ENSO and tropical Pacific metrics for coupled GCMs

By the ENSO metrics work group of the CLIVAR Pacific Panel

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1. Scope, goals and audience

The latest multi-model approach, derived from the IPCC AR4, allows, to an unprecedented scale, latest generation coupled GCMs to be analyzed together and compared. Associated analysis shows that El Niño is now an emergent mode of variability in complex models. However, the diversity of their simulations of El Niño contributes to a large uncertainty in projections of future tropical climate and the associated teleconnections and impacts. Part of this uncertainty is due to the model shortcomings and part is due to the "metric" used to evaluate ENSO in the models. We here propose to devise standard metrics to both help modellers make progress and provide model end users with community agreed evaluation of the main processes important for ENSO.

In the present document, we do not intend to summarize the numerous scientific issues that need to be addressed to make progress (these can be found elsewhere, e.g. Guilyardi et al. BAMS 2008) but rather present what tangible "products" can be organised at the community level to *facilitate* such undertakings: the real benefit will come not from these "products" per se, but from the new knowledge, understanding, and model improvements that the intercomparisons and human interactions would hopefully generate.

Multi-model analysis require common diagnostics to be analysed together. Moreover, the definition of some basic "metrics" to assess a phenomenon can have great value to the wider community engaged in model development and/or analysis. The notion of metrics is now discussed at PCMDI (Gleckler et al. 2008) in preparation of the future Coupled Model Intercomparison Projects (CMIP).

In devising such metrics, several goals are pursued:

- **Document** the performance of ENSO and tropical Pacific simulation in CMIP coupled models.
- Help **better understanding** of processes in models and identify new mechanisms
- Establish **guidance** for multi-model ensembles means (rejection of inadequate models, weighting, etc.)

Audience:

- Model developers
- Non ENSO specialists, producers/users of climate change projections

2. Devising metrics

2.1 Guidelines

Definition. A *metric* is defined as a single scalar which measures the model performance, i.e. some "distance" of the model result to the reference observation/reanalysis. Any other analysis is referred to as a *diagnostic*.

A ***prioritization*** will be needed (both for metrics and diagnostics) as computing too many metrics can be both time consuming and confusing to end users. Hence, a first target is to identify the "magic" 5 to 7 ENSO metrics that are essential among the many identified below.

It is also key to document the ***background systematic errors*** in the tropical Pacific (mean annual cycle and mean state). Indeed, ENSO is defined as an anomaly to these and ENSO errors can often be traced back to these systematic errors.

We propose to divide the metrics and diagnostics in several categories, listed below. For each metric / diagnostic, a description, a reference observation / reanalysis and a published reference study are needed. The "maturity" measures how well the community understands, defines and measures the metric/diagnostic *both* for models and observations/reanalysis (level 2 of maturity may also be discussed in section 2.3 "unresolved issues").

2.2 Proposed ENSO metrics

A1) Base metrics, ocean subsurface

Metric	Description	Ref. obs	Ref. study	Maturity
Warm water volume	Tbd	TAO, Topex	Meinen & McPhaden	1
Thermocline sharpness	Tbd			2
ENSO energetics	Tbd, complex		Fedorov et al.	2
Vertical current shear	Tbd			2

Variables required for A1: ocean surface currents, HTC300, D20, sea level, T, S (3d), 50+ years monthly time series, detrended data (3D currents additionally required by energetics)

A2) Base metrics, surface

Metric	Description	Ref. obs	Ref. study	Maturity
Niño 3 SST std dev.		HadiSST1.1		1
Niño N SST std dev.		HadiSST1.1		1
Niño N SST skewness		HadiSST1.1		1
Seasonal phase lock	Std dev of 12 Niño 3	HadiSST1.1		1

	SSTA std dev or season of max std dev and range of std dev			
Trans-Niño index		HadISST (1950-1999)	Trenberth & Stepaniak 2001	1
ENSO period	Tbd, either Niño 3 SSTA spectra, variance weighted freq., number of events in N years – requires precise protocol	HadISST		2
Meridional width of SST std dev	Tbd	HadISST (1950-1999)	Capotondi 2007	2
Meridional width of Taux std dev	Tbd, Niño 4 longitudes, half width ? fit to Gaussian ?		Capotondi 2007	2
SST propagation direction	East-west SST time lag	HadISST (1950-1999)		2
Seasonal cycle relative strength	Ratio of spectral energy =< 1 year	HadISST	Guilyardi 2006	2
Niño 4 Taux std dev		ERA40/NCEP		1

Boxes (N): Niño 3.4, Niño 4, Niño 1+2

Additional variables required for A2: SST, Taux, 50+ years monthly time series, detrended data

A3) Base metrics, atmosphere

Metric	Description	Ref. obs	Ref. study	Maturity
SOI	Traditional D-T diff in mslp or other (see 2.3)			1
ISO variability	See 2.3			2
Longitude of max precip. std dev at eq.			Neelin et al.	2
Std dev precip Niño 4				2

Additional variables required for A3: mslp, OLR, precip, 50+ years monthly time series, detrended data

B) Background systematic errors

Metric	Description	Ref. obs	Ref. study	Maturity
Cold tongue	Extent: longitude of	HadISST		1-2

	max negative SST gradient on equator Amplitude: min SST during annual cycle at equator (or rms error?)	(1950-1999)		
Annual cycle in east Pac.	Monthly rms error of SST in east Pacific (nino3)	HadISST (1950-1999)		1
Trade winds strength	Monthly rms error of taux in equatorial pac	ERA40 (1950-1999) ERSTAO (1992-1998) Other ?		1
Niño boxes SST	Mean + annual cycle rms	HadISST (1950-1999)		1
Eastern edge of Warm Pool				2
TIW variance and heat transport				2
Tilt of thermocline				2
Double ITCZ	- rms error of precipitation in SE trop pac - norm(precip 5N-15N) minus norm(precip 5S-15S) in eastern trop. Pacific - precip in south 160W-120W 5S-15S	CMAP (1979-2005)	Lin JC 2007	2
Edge of convection along equator	related to cold tongue pb / AMIP diag 4mm/day threshold	CMAP (1979-2005)		2

C) Feedbacks

Metric	**Description**	**Ref. obs**	**Ref. study**	**Maturity**
Bjerknes, coupling strength (mu)	Slope of Taux_nino4= F(SST_nino3) or of zonal_Taux =F(SST_nino3)	HadISST vs. ERA40	Jin et al. 2006 Guilyardi 2006	1
Total/SW/LH Heat flux feedback in Niño 3 and Niño 4	Slope of HF_nino3/4=F(SST_nino3/4)			2
BJ Index	Complex !		Jin et al. 2006	2

D) Teleconnections

Metric	Description	Ref. obs	Ref. study	Maturity
TNI lag correlation with all India rainfall (AIR)	Tbd			2
PNA index	Tbd			2
Atlantic/South America precip	Tbd ("Rank regression" à la David N.)			2
Other region rank regression	Tbd, Indonesia, Indian ocean, horse shoe pattern			2

E) Other metrics discussed

- Slope of SO vs. nino3 SSTA
- cross-metric correlation
- Oscillator type (recharged with zonal HTC lag with niño3 SSTA)
- Moving correlation of summer monsoon strength and summer niño3
- Transport indices (boundary and interior transports)
- SST equation terms (fit CGCM to simpler models refs.)
- precipitation centre location
- regression between longer term of interdecadal corr between SC and ENSO amplitude

2.3 Unresolved issues

ENSO understanding is still a very active field of research and many metrics/diagnostics proposed above still require careful evaluation before their can be recommended to non ENSO specialists.

Issues:

- Computation of "distance" between model and observations/reanalysis: rms, diff/ratio of averaged values,… ?

- Issue of obs/reanalysis data quality and period of comparison: reanalysis post 1980 better suited

- Subsurface proxy: D20, HTC300, sea level ?

- ISO variability:
  - MJO related
    - description of metric with MJO WG (see Chidong's table)
    - lag-corr WWB/nino3.4 SSTA (max lag)
  - 10-90 days Taux in Warm Pool region
  - Eastward propagation of coupled instability

- SOI definition (table A3):
  - Traditional D-T mslp diff
  - Others ?
    - Same boxes/region for GCMs
      - no because difficult to compare with obs
      - or make two metrics
    - equatorial SOI ?
    - each time series stats independently ?
    - East -West vp200 diff ?

- Others…

2.4 ENSO diagnostics

The following diagnostics were discussed but more work is required to define/prioritise them:

- xt hovmoellers at equator
- yt hovmoeller in East/Central/West Pacific
- Standard deviation maps
- Skewness maps
- Teleconnections (regression/correlation maps)
- Width autocorrelation of nino3 SSTA, decay scale
- Composites (definition of El Niño and La Niña ?)
- Moisture transport Atlantic-Pacific in atmosphere
- Spectra/wavelets nino3 SSTA

2.5 Reference data

Products needed:

Ocean:

- Re-analysis
  - ORA-S3 (http://ensembles.ecmwf.int/thredds/ocean/catalog.html)
  - SODA
  - ECCO
  - NCEP
  - Ishi
  - Forced references
  - Others (http://apdrc.soest.hawaii.edu/w_data/ocean3.htm)
- HTC300
- Velocity
  - TAO
  - OSCAR
  - ARGO
- Temperature
  - TAO

    - XBTs
    - ARGO

Surface:

- SST
    - HadISST
    - Reynolds OI
    - ERSST
    - Kaplan
    - TRMM
- Taux
    - ERSTAO
    - Quickscat
    - ERA40
    - NCEP
- Precip
    - GPCP
    - CMAP
- Heat Fluxes
    - ERA40
    - NCEP
    - SOC
    - HOAPS
    - OAFlux
    - ISCCP

Atmosphere:

- ERA40
- NCEP
- NOAA OLR
- A-train
- …

Comparison with observations/reanalysis: the pre 1980 and post 1980 may need to be distinguished for some metrics, especially those involving sub-surface ocean reanalysis.

Pathways to recommended observational datasets should be provided in an easy-to-use gridded format (DODS/OPeNDAP or NetCDF). Most of these could simply be links to the original data providers on the web; others might have to be processed and provided via a web site to make them more convenient. For all of these data, the documentation and/or scripts would be provided (or linked to) to show how they were obtained.

3. Practical considerations

Time line:

- Ready for CMIP5 analysis (2010)
- First draft of white paper Dec 08
- Circulate, get comments until mid 09
- Build web site and apply to obs and few models until end 2009

List of points tbd:

- Who hosts the reference data ? original centre if right format, otherwise tbd (BADC, ESG, PCMDI,…)

- Ensure variables/freq. are part of CMIP requirements.

- Web site;

    - Key audience ?
    - What is the "carrot"?
    - How will the metrics/scripts be provided & intercompared?
    - How to leverage from existing sites?
- Technical issues
    - Lay out
    - who writes html ?
        - APDRC
        - ES-ENES
        - other
    - who hosts the site ?
    - who maintains it and for how long ?

- Others…

Appendices

A. ENSO metrics work group:

Magdalena Balmesada (WGSIP), ECMWF
Helene Banks (WGOMD), UK MetOffice
Wenju Cai (Teleconnections), CSIRO
Amy Clement, RSMAS
Fei-Fei Jin, UH
Eric Guilyardi (WG coord.), IPSL/LOCEAN & NCAS Climate
Matthieu Lengaigne, IPSL/LOCEAN
Mike McPhaden, PMEL
David Neelin, UCLA
Scott Power, CSIRO
Ken Sperber (MJO), PCMDI
Axel Timmermann, IPRC, UH
Andrew Wittenberg, GFDL

Other potential contributors: Krishna AchutaRao, Christophe Maes

B. Related material:

- Freemind map: freemind format or clickable web page [to do]

- MJO US CLIVAR workgroup: http://www.usclivar.org/Organization/MJO_WG.html
- MJO metrics : http://climate.snu.ac.kr/mjo_metrics/index.htm
- Proposal for global monsoon metrics:
  - Wang and Ding, 2008: Global monsoon: Dominant mode of annual variation in the tropics. *Dyn. Atmos. Oceans,* **44**,165–183

C. References:

Gleckler P., K. E. Taylor and C. Dutriaux 2008: Performance metrics for climate models. J. *Geophys. Res.*, in press

Guilyardi E., A. Wittenberg, A. Fedorov, M. Collins, C. Wang, A. Capotondi, G.J. van Oldenborgh and T. Stockdale, 2008: Understanding El Niño in Ocean-Atmosphere General Circulation Models : progress and challenges. *Bull. Amer. Met. Soc*, in press