ENSO Metrics: Status & Next Steps

Presented by **Andrew Wittenberg**

with contributions from

Yann Planton, Jiwoo Lee, and the ENSO Metrics Team

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ENSO Metrics: Background

CLIVAR Research Focus: **ENSO in a Changing Climate**

http://www.clivar.org/research-foci/enso
2014-2018; then merged back into CLIVAR PRP
Co-chairs: E. Guilyardi (IPSL) & A. Wittenberg (NOAA GFDL)
Implementation & application: **Yann Planton** (IPSL/PMEL)
12 ENSO experts (France, US, Australia, Japan, Korea, UK)

Goals:

- Understand ENSO **processes** **&** **past/future changes**
- Develop **evaluation** protocol for ENSO in GCMs
- Target **obs** to improve models & projections

ENSO Performance: Andrew, Yann, Antonietta, Mike, Matt, Scott, …
Teleconnections: Scott, Yann, Shayne, Cai, …
Processes: Yann, Eric, Soon-Il, Fei-Fei, Tobias, …

Community package liaisons:

PMP: **Jiwoo Lee** & Peter Gleckler (PCMDI)
ESMValTool: Veronika Eyring (DLR); Bryan Lawrence (NCAS); Barcelona (BSC)
CliMAF: Jérôme Servonnat (IPSL)

ENSO metrics strategy

Start with a small subset of **essential, simple** metrics.

Avoid getting bogged down with complexity

Aim more at model *users* than model developers.

Expand as code, interfaces, use-cases take shape.

Metrics (scalars) are first step in a **diagnostic hierarchy**

Useful for intercomparing models & metrics

Dive-down diagnostics: Scalar → 1d → 2d → 3d

Want to see both “forest” and “trees”.

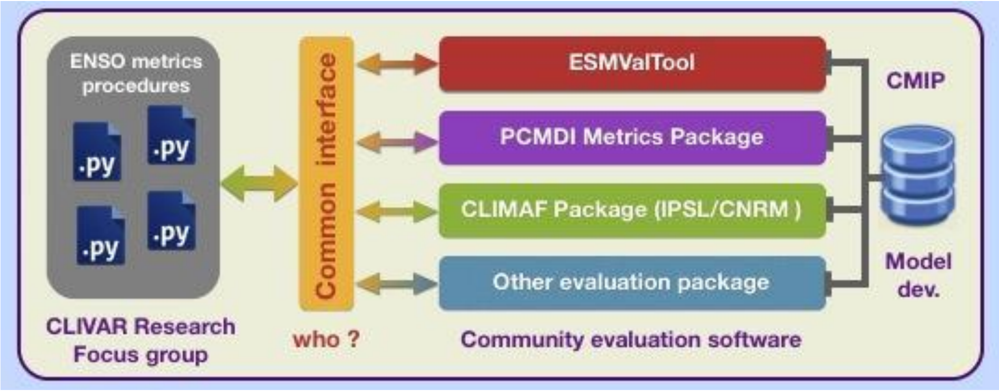
Account for:

- **Internal variability** (multiple historical ensemble members)
- **Obs uncertainties** (use multiple obs products, epochs)

Written in **Python**

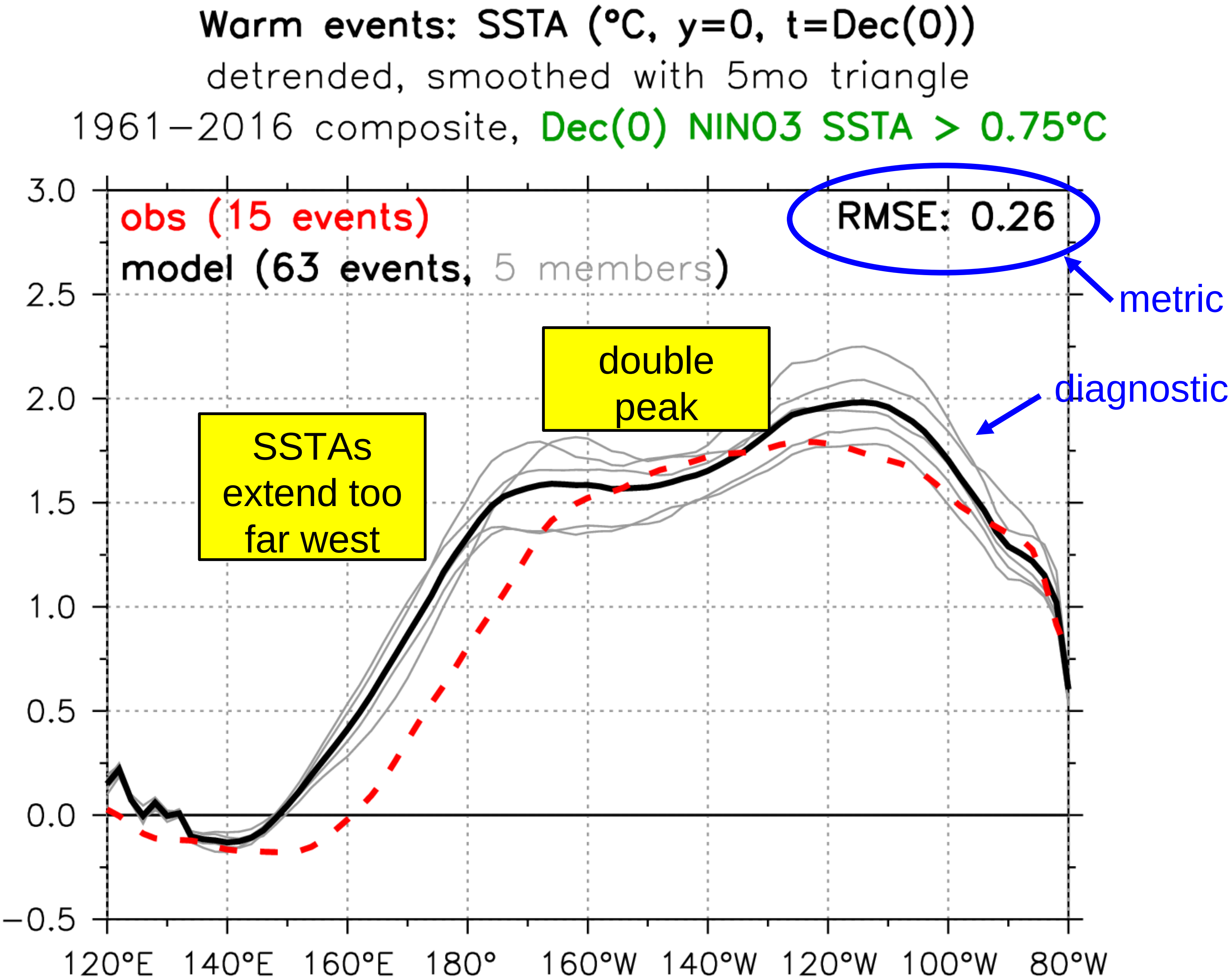
Powerful, flexible

Plugs into community efforts

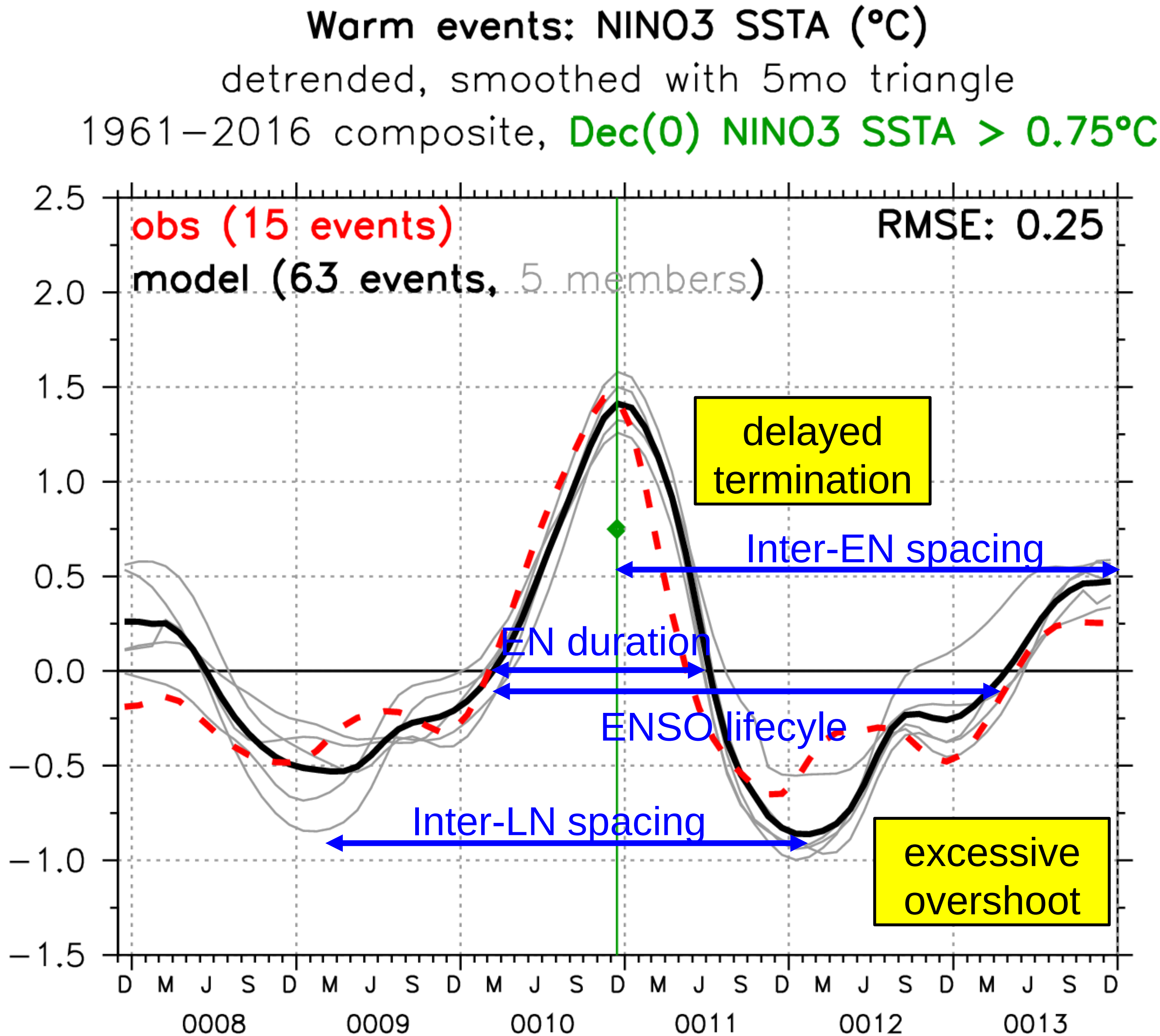


Metric Requirements

1. **Documentation:** Whys & hows of metric and collection
2. Math **definition** of metric (positive scalar "distance")
3. Input data **frequency** (monthly, daily, ...) and **grid** (1x1 lat/lon, region, etc.)
4. **Obs** (as many as possible) and **epoch** to use
5. Literature **reference** to show robustness/utility of metric
6. **Sample size** (duration or ensemble) needed for metric to make sense
7. Dive-down **diagnostics** (e.g. the spatial maps used to compute RMSE)
8. **Normalization** to use for multi-model intercomparison (single color bar)



Warm events: SSTA (°C, y=0, t=Dec(0))
detrended, smoothed with 5mo triangle
1961–2016 composite, Dec(0) NINO3 SSTA > 0.75°C
obs (15 events)
model (63 events, 5 members)
RMSE: 0.26
metric
diagnostic
double peak
SSTAs extend too far west
3.0
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
120°E
140°E
160°E
180°
160°W
140°W
120°W
100°W
80°W


Warm events: NINO3 SSTA (°C)
detrended, smoothed with 5mo triangle
1961–2016 composite, Dec(0) NINO3 SSTA > 0.75°C
obs (15 events)
model (63 events, 5 members)
RMSE: 0.25
delayed termination
Inter-EN spacing
EN duration
ENSO lifecyle
Inter-LN spacing
excessive overshoot
2.5
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
D M J S D M J S D M J S D M J S D M J S D M J S D
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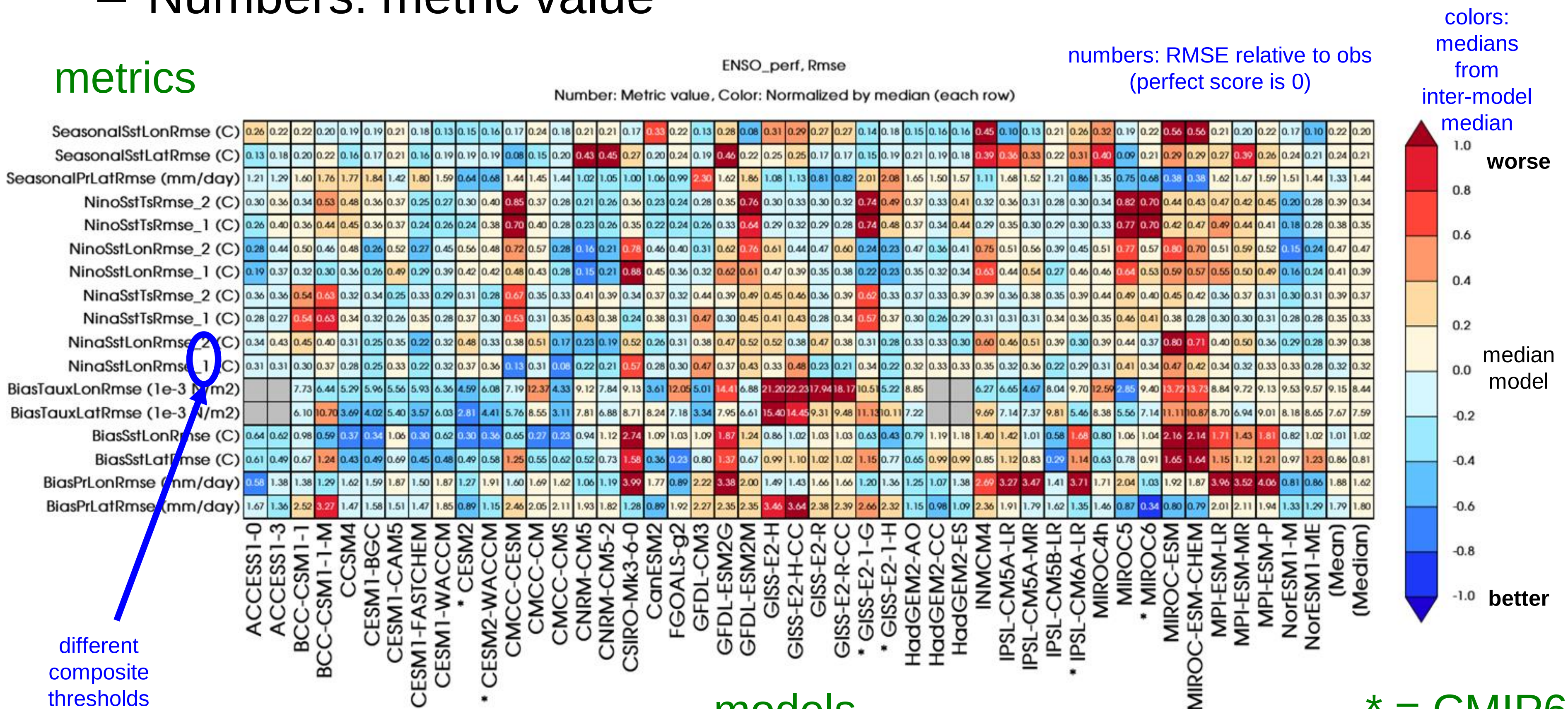
ENSO performance

RMSE-based metrics

– Colors: *relative* to median value of metric (last column)

– Numbers: metric value



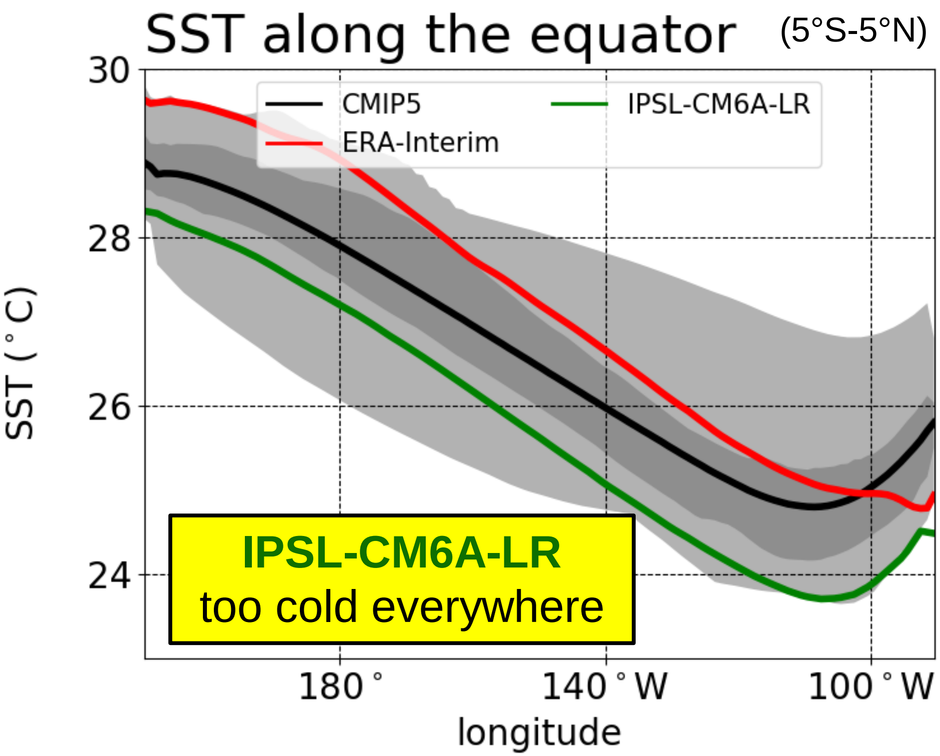
Dive-down diagnostics:
Annual-mean SST

Metric:

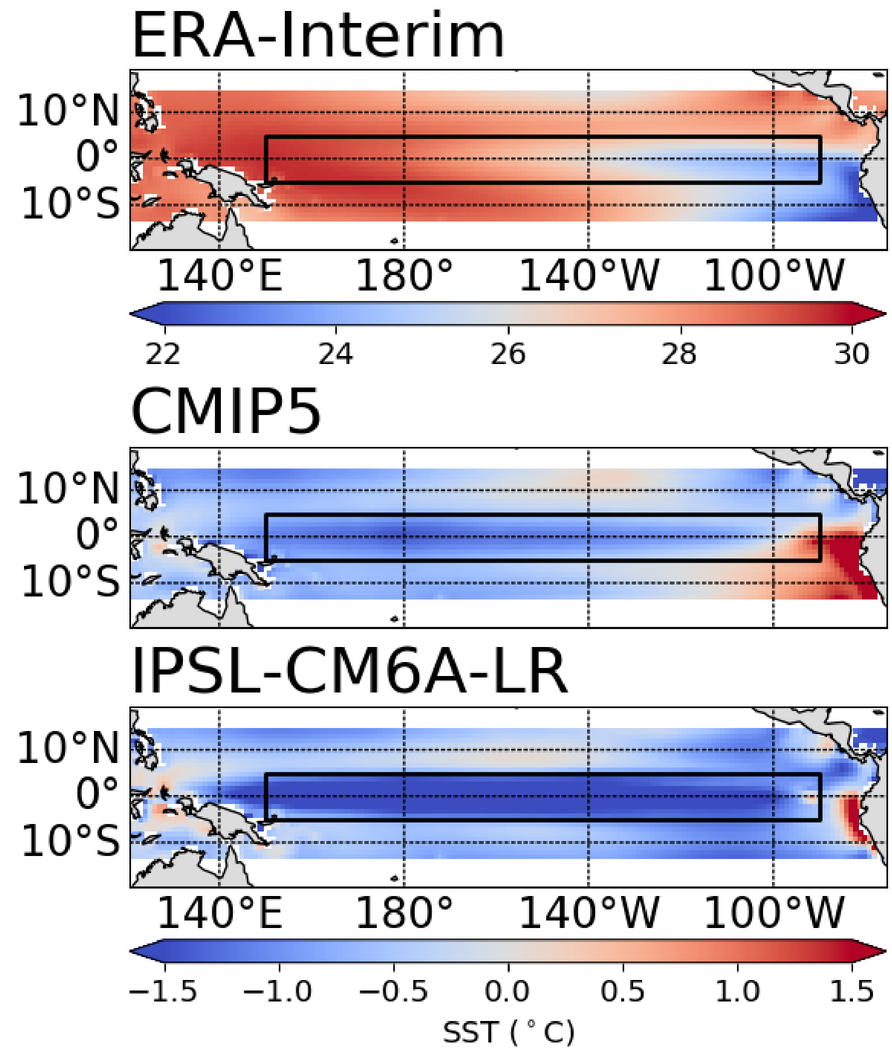
RMSE(obs, model)

IPSL-CM6A-LR = 1.6°C

Dive-down level 1:



Dive-down level 2:



ENSO Metrics:
Public Release
& Documentation

[Planton et al. (BAMS 2021)](#)

"Evaluating climate models with the CLIVAR 2020 ENSO metrics package."

- Documents & demonstrates the package
- **CMIP6 models mostly outperform CMIP5**, *except* for some process metrics (e.g., the h → SST coupling worsened)

CMIP5/6 ENSO Metrics summary

https://pcmdi.llnl.gov/research/metrics/enso

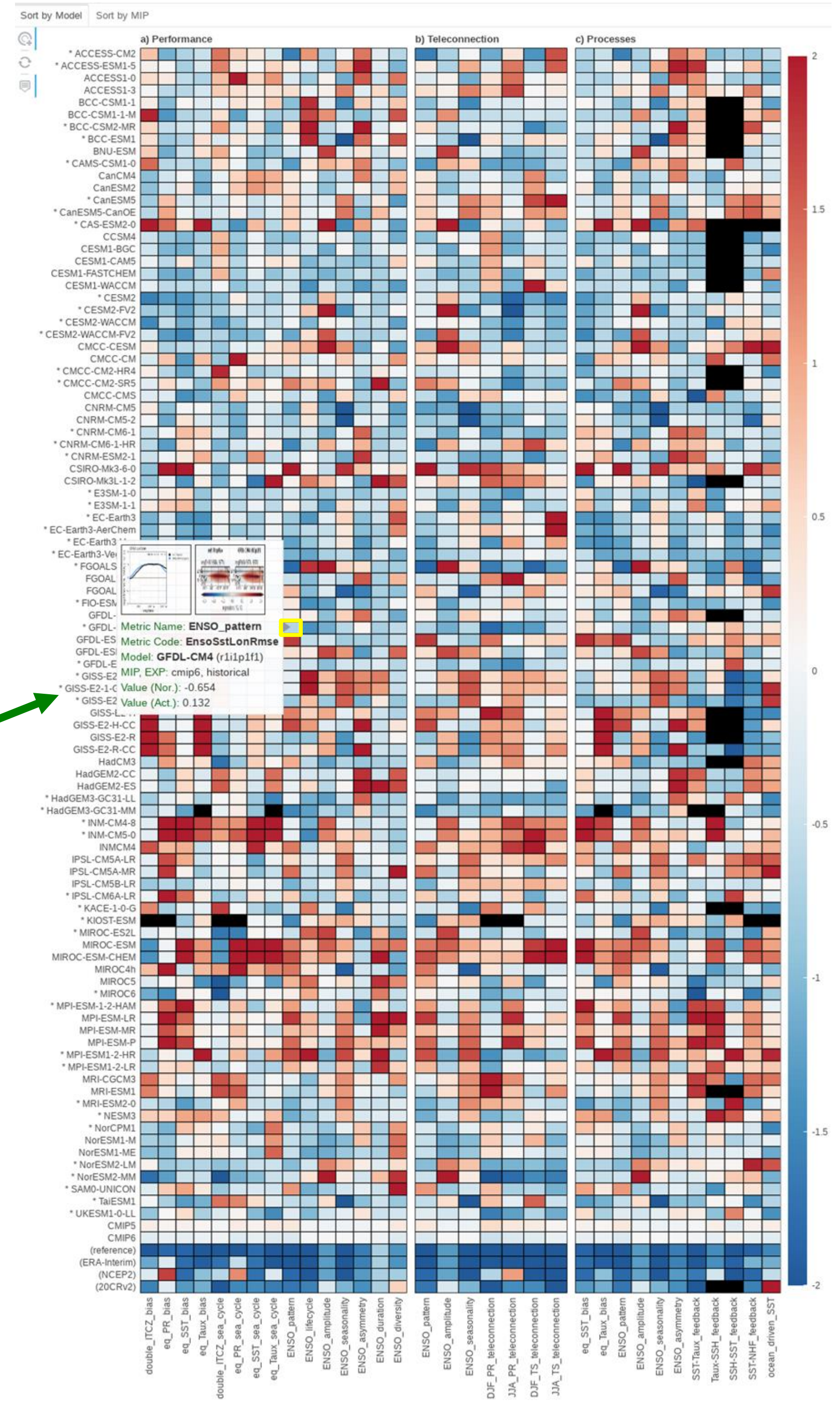
- **Interactive** dive-down diagnostics
- Pre-computed model metrics for download (JSON & Excel)

Wiki:

https://github.com/CLIVAR-PRP/ENSO_metrics/wiki

Software:

https://github.com/CLIVAR-PRP/ENSO_metrics



Recent studies using the ENSO Metrics Package

Lee et al. (GRL 2021): *"Robust evaluation of ENSO in climate models: How many **ensemble members** are needed?"*

- For **CMIP5/6 & LEs**, need $N \geq 50$ to constrain ENSO baseline & process metrics
- Less for climatology ($N \geq 6$) & ENSO teleconnections ($N \geq 12$)

  for 95% of N-ensemble means (of 1979-2018 metrics) to fall within 10% of actual mean metric

Xu et al. (JC 2022): "The Andes affect ENSO statistics"

- Elevate the Andes to more realistic levels in CESM_1.2.2
  - → better (more LN-like) troPac climate
  - → weaker ENSO; more asymmetric, irregular, evaporatively-damped

Planton et al. (in prep for JAMES): *"Detecting ENSO variance changes in a **warmer world**."*

- **CMIP6** historical runs: Sample size to detect past & future ENSO amplitude changes?

  Need 5 – 9 members, for ensemble-mean 30yr variance to fall within 15% of actual long-term variance
- If ENSO strengthens → more decadal modulation → later detection
- Quiet/hyperactive ENSO decades can aid earlier detection

Lee et al. (in prep for GMD): *"Diversifying objective summaries of Earth system model performance: An overview of the **PCMDI Metrics Package (PMP)**."*

- A section is devoted to the **ENSO metrics**

Community Connections

CLIVAR/ICTP **ENSO Summer School**

Yann Planton developed & ran student tutorials, applying package to CMIP6
→ supported the *WCRP Academy* Lighthouse Activity (LHA)

Jiwoo Lee joined the **CMIP7** Climate Model Benchmarking Task Team
→ Actively promoting the CLIVAR ENSO Metrics via the PMP framework

Connections with other community efforts

PMP, ESMValTool, CliMAF, MDTF
ES-Doc & Comparator: model resolution, lineage, parameterization schemes

Tropical Pacific Observing System (**TPOS**)

Obs targeting + new reference data

Next Steps for ENSO Metrics

Leverage recent enhancements

- Added more **obs datasets** to test robustness (Planton et al., in prep)
- **Index statistics**: mean, stddev, skewness, d.o.f. → significance
- **Wait times** between ENSO events: mean, stddev, skewness, PDFs, transition probabilities

New metrics in development

- ENSO regional **teleconnections**: regressions, composites (per McGregor et al. 2022)
- New ENSO **process metrics** (per Chen et al. JC 2021)
  BWJ indices, ML heat budget, nonlinear dynamical heating (NDH)
- Model-analogs as metrics of ENSO **evolution, predictability, forecast skill**
  Applied to NMME & CMIP5 historical: Ding et al. (JC 2018; GRL 2020)
  Applied to CMIP6 & LE, historical & future: Lou et al. (subm. & in prep.)
  + ongoing work at NOAA PSL & GFDL
- CLIVAR PRP Working Group on **Conceptual Models of ENSO**

New & proposed projects:

- Impact of **climate change** on ENSO (Planton, Lee, et al., in prep)
- EqPac **upwelling & mixing** in CGCMs (Wittenberg et al., NOAA CVP), funded 2023-25
- Dynamical ENSO metrics & **emergent constraints** (Jin et al., NOAA MAPP), submitted

Action Items for PRP

1. **Feedback** on metrics, interfaces, development, dissemination

2. Recommend **observational** references
   - Latest *gridded* products, reanalyses
   - How to best characterize obs uncertainties?
   - Best epochs to use?

3. Recommended **realizations** for model & obs (epochs, ensemble sizes)

4. Ideas for new metrics
   - **Expand** existing collections: e.g. connect to **conceptual models**
   - **New collections**: Climate change, teleconnection processes, impacts, …

5. Ideas for applications & tiering of metrics
   - Model evaluation & **selection/weighting**
   - Physical **links** among metrics; **emergent constraints** for future change

6. Resources: **Postdocs**, web/data techs, funding opportunities, ...