-to-noise ratio

Pattern correlation of tropical IndoPacific OLR hindcasts, 1982-2009, stratified by whether initial conditions strongly project on initial growth structure (SV1)

LIM



CFS2



Turn “off” coupling

LIM can be written in its component parts as:

$$\frac{d\mathbf{x}}{dt} = \frac{d}{dt} \begin{bmatrix} \mathbf{T}_O \\ \mathbf{x}_A \end{bmatrix} = \begin{bmatrix} \mathbf{L}_{OO} & \mathbf{L}_{AO} \\ \mathbf{L}_{OA} & \mathbf{L}_{AA} \end{bmatrix} \begin{bmatrix} \mathbf{T}_O \\ \mathbf{x}_A \end{bmatrix} + \begin{bmatrix} \text{SST noise} \\ \text{atmospheric noise} \end{bmatrix}$$

To “uncouple” ocean from atmosphere, define

$$\mathbf{L}_{uncoupled} = \begin{bmatrix} \mathbf{L}_{OO} & \mathbf{0} \\ \mathbf{0} & \mathbf{L}_{AA} \end{bmatrix}$$

This is *not* the same as constructing separate A-LIMs and O-LIMs.

Removing coupling: greatly decreases interannual power
almost no effect on intraseasonal power

Comparing L and $L_{\text{uncoupled}}$

Two distinct classes of eigenmodes of L

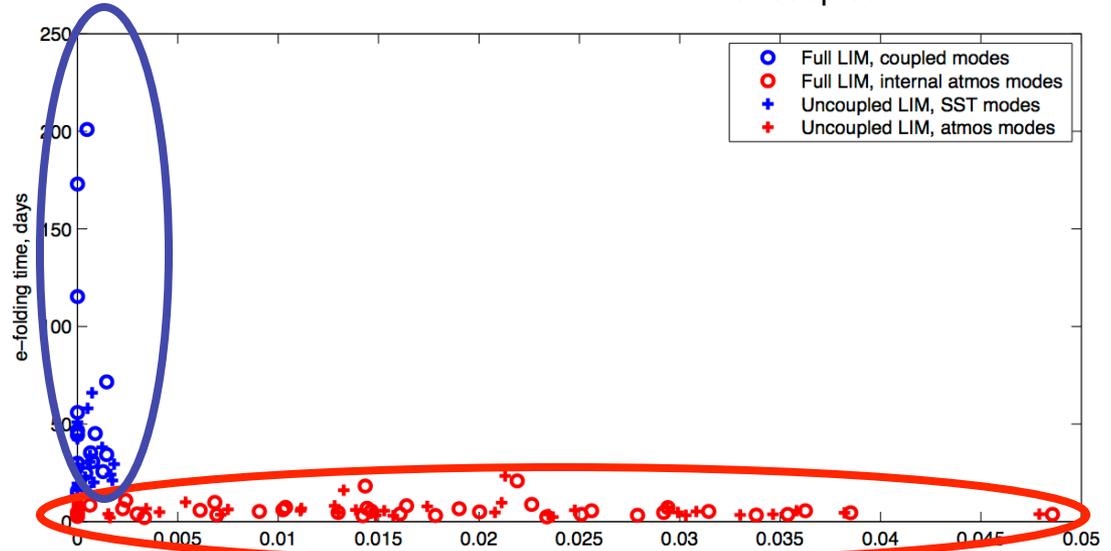
“coupled”

Longer e-folding time, low frequency modes strongly modified by coupling

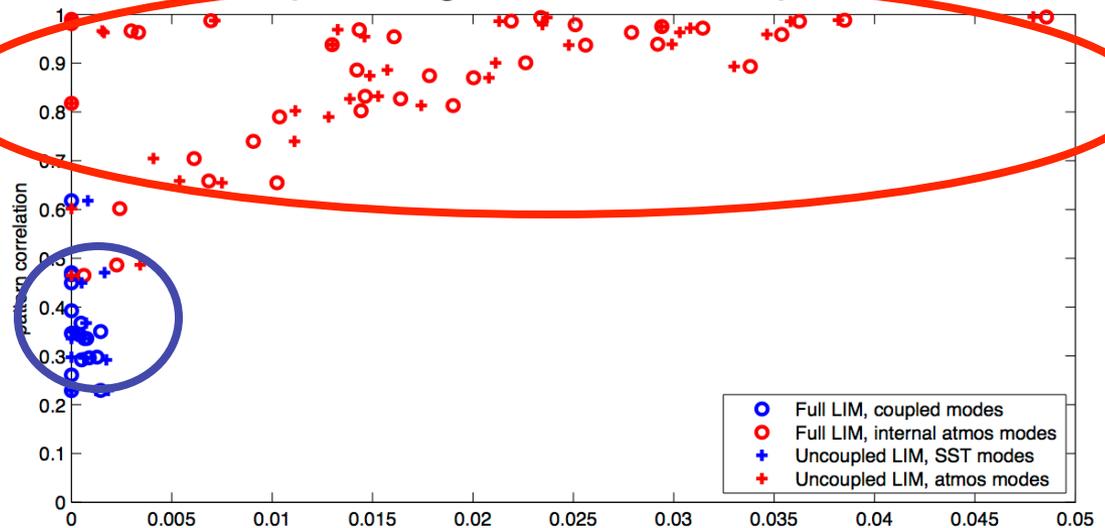
“internal atmospheric”

Short e-folding time, high frequency modes only slightly modified by coupling

Eigenvalues of L and $L_{\text{uncoupled}}$



Maximum pattern correlation between corresponding full and uncoupled modes



Frequency (days⁻¹)

Project tropical state vector \mathbf{x} into “coupled” and “internal” subspaces of full operator \mathbf{L}

Define

$$\mathbf{x} = \mathbf{x}^{\text{coup}} + \mathbf{x}^{\text{int}}$$

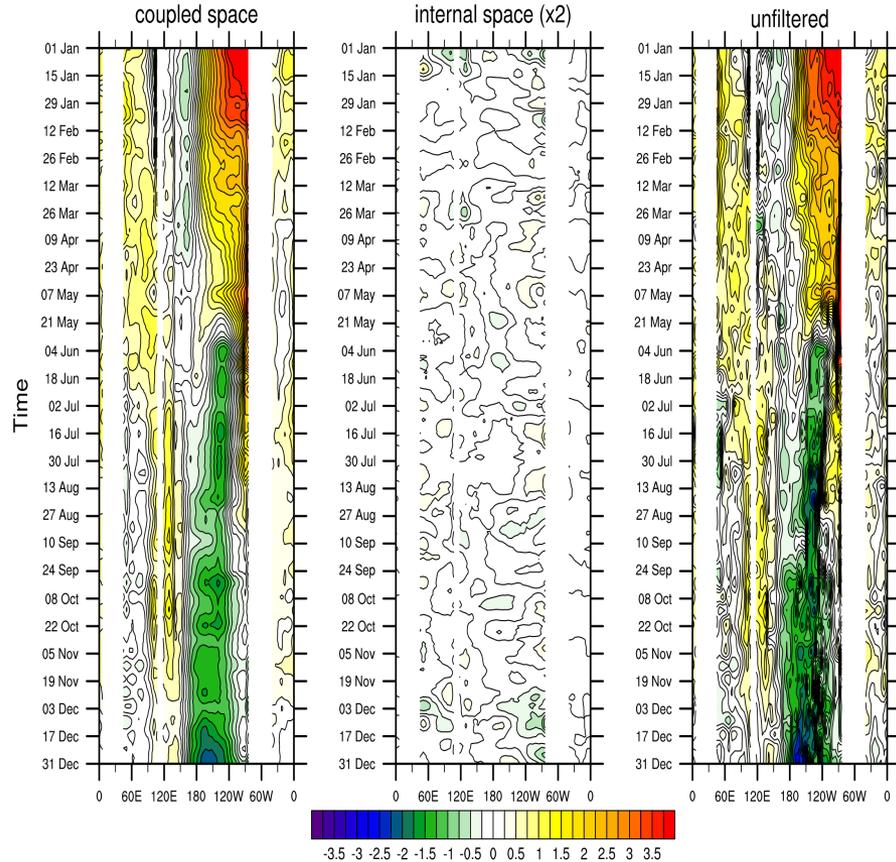
where

$$\mathbf{x}^{\text{coup}} = \sum_j \mathbf{u}_j^{\text{coup}} \alpha_j^{\text{coup}}(t) \quad \mathbf{x}^{\text{int}} = \sum_j \mathbf{u}_j^{\text{int}} \alpha_j^{\text{int}}(t)$$

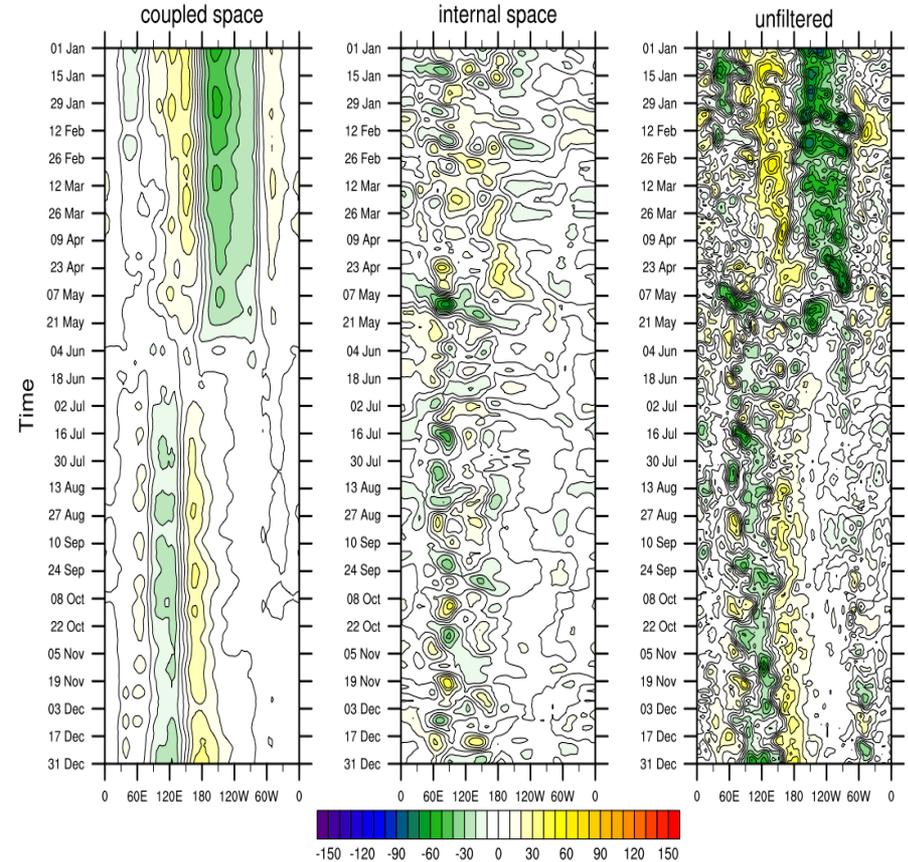
Note: \mathbf{x}^{coup} and \mathbf{x}^{int} need not be orthogonal

Using the LIM to “filter” the data

7-day running mean sst anomalies, lat=0, 1998



7-day running mean olr anomalies, lat=7.5S-7.5N, 1998

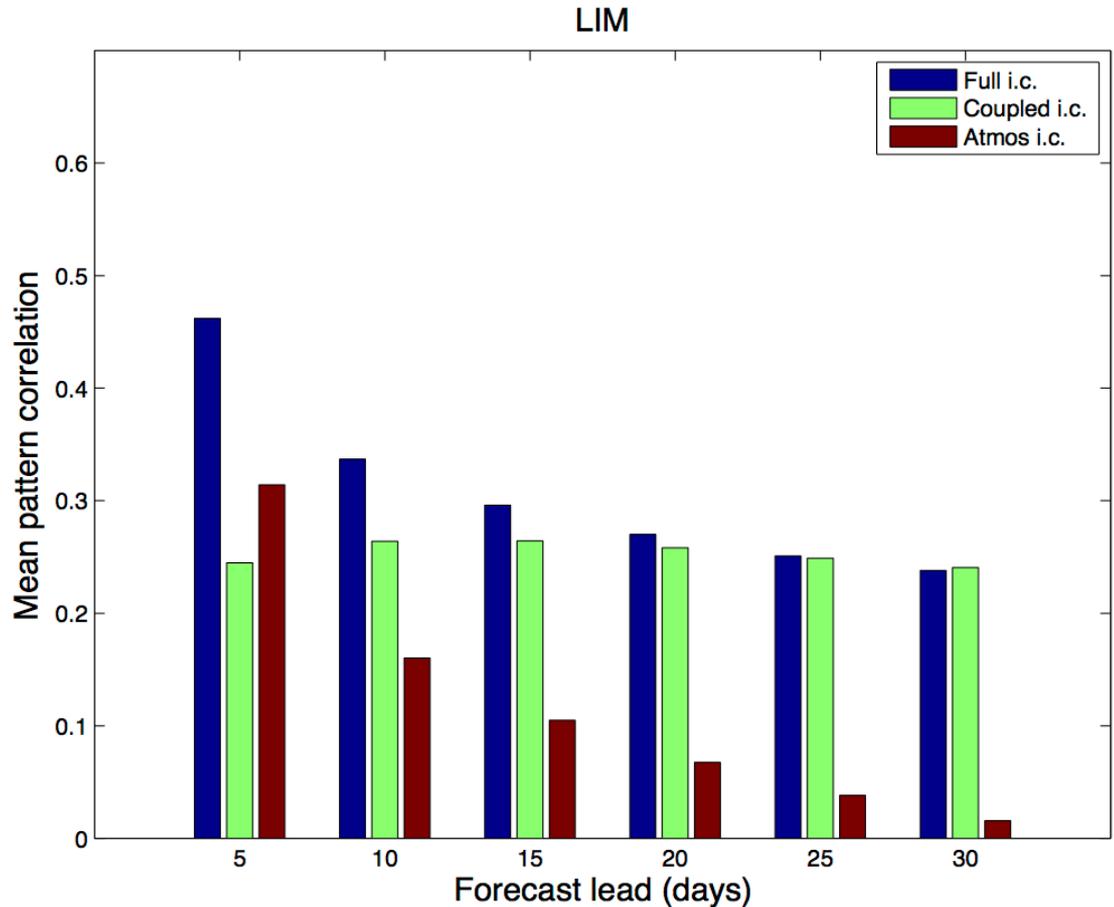


1. no temporal filter is applied
2. interannual variability defined dynamically

Most LIM skill due to coupled space initial conditions for leads > 15 days

Pattern correlation of tropical IndoPacific OLR LIM hindcasts, 1982-2009, where forecast initial conditions are either:

- Full**
- Coupled space only**
- Internal space only**



Conclusions

- LIMs useful for diagnosis of predictability, **because** its forecast skill is competitive with coupled GCMs and it reproduces observed spatio-temporal statistics
- In Tropics, two nonorthogonal linear dynamical systems:
 - Slow (~interannual) coupled space (more predictable)
 - Fast (~intraseasonal) internal atmosphere space (less predictable)
 - Projecting data onto coupled space acts as an effective “filter”; MJO indices may convolve dynamics
- Subseasonal forecasts skill may itself be *predicted* based on signal-to-noise
 - In LIM, there is no “spread/skill” relationship, but note this need not be a constraint for all linearly predictable systems
 - Plan to institute “forecasts of forecast skill” in LIM forecast web page <http://www.esrl.noaa.gov/psd/forecasts/clim/>

Near realtime tropical forecasts (“C-LIM”)

ESRL : PSD : C-LIM OLRA/SSTA Forecast

ESRL : PSD : C-LIM OLRA/SSTA ...



www.esrl.noaa.gov/psd/forecasts/clim/

Google



Bookmarks

Forecasts of Tropical Convection, Wind, and SST Pentads using a Coupled Linear Inverse Model (C-LIM)

(Experimental NOAA/ESRL PSD and CIRES/CDC Forecast)

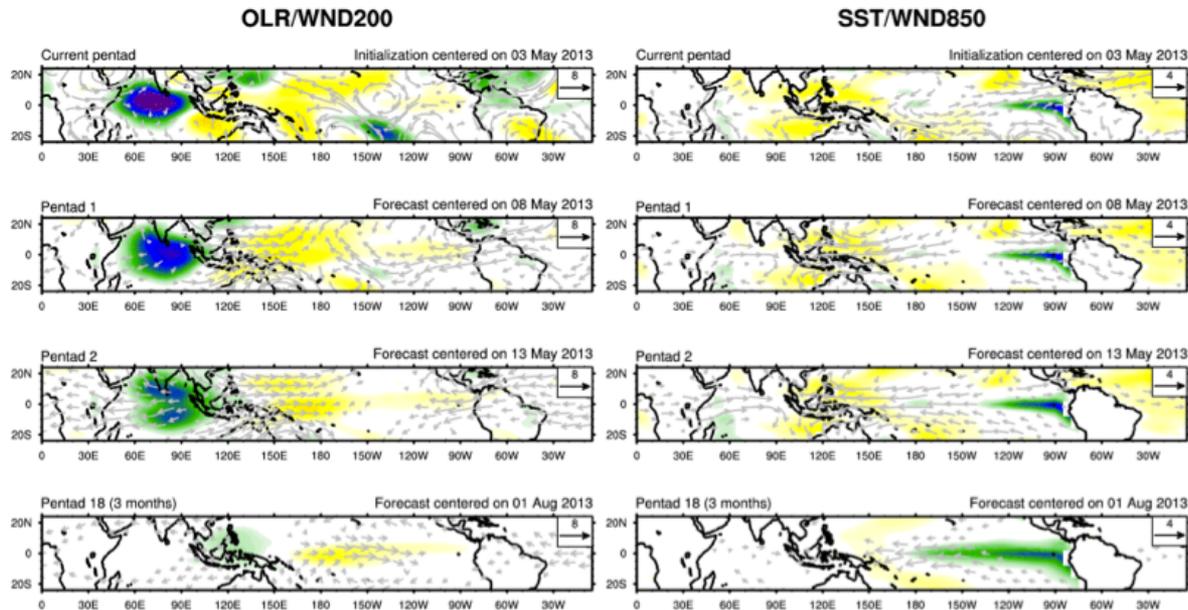
New! C-LIM VERSION 2.0: Now with 1) 200 and 850 mb winds (including vertical shear), 2) 5-day running means, 3) finer (2 degree) latitude resolution.

Forecasts and verifications:

- Pentads 1-6
- Pentads 12, 18, 24, 30, 36, 42
- Separation of tropical anomalies into coupled and uncoupled fields, 1982-present
- How we make these Tropical forecasts

Experimental forecasts of three key tropical fields, outgoing longwave radiation (OLR), 200 and 850 mb winds, and sea surface temperature (SST); other variables may become available at a later date. Anomalies are averaged with a 5-day running mean and are relative to a 1982-2009 daily climatology (smoothed with a 31-day running mean). Forecast verification time is the central day of the forecast period.

Current initialization and a few selected forecast anomalies of OLR (W/m^2), winds (m/s), and SST ($^{\circ}C$):



PSD Climate monitoring and Forecasting Products

C-LIM Pentad Forecasts

- Pentads 1-6
- Pentads 12,18,24,30,36,42
- C-LIM filtered anomalies

LIM Seasonal SST Forecasts

Tropical

Contact

Matt Newman

Related Information

- How to Reference Forecast PSD MJO monitoring page

PSD Branches

- Climate Analysis
- Water Cycle
- Weather & Climate Physics