

Multi-Model Ensemble ENSO Prediction with CCSM3.0; CCSM3.5 and CFS

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Studies



Why?

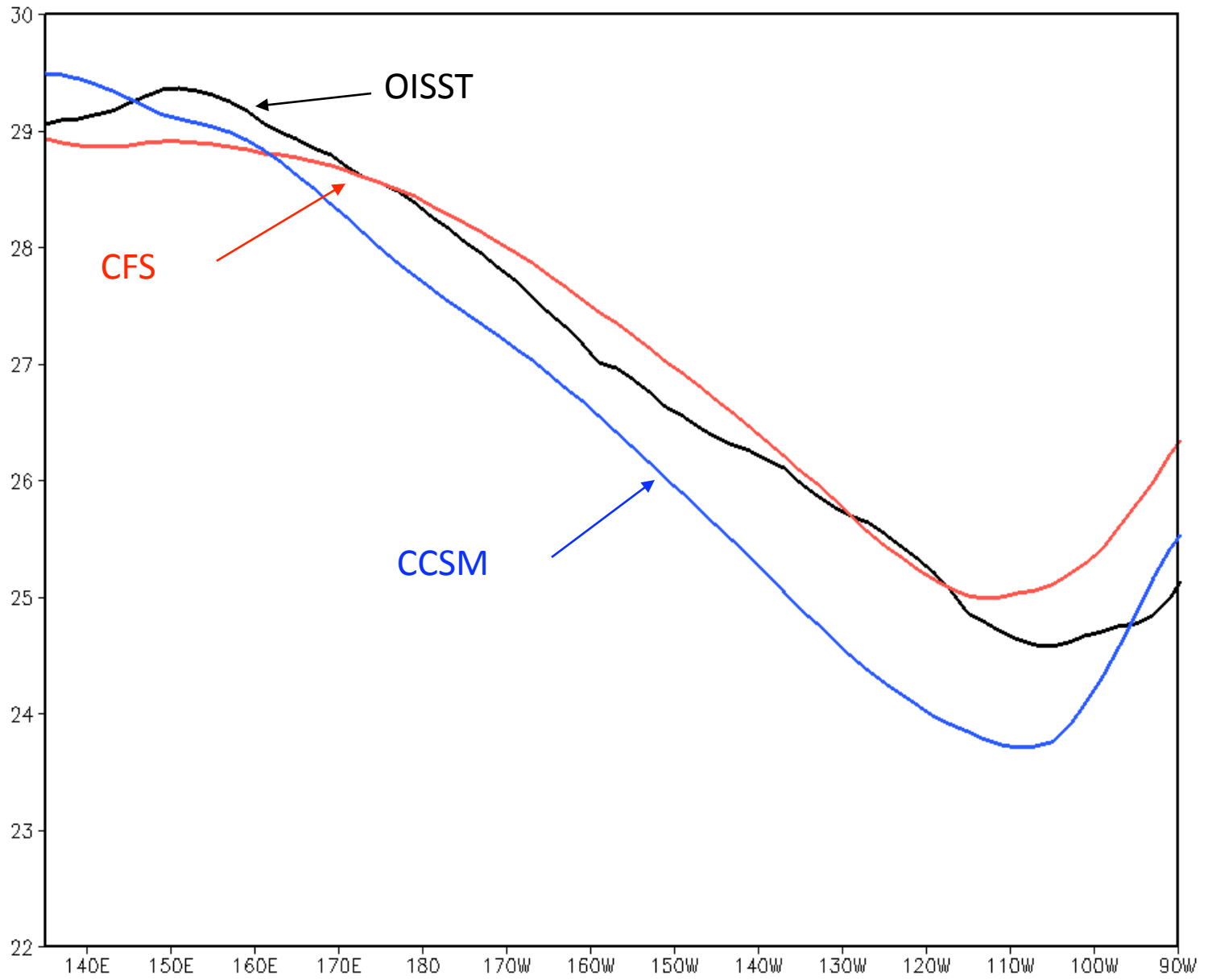
- Multi-Model Methodologies Are a Practical Approach to Quantifying Forecast Uncertainty Due to Uncertainty in Model Formulation
 - And, Apparently Improve Forecast Quality
- US National Multi-Model Capability
 - Results with CCSM3.0 (and 3.5) Encouraging
 - Use Existing Operational Analyses for Initialization (CFSRR for Retrospective Forecasts)
- Another way of Validating Model

No Determination of Which Model is “Better” - Depends on Time and Start Month and the Debate is Counter Productive

ENSO Prediction with CCSM and CFS

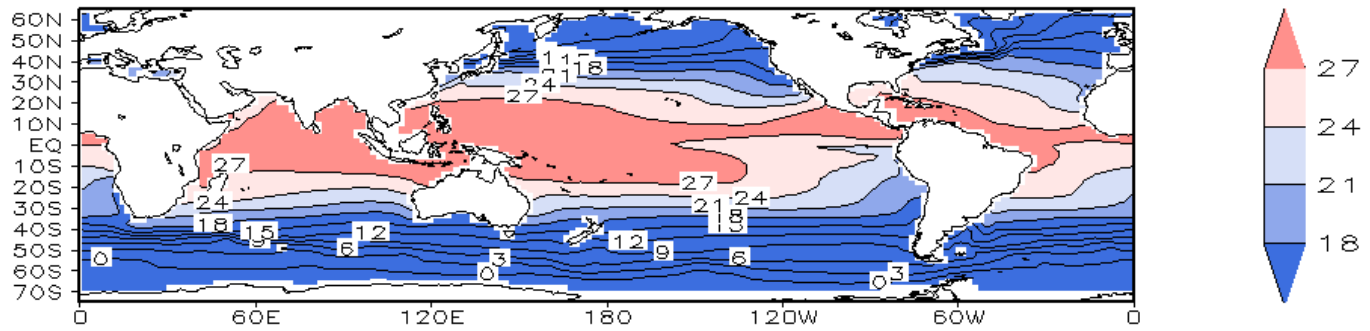
- Largely Focus on Nino3.4 Forecast Quality (skill)
- Simulation Issues (Characteristics/Errors) Relevant to the Problem
- Ocean Initialization
 - Crude, A Lot More Can Be Done
- Forecast Quality Assessment
 - CCSM3.0 vs. CFS
 - Deterministic and Probabilistic
- **Prediction Results with CCSM3.5**
 - Good News
 - Rainfall Results
- Random Thoughts

Equatorial Pacific SST

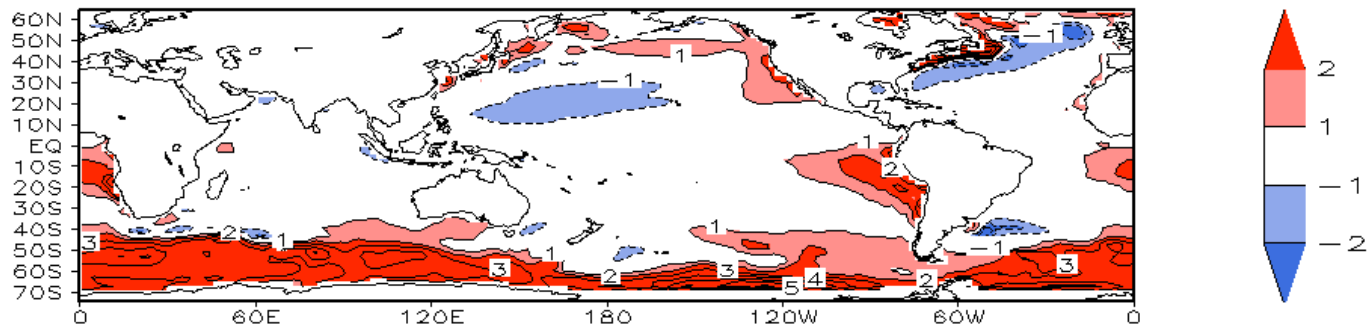


Annual Mean Sea Surface Temperature

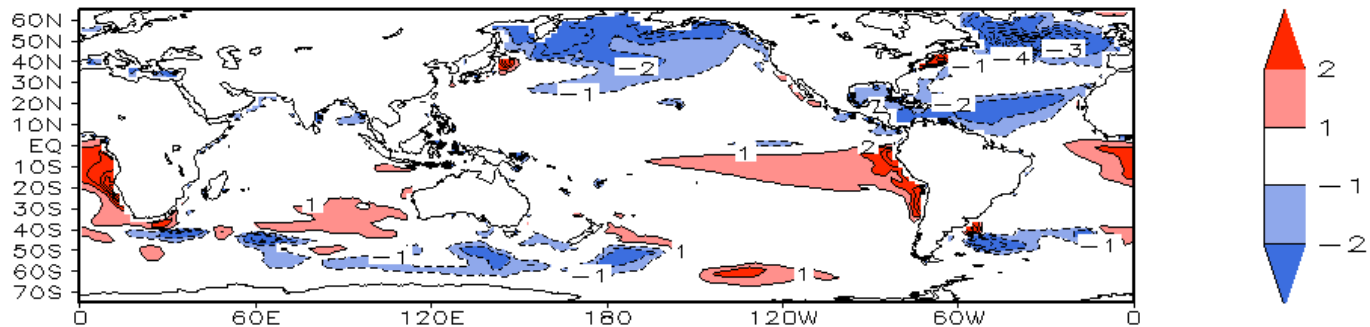
OISST



CFS Error

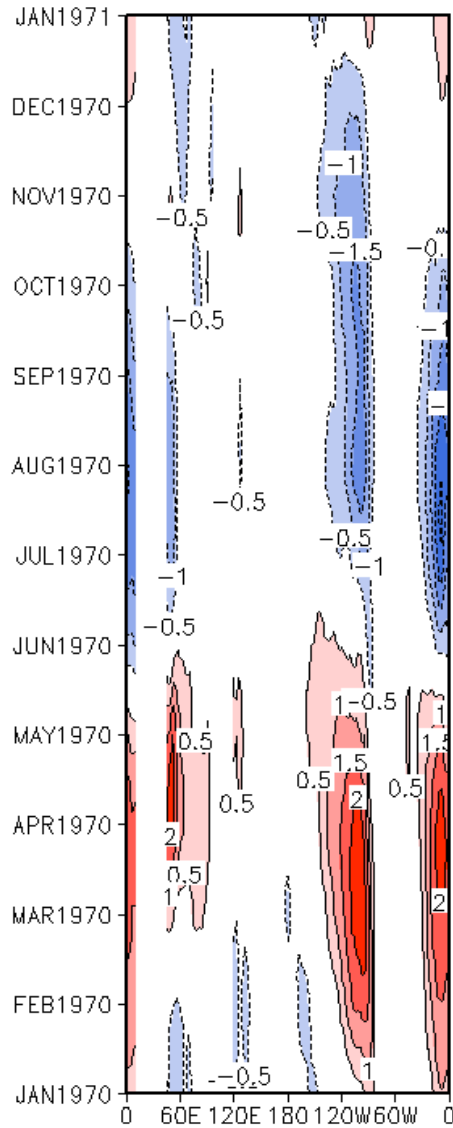


CCSM Error

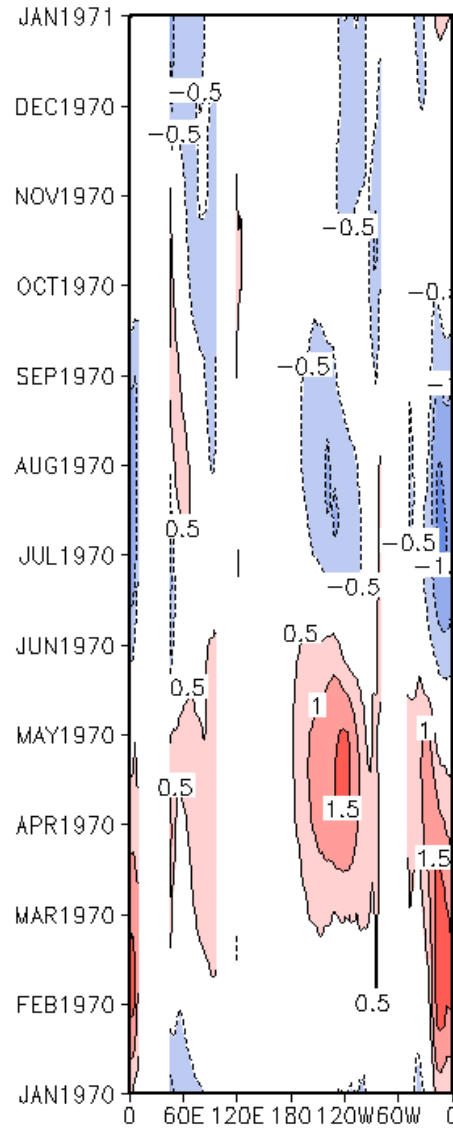


Equatorial SST Annual Cycle

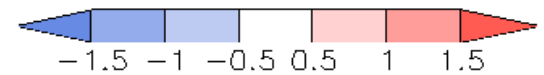
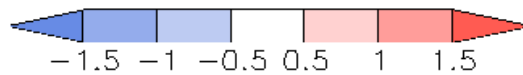
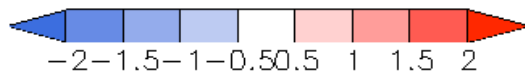
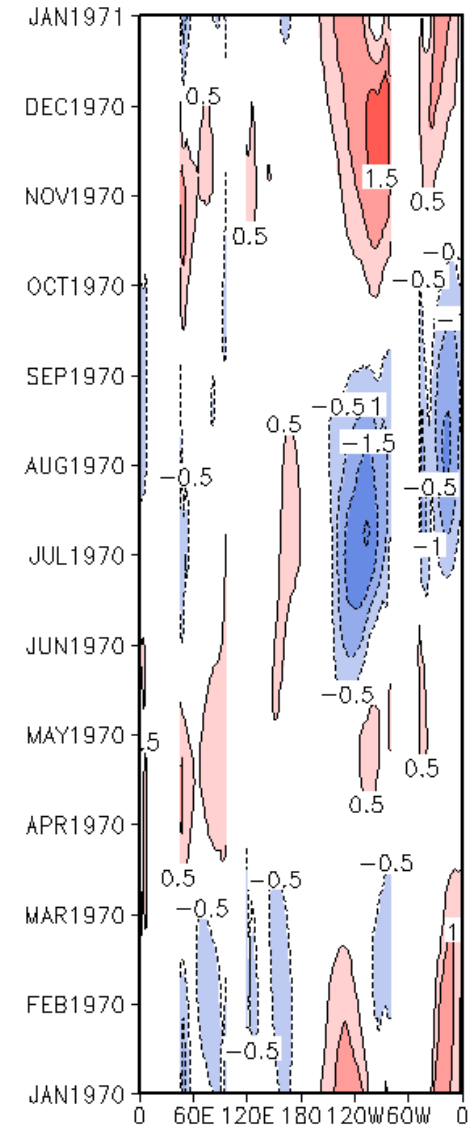
OISST



CFS

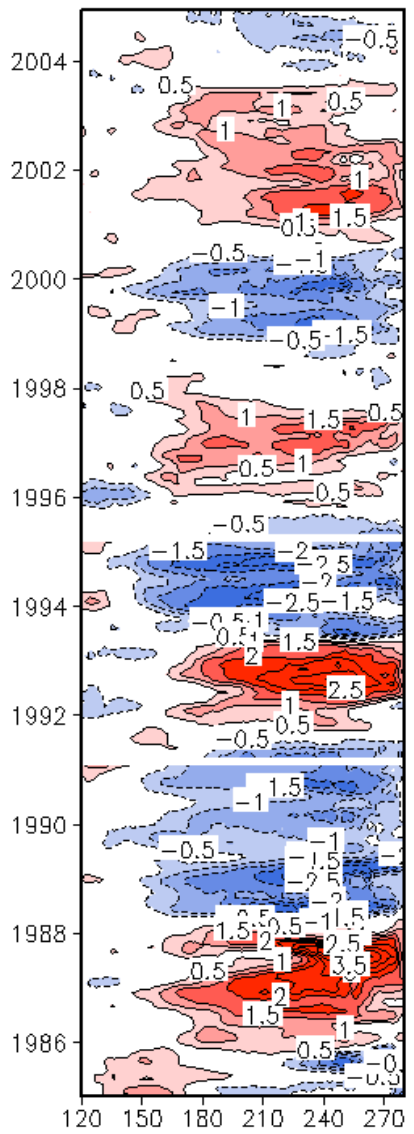


CCSM

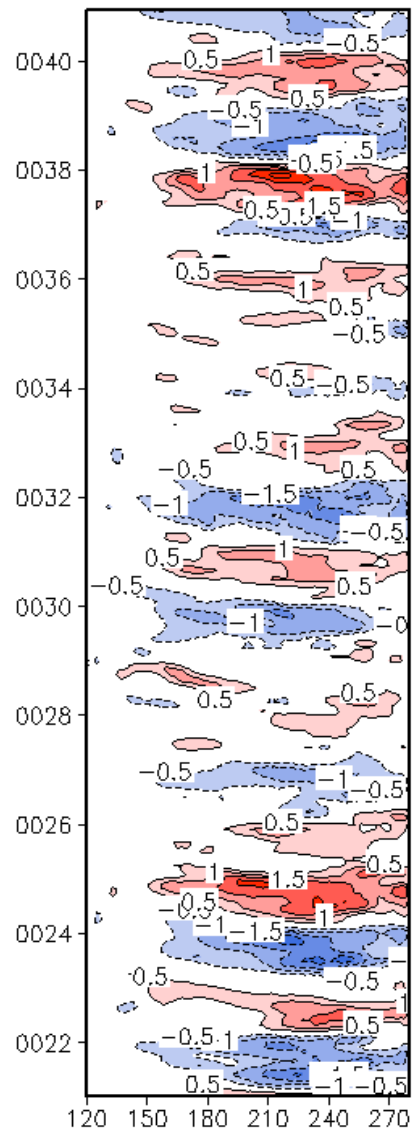


Equatorial Pacific SSTA

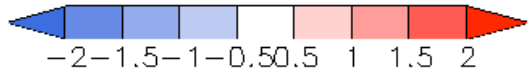
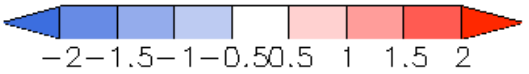
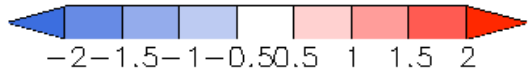
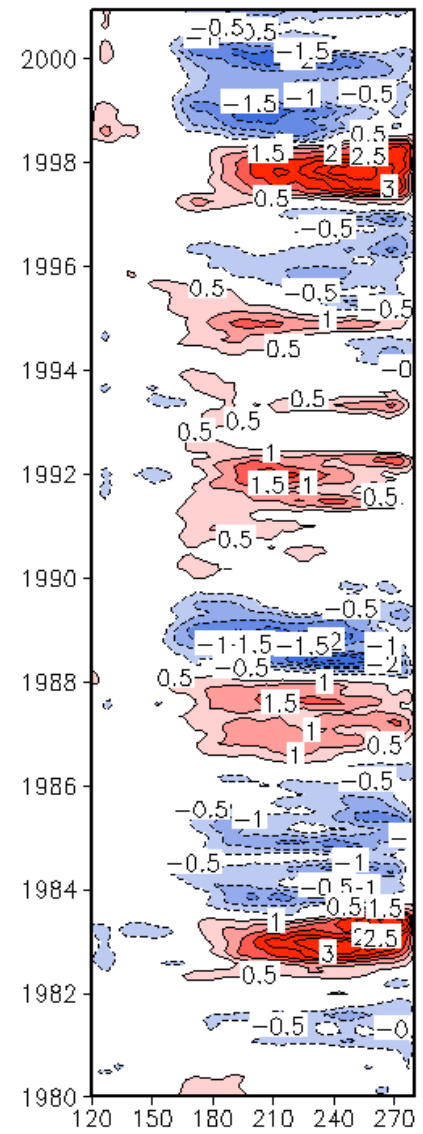
CFS



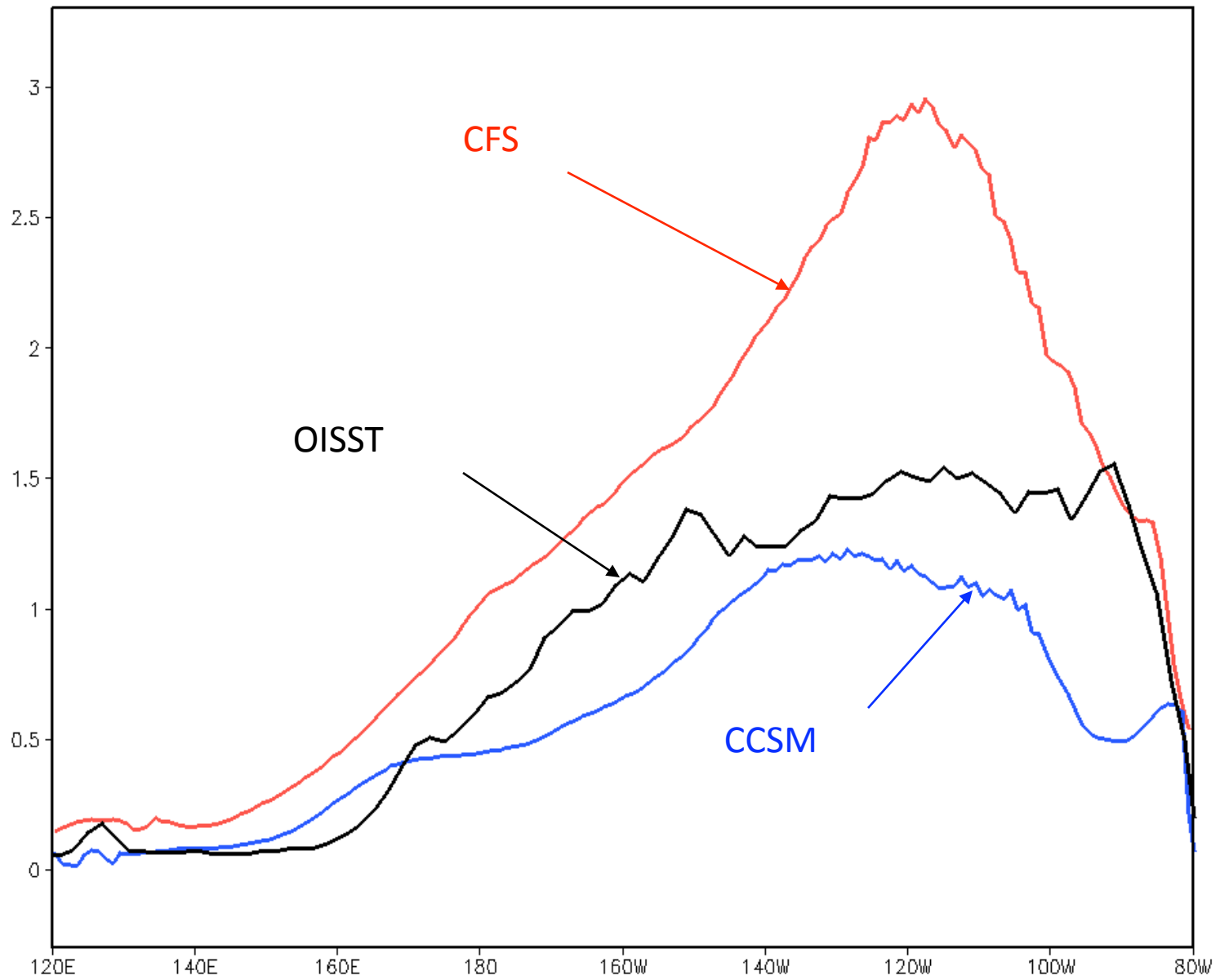
CCSM



OISST



Equatorial Pacific SST Variance



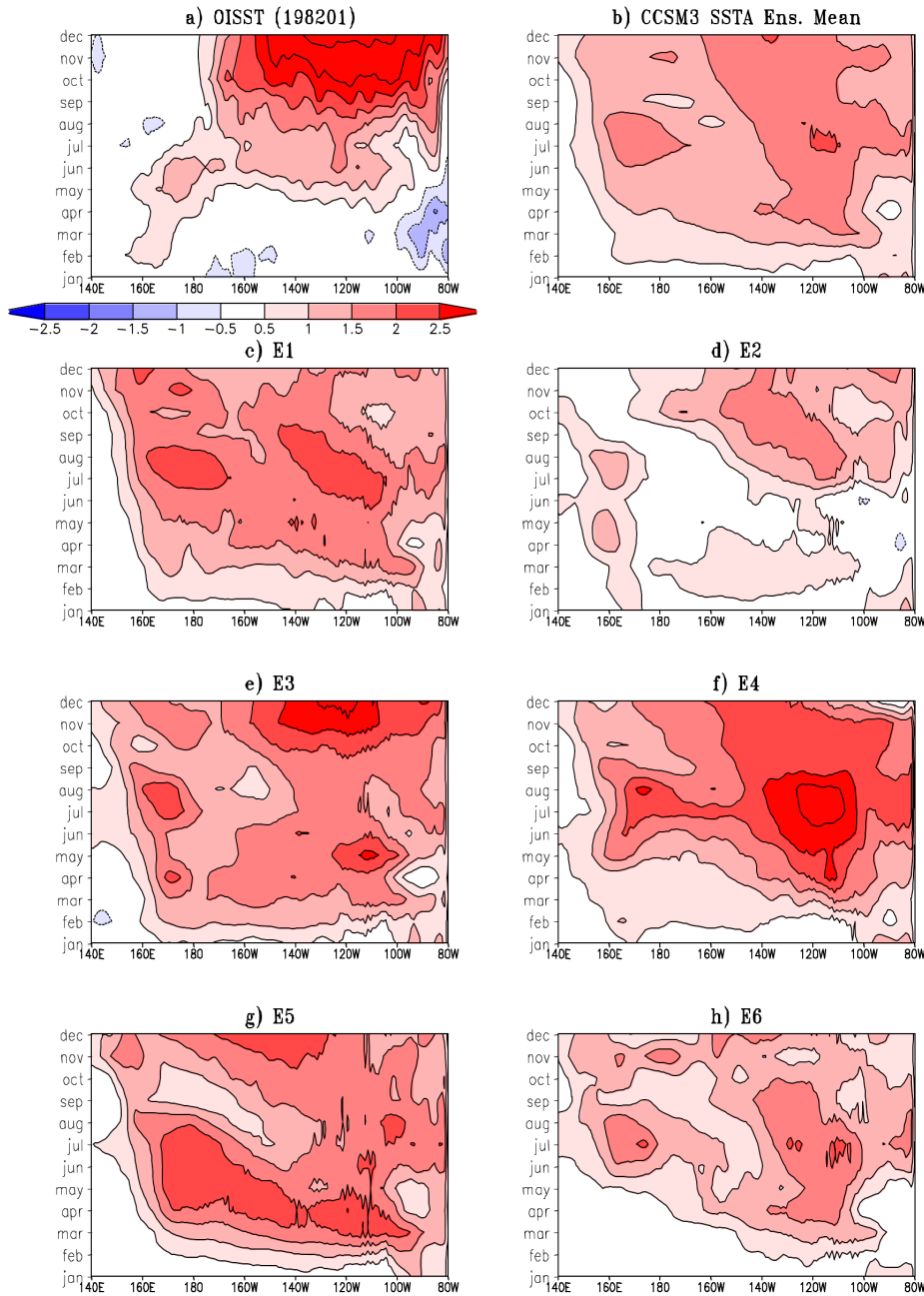
Forecast Initialization

- Atmosphere-Land-Sea Ice Initialization via “AMIP” e.g., No Observational Data
 - **Land-Atmosphere Initialization Experiments Completed (Paolino et al.)**
- GFDL MOM3 Ocean Data Assimilation Interpolated to CCSM3 (POP)
 - Number of Technical Issues
 - Room for Improving Forecast Initialization
- Future Use CFSRR and Operational Analysis

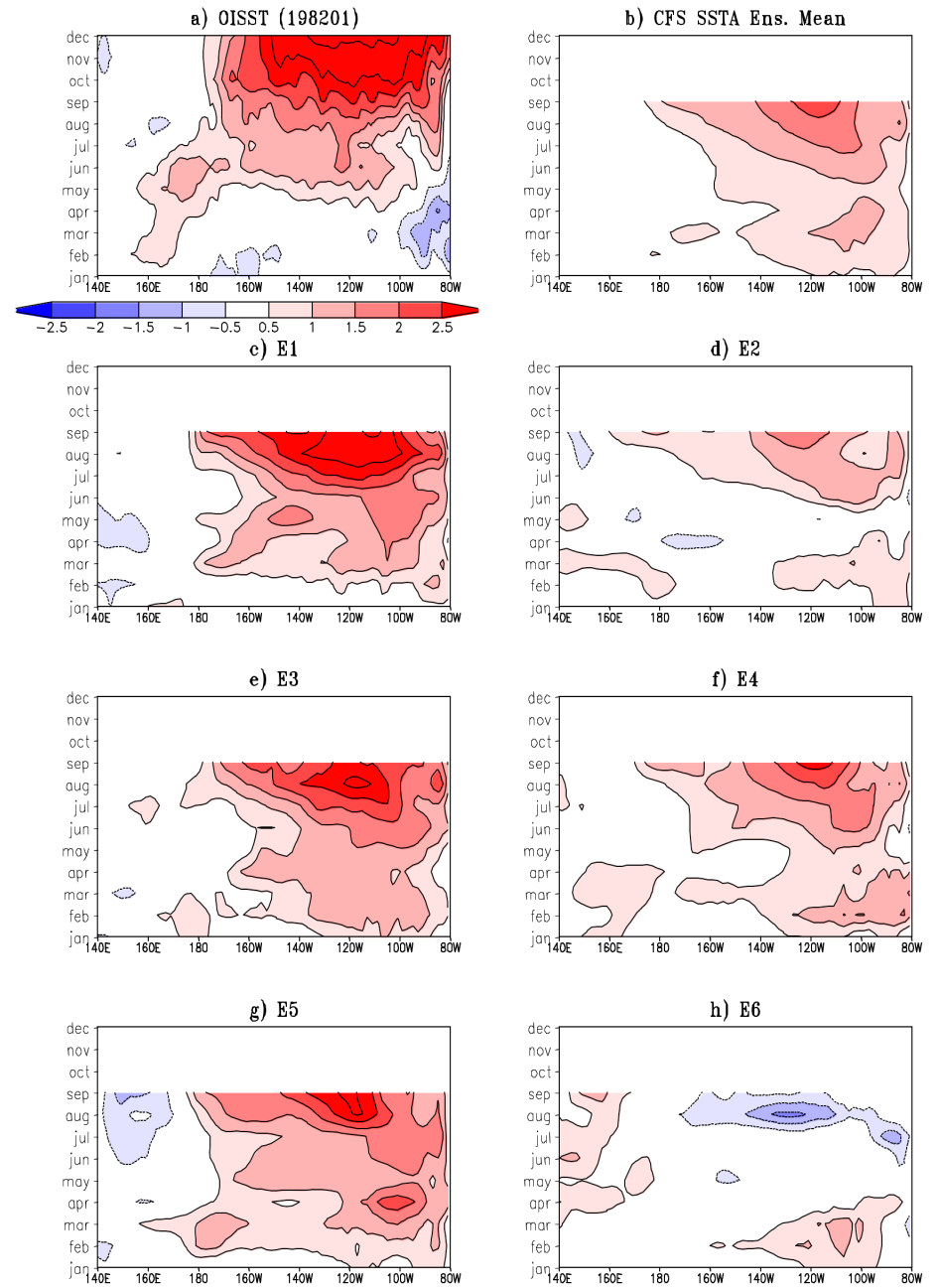
Nino3.4 Multi-Model Forecast Assessment

- **Initial Conditions**
 - CFS: 5-Member Ensembles, December 30-January 3 (ODA-January 1) 1982-1998
 - CCSM3: 6-Member Ensembles January 1 1982-1998
 - Similarly with April, July and November Starts
- **Emphasis on Nino3.4**
 - Deterministic and Probabilistic Verification
- **Much More Work Needed Verifying and Diagnosing Forecast**

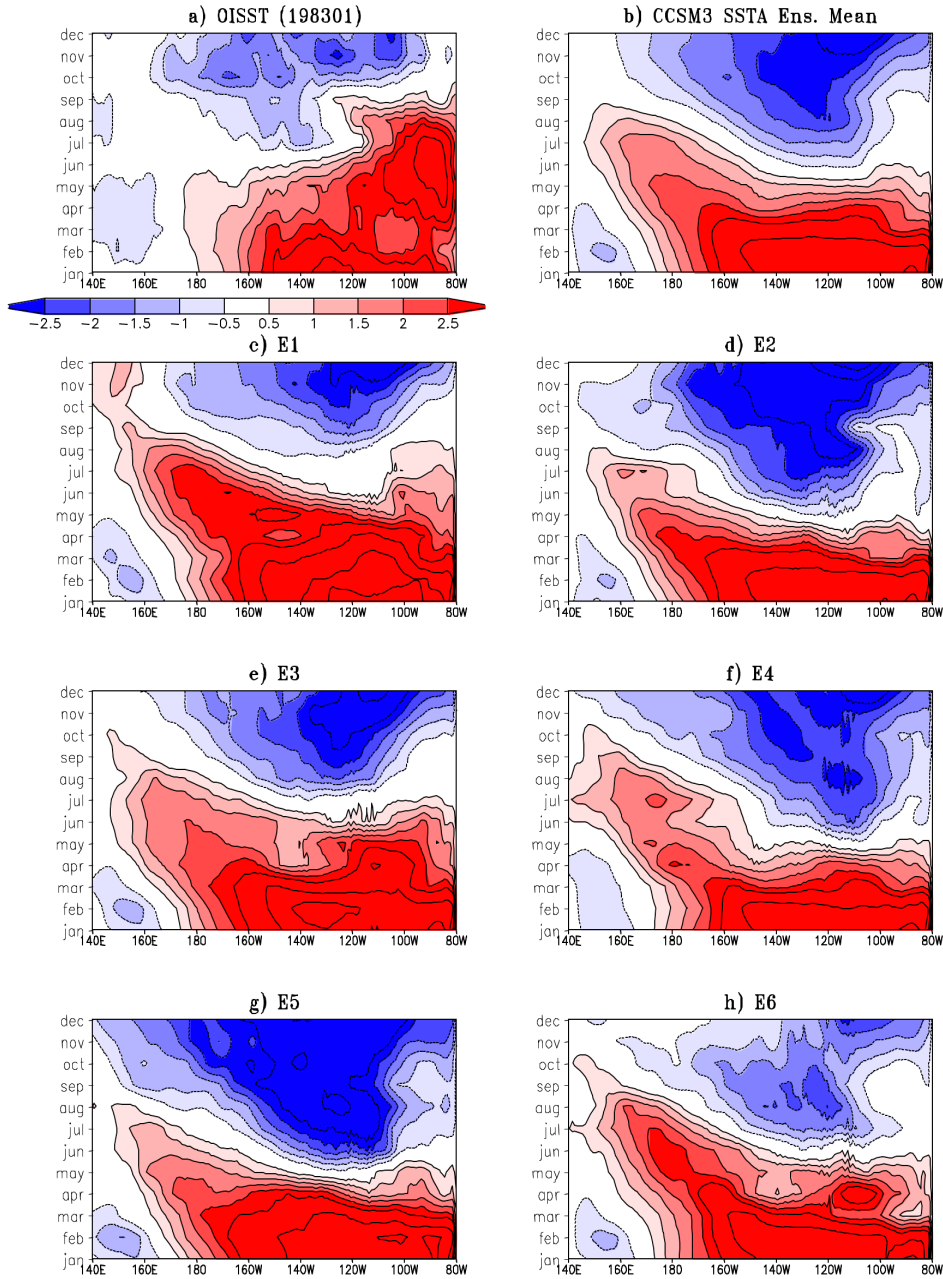
CCSM3.0 Jan 1982 IC



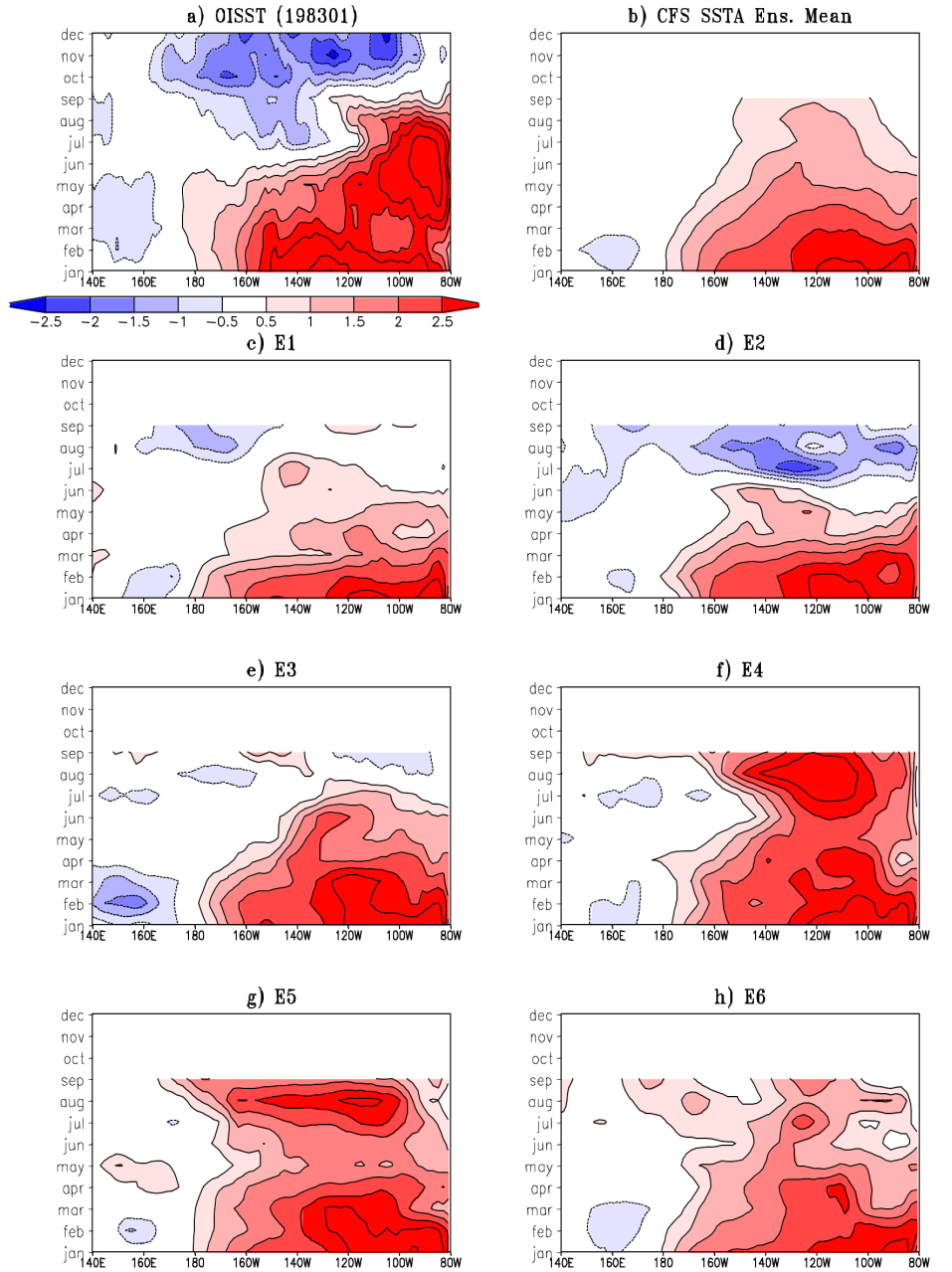
CFS Jan 1982 IC



CCSM3.0 Jan 1983 IC

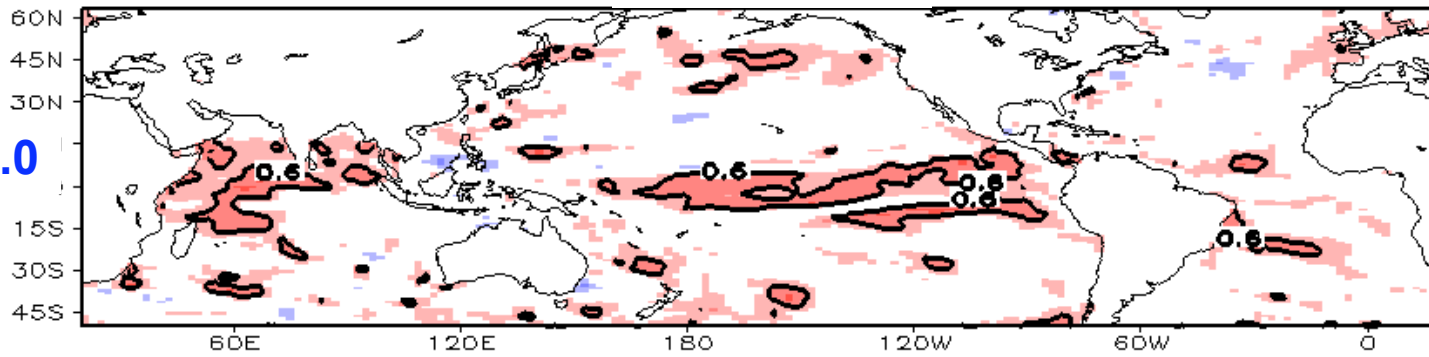


CFS Jan 1983 IC

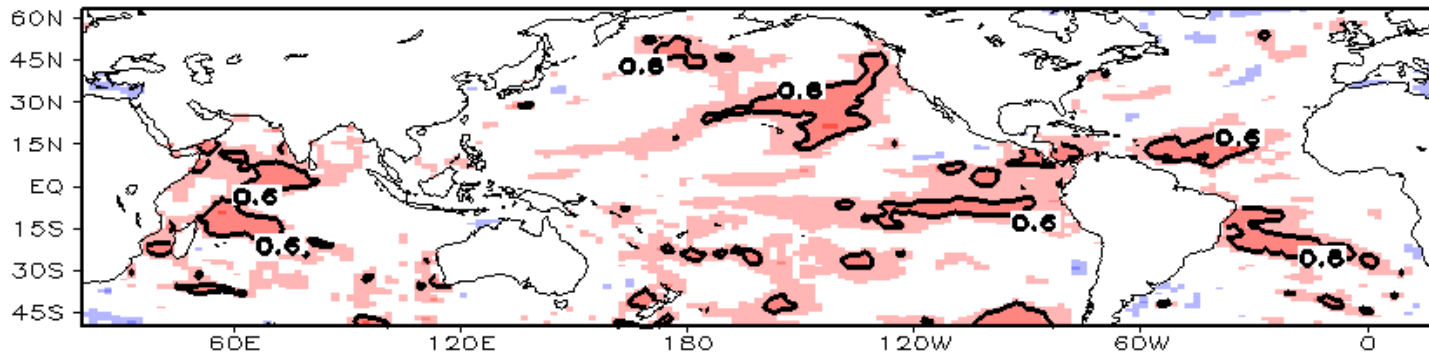


Correlation (Jan IC 6 Month Lead Time)

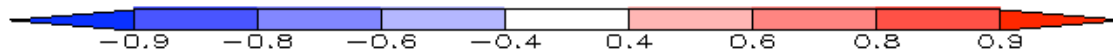
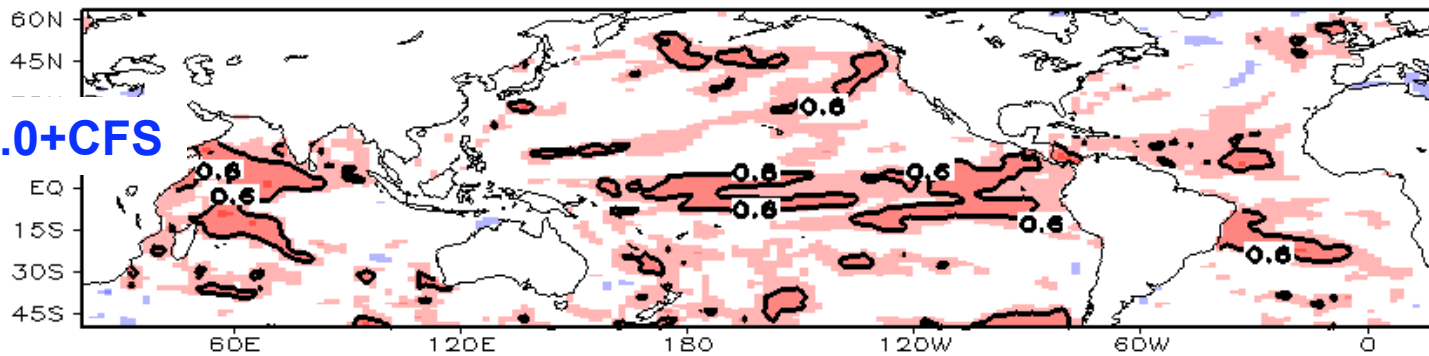
CCSM3.0



CFS

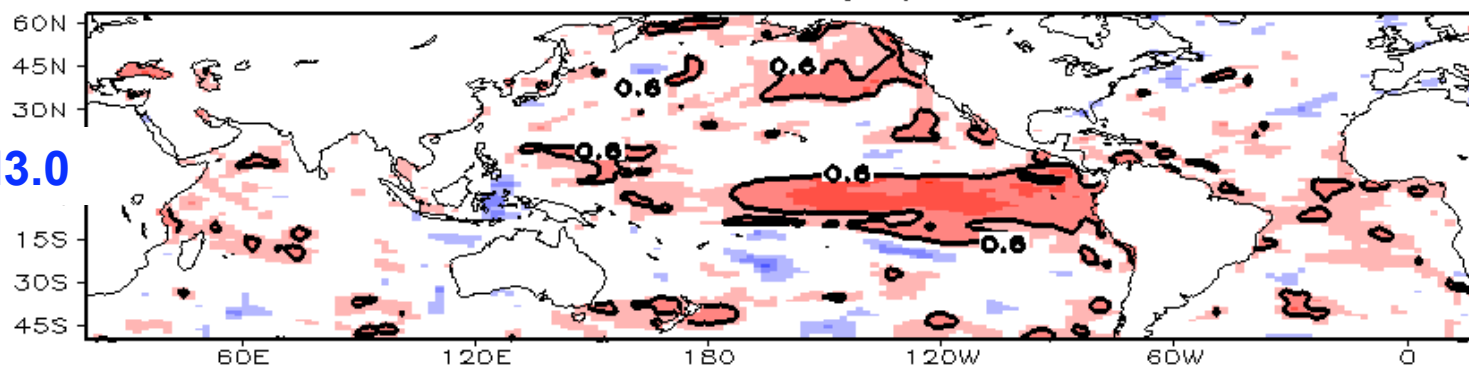


CCSM3.0+CFS

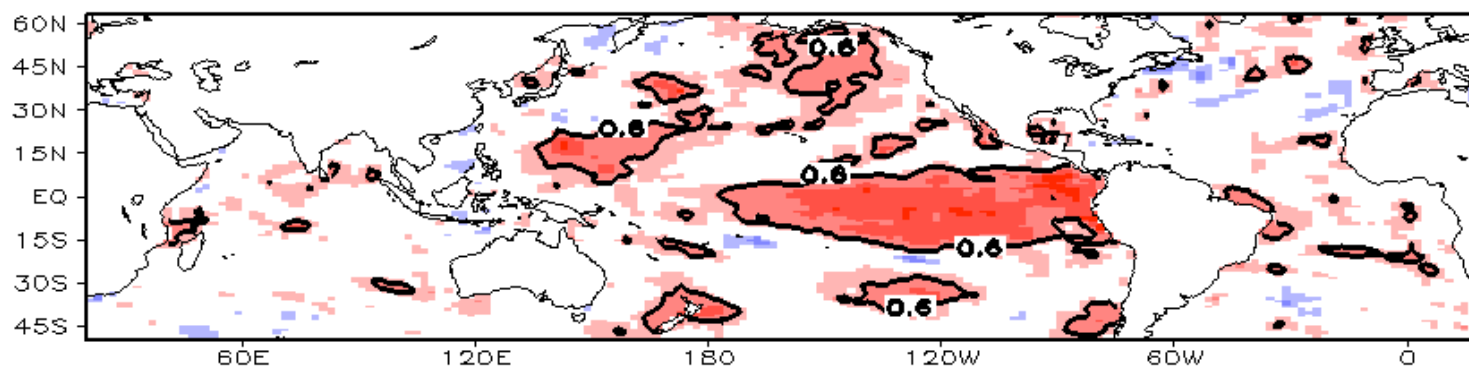


Correlation (Jul IC 6 Month Lead)

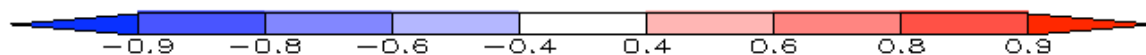
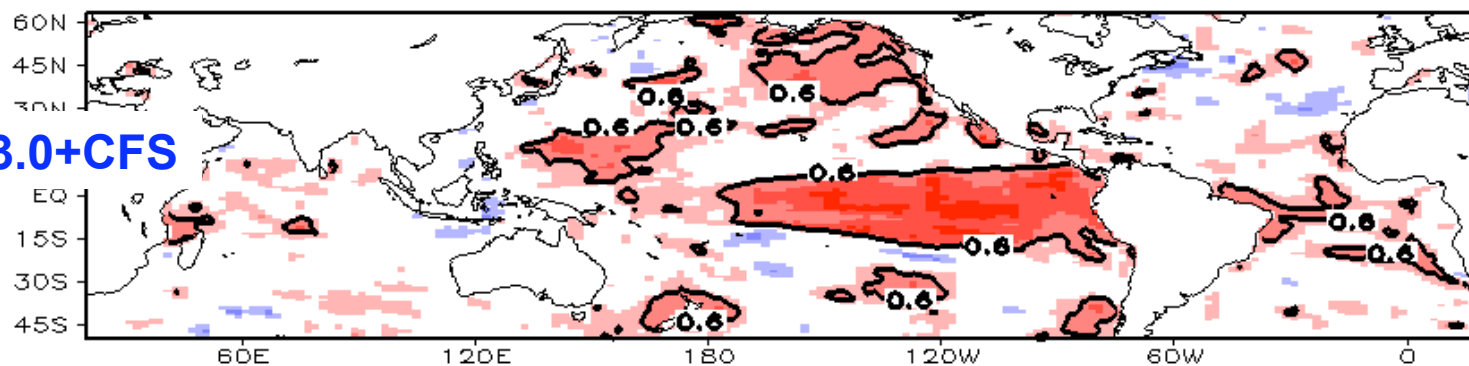
CCSM3.0



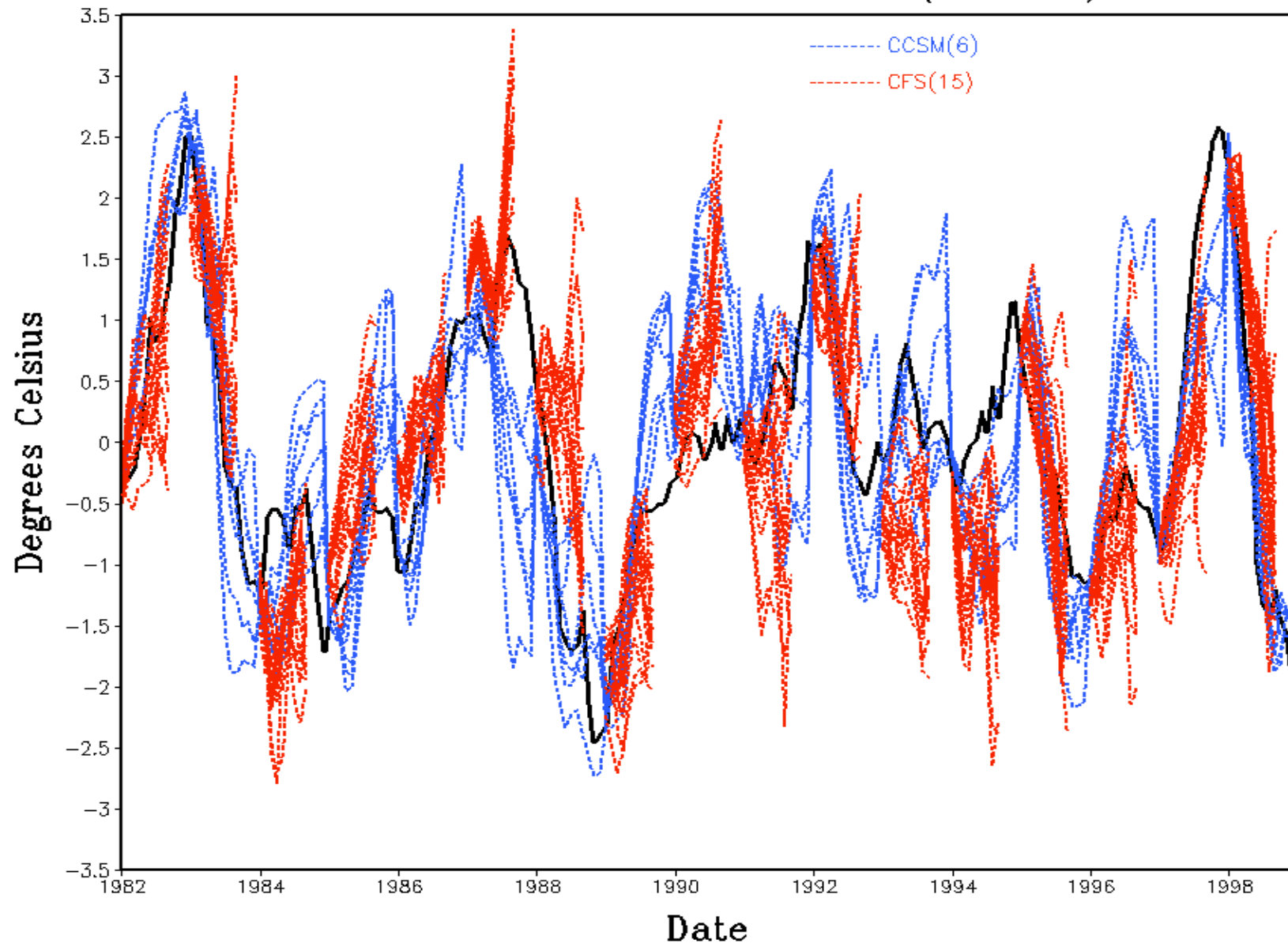
CFS



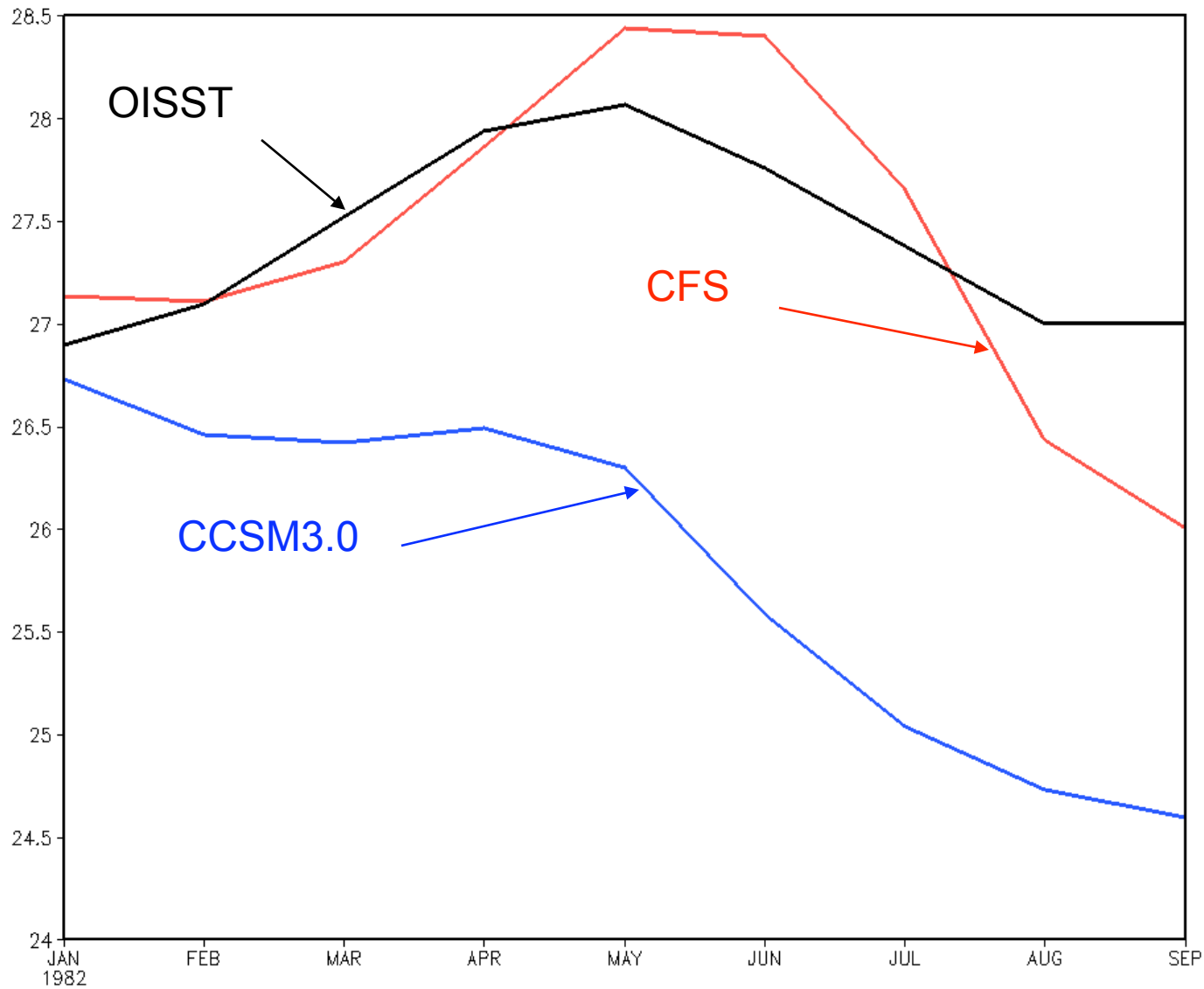
CCSM3.0+CFS



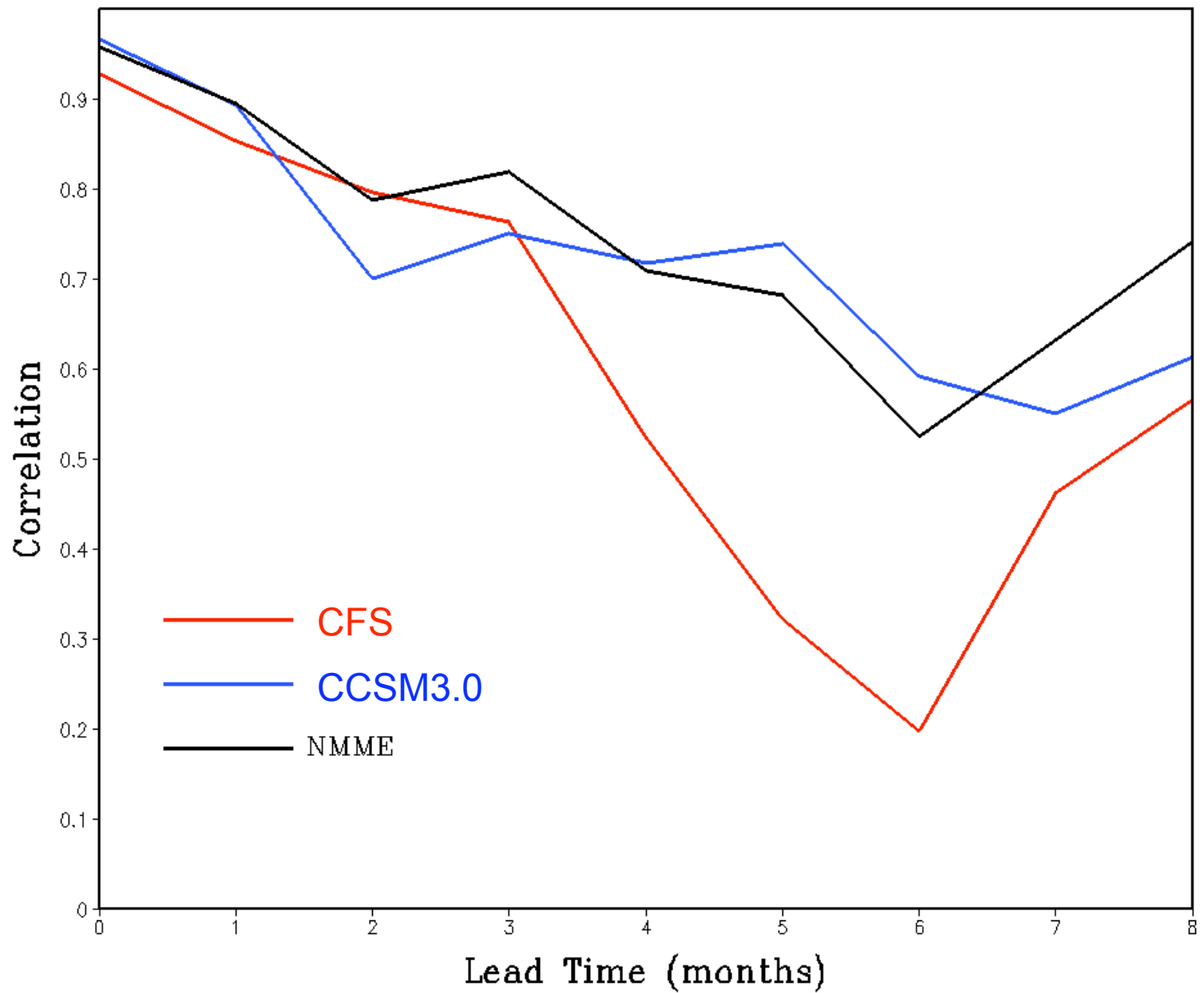
Nino3.4 SSTA Ensembles (JAN IC)



January Starts: Nino3.4 Systematic Evolution

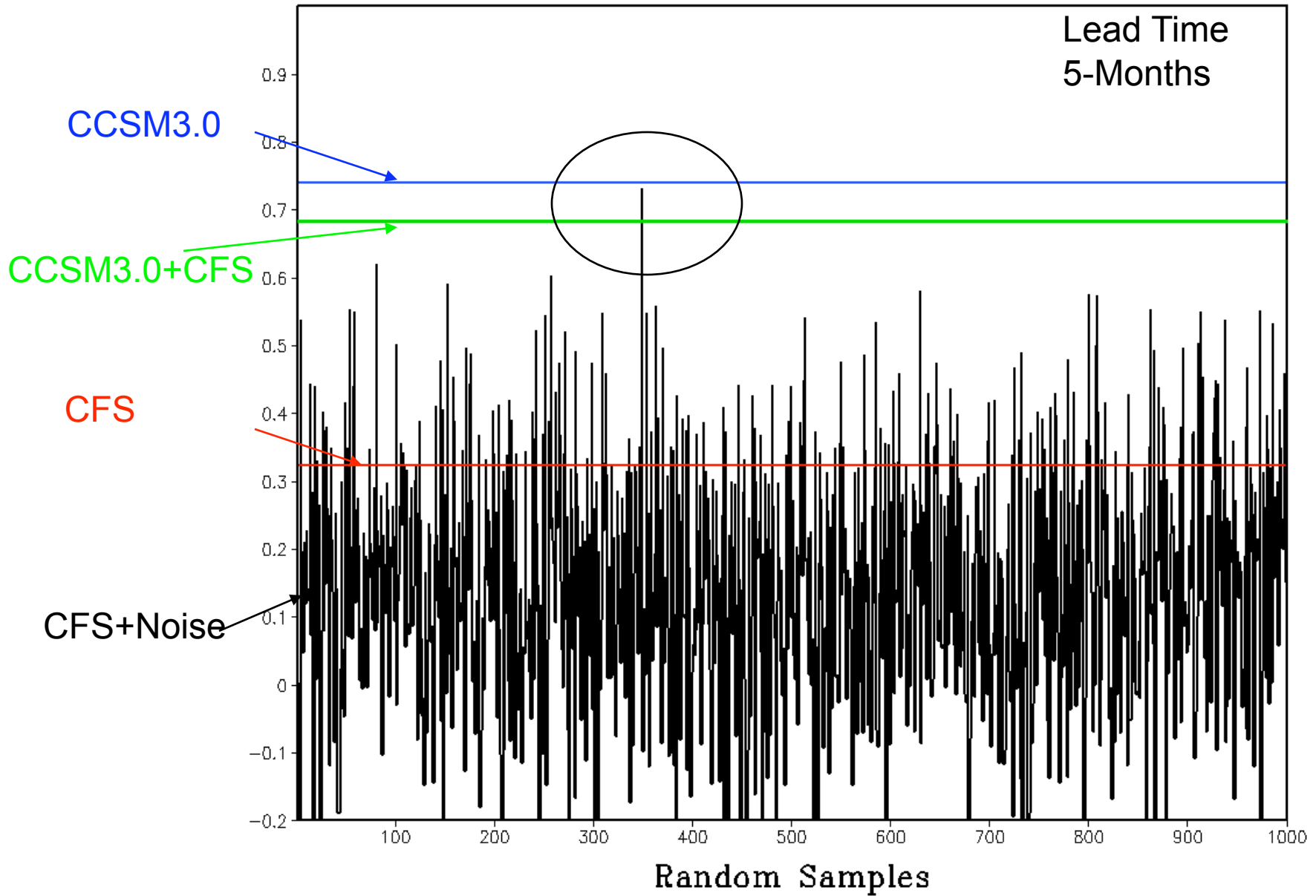


Nino3.4 Correlation 1982-1998: Jan 01 Oics

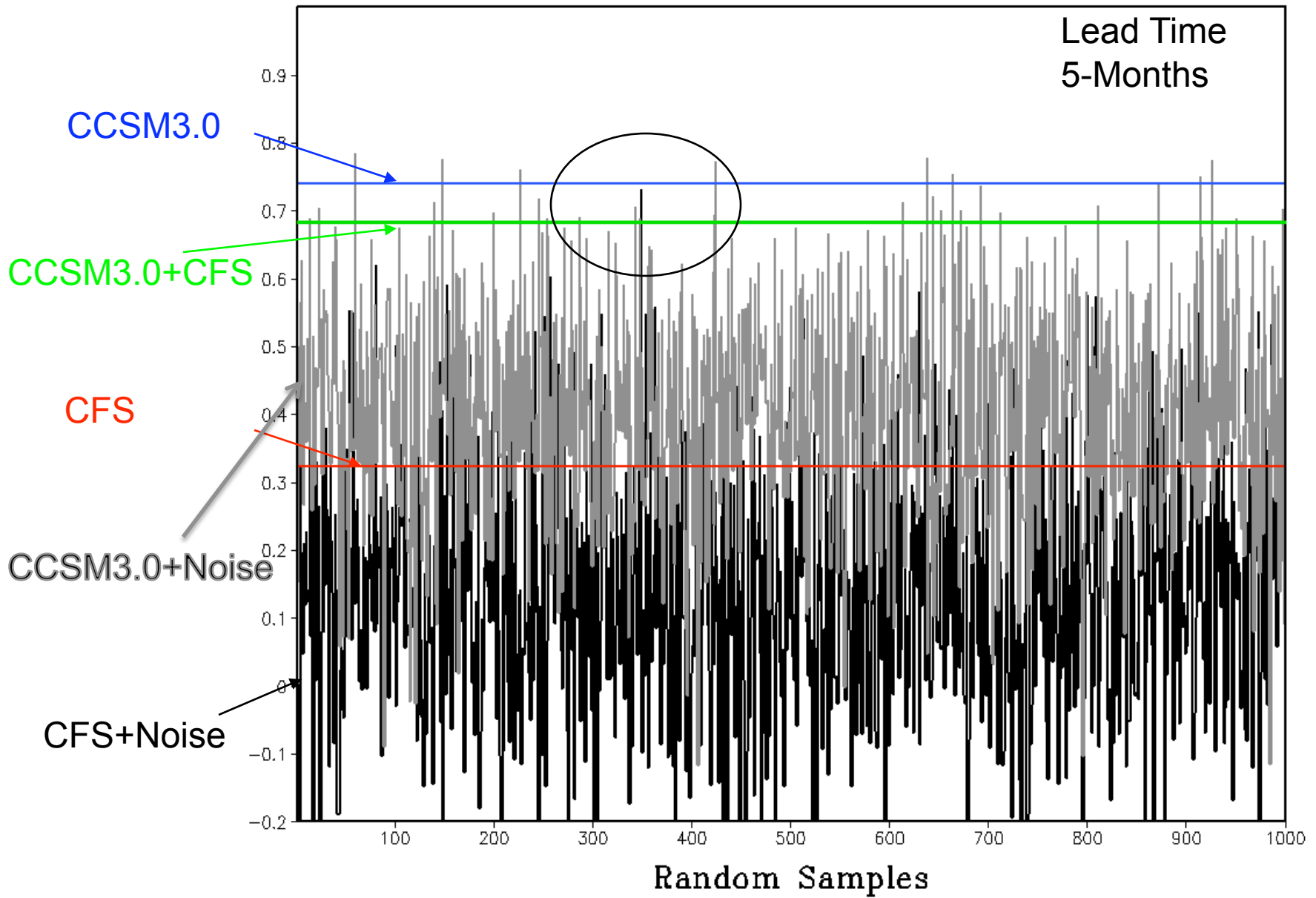


Is Multi-Model Better than Noise?

Nino34 Correlation Coefficient

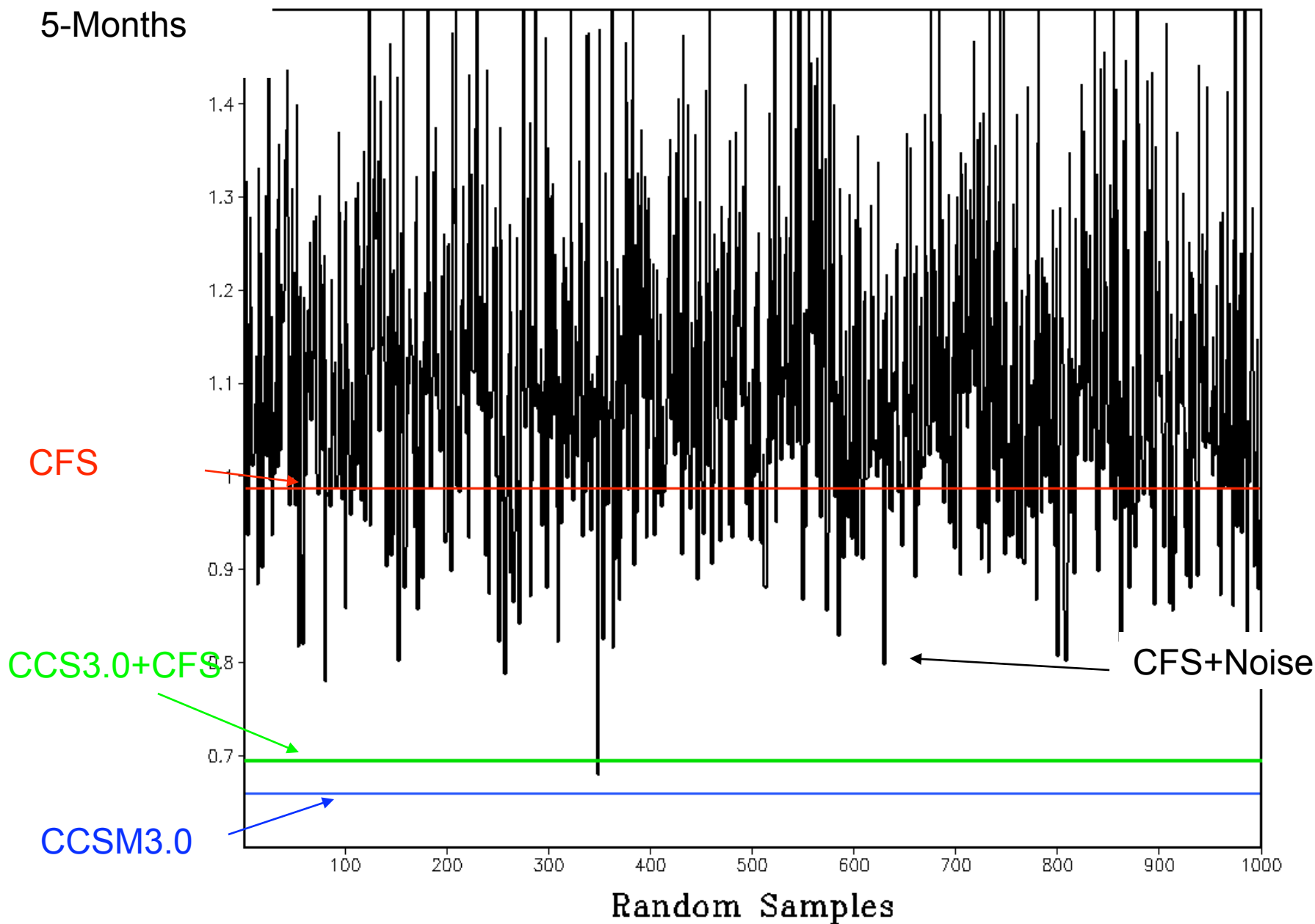


Nino34 Correlation Coefficient



Lead Time:
5-Months

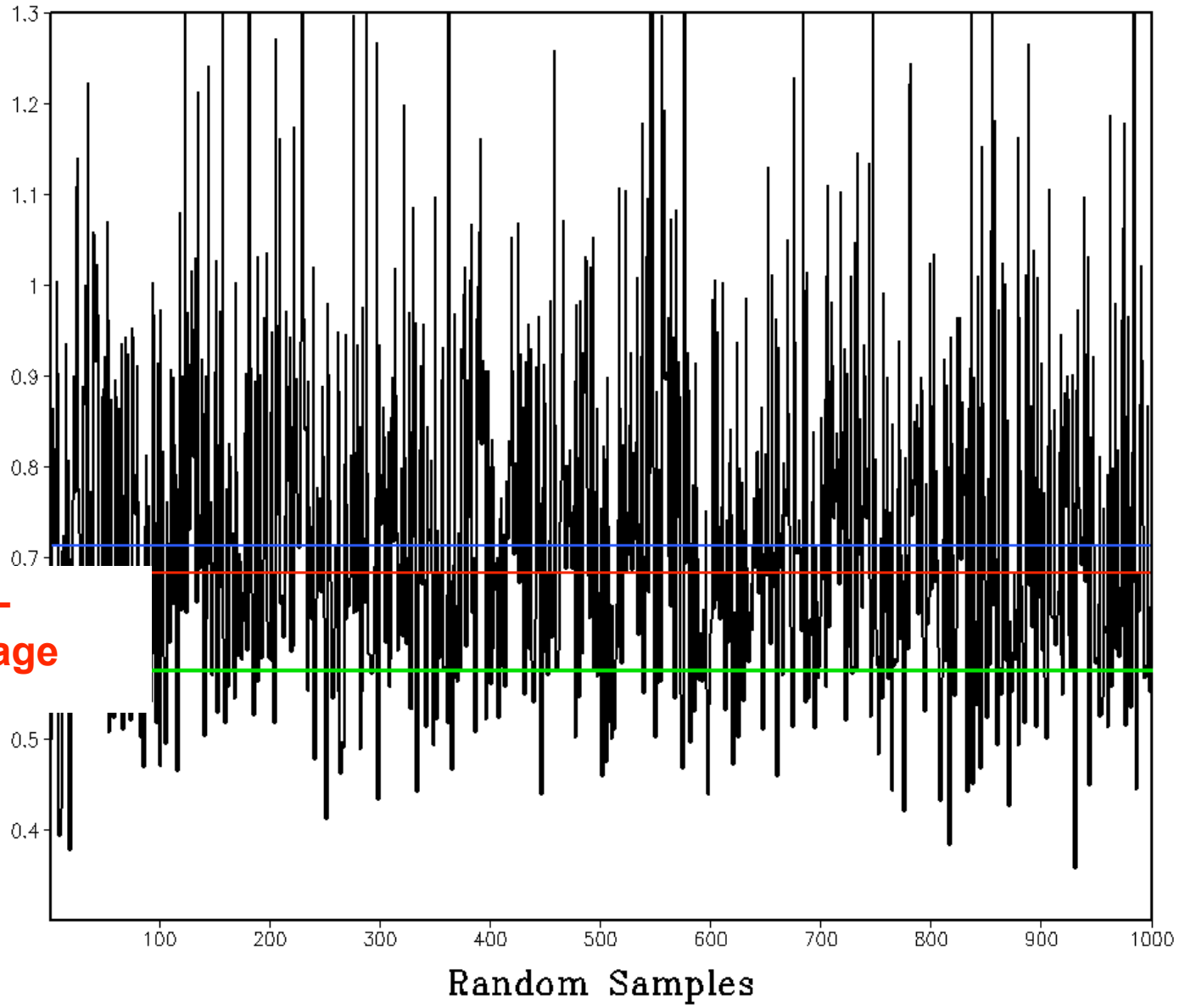
Nino34 RMSE



Nino34 RMSE

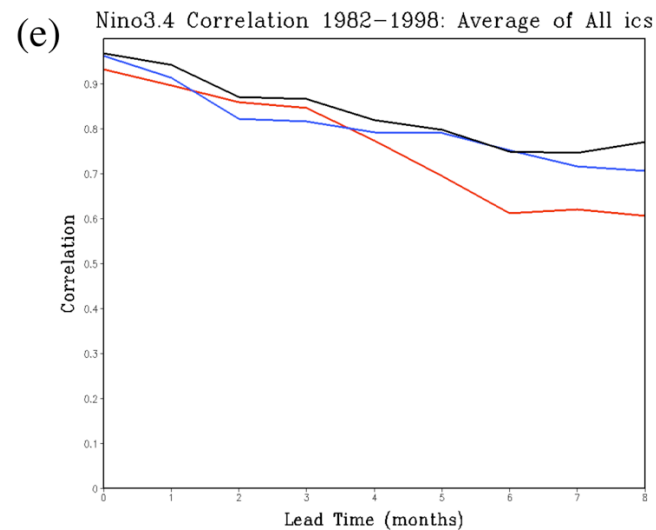
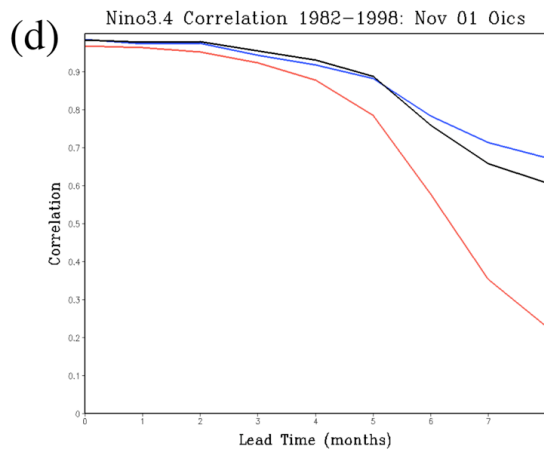
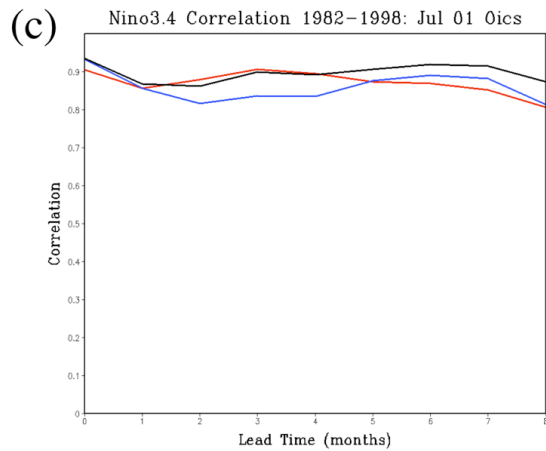
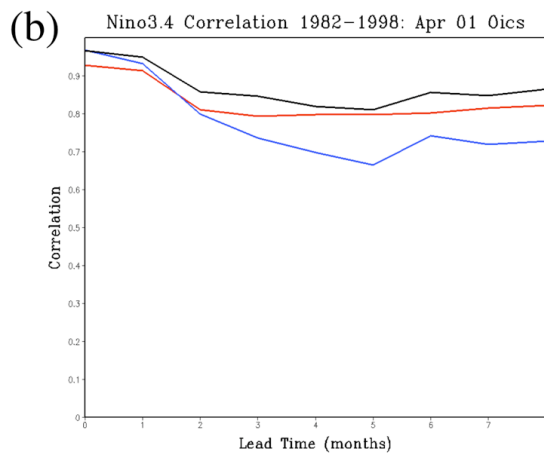
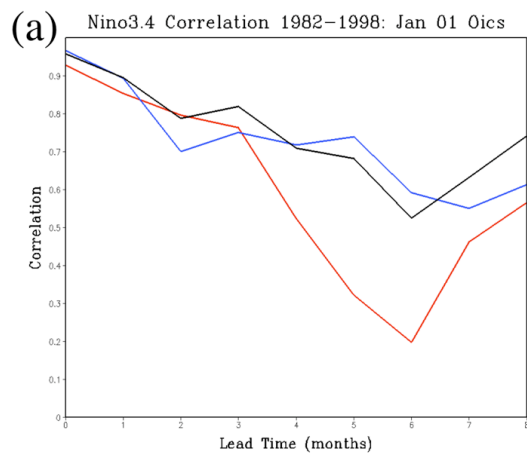
Lead-Time:
3-Months

**No Clear Multi-
Model Advantage**



Other Initial States

Nino3.4 Correlation Coefficient

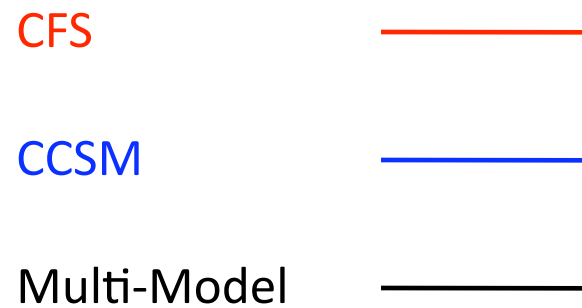
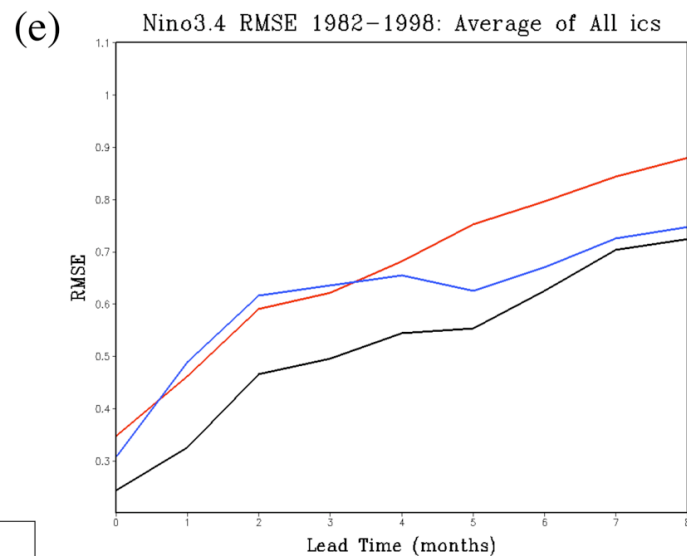
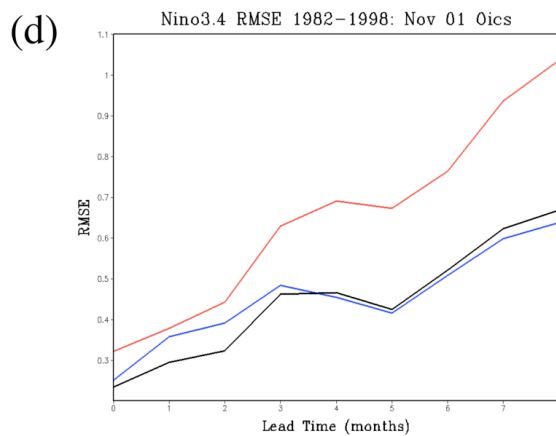
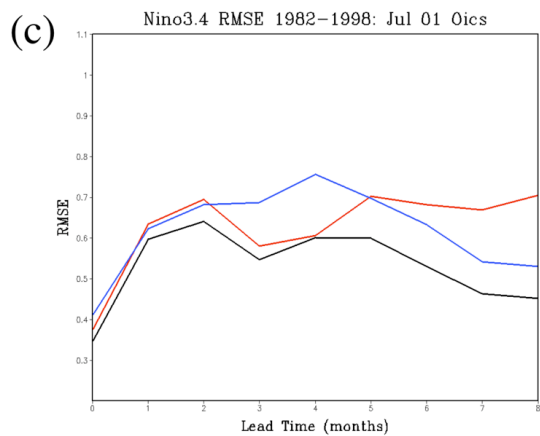
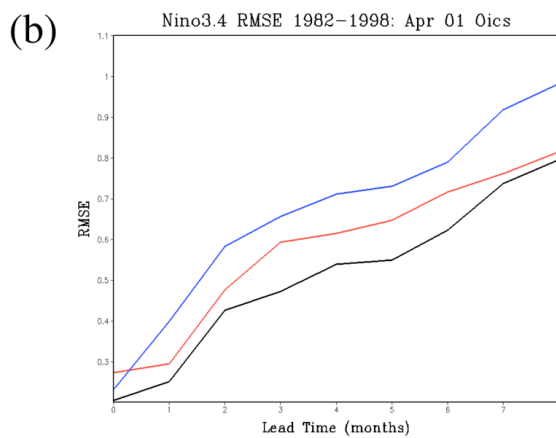
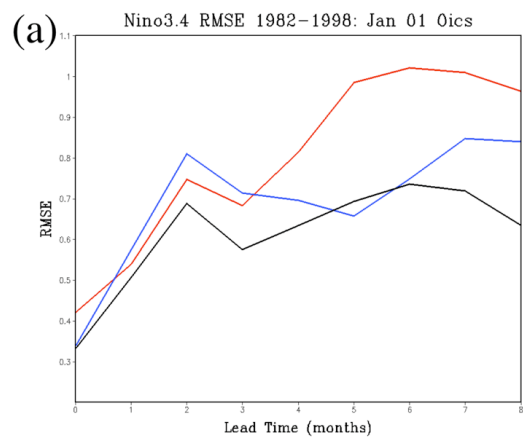


CFS —

CCSM —

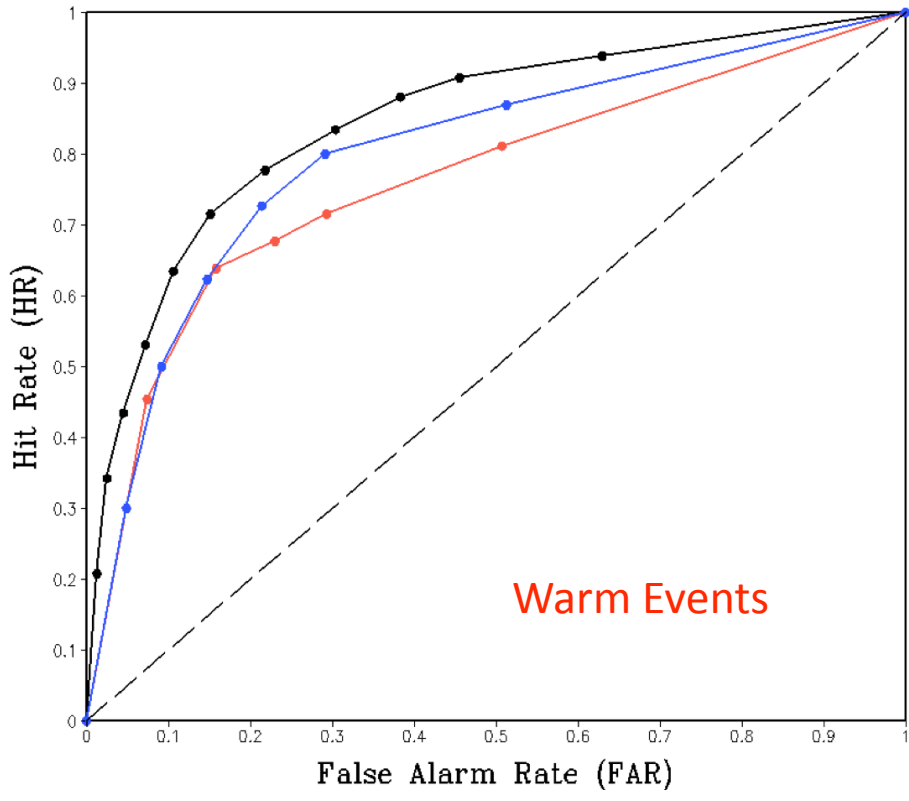
Multi-Model —

Nino3.4 Root Mean Squared Error



Probabilistic Verification

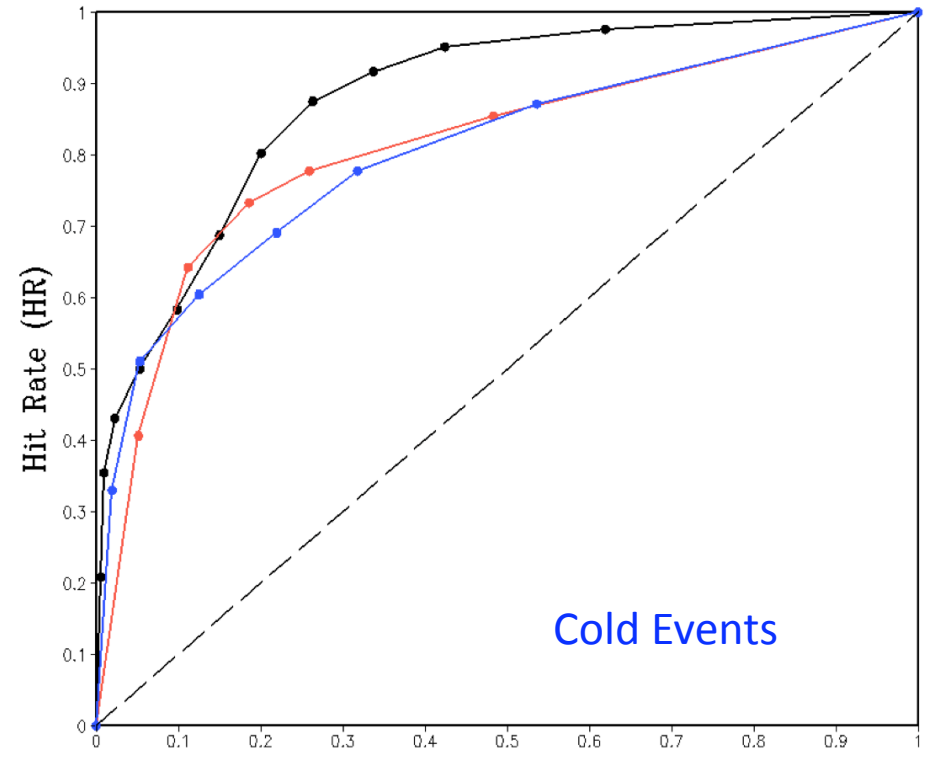
ROC Curve Warm Events 6 Month Lead



- CFS
- CCSM
- Multi-Model

Relative Operating Characteristics

ROC Curve Cold Events 6 Month Lead



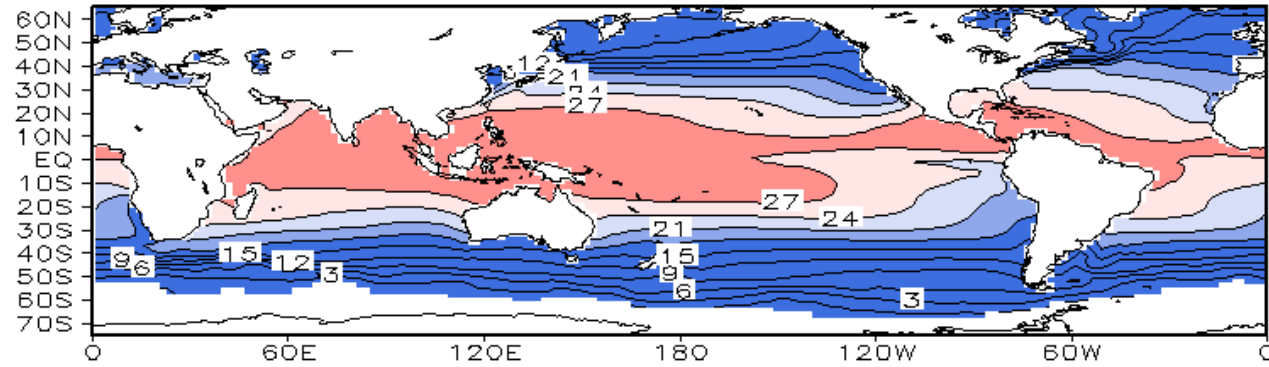
Cold Events

CCSM3.0 vs. CCSM3.5

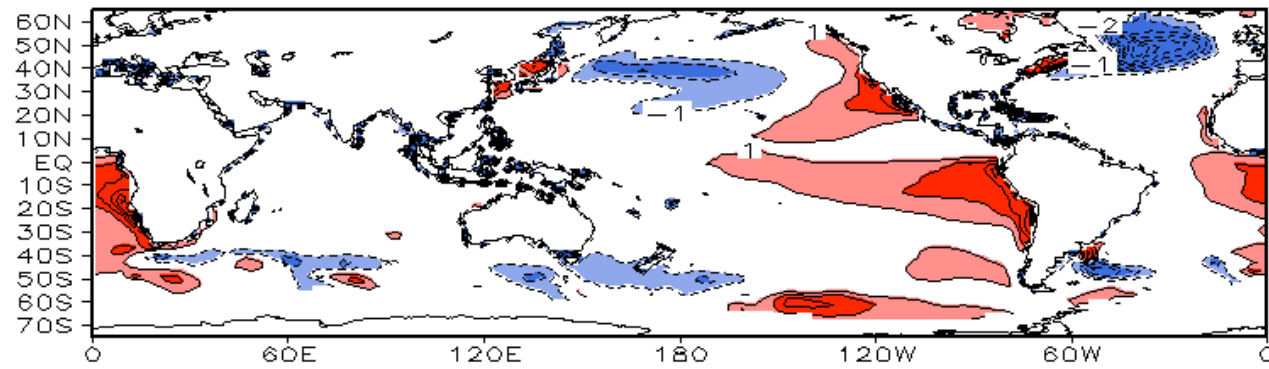
- January Cases Only
- Identical Initialization Strategy

Annual Mean Sea Surface Temperature

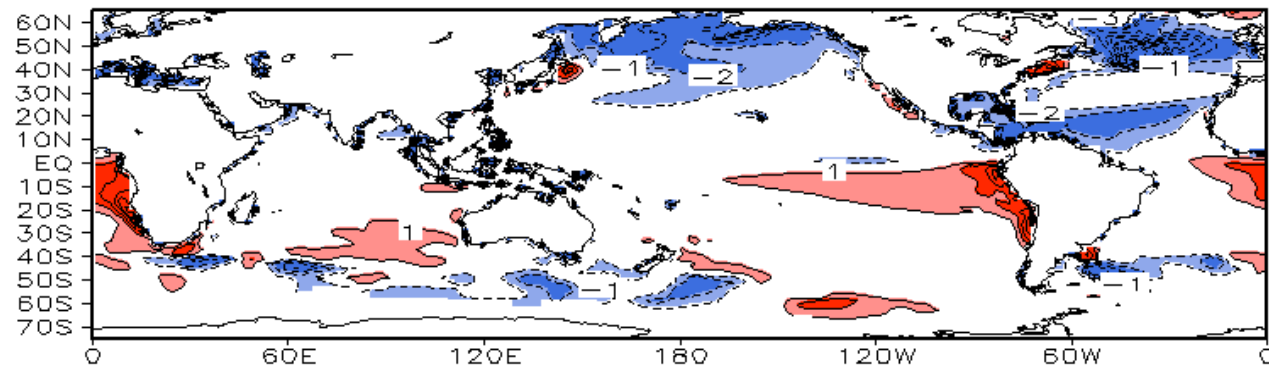
OISST



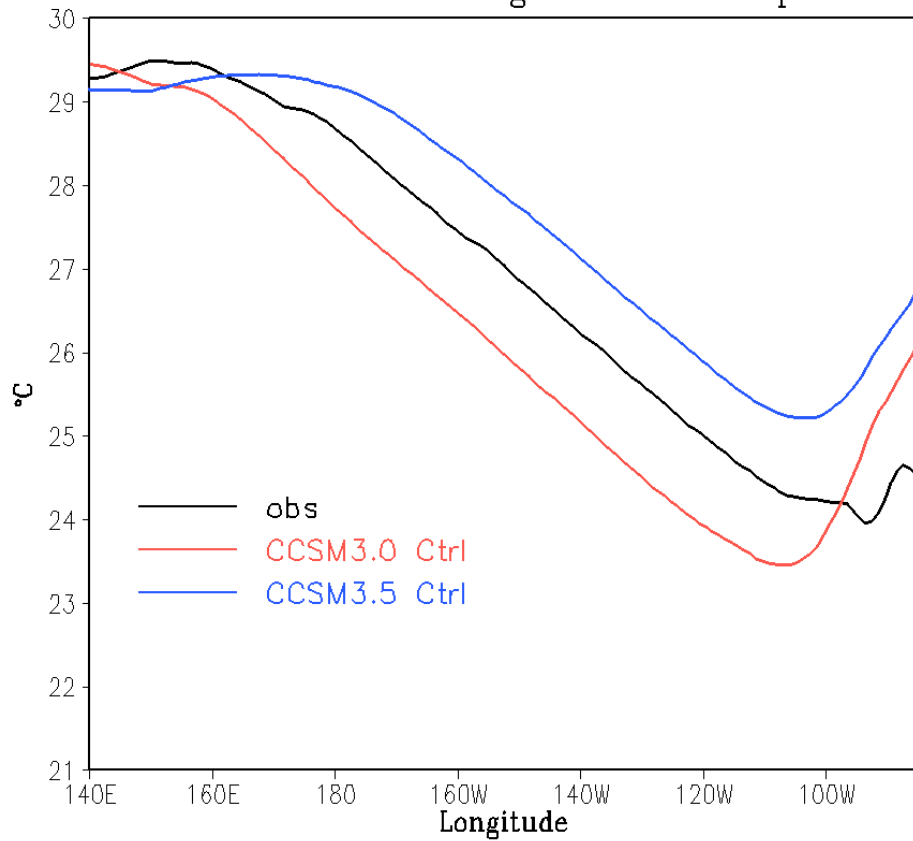
CCSM3.5 Error



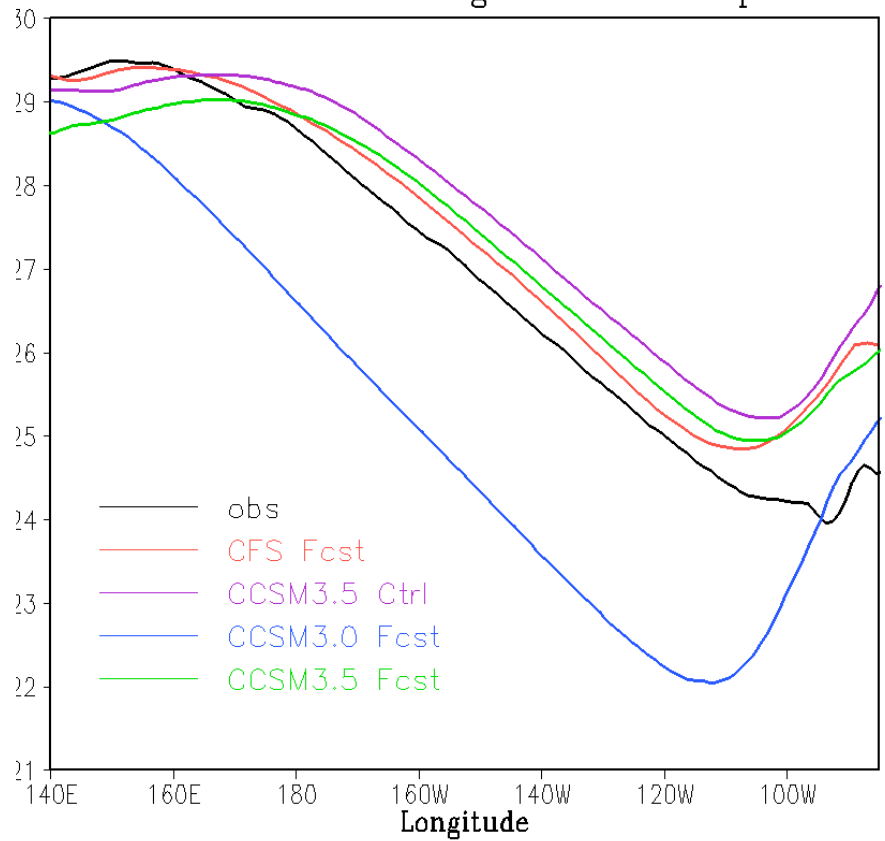
CCSM3.0 Error



Annual Mean SST Along the Pacific Equator

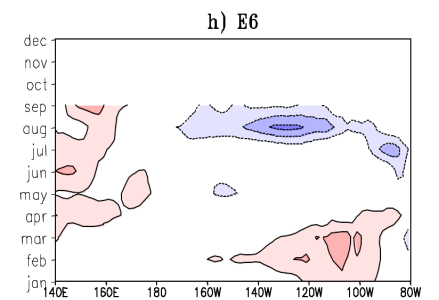
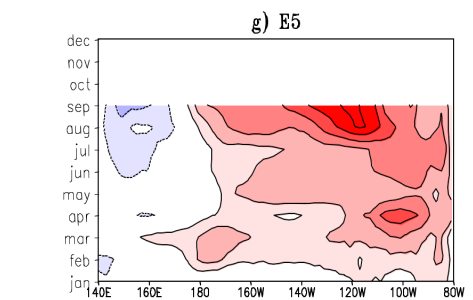
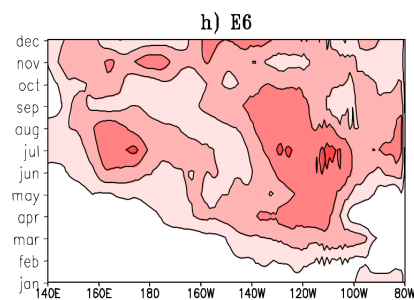
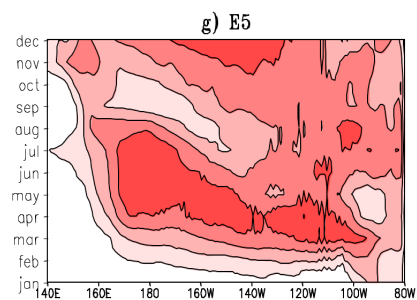
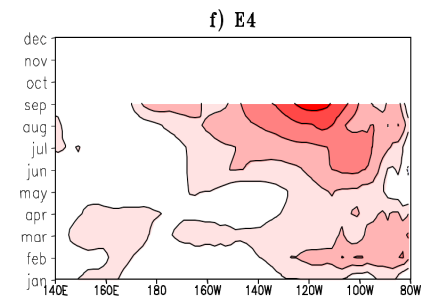
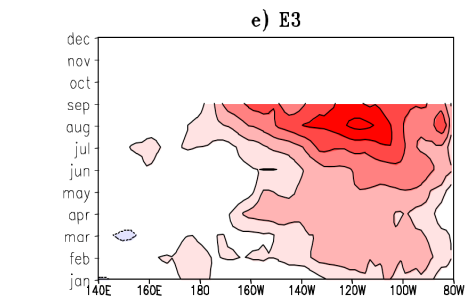
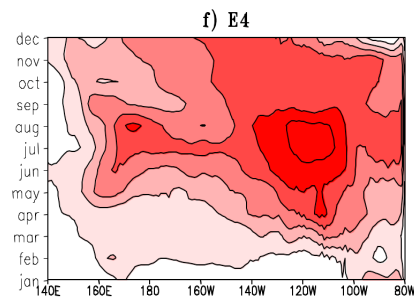
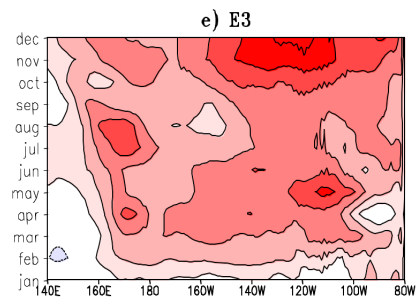
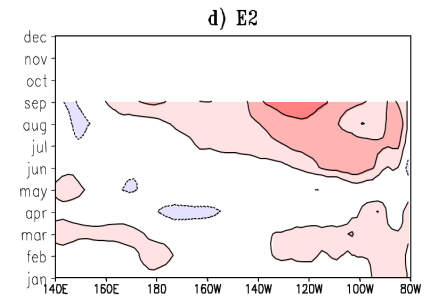
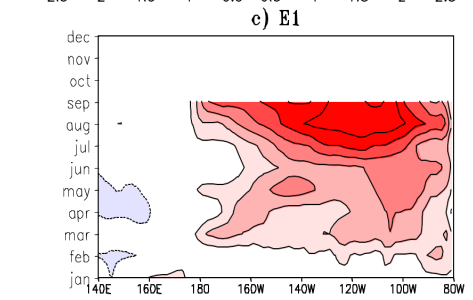
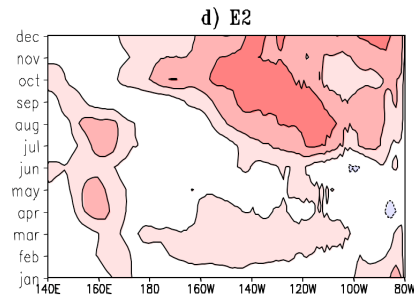
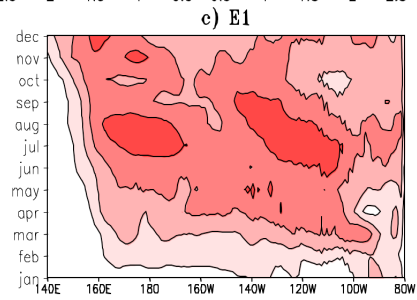
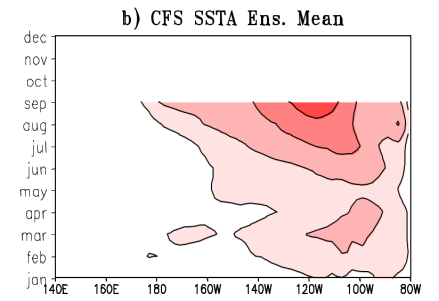
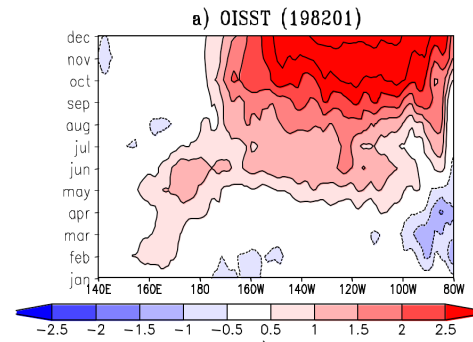
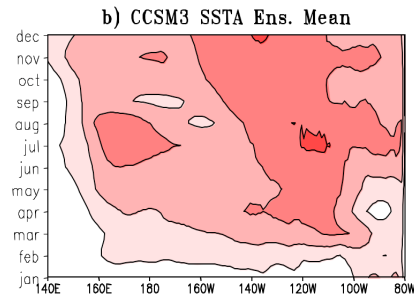
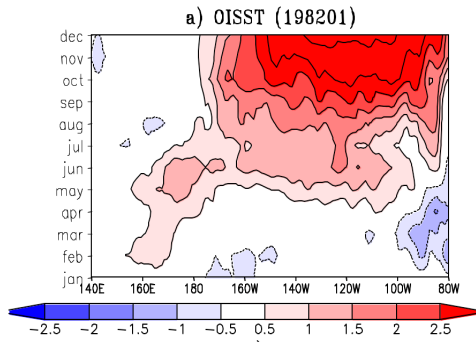


Annual Mean SST Along the Pacific Equator



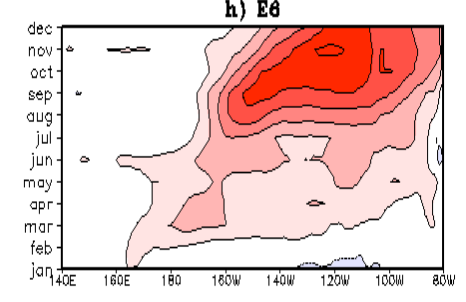
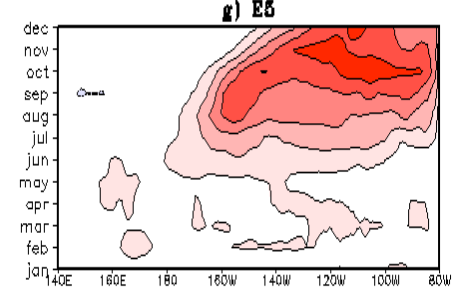
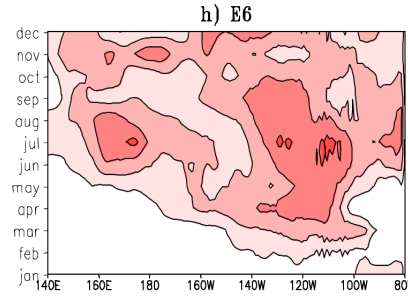
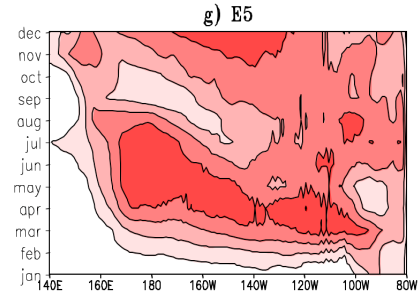
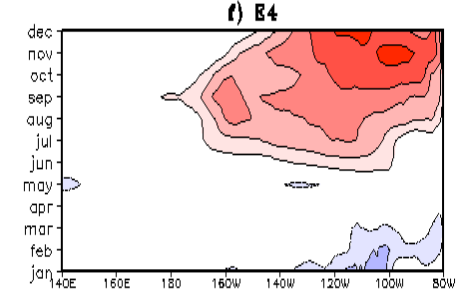
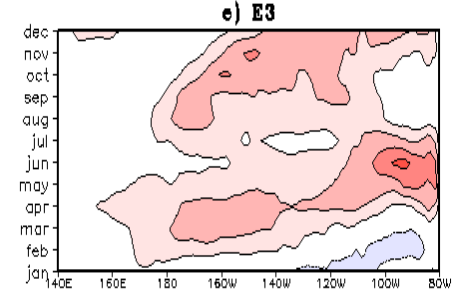
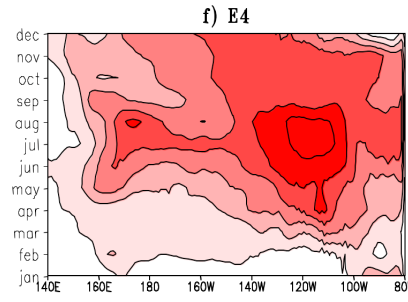
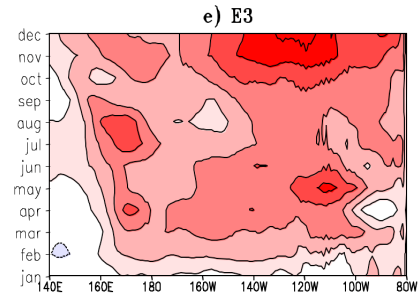
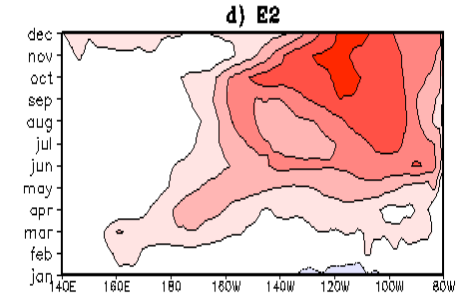
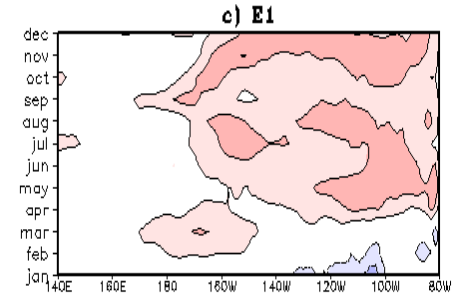
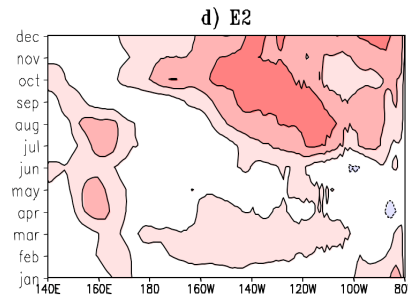
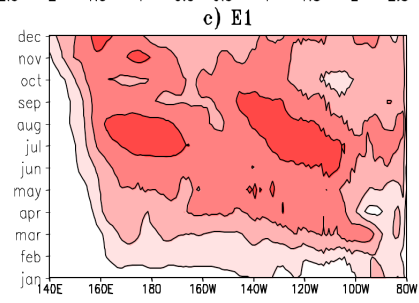
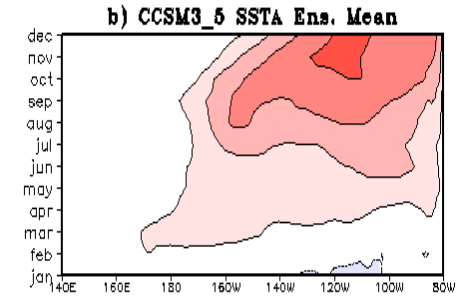
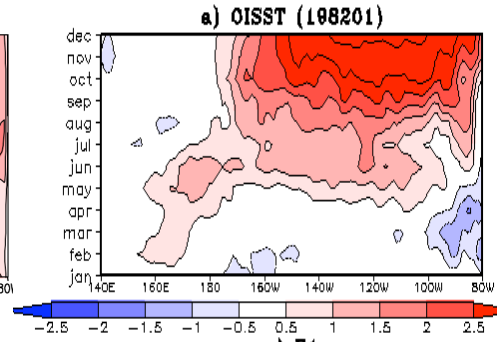
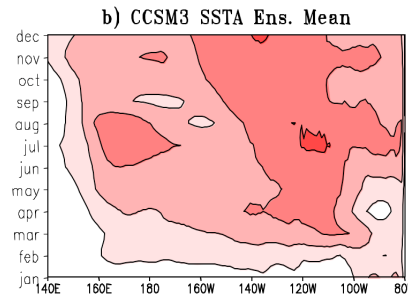
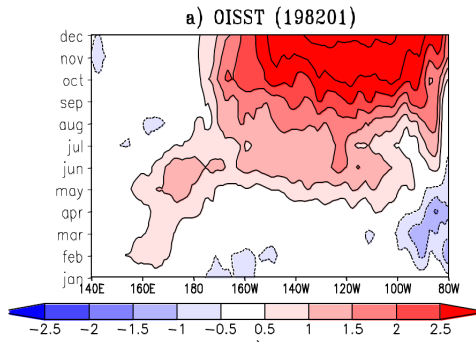
CCSM3.0 Jan 1982 IC

CFS Jan 1982 IC

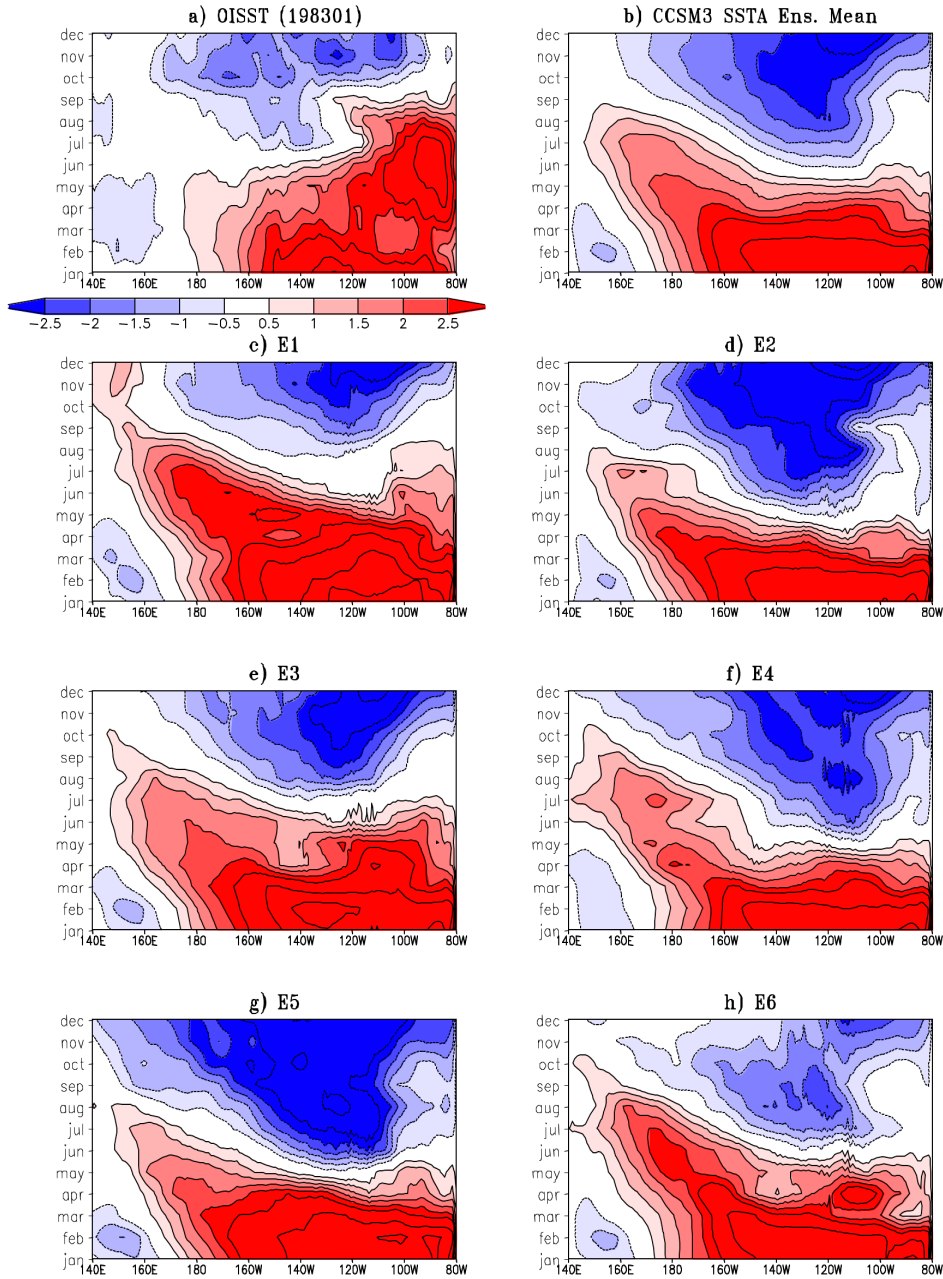


CCSM3.0 Jan 1982 IC

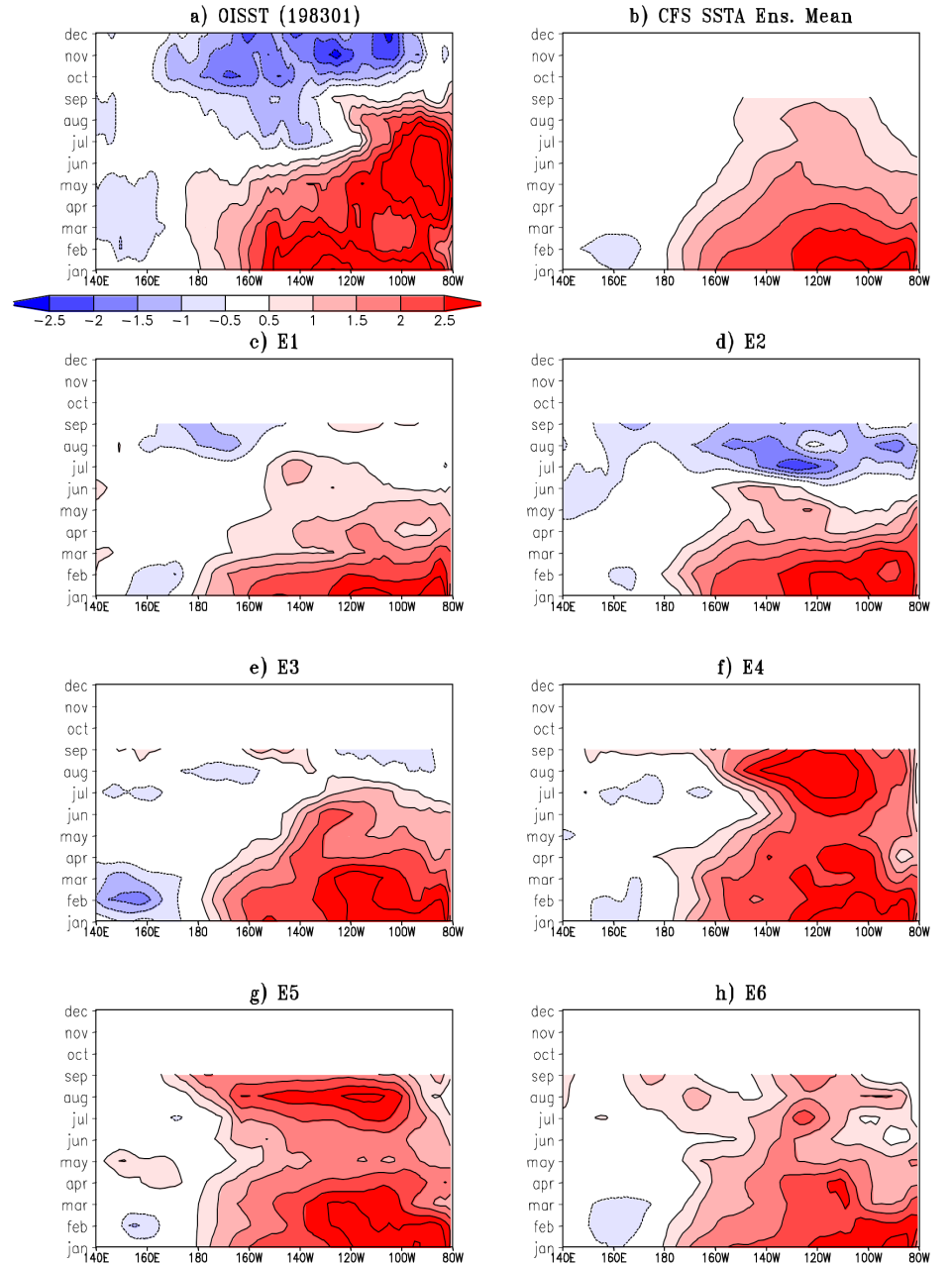
CCSM3.5 Jan 1982 IC



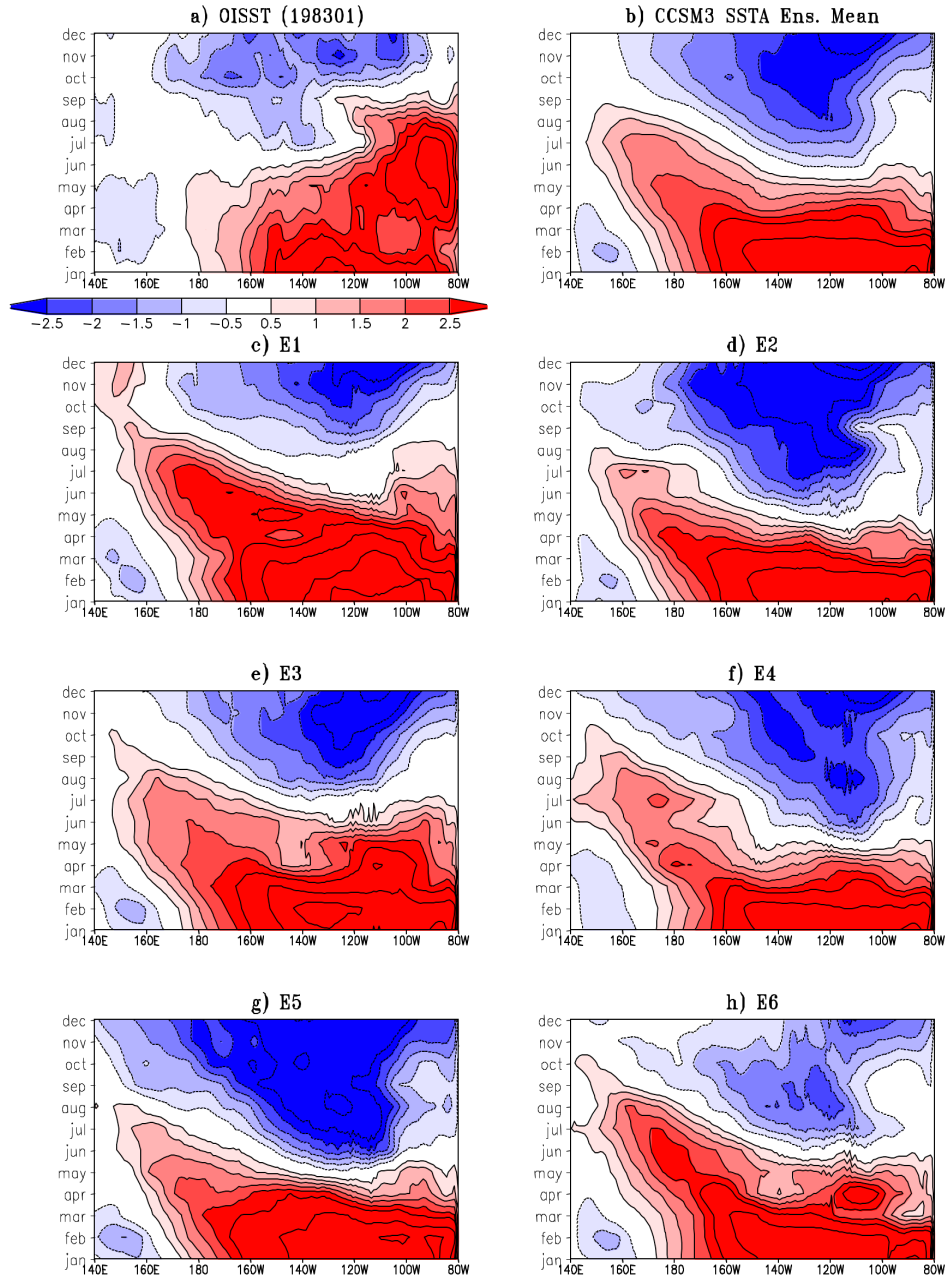
CCSM3.0 Jan 1983 IC



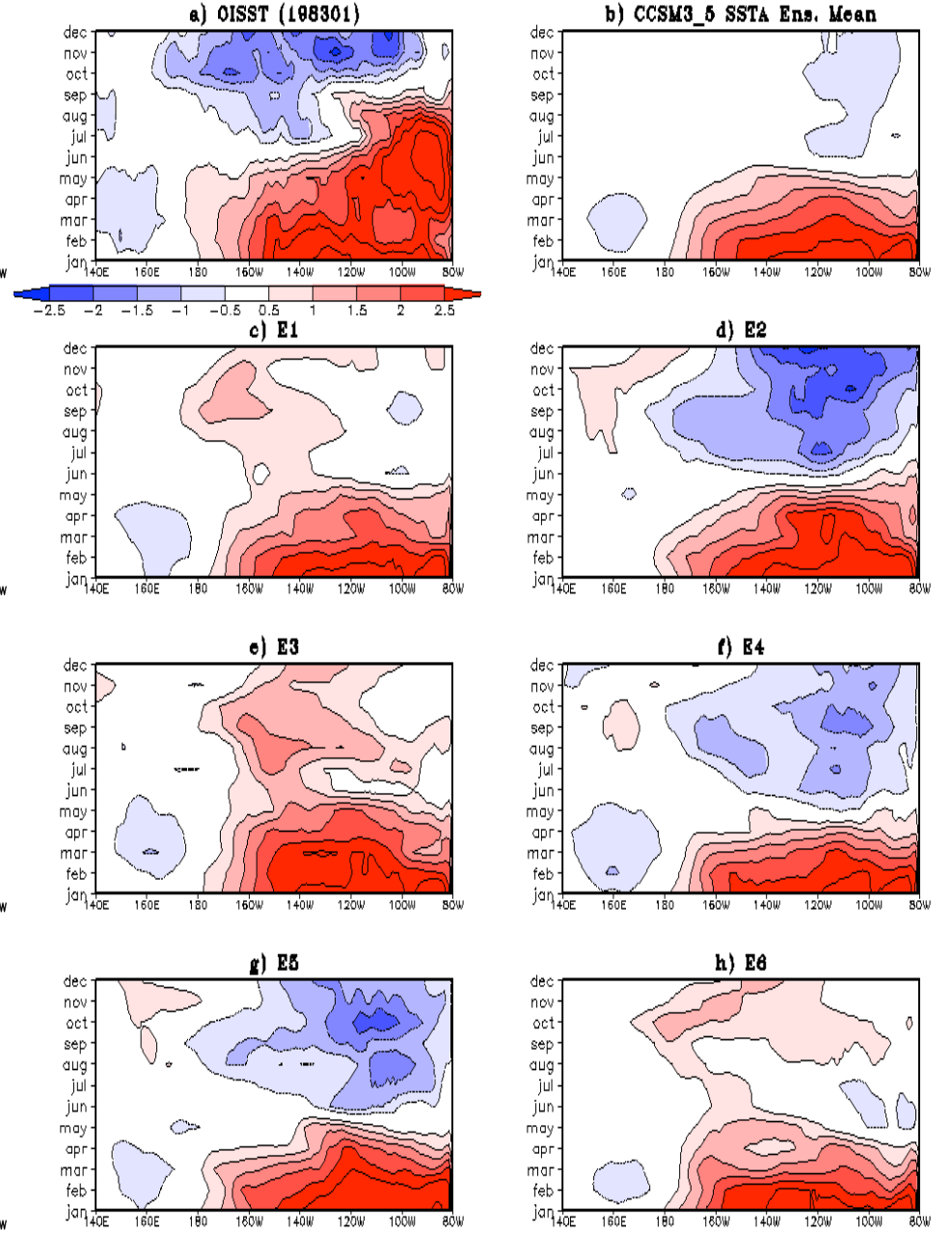
CFS Jan 1983 IC



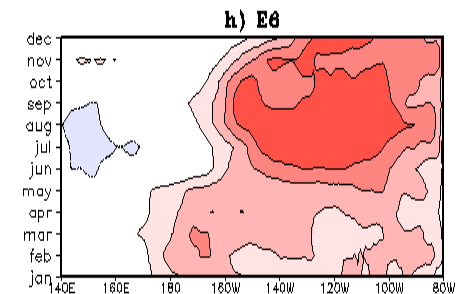
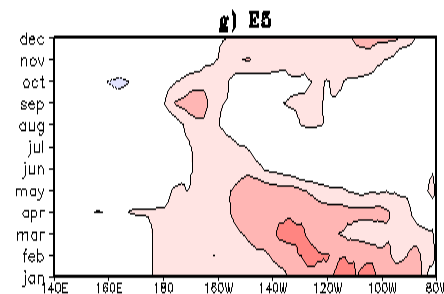
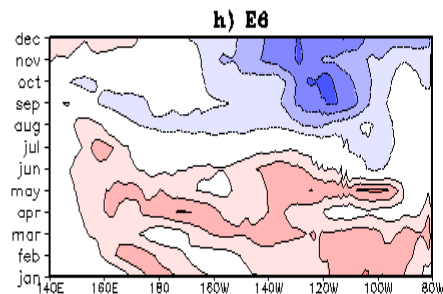
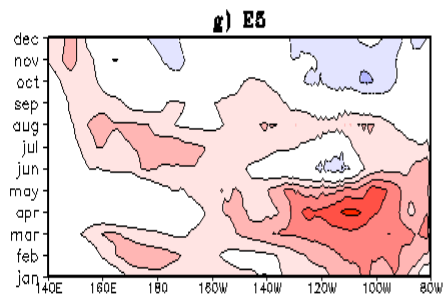
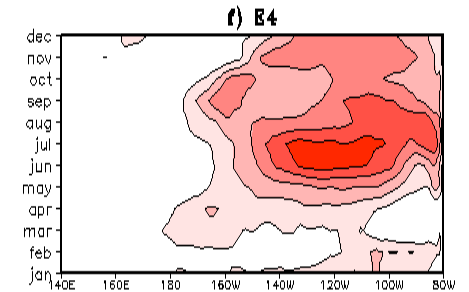
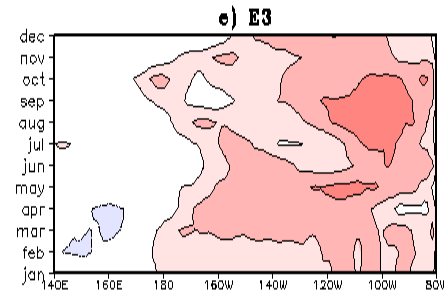
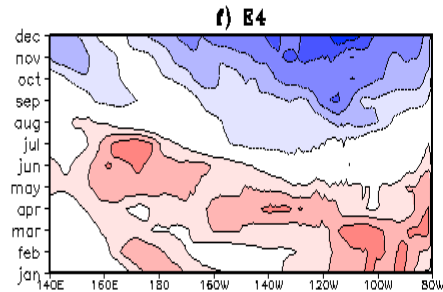
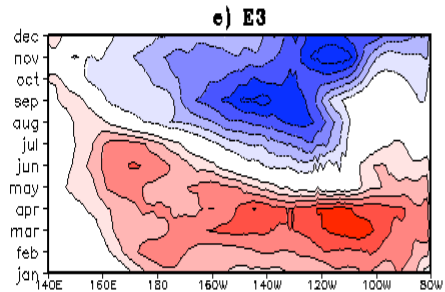
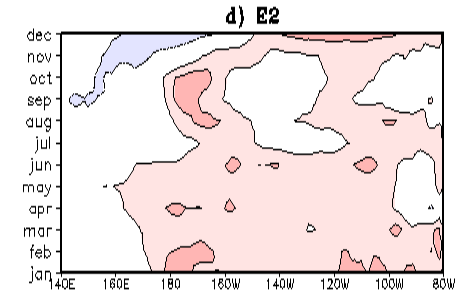
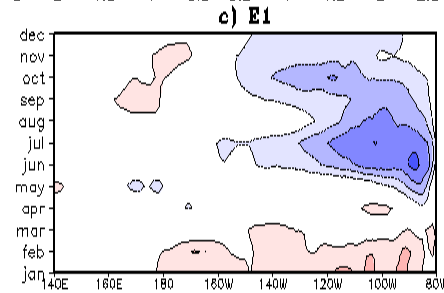
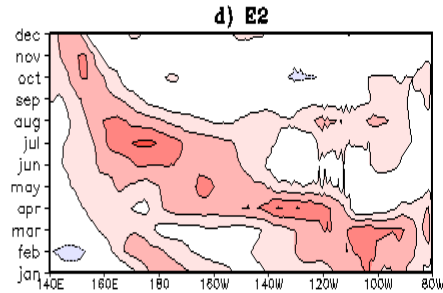
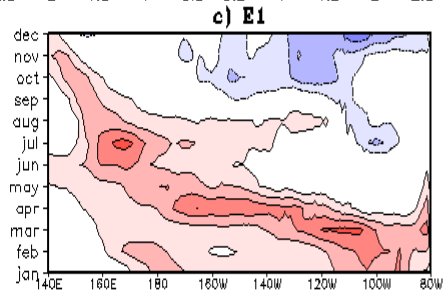
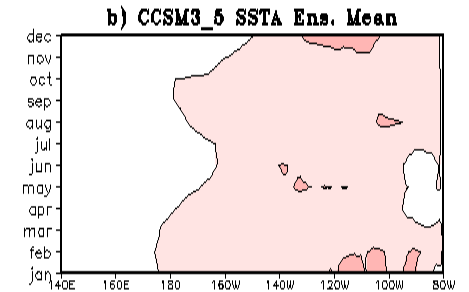
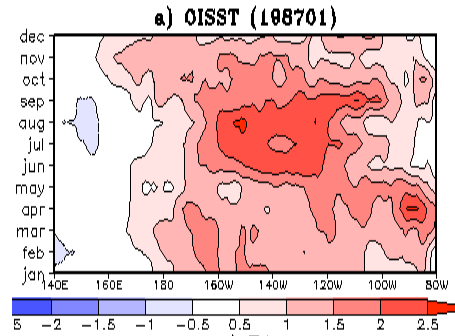
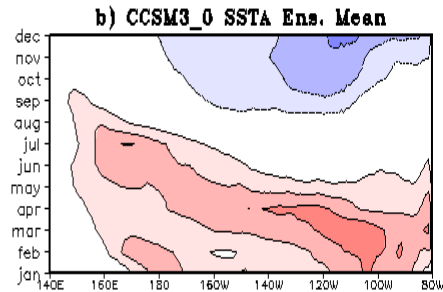
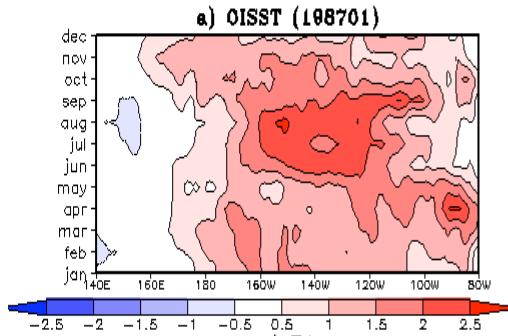
CCSM3.0 Jan 1983 IC



CCSM3.5 Jan 1983 IC

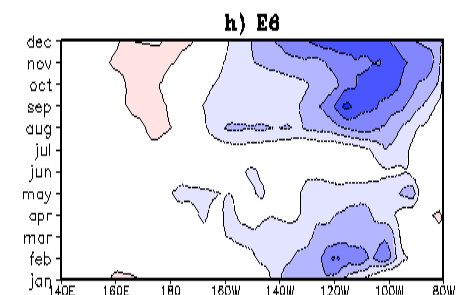
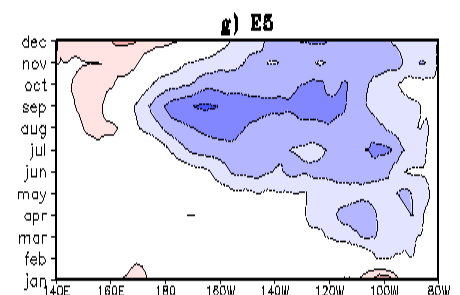
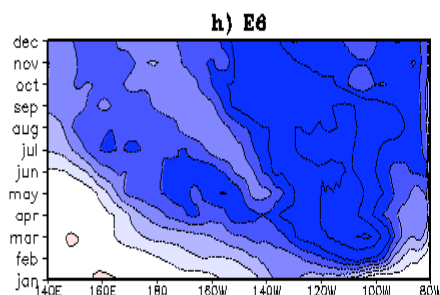
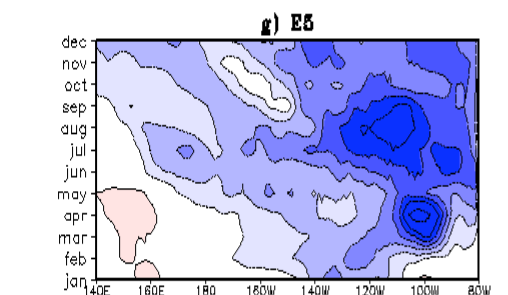
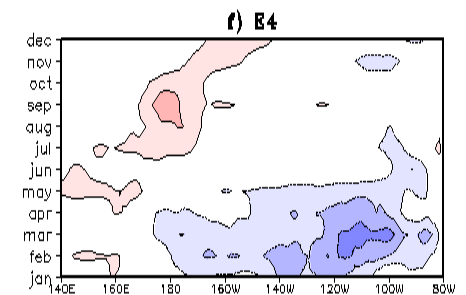
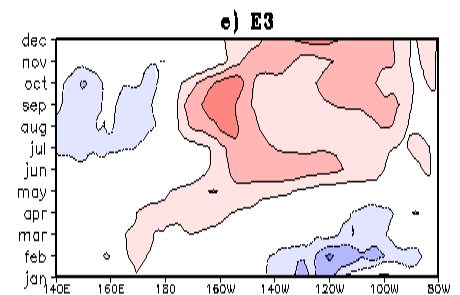
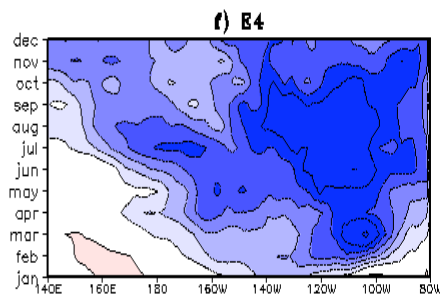
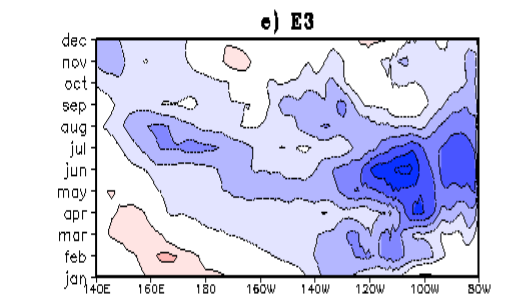
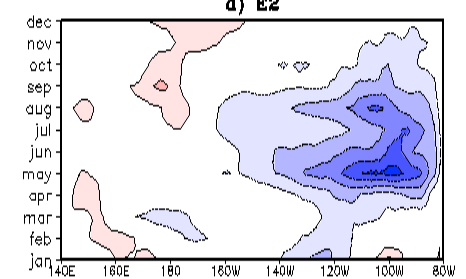
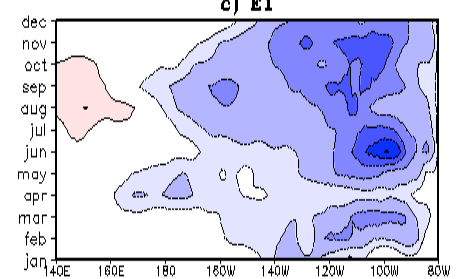
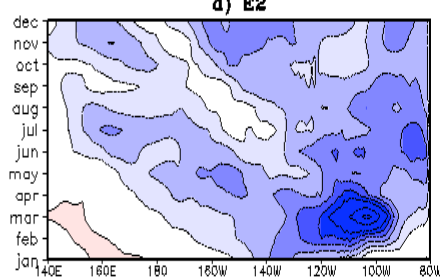
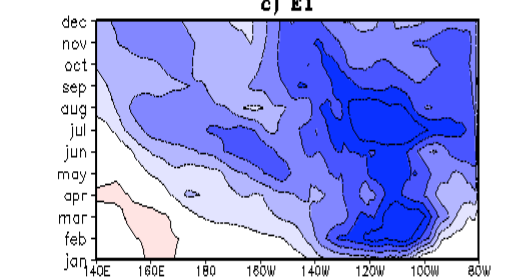
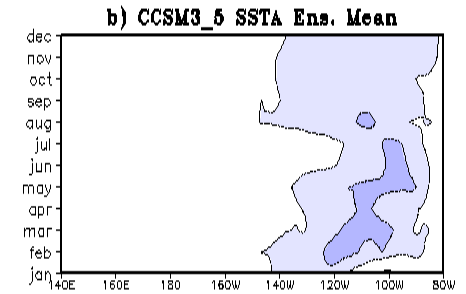
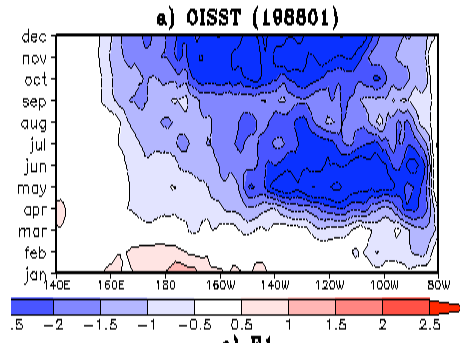
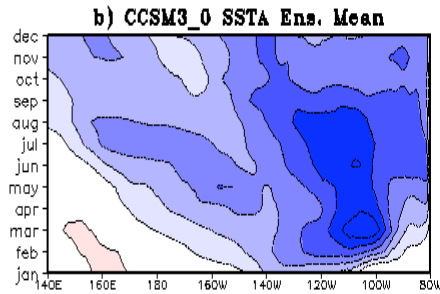
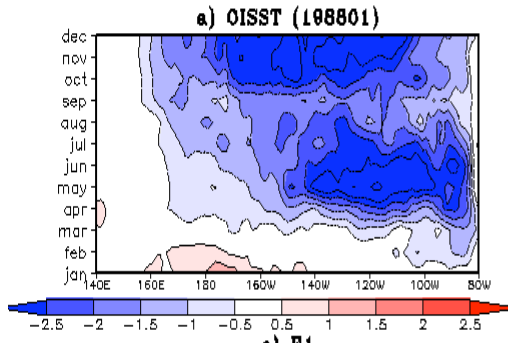


CCSM3.0 Jan 1987 IC

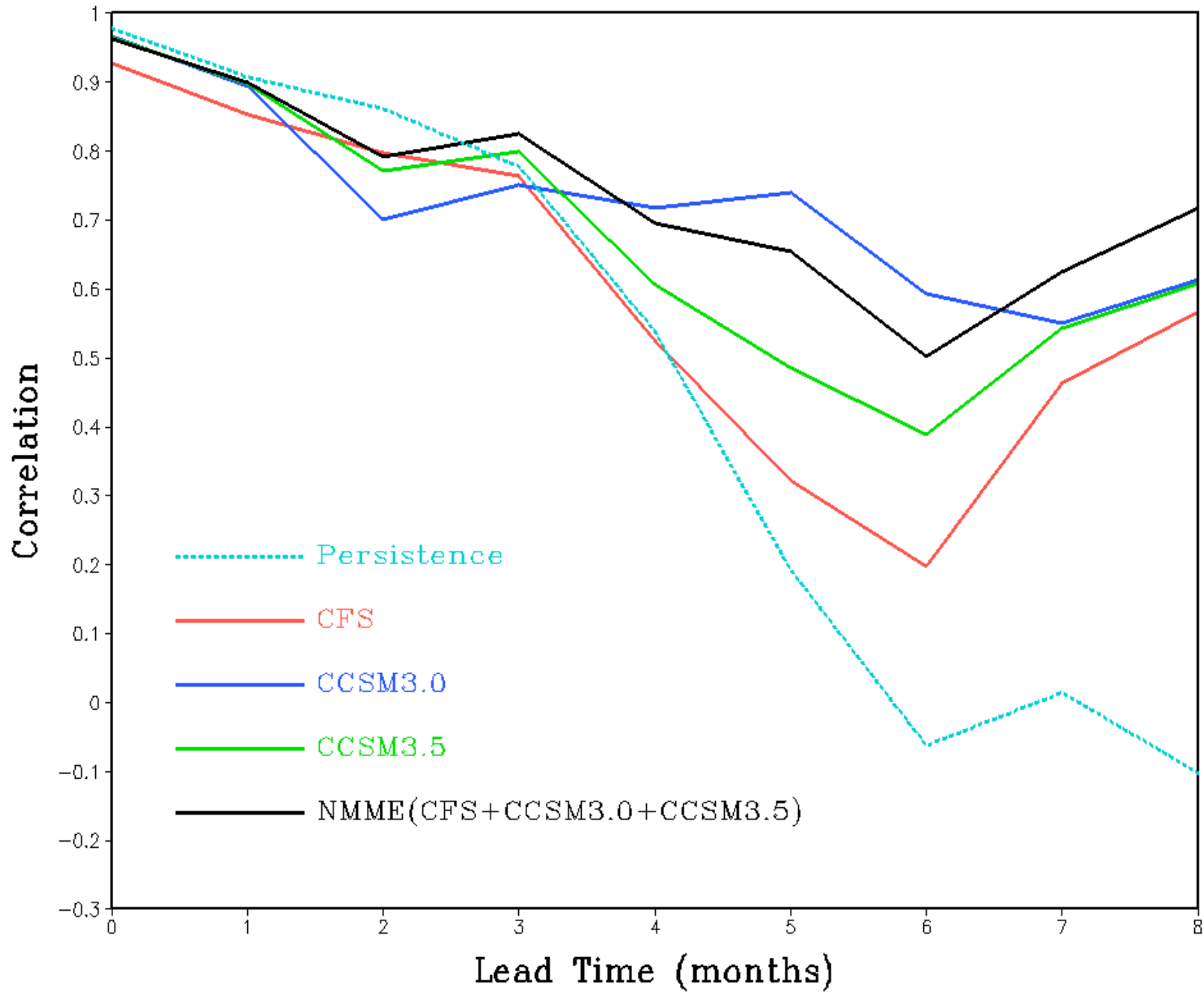


CCSM3.0 Jan 1988 IC

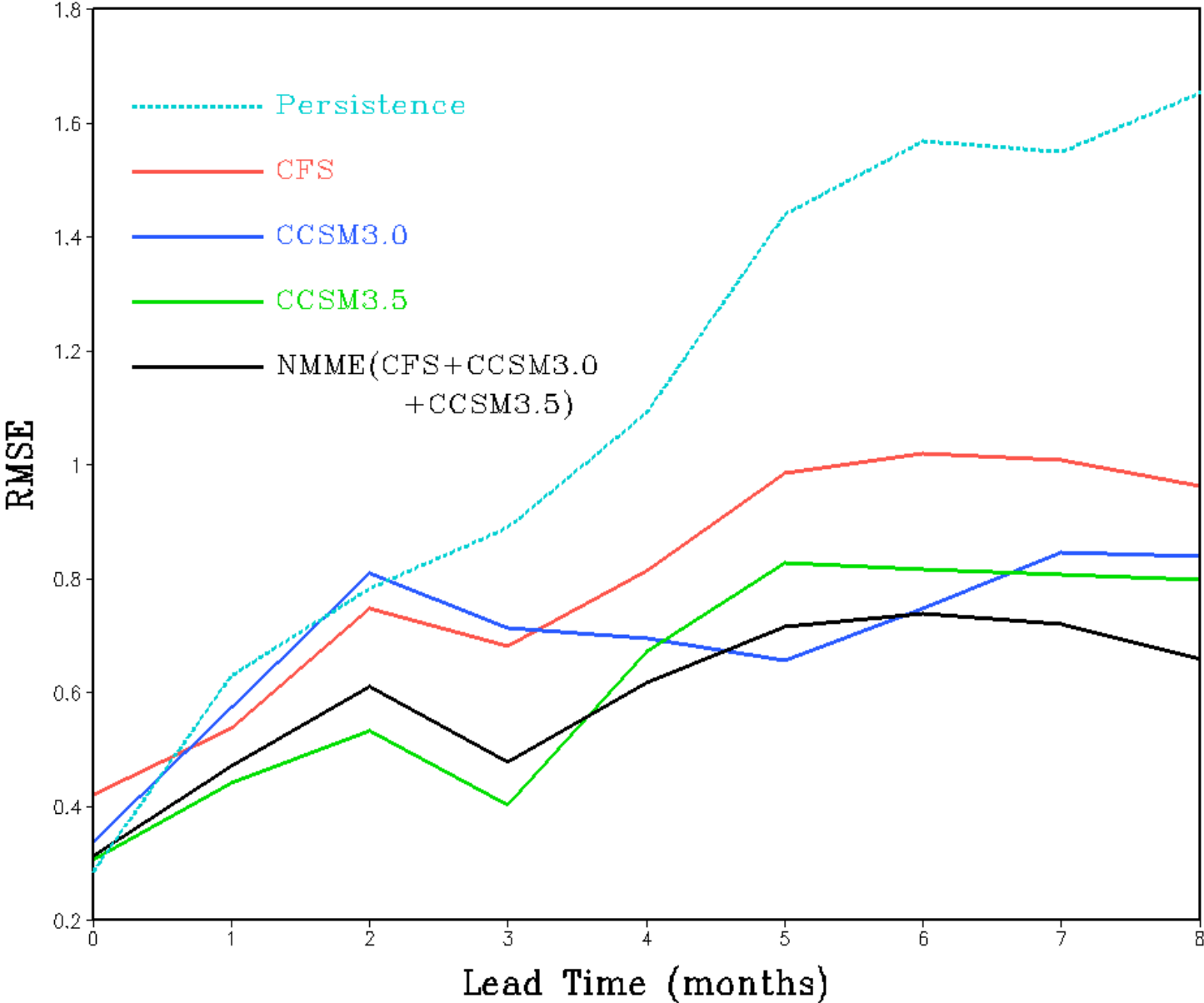
CCSM3.5 Jan 1988 IC



Nino3.4 Correlation 1982-1998: Jan 01 Oics

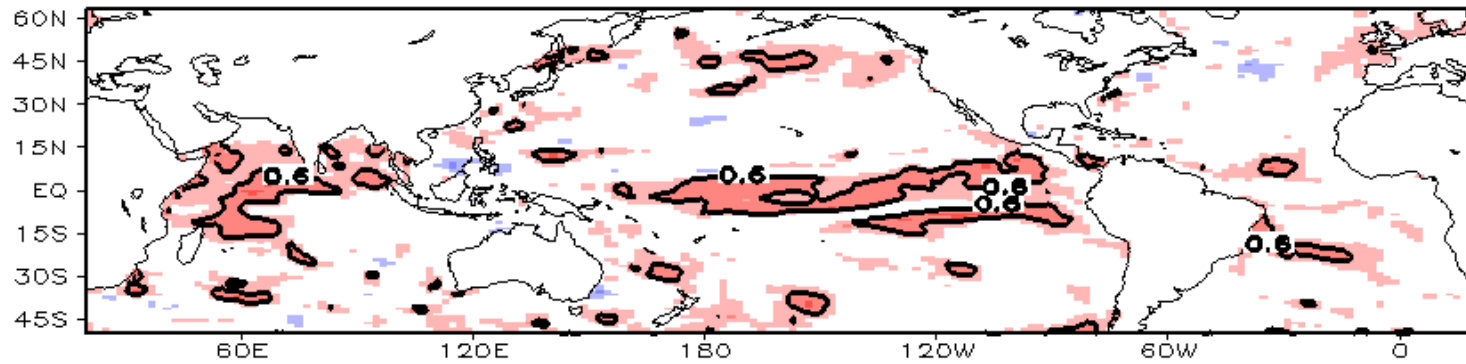


Nino3.4 RMSE 1982-1998: Jan 01 Oics

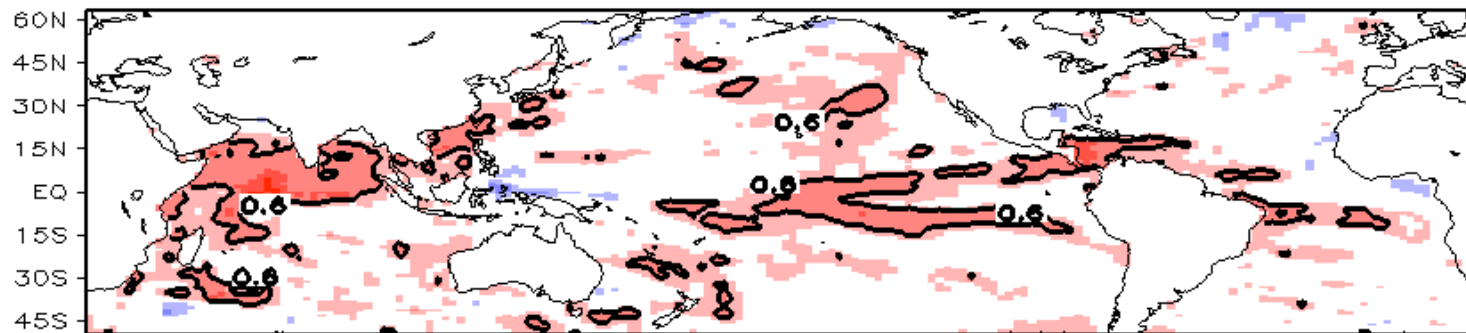


Anomaly Correlation (Jan IC: 5 Month Lead Time)

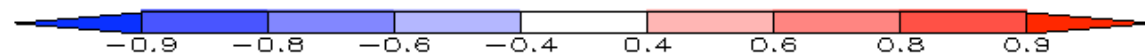
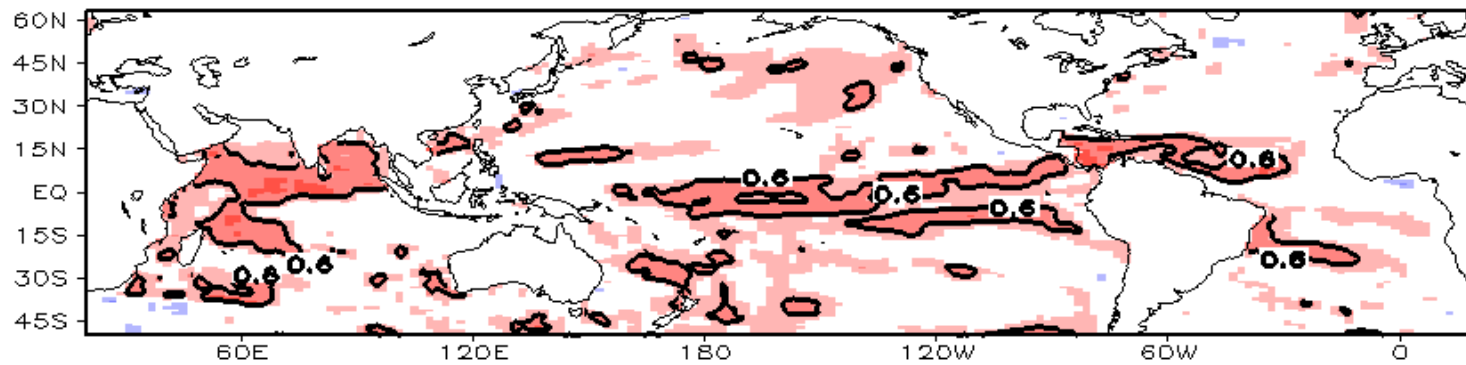
CCSM3.0(6)



CCSM3.5(6)

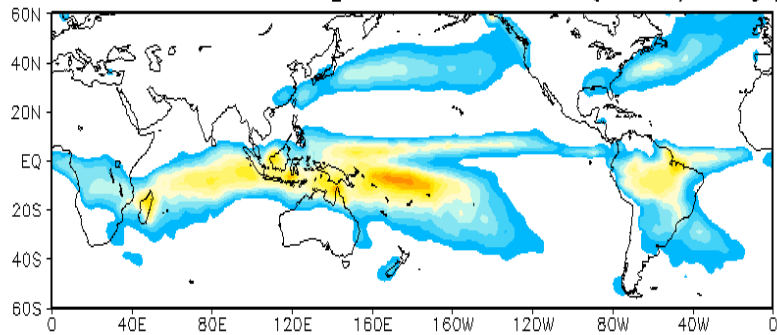


CCSM3.0(6) + CCSM3.5(6) + CFS(5)

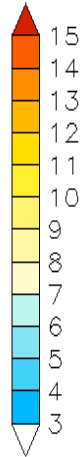
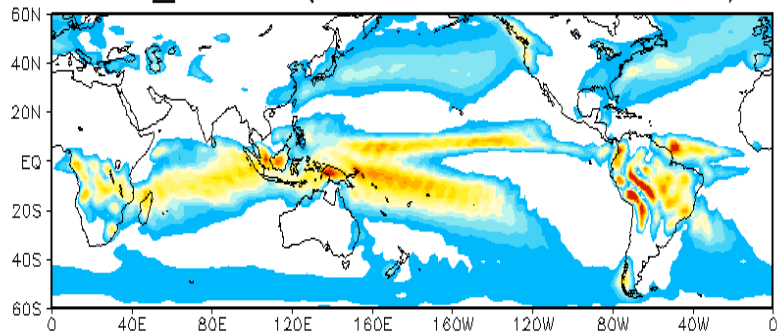


CCSM3.5 Precipitation Hindcasts

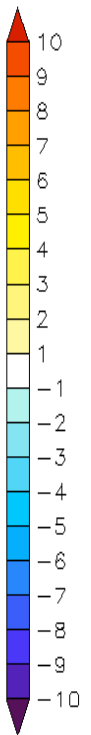
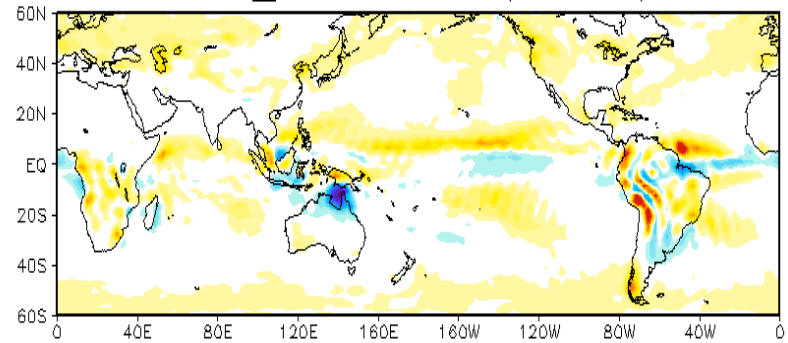
Xie-Arkin Precip JFM Mean (mm/day)



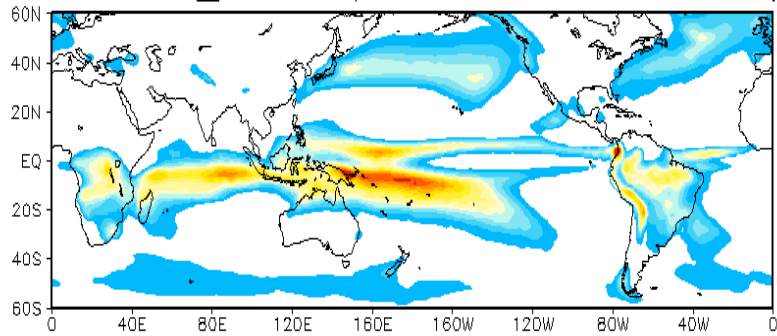
CFS_Fcst (Jan IC : 5 Ens Mean)



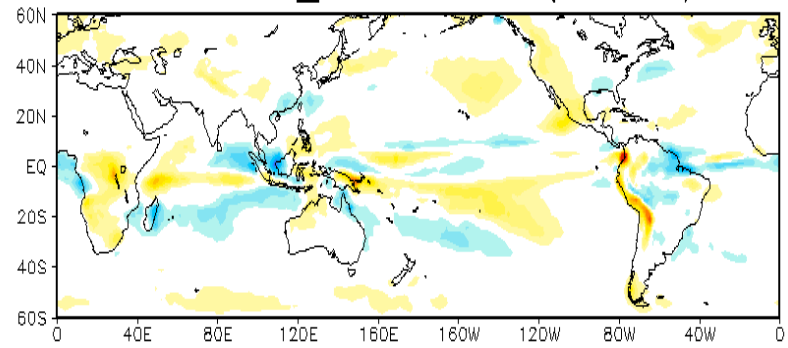
CFS_Fcst - XA (Jan IC)



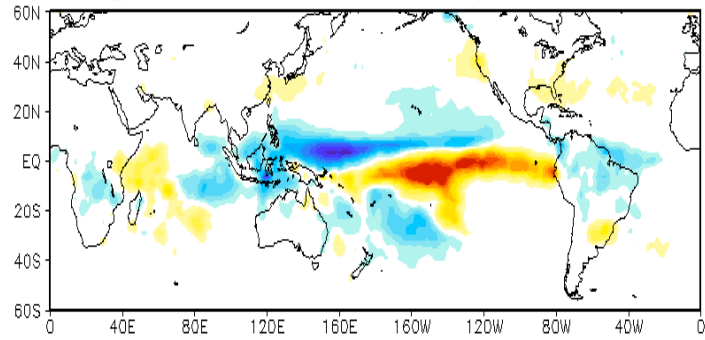
CCSM3.5_Fcst (Jan IC : 6 Ens Mean)



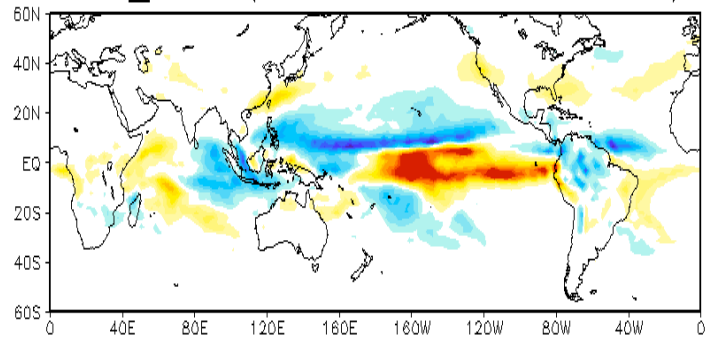
CCSM3.5_Fcst - XA (Jan IC)



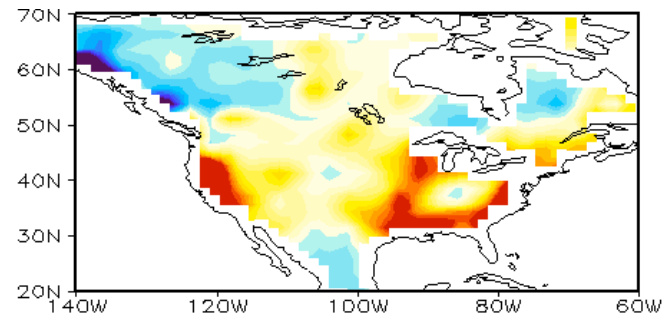
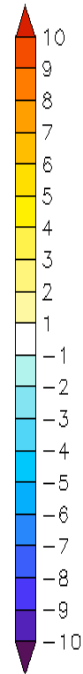
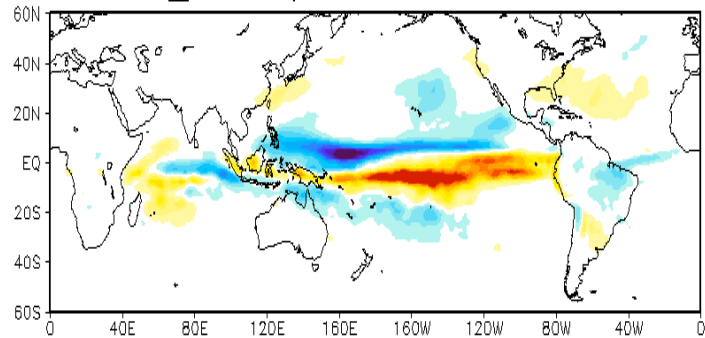
X-A Precip JFM Mean Anomaly 1998 (mm/day)



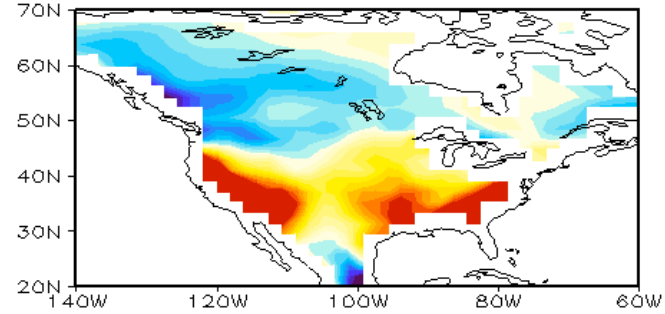
CFS_Fcst (Jan IC :Lead 0,1,2 Mon)



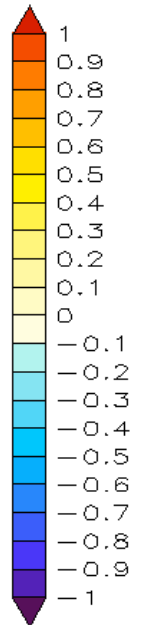
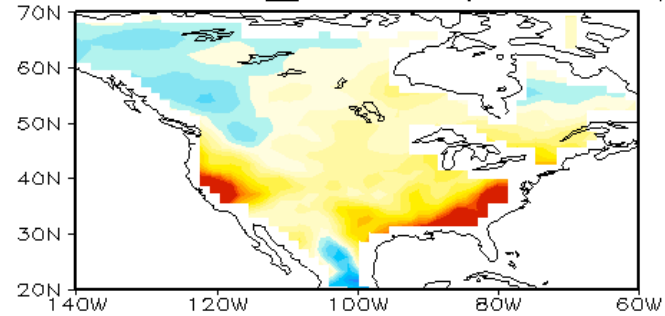
CCSM3.5_Fcst (Jan IC :Lead 0,1,2 Mon)



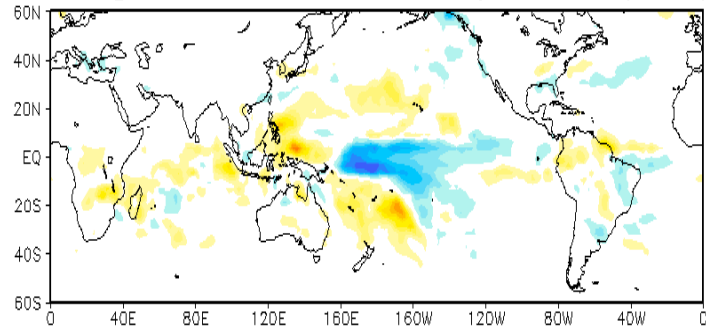
CFS_Fcst (Jan IC)



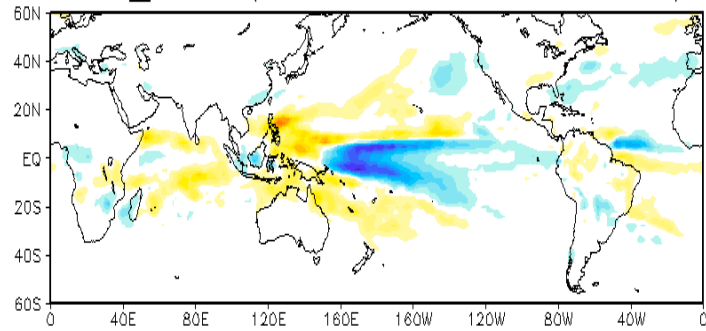
CCSM3.5_Fcst (Jan IC)



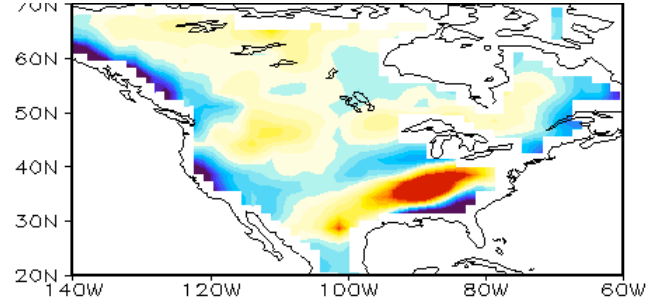
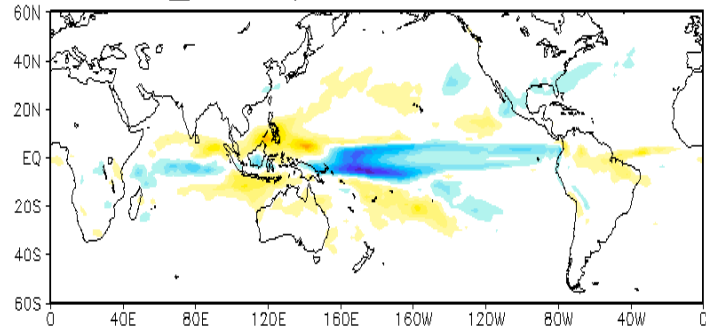
X-A Precip JFM Mean Anomaly 1989 (mm/day)



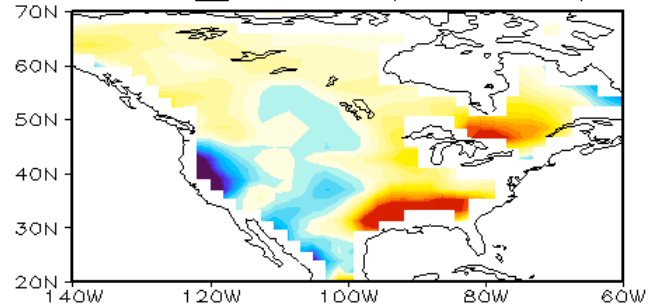
CFS_Fcst (Jan IC :Lead 0,1,2 Mon)



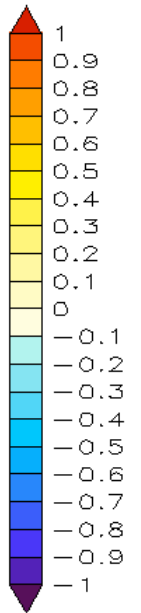
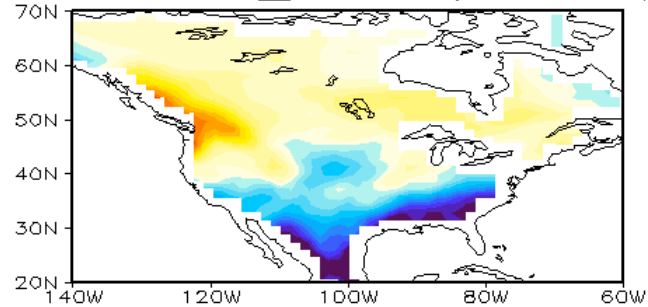
CCSM3.5_Fcst (Jan IC :Lead 0,1,2 Mon)



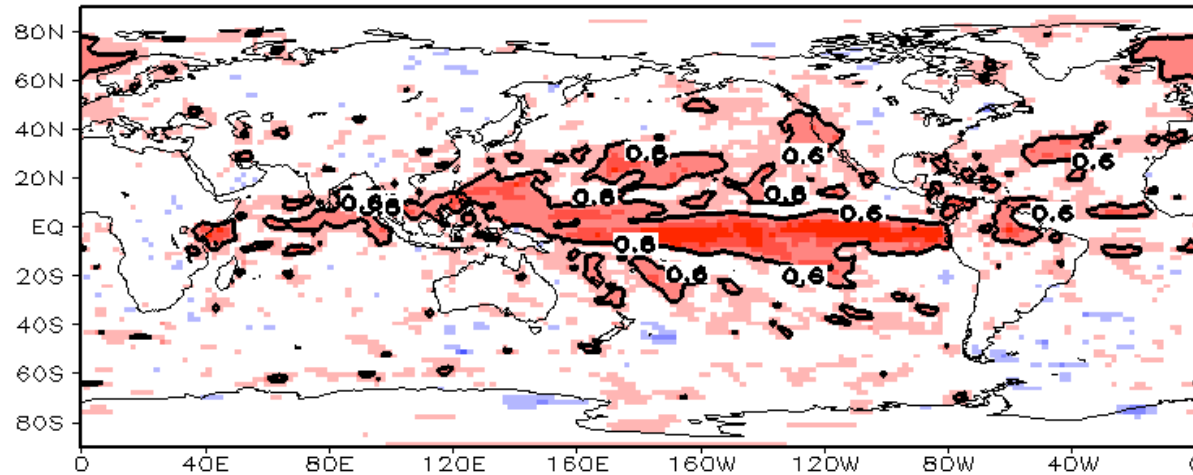
CFS_Fcst (Jan IC)



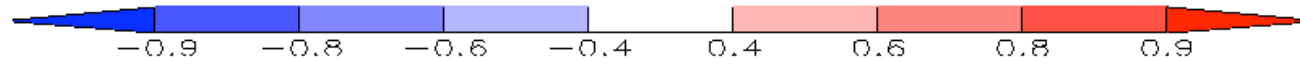
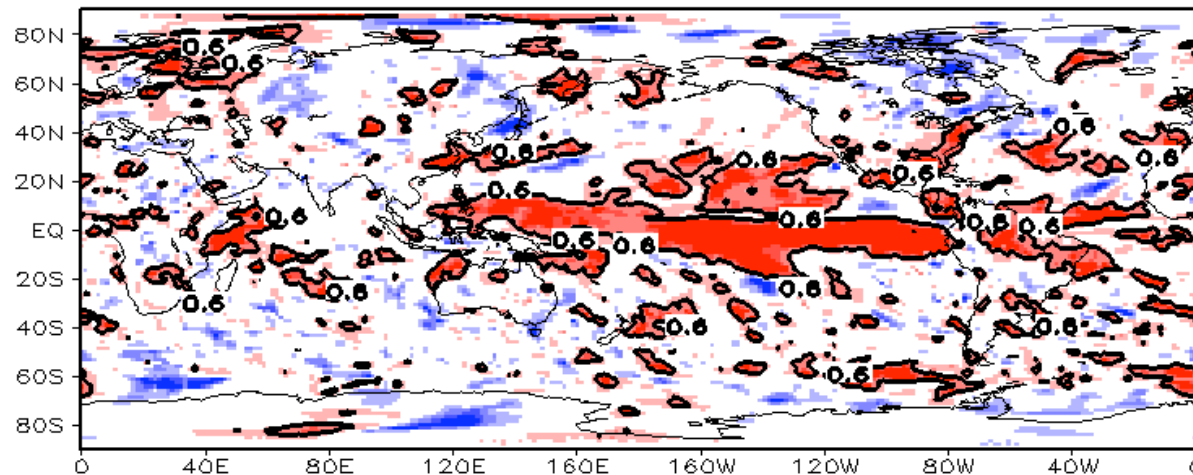
CCSM3.5_Fcst (Jan IC)



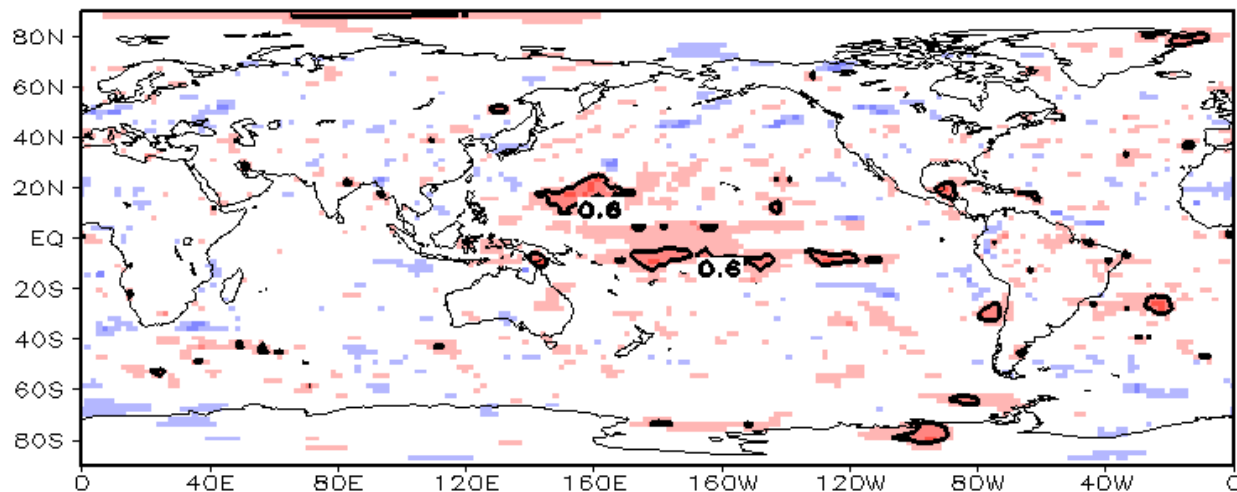
Correlation with XA-CMAP
CFS_Fcst JFM Mean Precip (Jan IC)



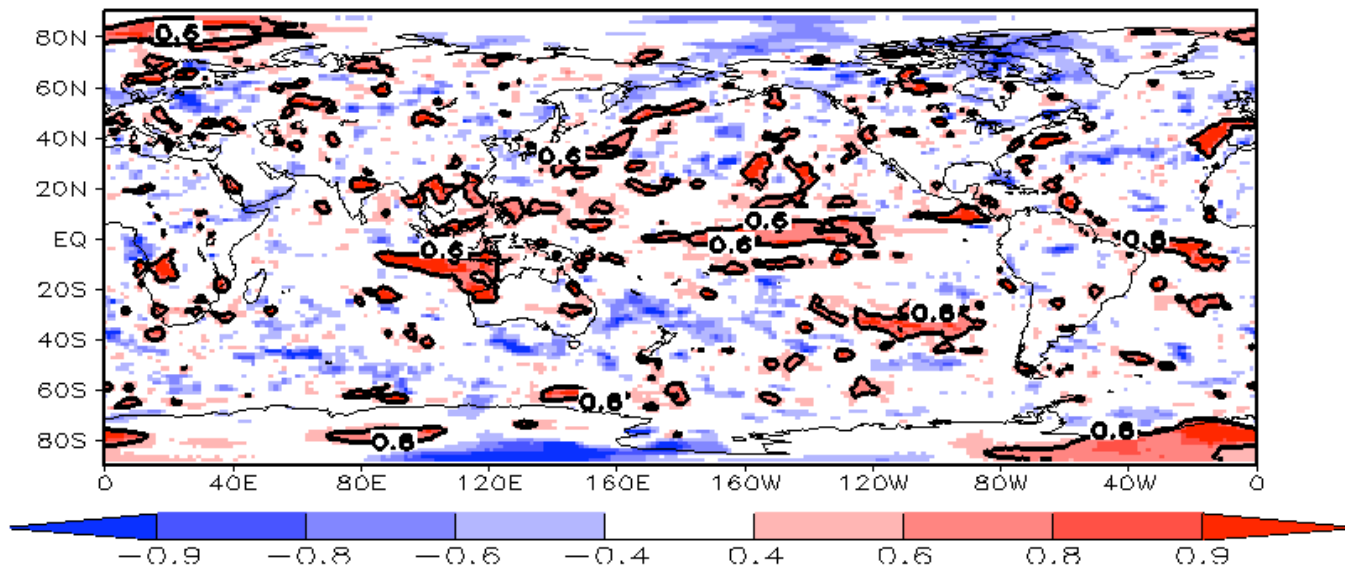
Correlation with XA-CMAP
CCSM3.5_Fcst JFM Mean Precip (Jan IC)



Correlation with XA-CMAP
CFS_Fcst JJA Mean Precip (Jan IC)



Correlation with XA-CMAP
CCSM3.5_Fcst JJA Mean Precip (Jan IC)



Random Thoughts

- **Multi-Model is Promising**
 - Generally (but not always) Better Forecast Quality
- **In Practice Multi-Model is Ad-Hoc**
 - Counting on Orthogonal Skill
 - Biggest Improvement Found in Adding Second Model
- **Multi-Model Should not be Used as an Excuse to Avoid Model Improvement**
- **CCSM3.0 Vs. CCSM3.5**
 - Notable Improvement in ENSO Statistics Detected in Forecast Evolution
 - Reduced Initialization Shock
 - Comparable Hindcast Skill
 - RMSE
 - Rainfall