

Skillful seasonal forecast of the Tropical Indo-Pacific SST Variability Using Model-Based Analogs

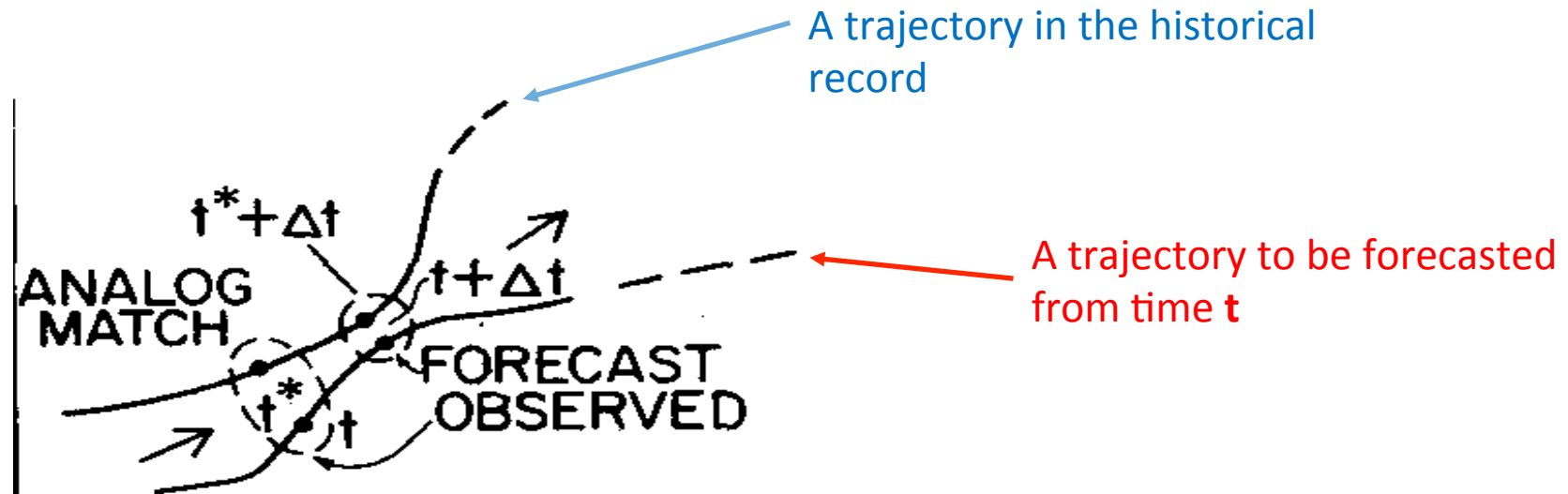
Hui Ding¹, Matt Newman¹, Mike Alexander²,
Andrew Wittenberg³ and Xiaowei Quan¹

1. CIRES, University of Colorado Boulder and NOAA ESRL PSD
2. NOAA ESRL PSD
3. NOAA GFDL



What is analog forecast?

- If two states in the atmosphere or climate system are very close to each other, they can be called each other's analog.
 - Analog forecasting is a very old idea in meteorology (e.g., Namias, 1951, Lorenz, 1969).
- The assumption of an analog forecast is that if two states are very close initially, they will remain close for a period of time and thus can be used to predict future conditions (e.g., Namias, 1951, Lorenz, 1969, Barnett and Preisendorfer, 1978).



Schematic of an analog forecast (Barnett and Preisendorfer, 1978)

Motivation

- Analog method has not yet been applied to make ENSO forecasts
 - ENSO (tropical SSTs) may be a good candidate as it is a low order system
- Usually analogs are identified from previous observations
- However, the observational record maybe too short to obtain good analogs even for low-order system (van den Dool 1994)
- Here analogs of previous model states are searched from a long control simulation:
 - To insure a sufficient record length to identify analogs
 - Model-based analog forecasts also avoid coupling shock and drift
- We examine the ability of the model analog method to predict
 - The evolution of the model
 - To make forecasts of the real world

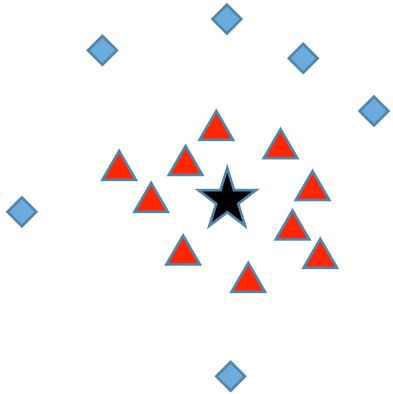
Definition of analogs

- Monthly output from a 700-year control simulation of CESM1 are employed.
- Sea surface height (SSH) and sea surface temperature (SST) anomalies from the tropical Indo-Pacific sectors (30E-80W, 30S-30N).
- A root-mean-square (RMS) distance is defined to measure similarity between states.
- For a given state, an ensemble of the nearest states according to the RMS distance are defined as analogs.
- Analogues are constrained to be from the same calendar month.

Analog forecast in perfect model setup

1.

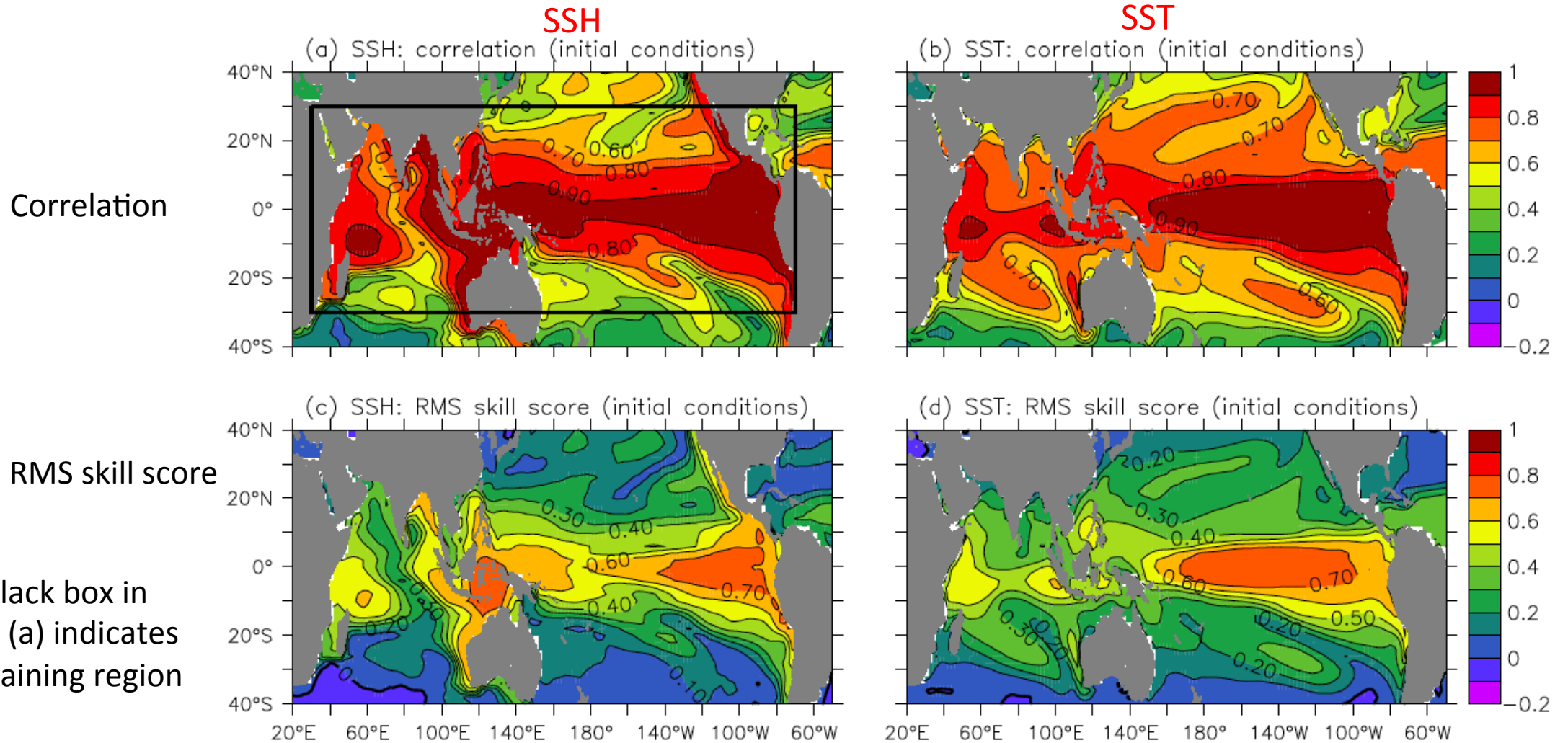
The first 350 years as training period from which analogs are searched	The second 350 years for verification purpose
---	---

2. 
 - ★ : a target state
 - ▲ : analogs defined as the nearest 10 states to the target state
 - ◆ : other states in the training period

3. Ensemble mean of 10 analogs is performed and shown

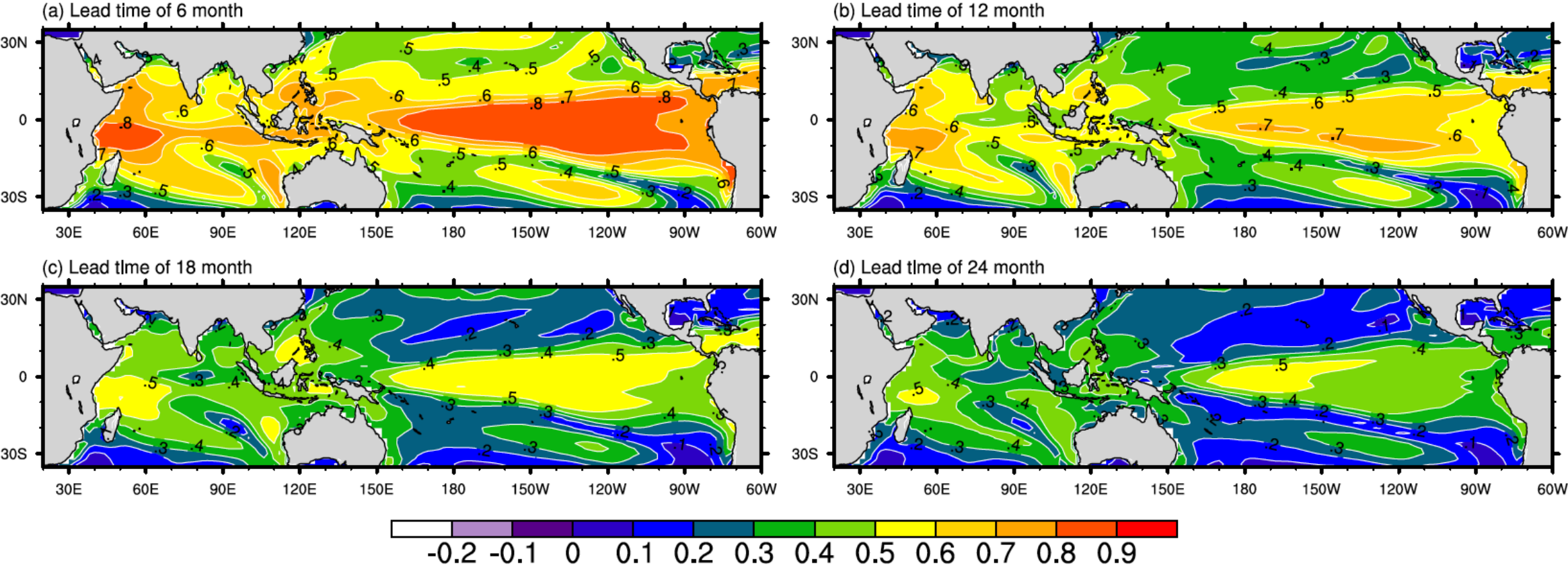
Evaluation of analog forecasts at the initial time

Analog forecasts are evaluated against SSH and SST from the second 350 years



RMS skill score = 1 – standardized RMS error

Evaluation of analog forecasts in SST using correlation

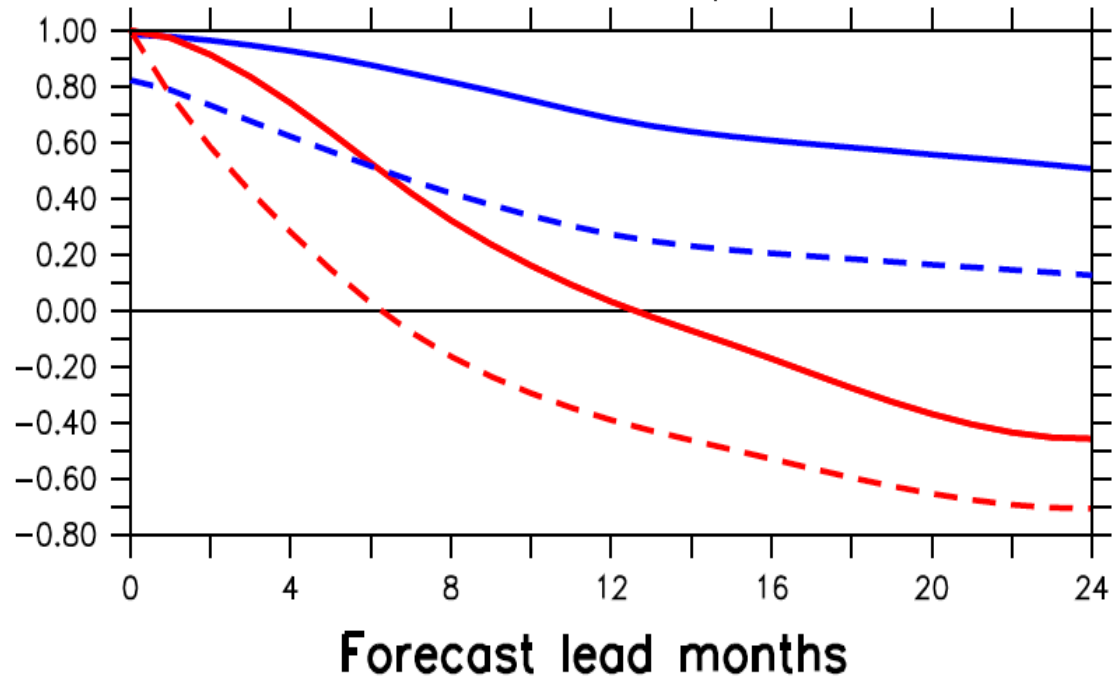


Analog forecasts are evaluated against SST from the second 350 years

Swap the training and verification periods in the CESM1 experiment

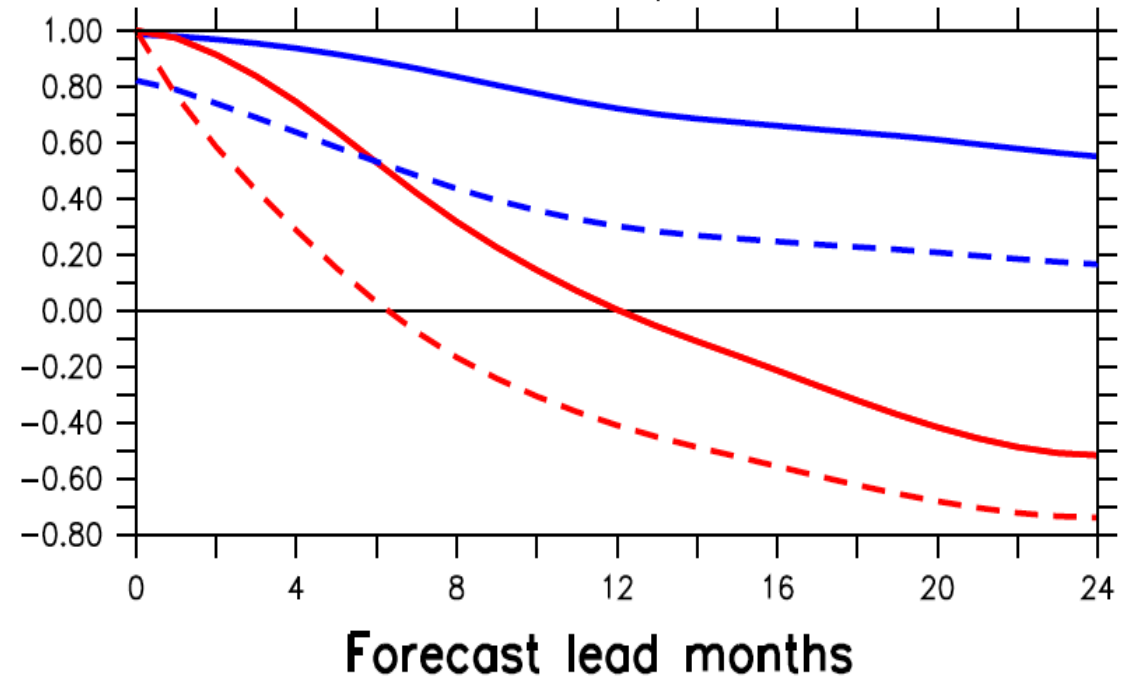
Evaluation of analog forecasts in Nino3.4 SST by correlation (solid) and RMS skill score (dashed)

(a) First half as training period
second half as verification period



Persistence

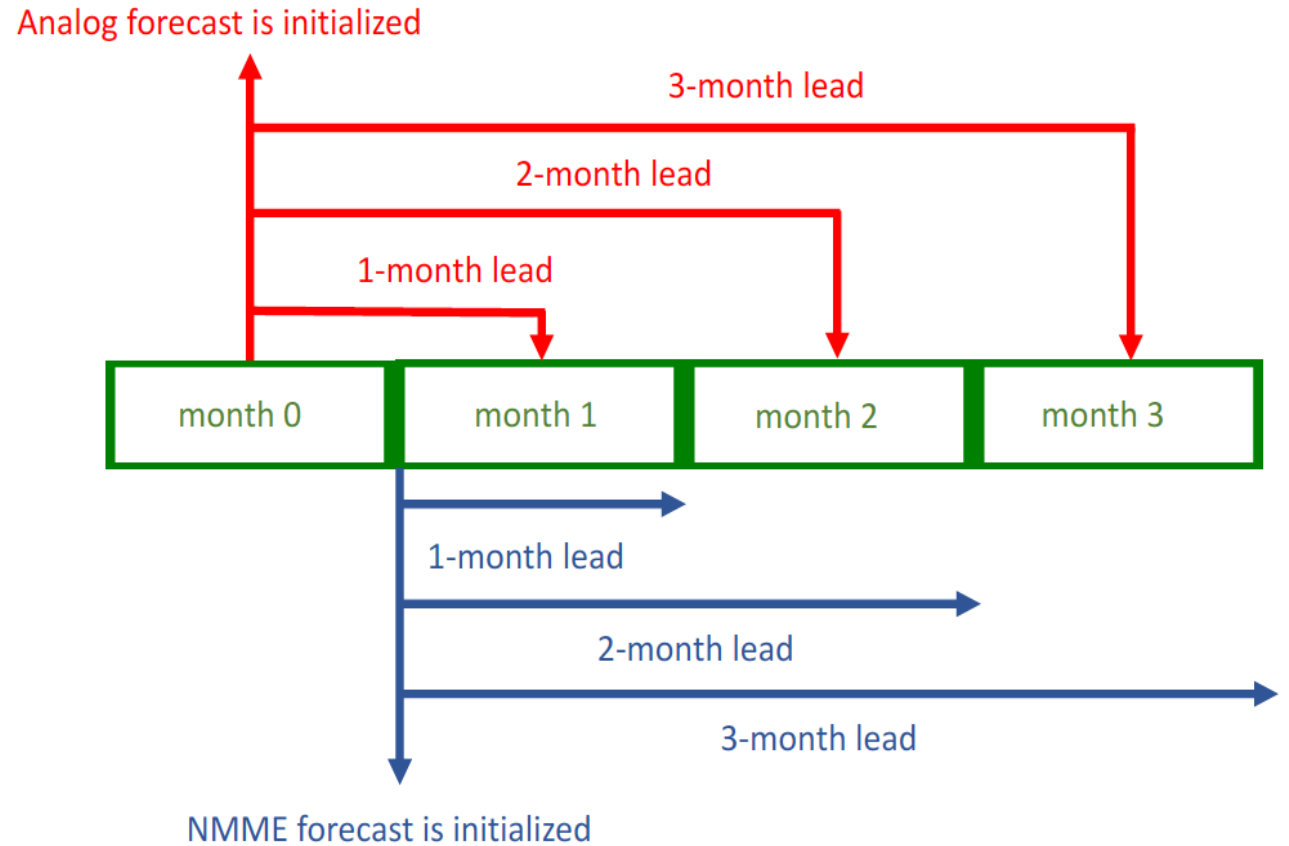
(b) Second half as training period
first half as verification period



Analog forecast

Retrospective forecasts of observed SST

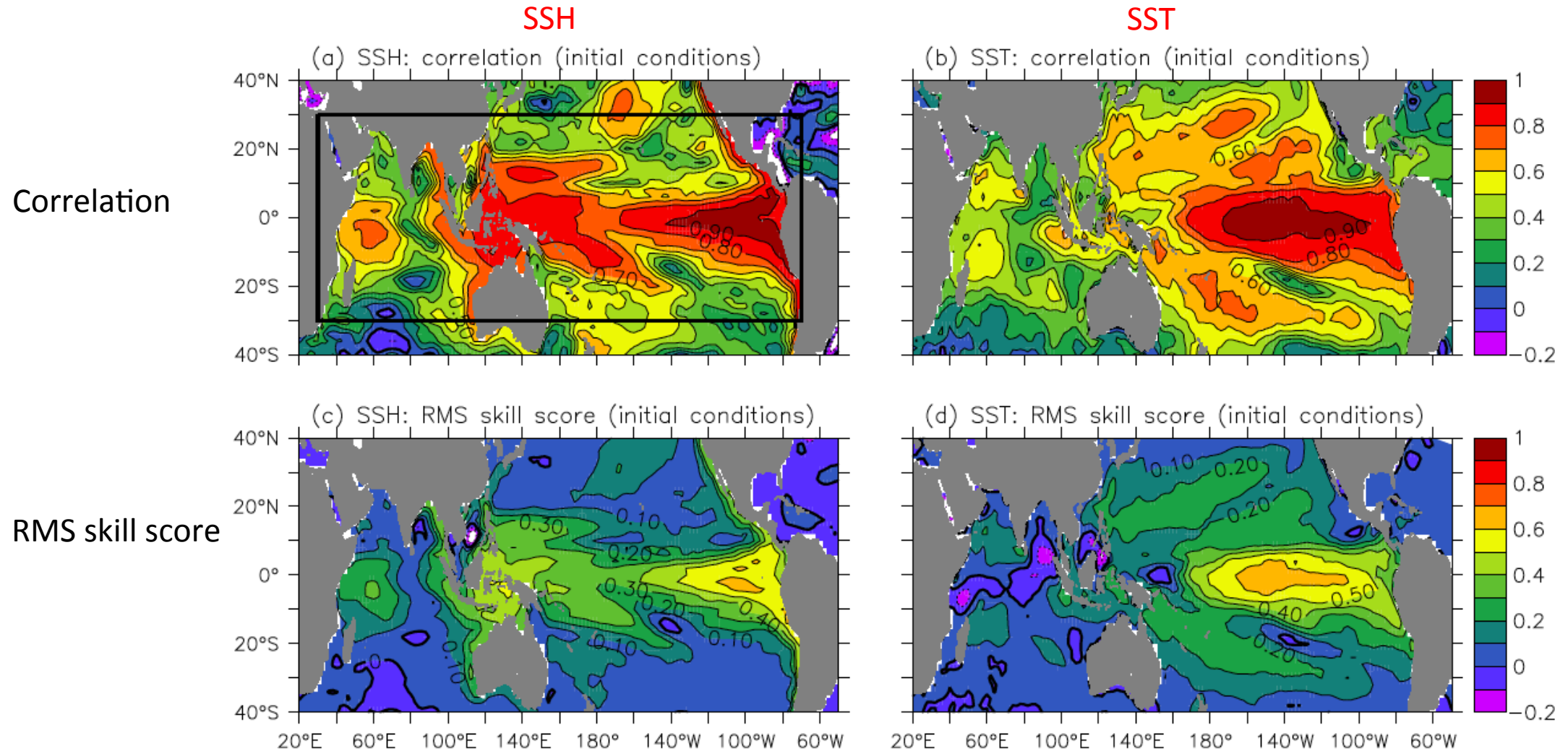
- Analogs are searched from the whole CESM1 simulation for observed states consisting of ORA-S4 SSH and NOAA OISST V2 (Dec of 1981 - Nov of 2009).
- Forecast time evolution in observations using time evolution in the CESM1 control run.
- CESM1 seasonal forecasts from the NMME (Kirtman et al. 2014) are compared with analog forecasts.



Schematic of forecasts from the analog method and the NMME

Evaluation of CESM1-based analog forecast at initial conditions

Analog forecasts are evaluated against ORA-S4 SSH (left) and NOAA OISST (right)



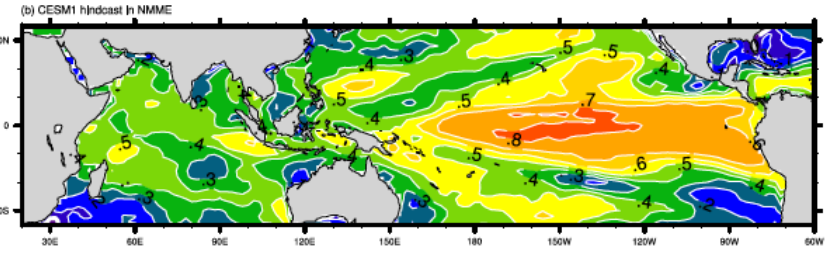
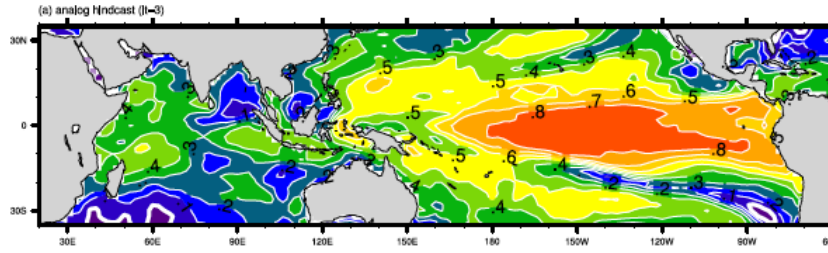
RMS skill score = 1 – standardized RMS error

SST forecast skill using correlation: **CESM1-based analog forecast vs CESM1 forecast in NMME**

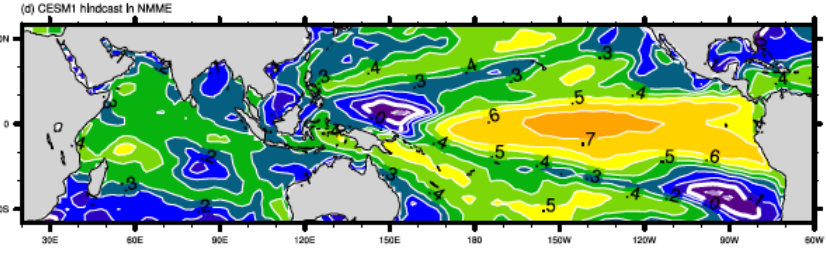
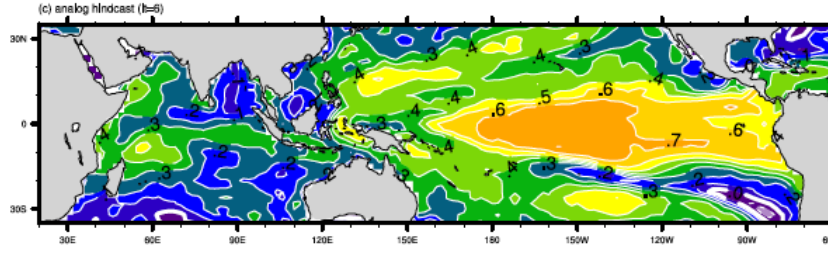
Analog forecast initialized between Dec of 1981 and Nov of 2009

CESM1 forecast in NMME initialized between Jan of 1982 and Dec of 2009

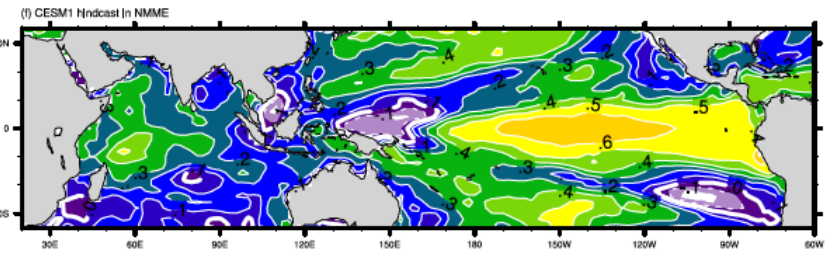
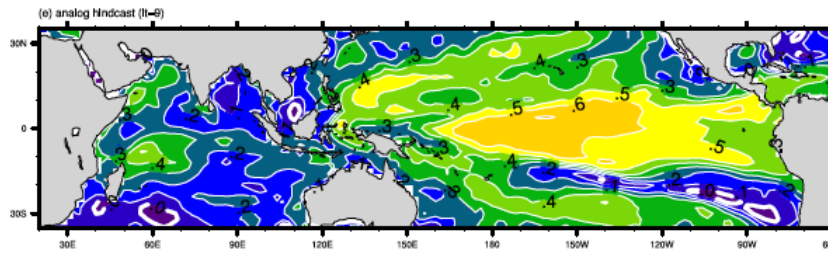
3-month lead



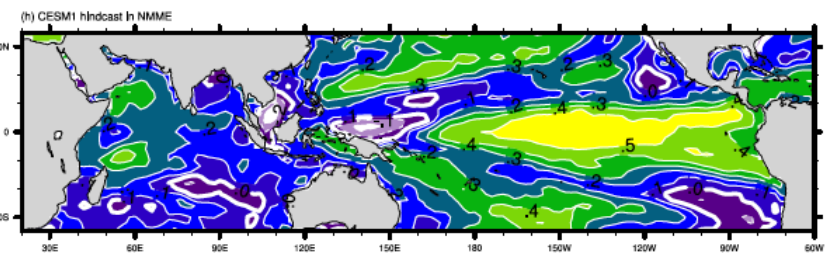
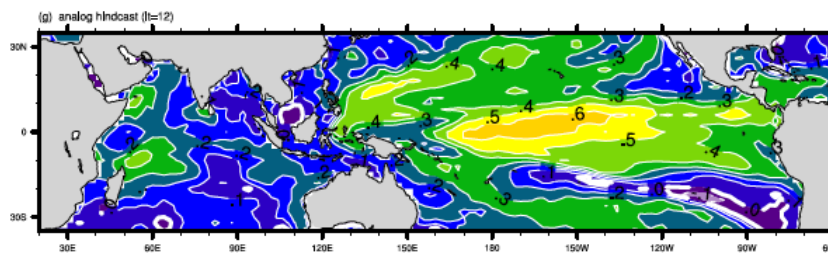
6-month lead



9-month lead



12-month lead

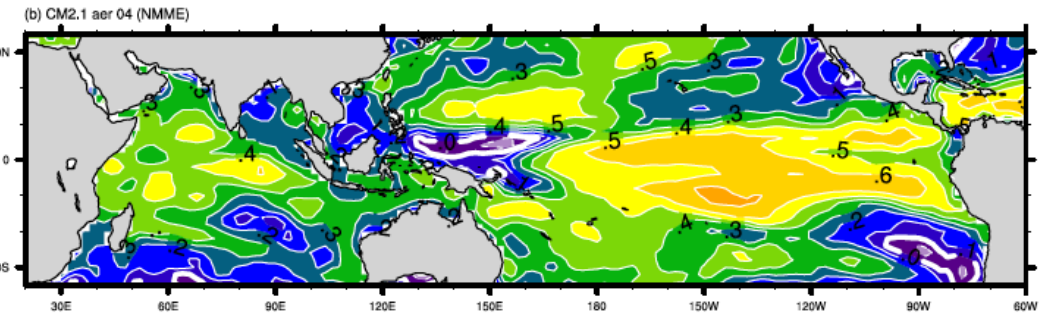
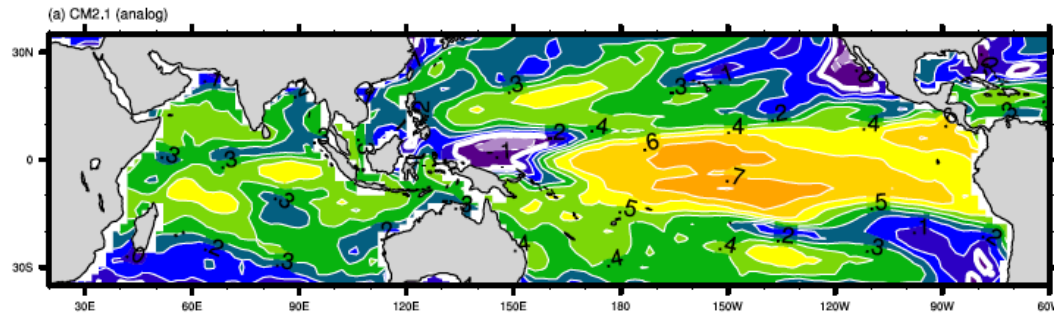


Evaluation of SST forecast at **six-month lead** using correlation

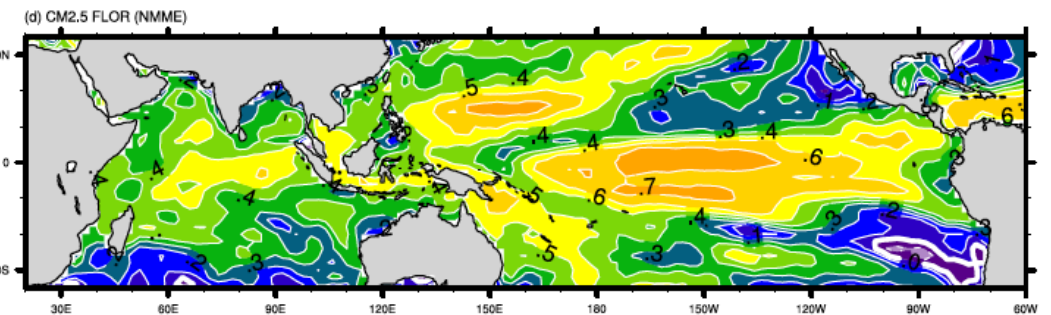
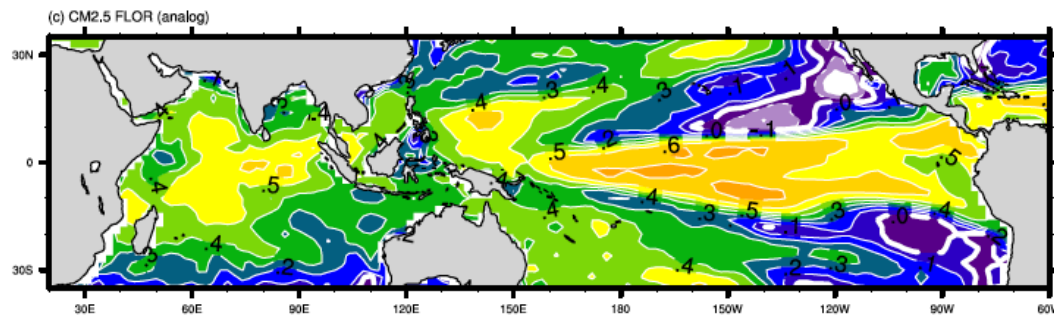
Model-based analog forecasts

Forecasts in NMME

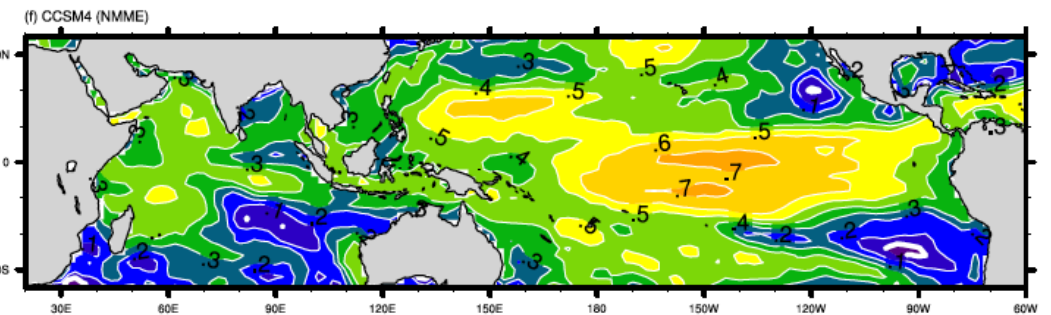
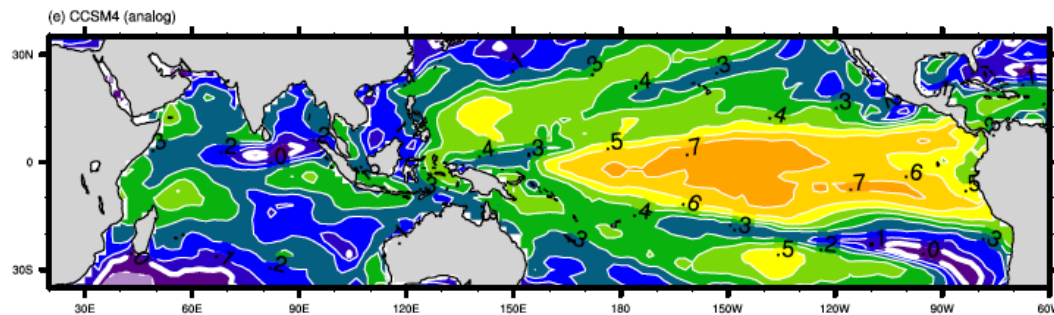
CM2.1



CM2.5 FLOR

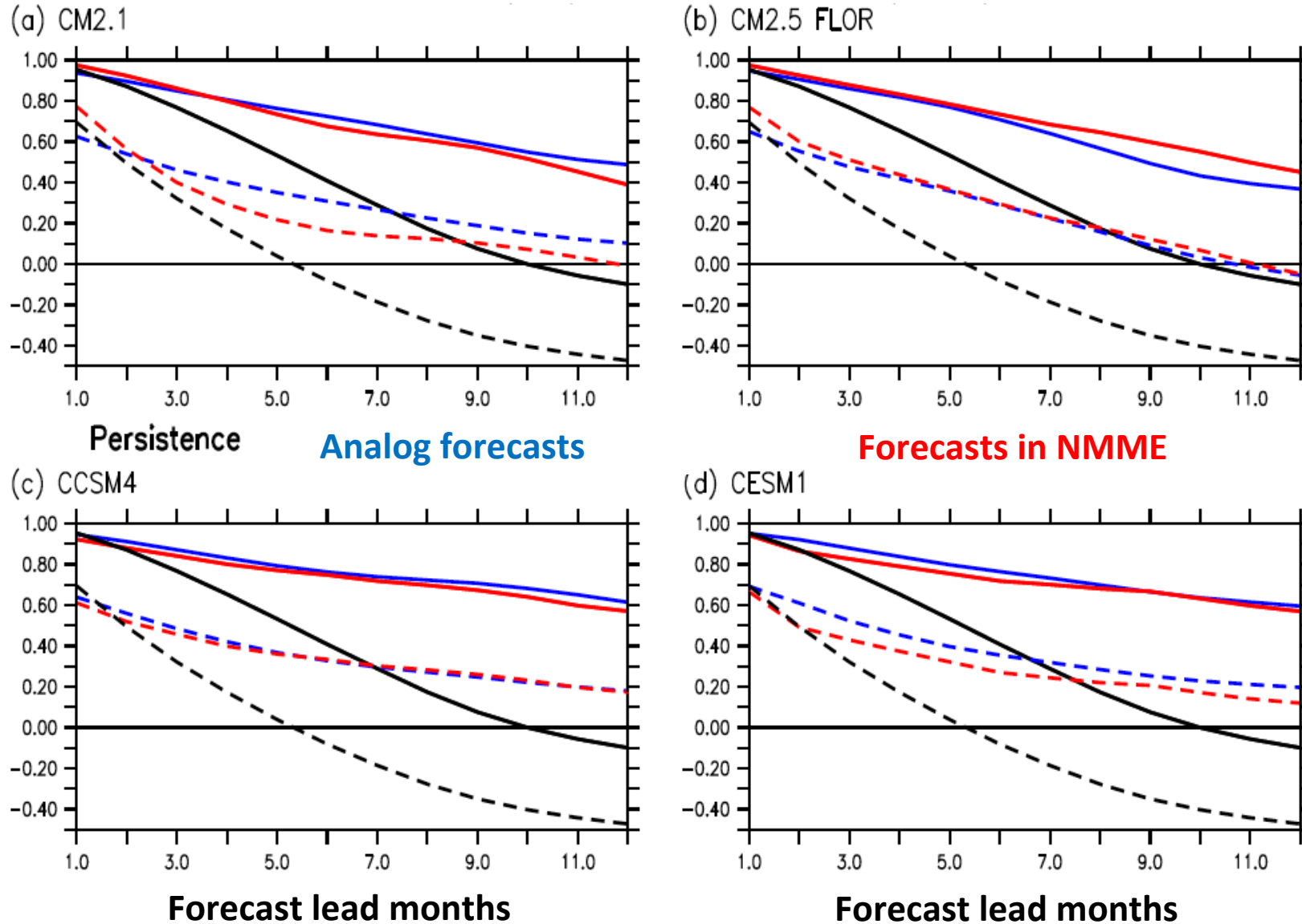


CCSM4



Nino3.4 SST forecast skill: model-based analog forecasts vs forecasts in NMME

Correlation (solid lines) and RMS skill score (dashed lines)



Summary

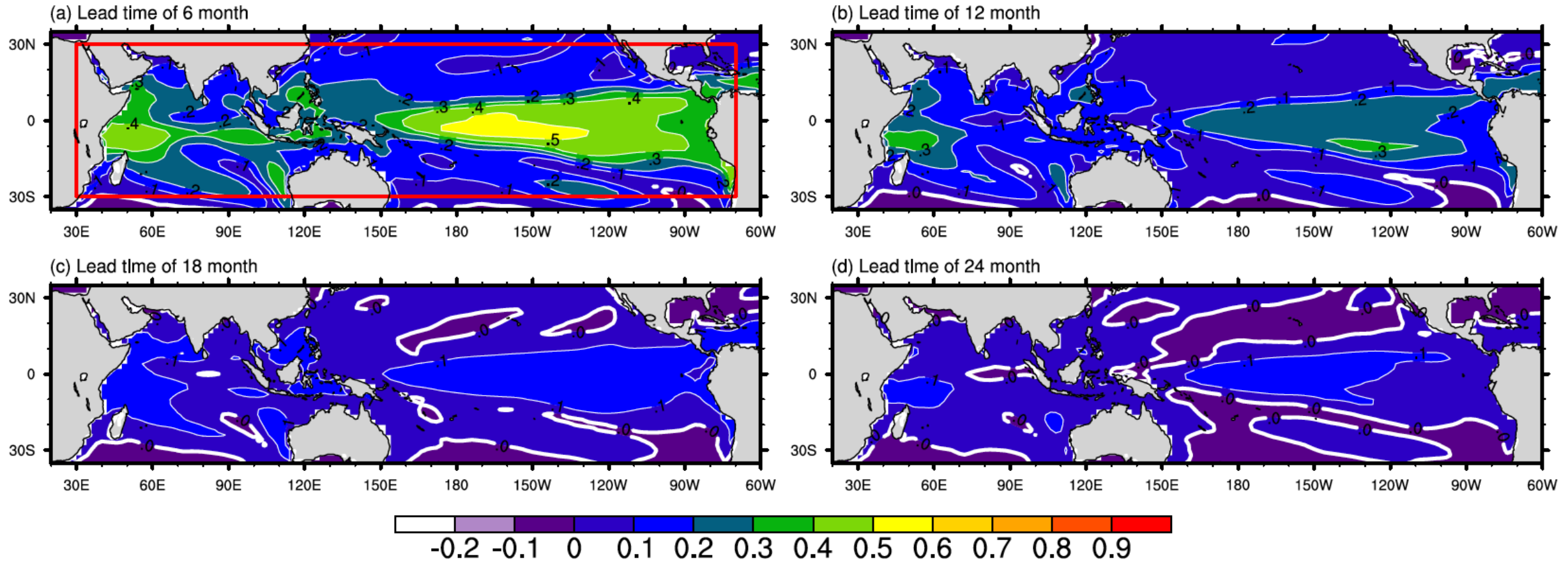
- We examined model based analog forecast skill of SST variations in the tropical Indo-Pacific Ocean.
- In both perfect model setup and the retrospective forecast of observed SST variations, analog forecasts were skillful.
 - Based on an ensemble of 10 SST+SSH analogs and a 350-year training period in perfect model setup
 - Bases on an ensemble of 40 SST+SSH analogs and a 700-year training period in the retrospective forecast
- Analog forecasts display comparative skill to seasonal forecasts conducted using initialized forecasts from the NMME.

Thank you very much!

The following slides are supplemental materials

Perfect model setup

Evaluation of analog forecast in SST using RMS skill score



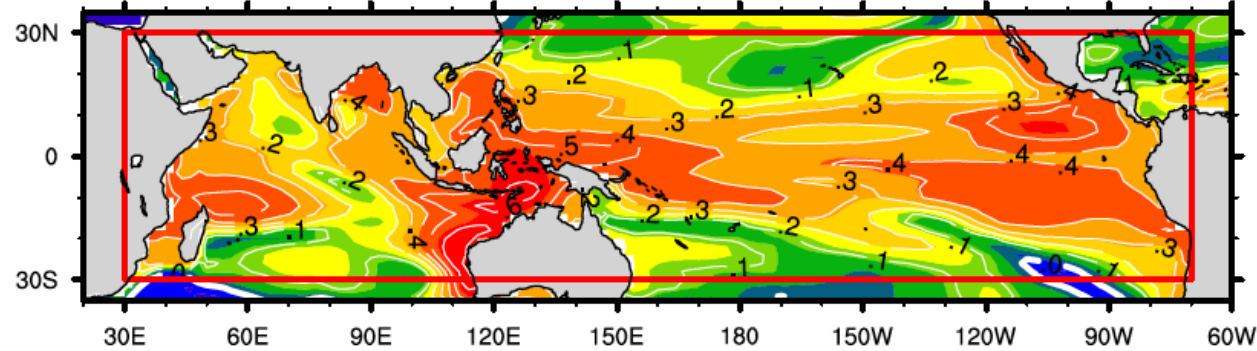
The red box in panel (a) indicates the training region

Perfect model setup

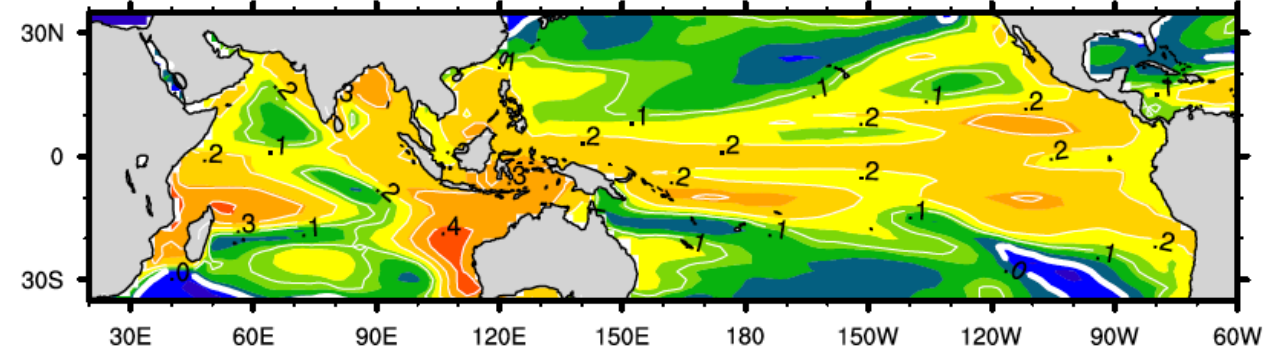
Evaluation of analog forecast in SSH

Correlation (shading) and RMS skill score (contours)

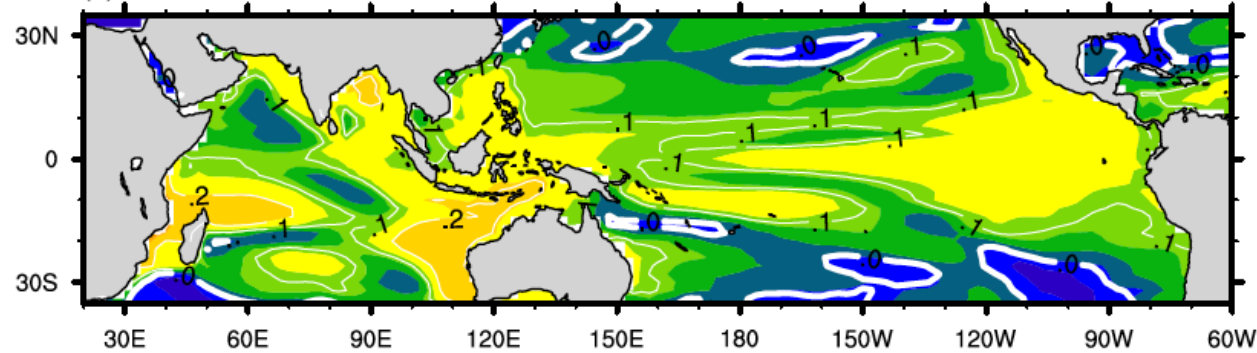
(a) Lead time of 6 month



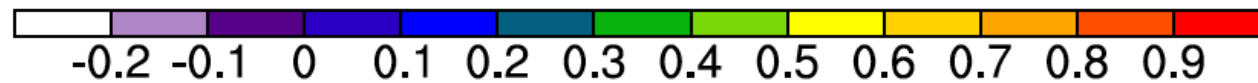
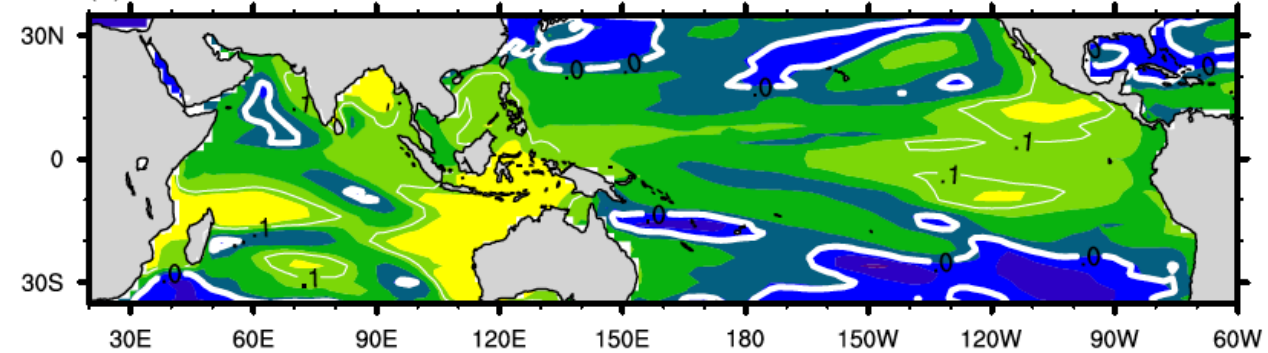
(b) Lead time of 12 month



(c) Lead time of 18 month

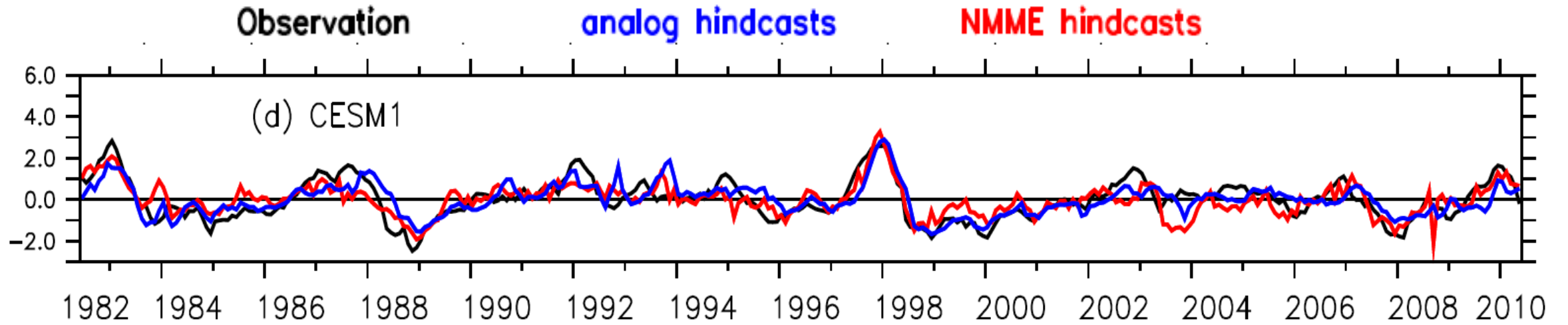


(d) Lead time of 24 month



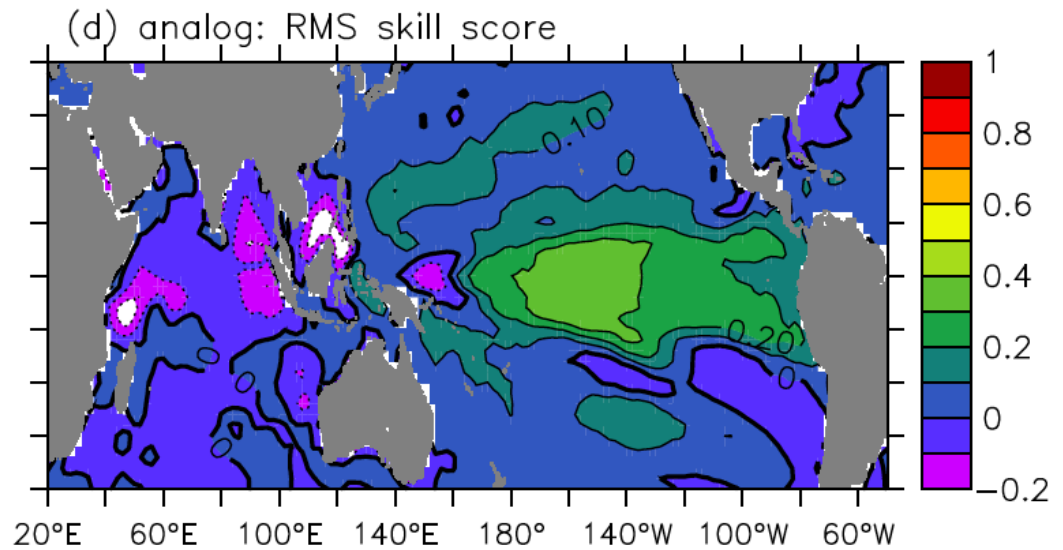
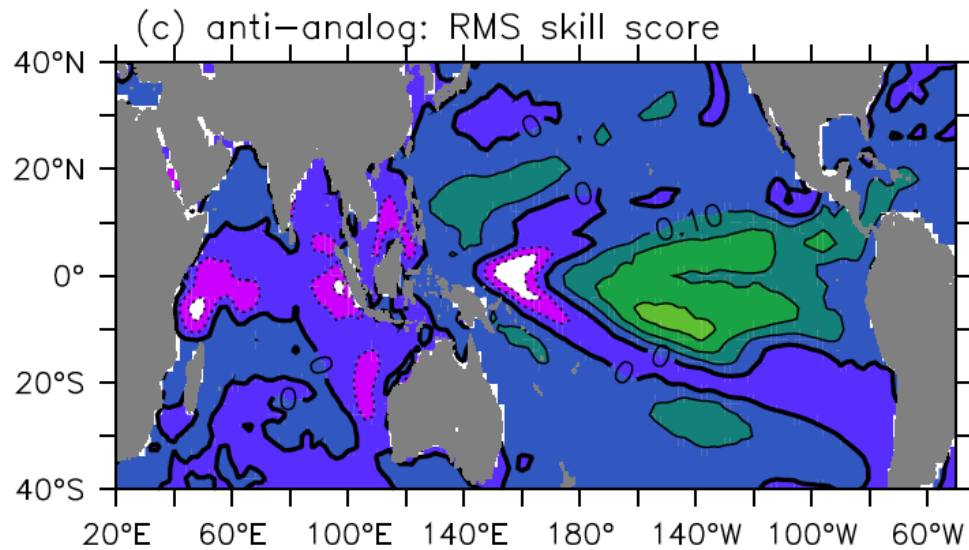
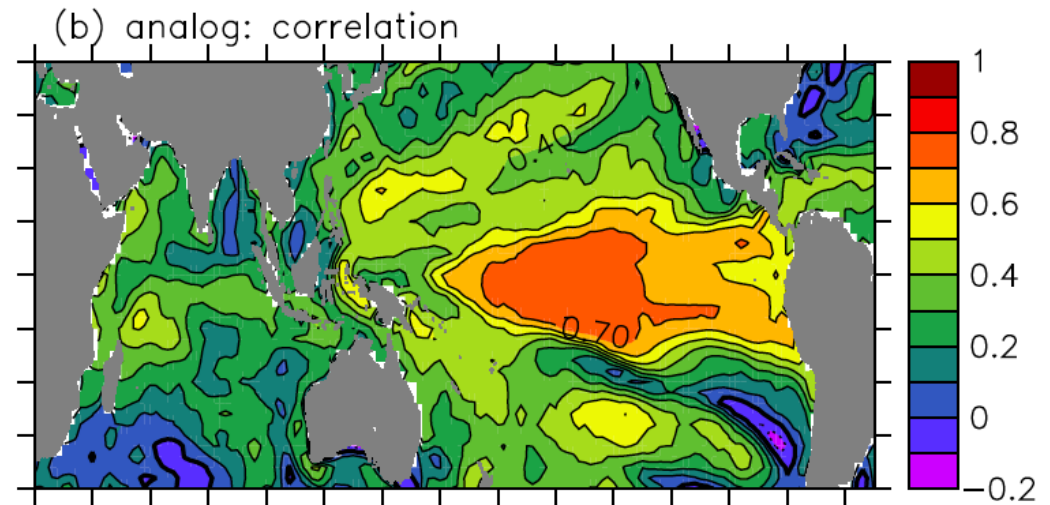
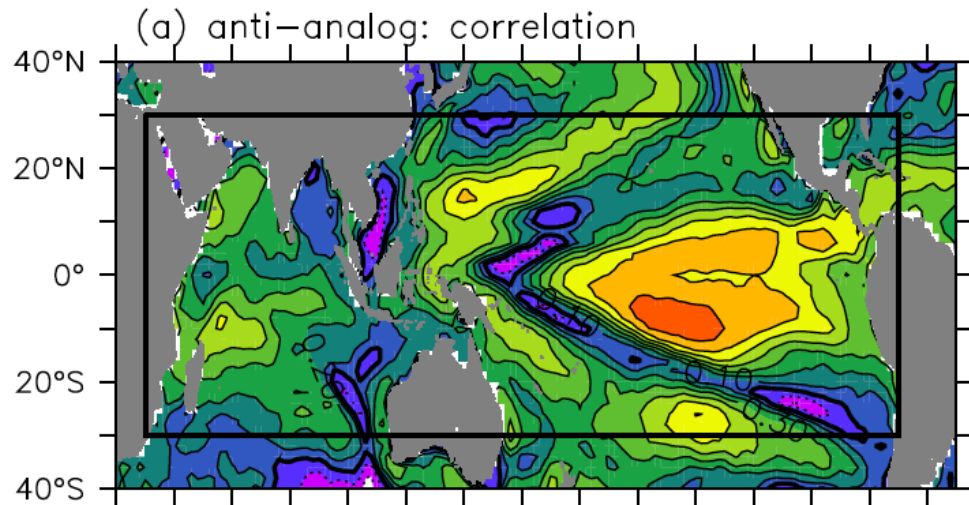
The red box in panel (a) indicates the training region

Nino3.4 SST anomalies at six-month lead



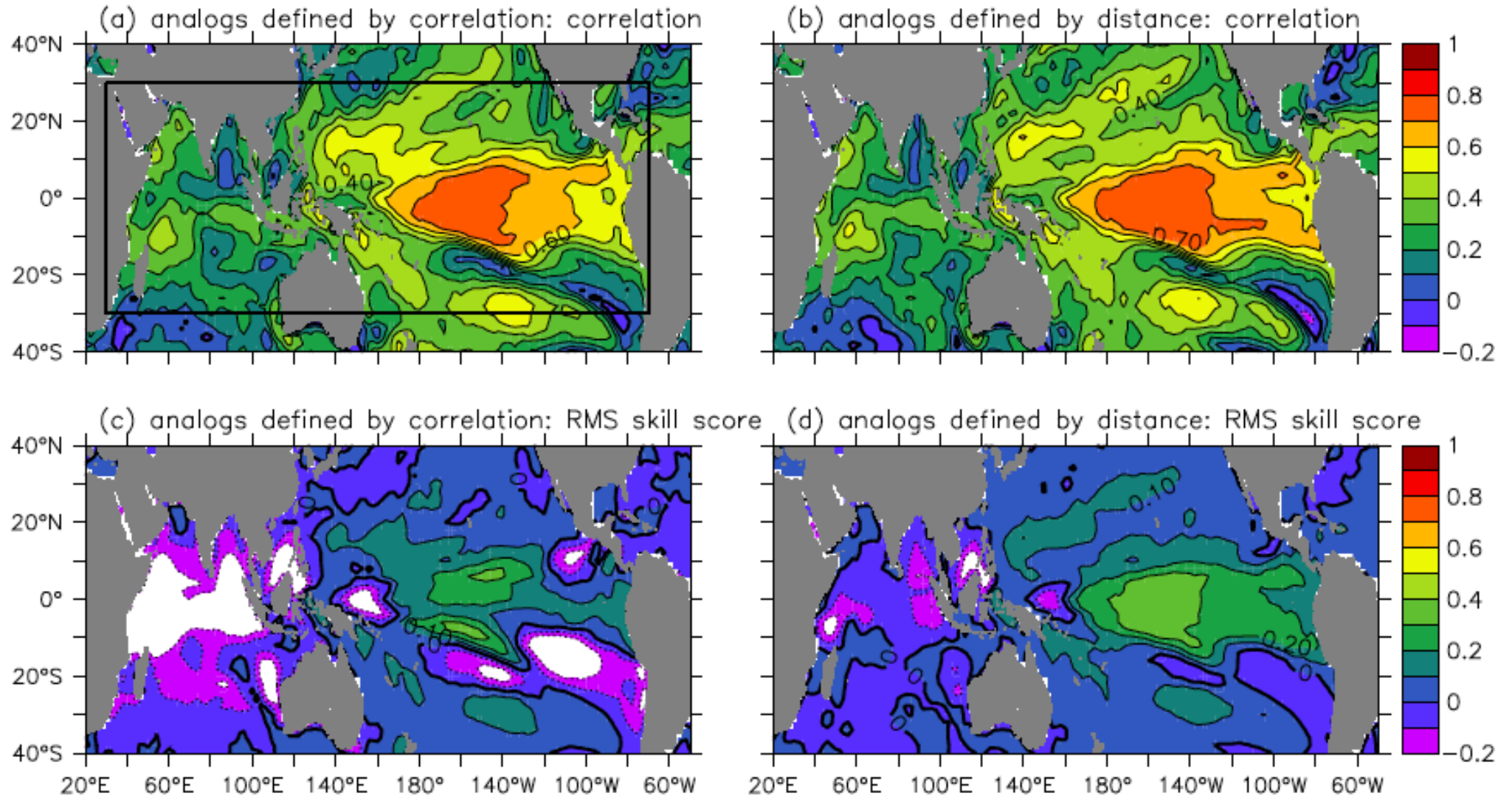
Anti-analog vs analog

Evaluation of SST hindcast at six-month lead



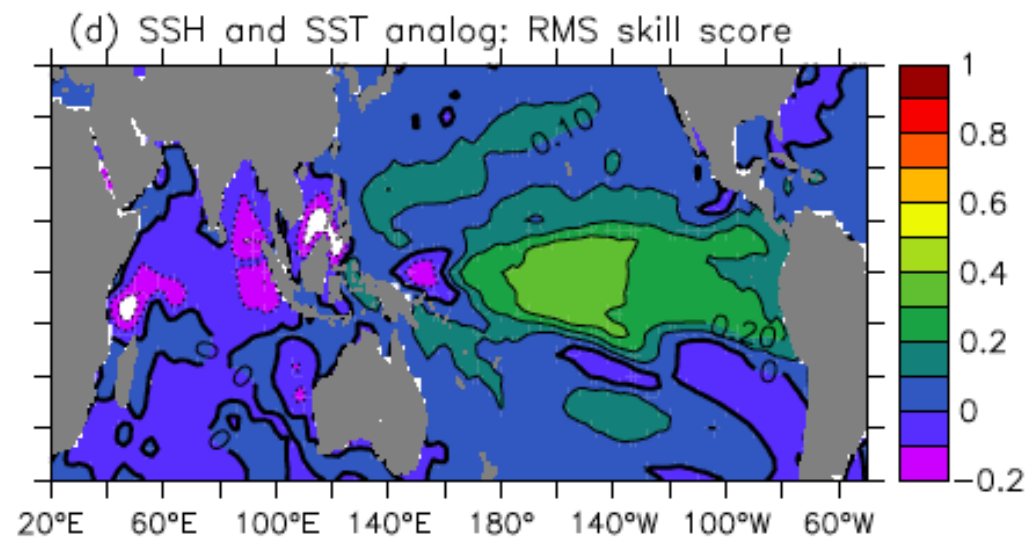
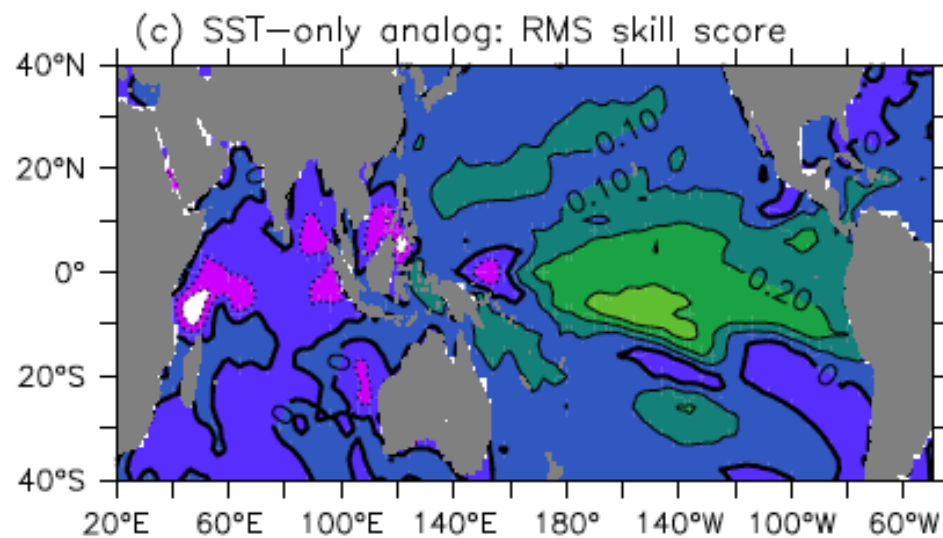
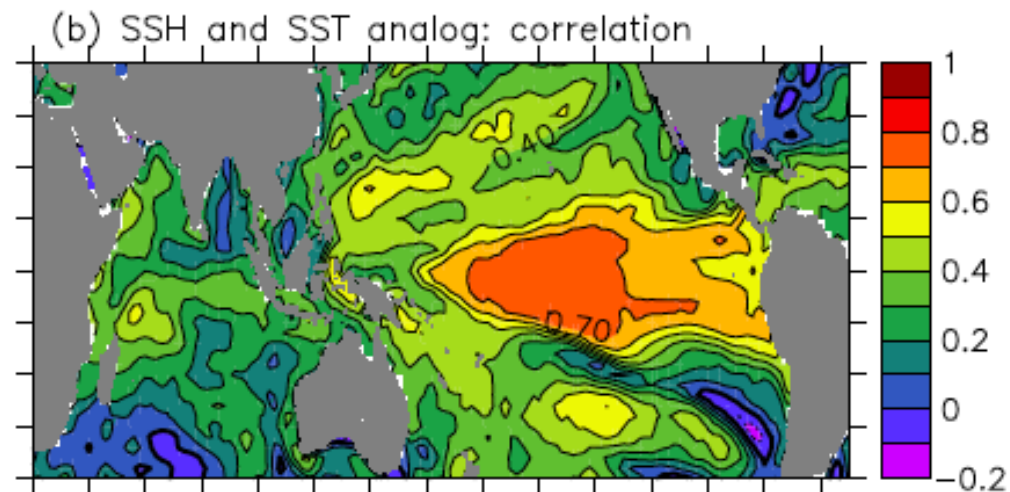
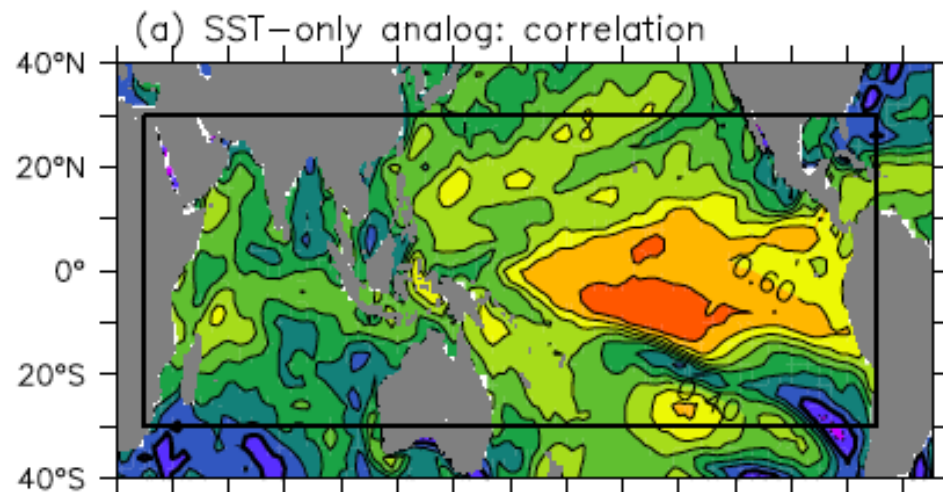
Analogues defined by pattern correlation

Evaluation of SST hindcast at six-month lead

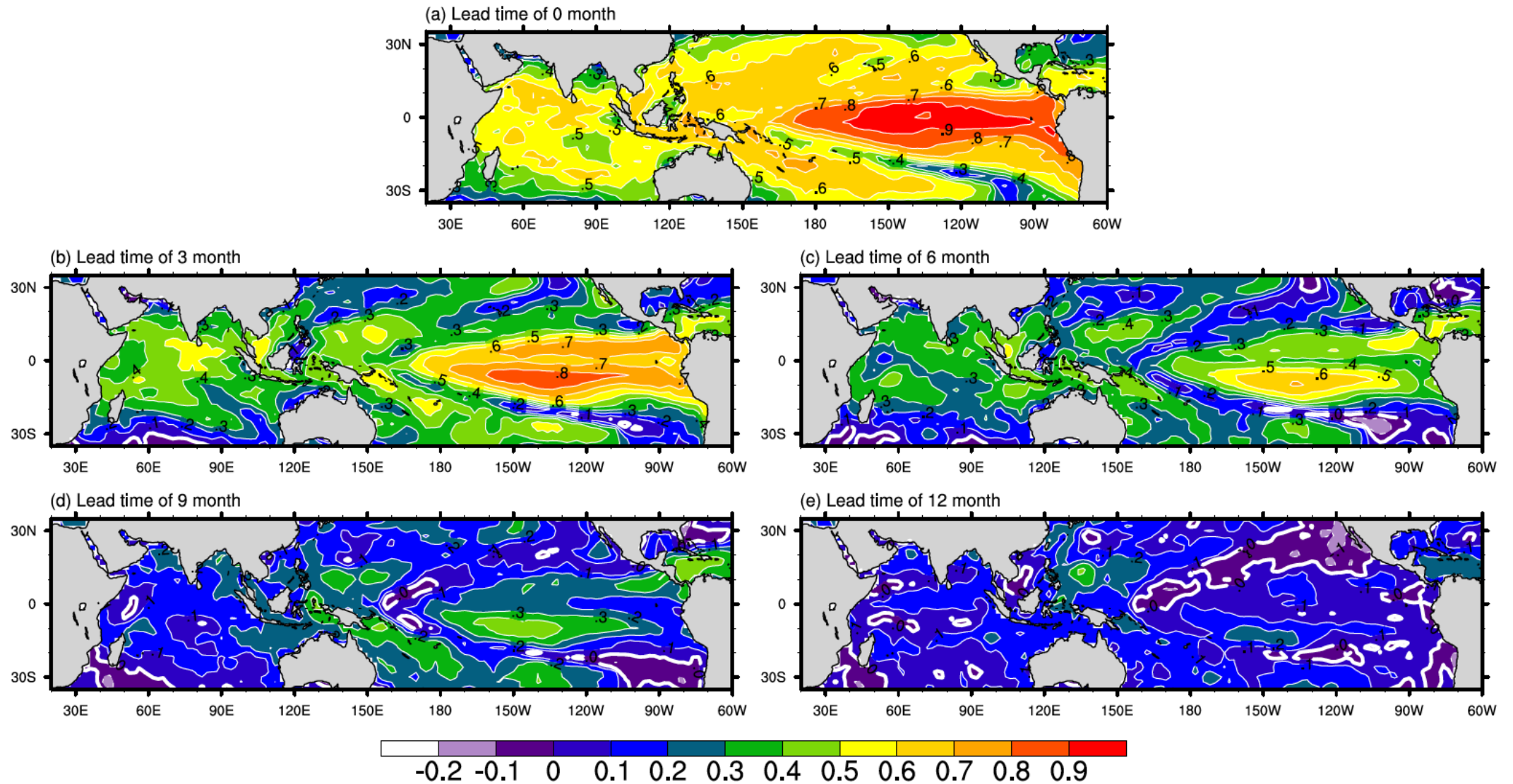


SST-only CESM1-based analogs

Evaluation of SST hindcast at six-month lead



SST-only observations-based analogs



CESM1-based analog forecasts of Nino3.4 SST at **six-month lead** as a function of the number of analogs (abscissa) and the length of training periods (ordinate)

