Diagnosing ENSO predictability from observations and models Matt Newman

CIRES, University of Colorado and NOAA/ESRL/PSD

		1 0 ≡	esrl.noaa.gov	Ċ	₫ ₽ 0
ipod 🗸 Nev	vs v blogs v CDC v Apple v food v	wx v Entertainment v Summer 201	15 v Fantasy Baseball kids v OneDrive	Houses MLB.tv ipod V Read Later My BCH	page The Fermi PWait But Why >>
Political Animal	Amazon.com: A journals.amets.	Western Acade	Jobvite www.meteo.ps	ocw.umb.edu/e BAMS Authors E	SRL: PSD: C screen capture +
U.S. Department of Comm	erce I National Oceanic & Atmospheric Administration I NOAA Re	search			
Earth System Research Laboratory Physical Sciences Division Calendar / People I Publications Calendar / People I Publications					
Projects Sciences Unsion About Contact Research Data Products News Outreach PSD Climate Monitoring Forecasts of Tropical Convection, Wind, and SST Pentads using a Coupled Linear Inverse Model (C-LIM)					
C LIM Ponted Ecrosofte	(Experimental NOAA/ESRL PSD and CIRES/U. of Colorado	Forecast)			
C-Lim Pentad Porecasts					
Pentads 1-8 Pentads 12-60	New forecasts running and updated daily, but archives of past forecasts/verifications before 2014 are not installed vet.				
C-LIM filtered					
anomalies	Pertads 1-8				
LIM Seasonal SST	Pentads 12, 18, 24, 30, 36, 42, 48, 54, 60				
Forecasis	Separation of tropical anomalies into coupled and uncoupled fields, 1982-present How we make these Tropical forecasts				
Tropical	Experimental forecasts of four key tropical fields, outgoing longwave radiation (OLR), 200 and 850 mb winds, and thermocline depth 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 1982-2011 daily				
Contact	climatology (smoothed with a 31-day running mean). Forecast verification time is the central day of the forecast period.				
Matt Newman	Current initialization and a few selected forecast anomalies of OLR (W/m ²), winds (m/s), 20 C isotherm depth (m, blue=positive), and SST (^O C):				
Related Information	OLR/WND200	SST/Z20/WND850			
How to Reference Forecast PSD MJO monitoring	Current pentad initialization: 02-06 Feb 2015	Current pentad initialization: 02-06 Feb 2015			
PSD Branches Climate Analysis	Pentad 2 forecast: 12-15 Feb 2015 Projected of raul = 0.41	Pentad 2 forecast: 12-16 Feb 2015 Projected set skill = 0.79			
Water Cycle Weather & Climate Physics	Pentad 4 forecast: 22-26 Feb 2015 Projected or skill = 0.29	Pantad 4 forecast: 22-26 Feb 2015 Projected sat skill = 0.73			
	Pentad 6 forecast: 04-08 Mar 2015 Projected or skill = 0.27	Pentad 6 forecast: 04-08 Mar 2015 Projected sat skill = 0.68			
	Pentad 18 forecast: 03-07 May 2015 Projected or skill = 0.20	Prentad 18 forecast: 03-07 May 2015 Projected sai skill = 0.50			
	Pentad 42 forecast 31 Aug - 04 Sep 2015	Pentad 42 forecast: 31 Aug - 04 Sep 2015 Projected set skill = 0.29 CONTOUR FROM: 31 TO 79 EVS			
-2.16 -1.44 -0.72 0 0.72 1.44 2.16 NOAA/ESRL/PSD & CRESU. of Colorado Experimental C-LIM Forecast					

"Multivariate Red Noise*" null hypothesis

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

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

- Determine L and F_s using "Linear Inverse Model" (LIM)
 - x is ocean (SST/Z20) and atmosphere (OLR/200&850 mb wind) 5-day running mean anomalies in Tropics, 1982-2011 (similar to Newman, Sardeshmukh, Penland 2009 and Newman, Alexander, Scott 2011)
 - prefiltered in reduced EOF space
 - LIM determined from specified lag τ_0 =5 days (e.g., the data averaging interval) as in AR1 model, using τ_0 and zero-lag covariance of **x**
 - Test the LIM over much longer time intervals: observed spatio-temporal lag-covariance statistics very well reproduced
 - Hindcasts determined from cross-validation (10% data withheld to recompute L)

*Multivariate Ornstein-Uhlenbeck process

Using LIM to estimate predictability

 $dx/dt = Lx + F_s$



Expected forecast anomaly correlation



Larger signal related to leading singular vector of $G(\tau)$ Assumption (overly restrictive?): $E(\tau)$ depends *only* on τ

"Optimal" structure leading to greatest tropical SST anomaly growth over 180 days

Shading: SST Contours: Z₂₀ Vectors: 200 mb winds



Compare LIM to (some of the) National Multi-model Ensemble (NMME) Hindcasts, 1982-2010

LIM hindcasts averaged into 35-day "months" so "Month 6" skill is days 146-180

NMME hindcast ensemble monthly means from

- NCEP CFSv2
- NASA GEOS5
- NCAR CCSM3
- GFDL CM2.1/2.5
- CMC1-CanCM3/4
- ECHAM 4.5

"Month 0.5" skill is first month, initialized in mid-month (see Kirtman et al. 2014)

Comparing predicted and actual forecast skill, or: some places are more predictable than others



Comparing predicted and actual forecast skill, or: some years are more predictable than others

Skill averaged by year (based on initialization date)

Actual skill: Pattern correlation of tropical SST anomaly with SST forecast anomaly

Blue: LIM (0.40) Red: NMME (0.45) Predicted: ρ_{∞} (0.43)



NMME and LIM skill correlated with ρ_{∞} at 0.8

A few other points

- LIM useful for diagnosis of predictability, because its forecast skill is comparable with coupled GCMs and it reproduces observed spatio-temporal statistics
- Subseasonal-interannual forecast skill may itself be predicted based on LIM signal-to-noise
 - In LIM, there is no "spread/skill" relationship, but note this need not be a constraint for all linearly predictable systems
- Year-to-year variations in forecast skill in the last few decades may be due to random variations in initial conditions and not necessarily to long-term "base state" changes

But...

what if there is a base state change?

To answer,

travel to other M-class planets

LIM based on one-season lag (now using **SST, Z20**, **zonal wind stress**) reproduces observed spectra; use for significance testing (blue: significantly different)



LIM based on one-season lag reproduces observed spectra and can be used for significance testing *CMIP5: Nino4 significantly too strong compared to Nino3*

Ratio of Nino4/Nino3 highpass (<10yr)



Control

Historical

CMIP5 model index

LIM based on 1-season lag reproduces evolution statistics at much longer leads.



How nonlinear is PC1/2 in the models compared to observations?





How nonlinear is ENSO in models compared to obs? *CMIP5: nonlinearity in PC1/PC2 plane depends on ENSO strength*

Measure of "nonlinearity":

std error of cubic fit std error of linear fit

OBS CCSM4 CESM1-CAM5



PC1 amplitude

Evolution of 6-month optimal structure



Thermocline term *strengthens* ENSO in east but slightly damps in central Pacific

Evolution of 6-month optimal structure



Conclusion 2

- Coupled GCMs may not represent observed dynamics sufficiently well enough to study ENSO diversity if they have:
 - Strong and unrealistic Nino4 variability within "east Pacific" ENSO events that swamps more purely "central Pacific" ENSO variability
 - Too strong "nonlinear" relationship in PC1/2 plane
 - Optimal structure for central Pacific ENSO in west Pacific
 - Thermocline term acting *damps too much* in central Pacific and drives *growth too little* in east Pacific

Compare LIMs constructed from:

- CCSM4, 1100 yr run under radiative conditions from
 - 1850 (B1850)
 - 2000 (B2000)
- CESM1-CAM5, 700 yr run under radiative conditions from
 - 1850 (B1850)
 - 2000 (B2000)

For all four cases, construct LIM from each half of record, use to make "forecasts" for the other half.

Variables are monthly anomalies of SST, Z20, and zonal wind stress.

Tropical SST variance



-5 -4.5 -4 -3.5 -3 -2.5 -2 -1.5 -1 -0.5 0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5

Test LIM: Tropical SST lag covariance

OBS

LIM - OBS



-1.8 -1.5 -1.2 -0.9 -0.6 -0.3 0 0.3 0.6 0.9 1.2 1.5 1.8

CCSM4 B1850

Test LIM: Tropical SST lag covariance

OBS

LIM - OBS



CESM1-CAM5 B1850

Comparing predicted and actual forecast skill, or: some places are more predictable than others

Predicted Month 6 LIM skill

Actual Month 6 LIM skill



Comparing predicted and actual CCSM4 forecast skill

Skill averaged by **decade** (based on initialization date)

Actual skill: Pattern correlation of tropical SST anomaly with SST forecast anomaly

Blue: LIM (0.49/0.47)

Predicted: ρ_{∞} (0.53/0.52)





LIM skill correlated with ho_{∞} at 0.9

Comparing predicted and actual forecast skill, or: some years are more predictable than others

Skill averaged by decade (based on initialization date)

Actual skill: Pattern correlation of tropical SST anomaly with SST forecast anomaly

Blue: LIM (0.51/0.57) Predicted: ρ_{∞} (0.55/0.62)





LIM skill correlated with ho_{∞} at 0.9

Conclusions

- LIM useful for diagnosis of predictability, because its forecast skill is comparable with coupled GCMs and it reproduces observed spatio-temporal statistics
- To use coupled CGMs to investigate changes in ENSO and its predictability we first need to gauge how well do they reproduce observed ENSO dynamics
- Year-to-year variations in forecast skill in the last few decades may be due to random variations in initial conditions and not necessarily to long-term "base state" changes
- Even if "base state" changes drive variations in forecast skill, these may be swamped by random variations in initial conditions