

ENSO Predictions and Ocean Observations

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Ocean observations have multiple uses:

- Improving representation of physical processes in models
- Ocean analysis and prediction for societal benefits

The focus of this discussion is the requirements for ocean observations in the context of ENSO prediction

Question: What are the spatial and temporal sampling requirements for ENSO prediction?

Three approaches are considered:

1. Can we discern the signatures of variations in number of ocean observations on ENSO prediction skill?
2. Because equatorial Pacific is a strongly coupled system, specification of surface observations alone (e.g., SSTs) can generate sub-surface ocean variability. What is the contribution of surface observations in simulating sub-surface ocean variability?
3. How linear or non-linear ENSO dynamics is?

Variations in ENSO skill with evolution of the observing system

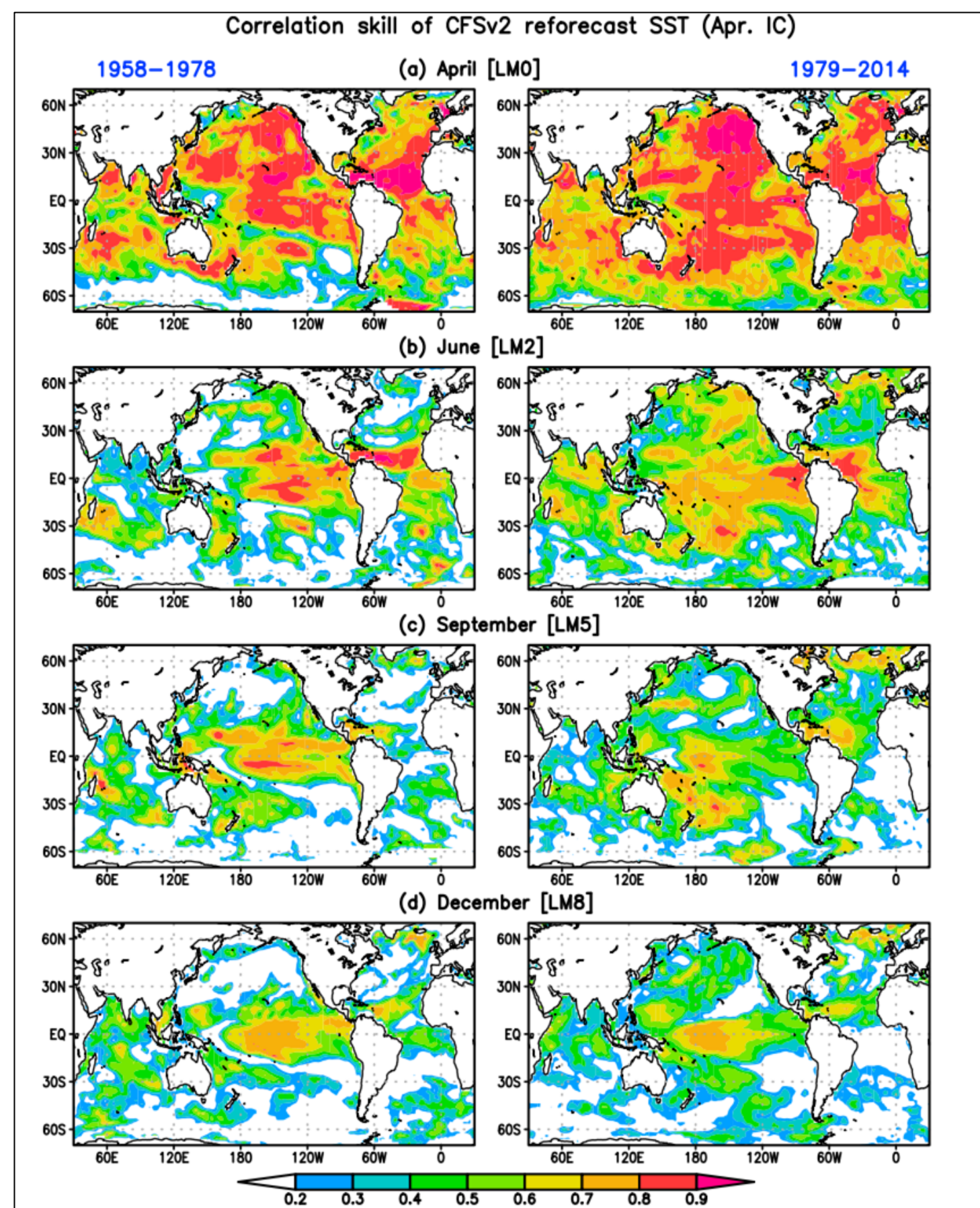


Fig. The spatial distribution of the correlation skill for the SST anomalies from the 57-yr ensemble mean hindcast initialized at the beginning of April. [Hunag et al. 2017]

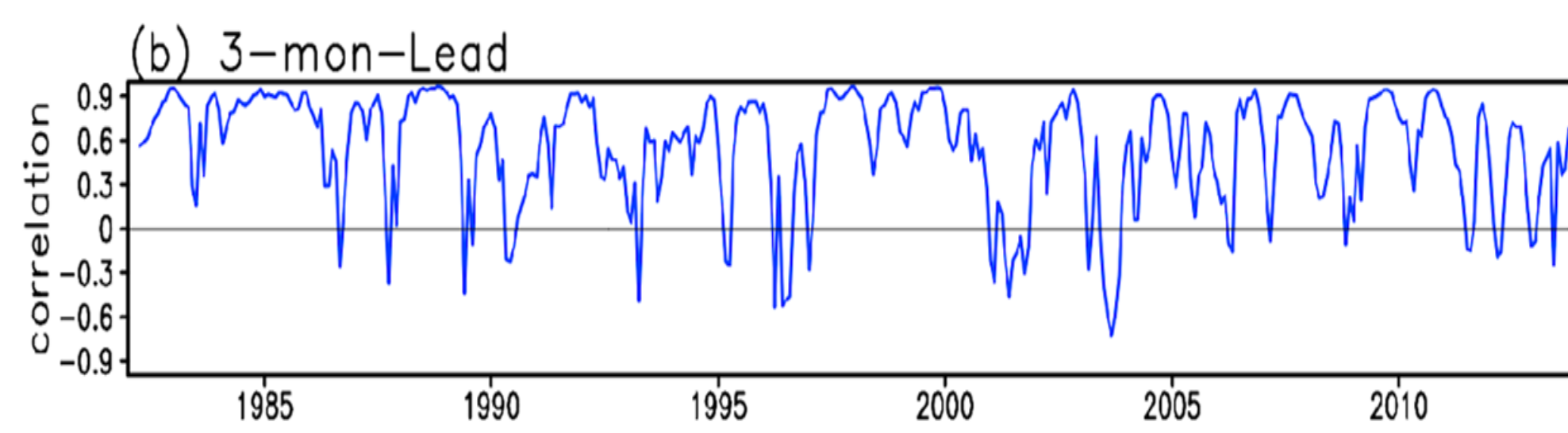


Fig. Time evolution of SST prediction skill in equatorial Pacific. Skill is measured as anomaly correlation (AC) between ensemble mean predicted and observed SST anomaly, and AC is computed over the region (10°S–10°N, 130°E–80°W) [Kumar et al. 2015]

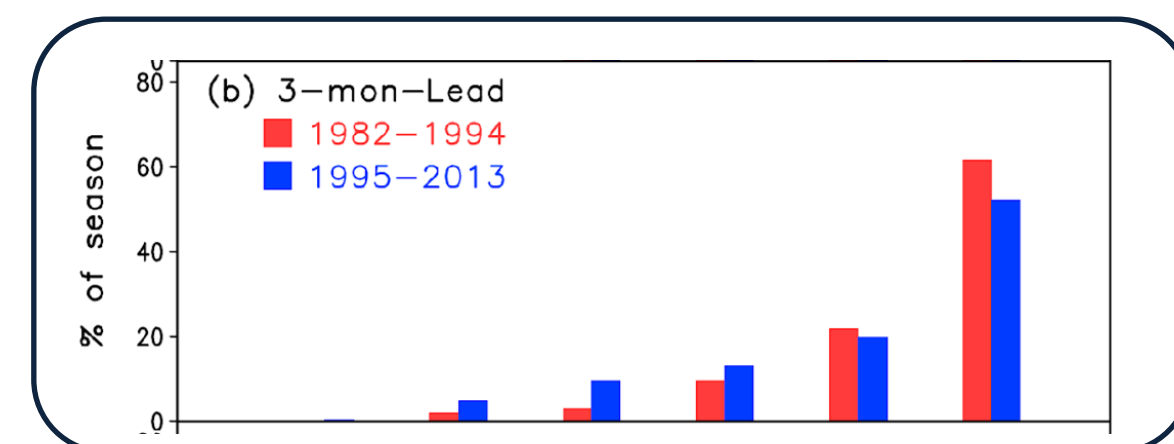


Fig. Frequency distribution of anomaly correlations for forecasts between 1982 and 1994 (red bars), and forecasts between 1995 and 2013 (blue bars) for 3-month Lead forecasts. Anomaly correlations were binned at the intervals of 0.3, and bin range values are shown on the x axis. [Kumar et al. 2015]

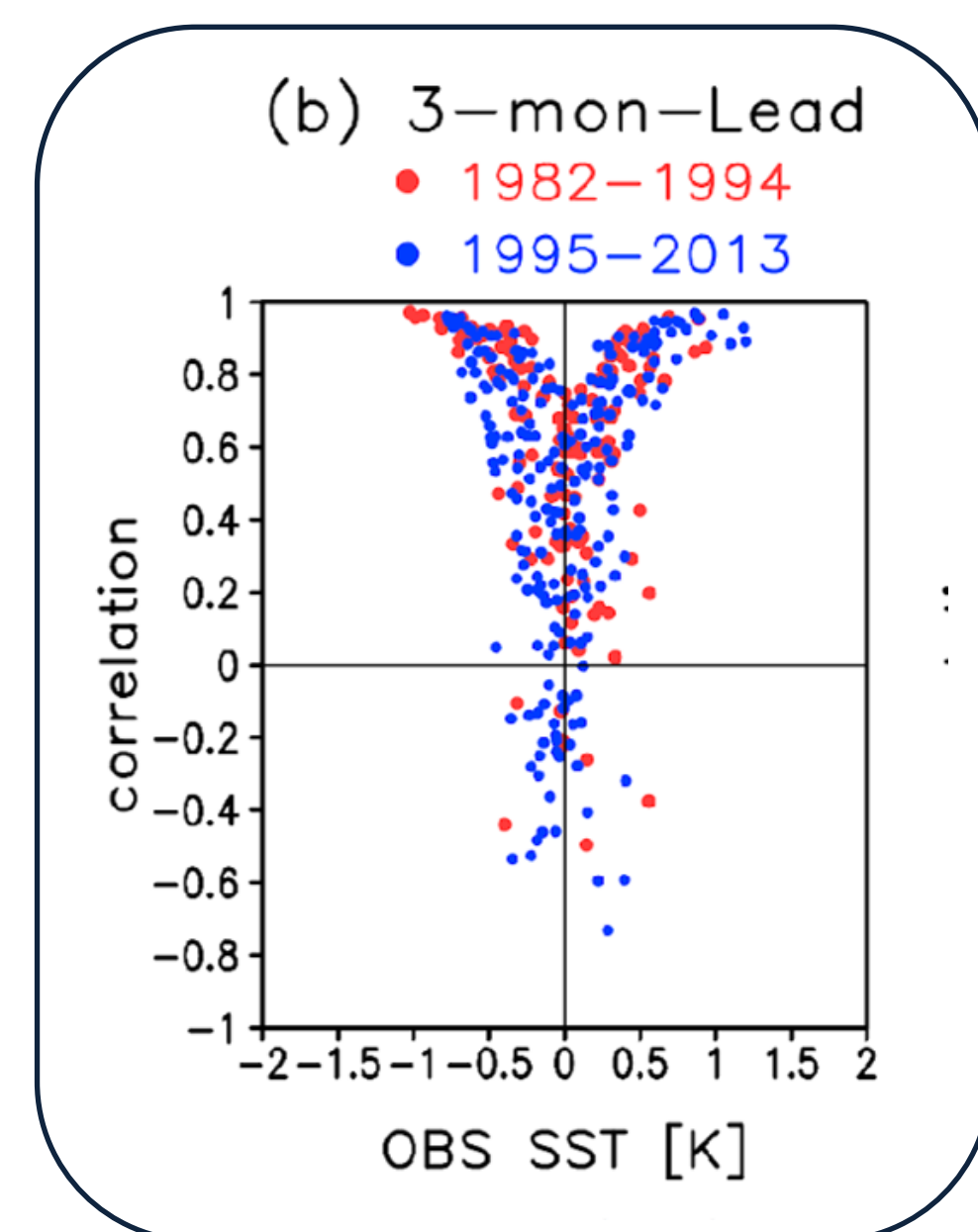


Fig. Scatterplot between mean amplitude of observed SST anomaly (x axis) and SST prediction skill (y axis) for 3-month forecasts (time-series above) and the amplitude of Niño 3.4 SSTs [Kumar et al. 2015]

Implications:

- Finding relationship between the evolution of observing system and skill of ENSO prediction is not straightforward.
- Small sample, and variations in skill with signal-to-noise is an issue.

Role of surface observations in sub-surface ocean variability

Approach

- Ocean only simulations with specification of observed surface variability (SSTs, surface winds,...)
- Coupled simulations with predicted SSTs nudged to observations

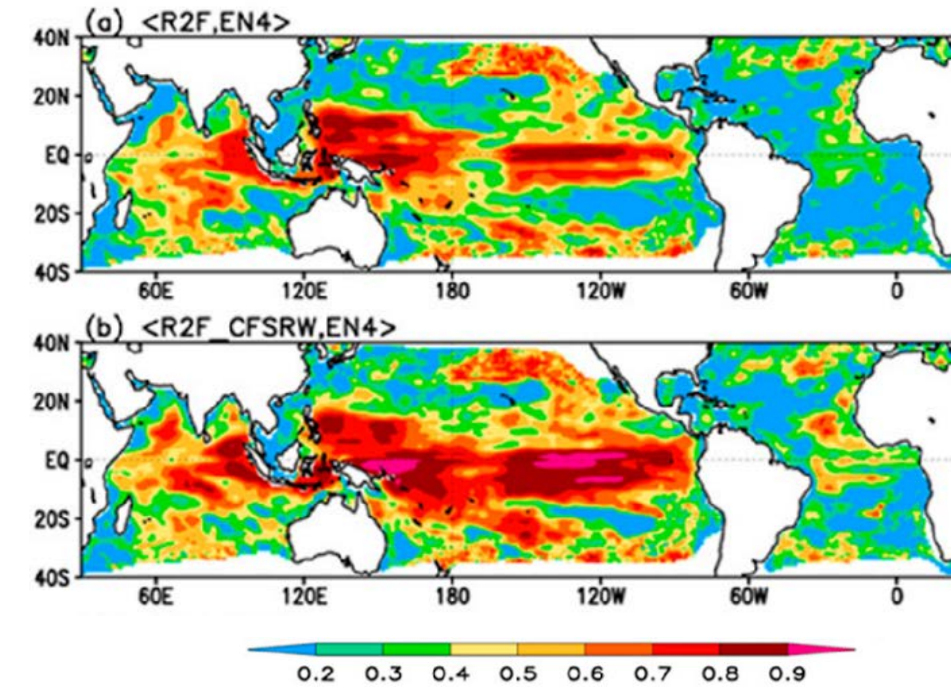


Fig. Temporal anomaly correlation for D20 for various ocean model simulations and observed ocean analysis based on EN4: (a) ocean model simulation with R2 forcing; (b) ocean model simulations with R2 forcings, but with surface wind stress from the CFSR. The anomaly correlation is computed for the respective ocean model simulations over the 1999–2013 period. [Kumar et al. 2017]

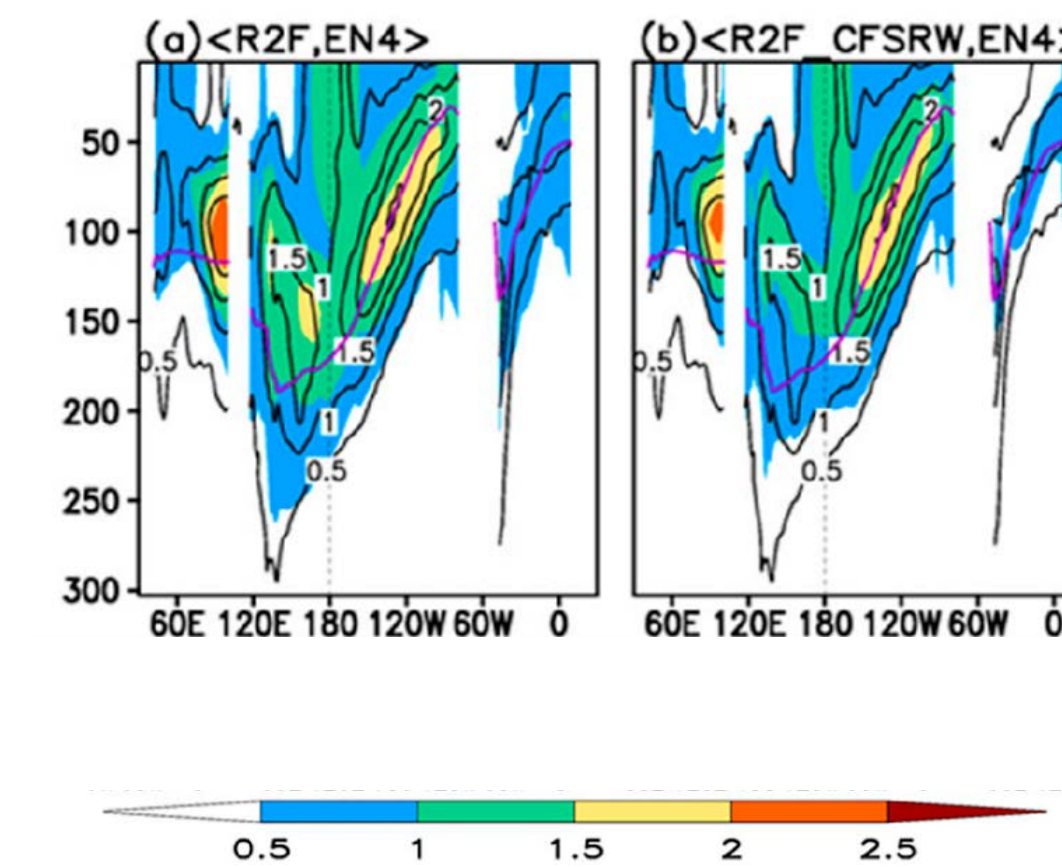


Fig. Standard deviation of monthly mean subsurface ocean temperature averaged between 28S and 28N for (a) ocean model simulation with R2 forcing; (b) ocean model simulations with R2 forcings, but with surface wind stress from the CFSR. Shading is for model simulations; contours are for EN4. Units are in degrees squared. Purple lines denotes climatological mean of depth of 20°C in EN4. [Kumar et al. 2017]

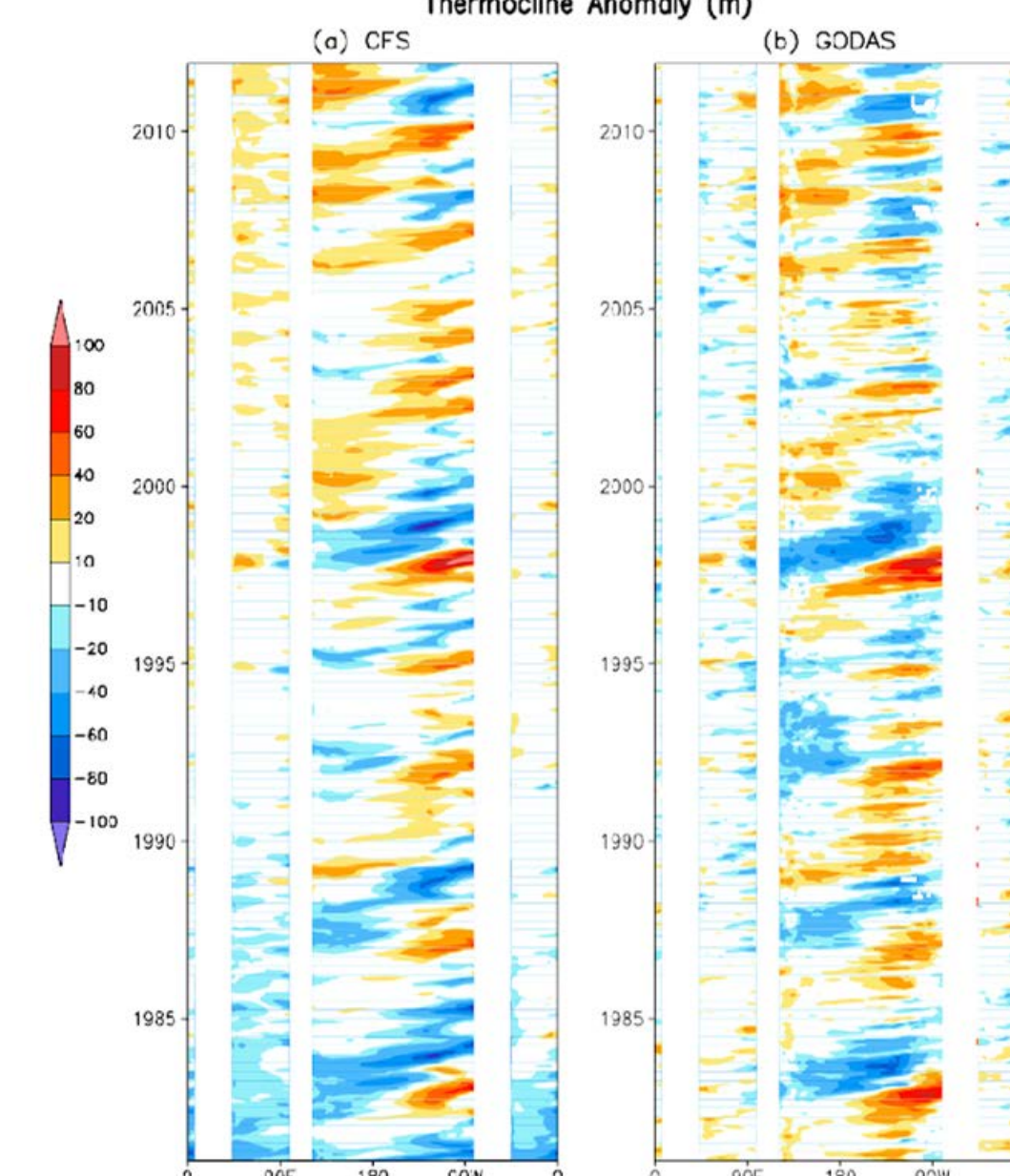


Fig. Thermocline anomaly at the equator (unit: m) for (a) ensemble mean of coupled simulations forced with observed SSTs and (b) GODAS ocean analysis. The depth of the thermocline is derived based on the depth of the 20°C isotherm. [Kumar et al. 2015]

Implications:

- Specification of the observed surface forcings, via coupled interactions (SST → Precipitation → Surface Winds → sub-surface ocean variability → SST) can provide information about the evolution of sub-surface ocean anomalies in equatorial Pacific.
- Forecast with ocean analysis with SST nudging have shown to have reasonable ENSO prediction skill. [Zhu et al. 2017]

How linear or non-linear is the predictable component of ENSO?

A summary of results from:

Newman and Sardeshmukh, 2017: Are we near the predictability limit of tropical Indo-Pacific sea surface temperatures? *GRL*, 2017.

The analysis compares ENSO skill based on Linear Inverse Model (LIM) with coupled models, e.g., NMME

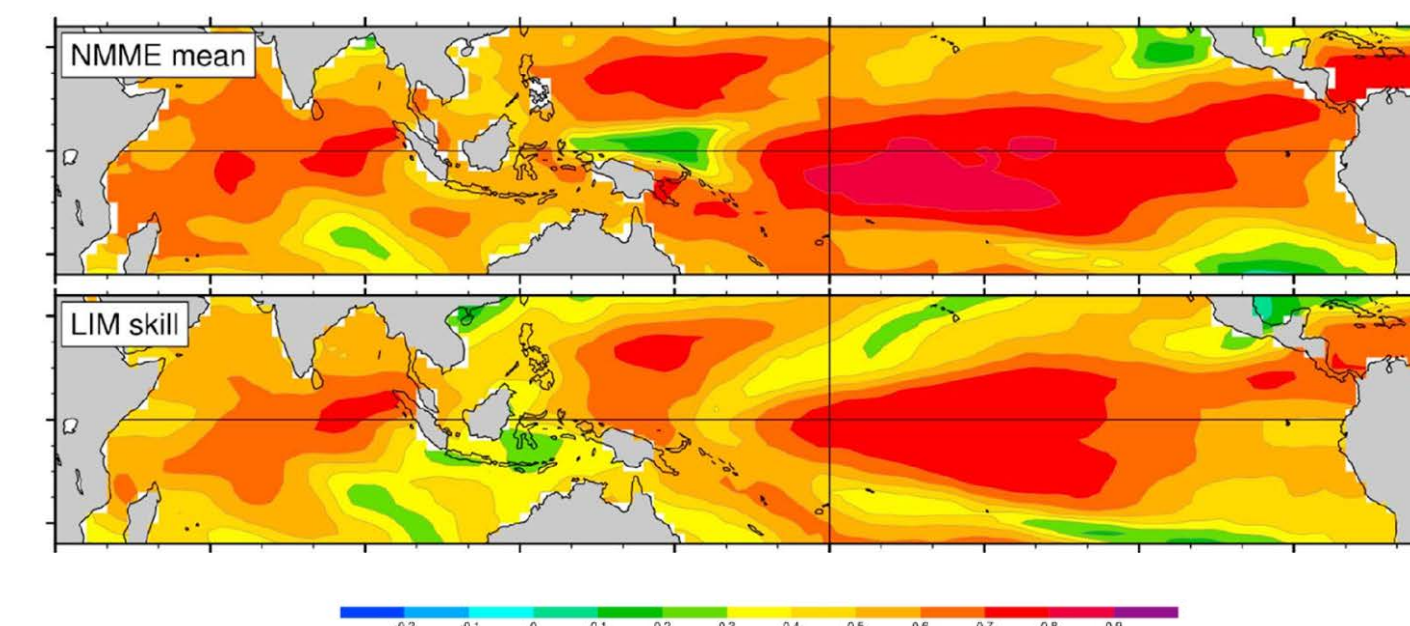


Fig. Local anomaly correlation (AC) skill of Month 6 SST anomaly (SSTA) hindcasts over the period 1982–2010. The panels show the NMME ensemble mean skill (top), and LIM skill (bottom).

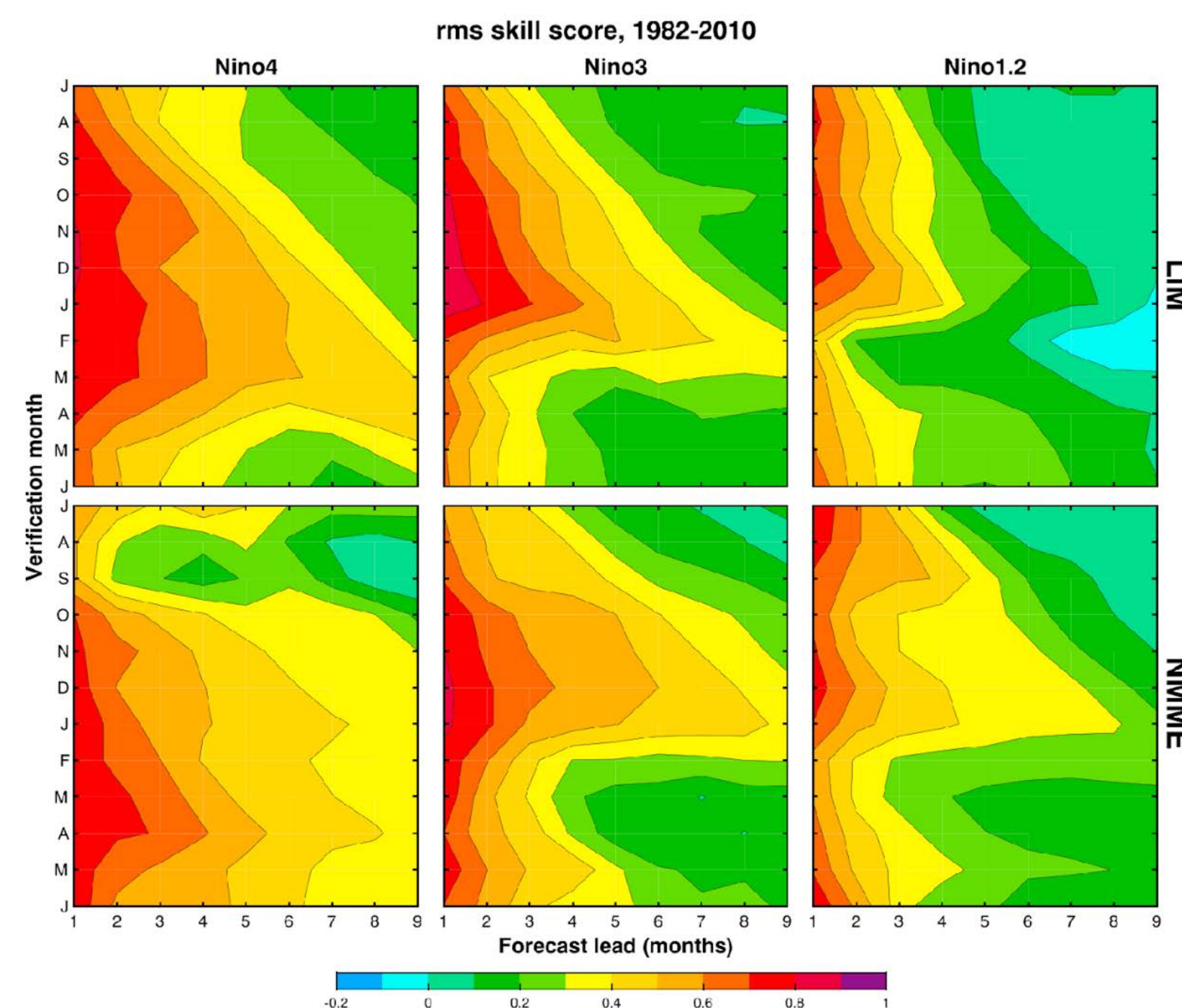


Fig. Root-mean-square (RMS) skill scores of the LIM and NMME mean hindcasts of three equatorial Pacific SST anomaly indices over the 1982–2010 period. (top row) The LIM skill and (bottom row) the NMME mean skill of area-averaged SST anomalies in the (left column) Nino4, (middle column) Nino3, and (right column) Nino1.2 regions. All panels show skill as a function of forecast lead (abscissa) and verification month (ordinate).

Implications:

- Predictable component of ENSO variability (i.e., the dynamics of ensemble mean) may be dominated by linear dynamics.
- Resolving large scale structures in sub-surface oceanic heat content variability may be sufficient to realize potential predictability associated with ENSO.
- In ensemble prediction systems, the non-linear dynamics (growth of initial perturbations) determines the evolution of individual forecasts, i.e., the unpredictable component of ENSO variability. This component cannot be observed or predicted.

References:

Hunag et al., 2017: Reforecasting the ENSO Events in the Past 57 Years (1958–2014). *J. Climate*.

Kumar et al. 2017: Sensitivity of Subsurface Ocean Temperature Variability to Specification of Surface Observations in the Context of ENSO. *J. Climate*.

Kumar et al. 2015: An Analysis of the Temporal Evolution of ENSO Prediction Skill in the Context of the Equatorial Pacific Ocean Observing System. *J. Climate*.

Kumar et al. 2014: How Much of Monthly Subsurface Temperature Variability in the Equatorial Pacific Can Be Recovered by the Specification of Sea Surface Temperatures? *J. Climate*.

Zhu et al., 2017: Seasonal predictions using a simple ocean initialization scheme. *Climate Dynamics*.

Summary:

- For the design of a sustained observing system in equatorial Pacific for ENSO prediction, analysis of what spatial and temporal scales in surface and sub-surface oceanic variability need to be observed should be explored.
- Circumstantial evidence based on various analysis approaches (variation in ENSO skill with the evolution of oceanic observing system; influence of surface observations in simulating sub-surface oceanic variability; predictable component of ENSO dynamics being dominantly linear) may provide some indications for the spatial and temporal scales to be sampled for ENSO prediction.
- There are other usage of observations, e.g., validation data sets for improving models, and such requirements may determine the observational needs over a limited duration (e.g., via field programs).