

Importance of Air-Sea Coupling for Atmosphere-Ocean Co- Variability

A Proposal for *Coupled* Tier-2 Predictions

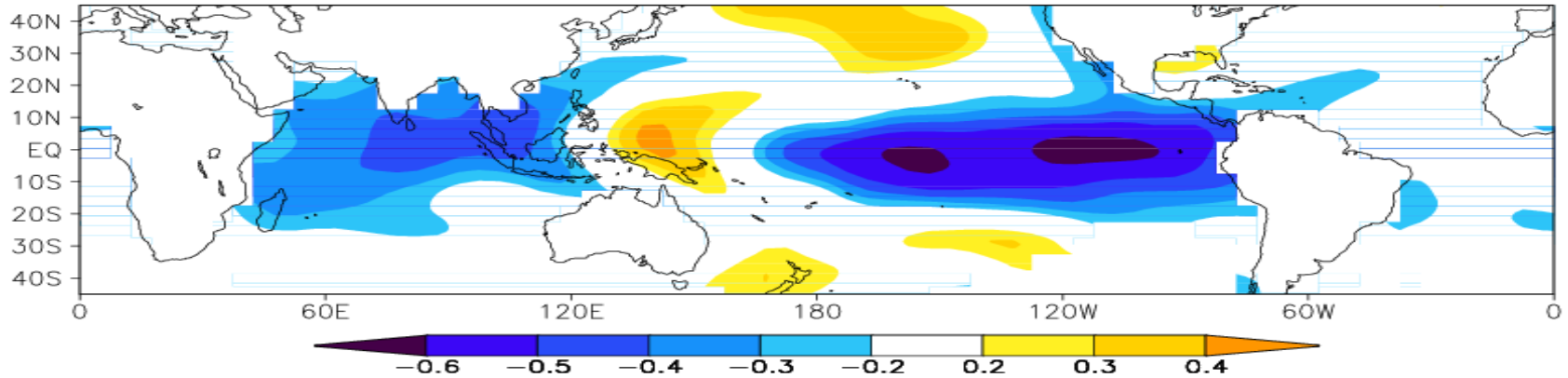
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Acknowledgements: Randy Wu and Kathy Pegion

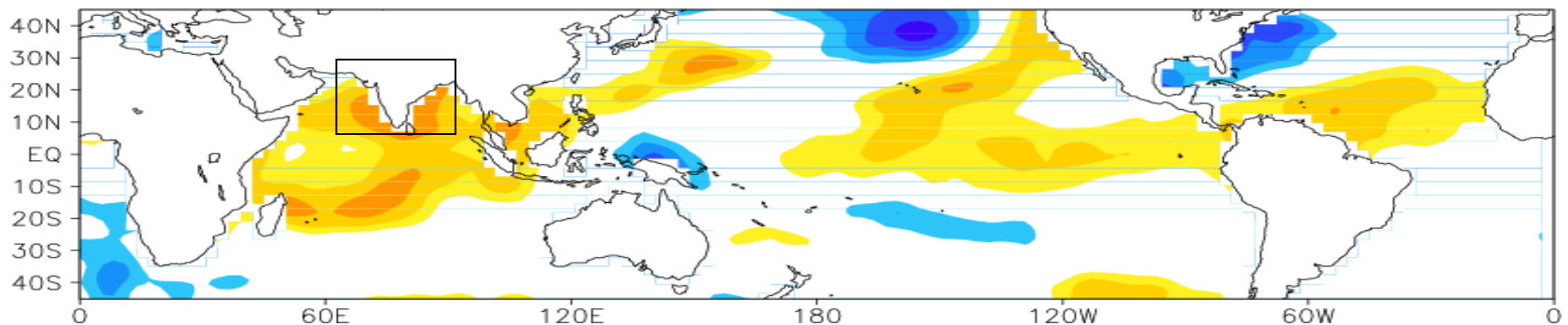
JJAS IMR Correlation with DJF(1) SST Observed



Indian Monsoon – Global Ocean Teleconnections

- Why do the (uncoupled) AGCMs Fail?
 - (i) Internal Atmospheric Dynamics? – Ensembles
 - (ii) Model Error?
 - (iii) Coupled Air-Sea Interactions?**

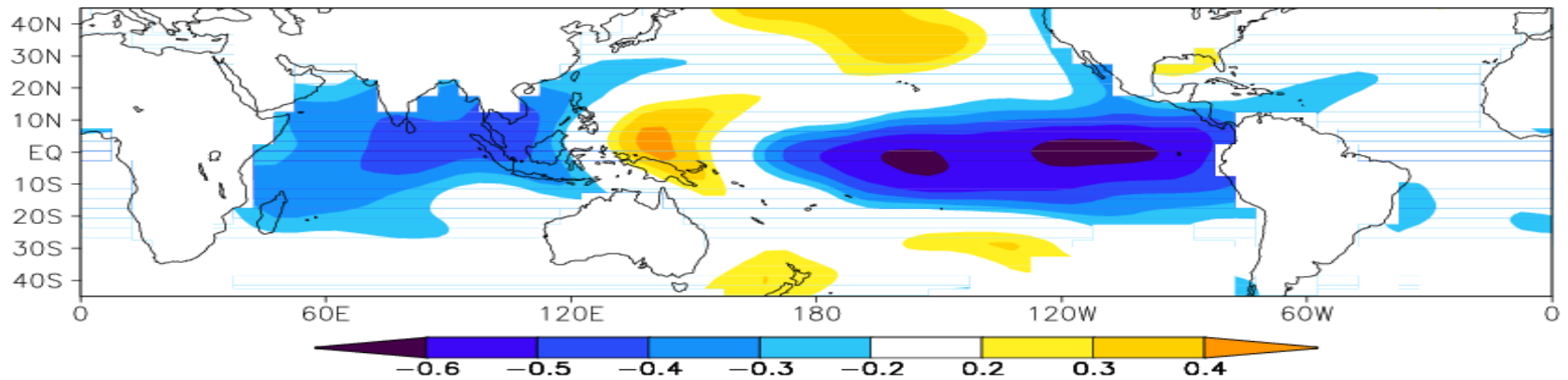
Uncoupled COLA AGCM



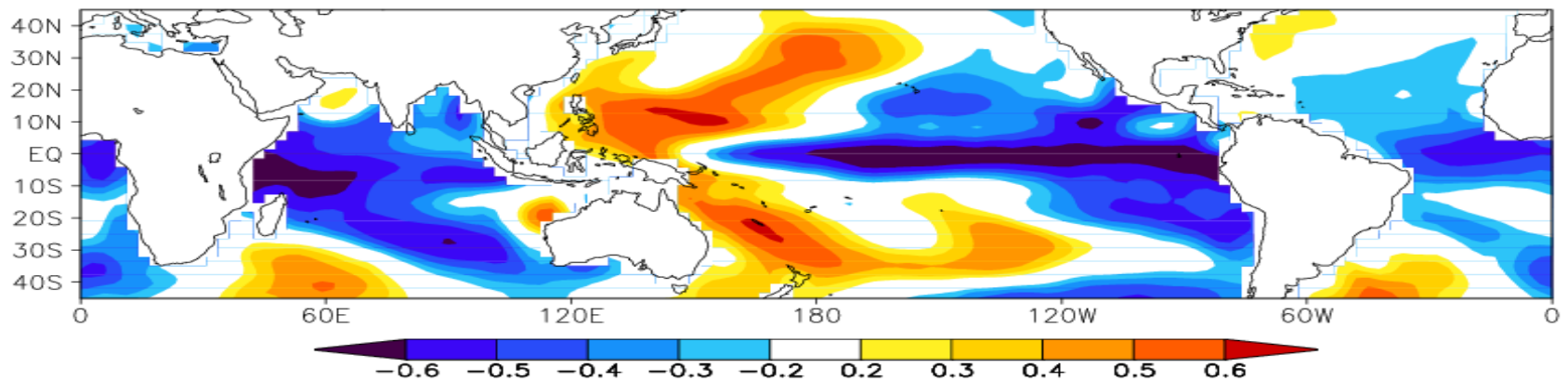
Outline

- Coupled Model that Captures ENSO-Monsoon Relationship
- Prescribed SST Experiments: CGCM Context
 - Perfect AMIP
 - Regional Coupling
 - How Coupled Feedbacks Impact the Variability and Co-Variability
 - SST vs. Surface Heat Flux Boundary Conditions
- Proposed *Coupled* Tier-2 Prediction Experiment

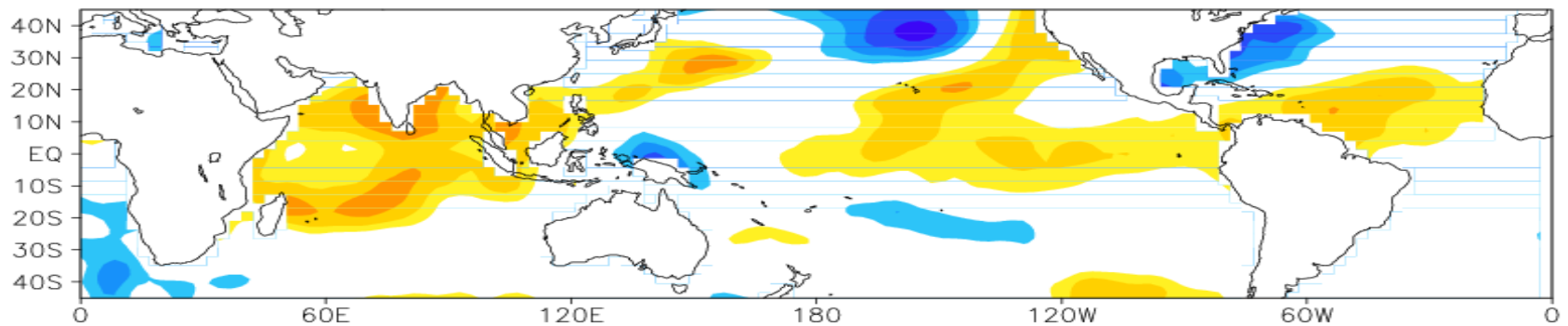
JJAS IMR Correlation with DJF(1) SST Observed



COLA ACGCM Interactive Ensemble

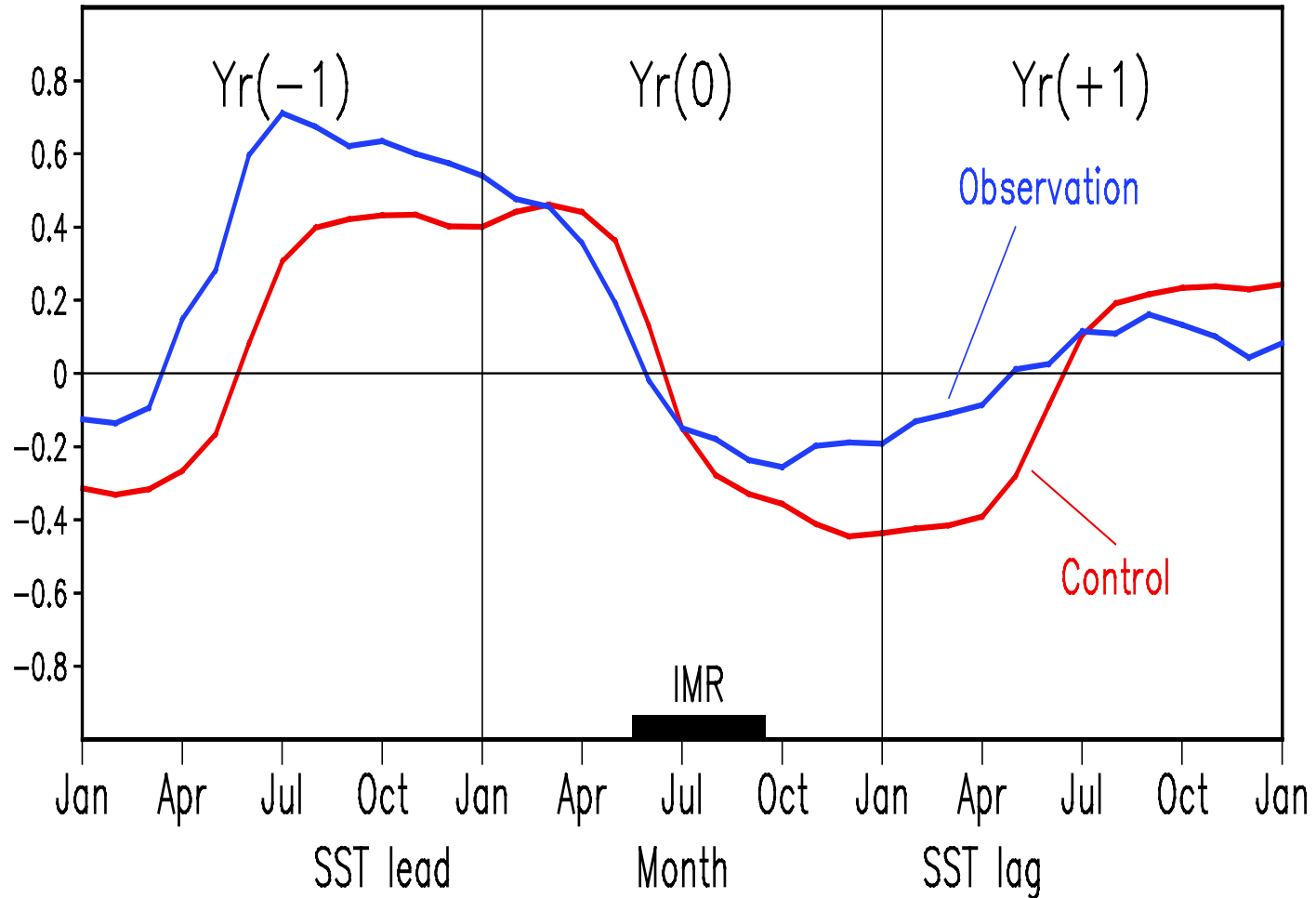


Uncoupled COLA ACGCM



Start with Coupled Model that Reproduces Observed Relationship

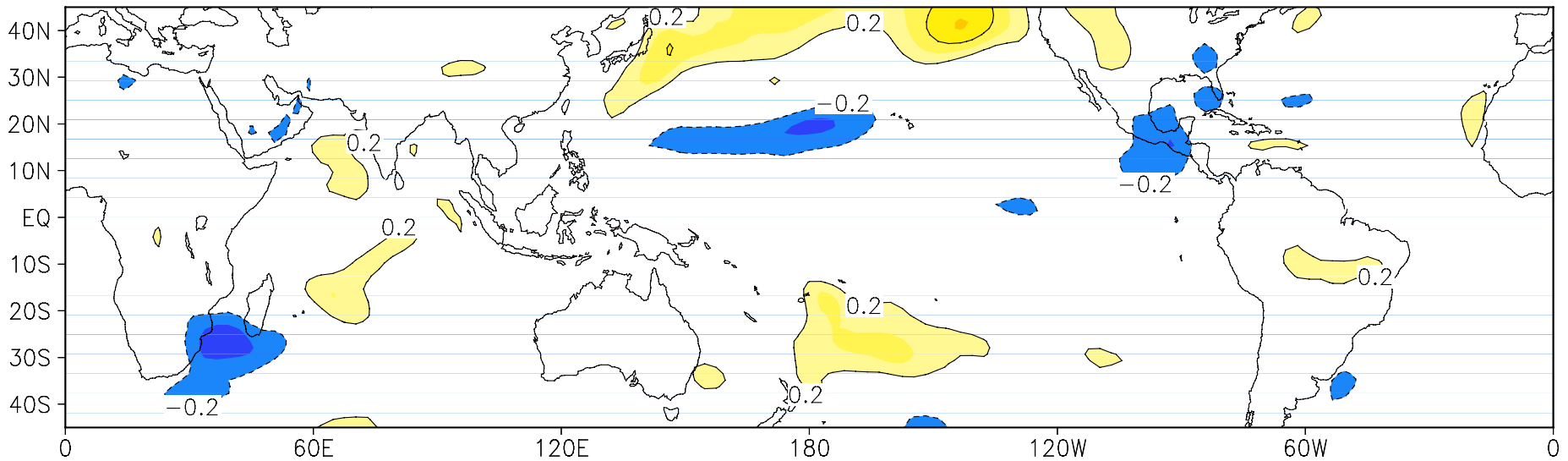
JJAS IMR lag-cor with monthly NINO3.4 SST



Hypothesis

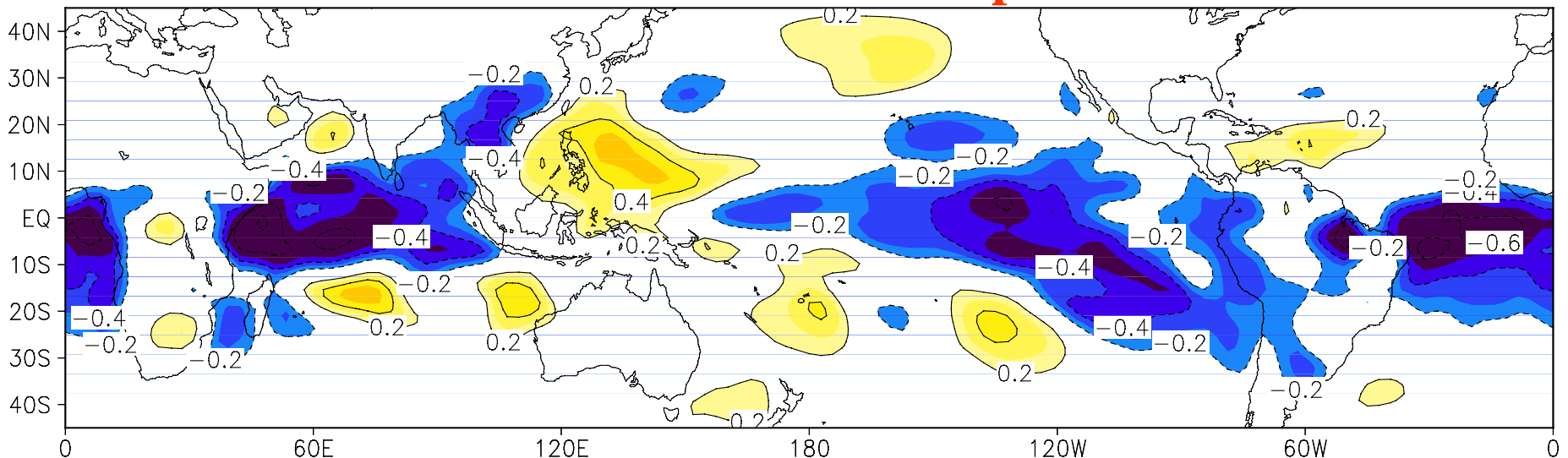
- Coupled Air-Sea Interaction Essential for Capturing Monsoon-Global SST Teleconnections
 - Latent Heat Flux – SST Feedbacks
 - Modifies Competition Between Local vs. Remote Influences
- Test: “Perfect AMIP”
 - **Prescribe** Exactly Coupled Model SST
 - But with Perturbed Atmospheric Initial State
 - With Identical Atmospheric Initial Conditions the Coupled Model Solution is Recovered Exactly
 - 50 Year Simulation

Global SST-Monsoon Correlation: Perfect AMIP



Overlapping 50-Year Period

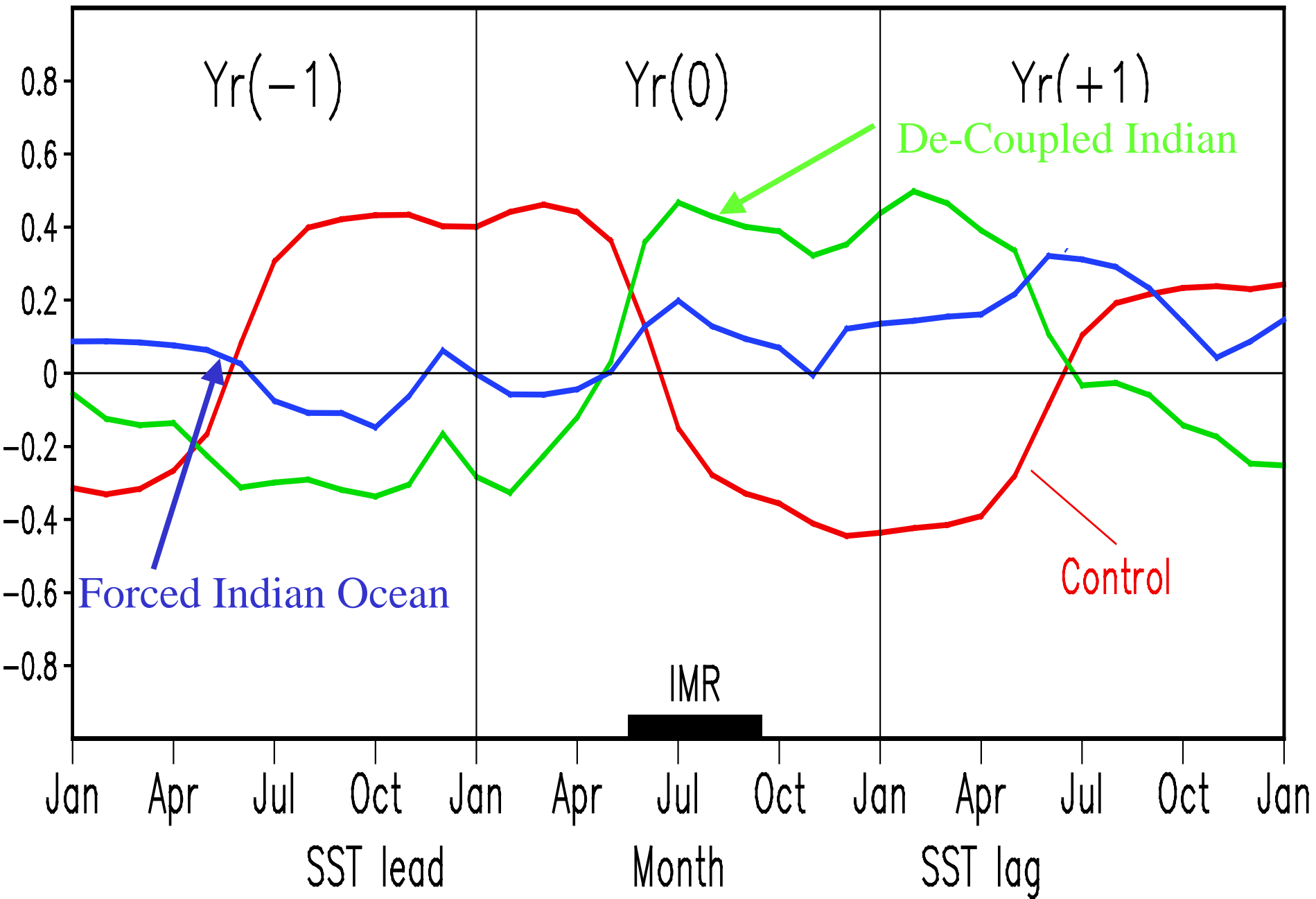
Global SST-Monsoon Correlation: Coupled Simulation



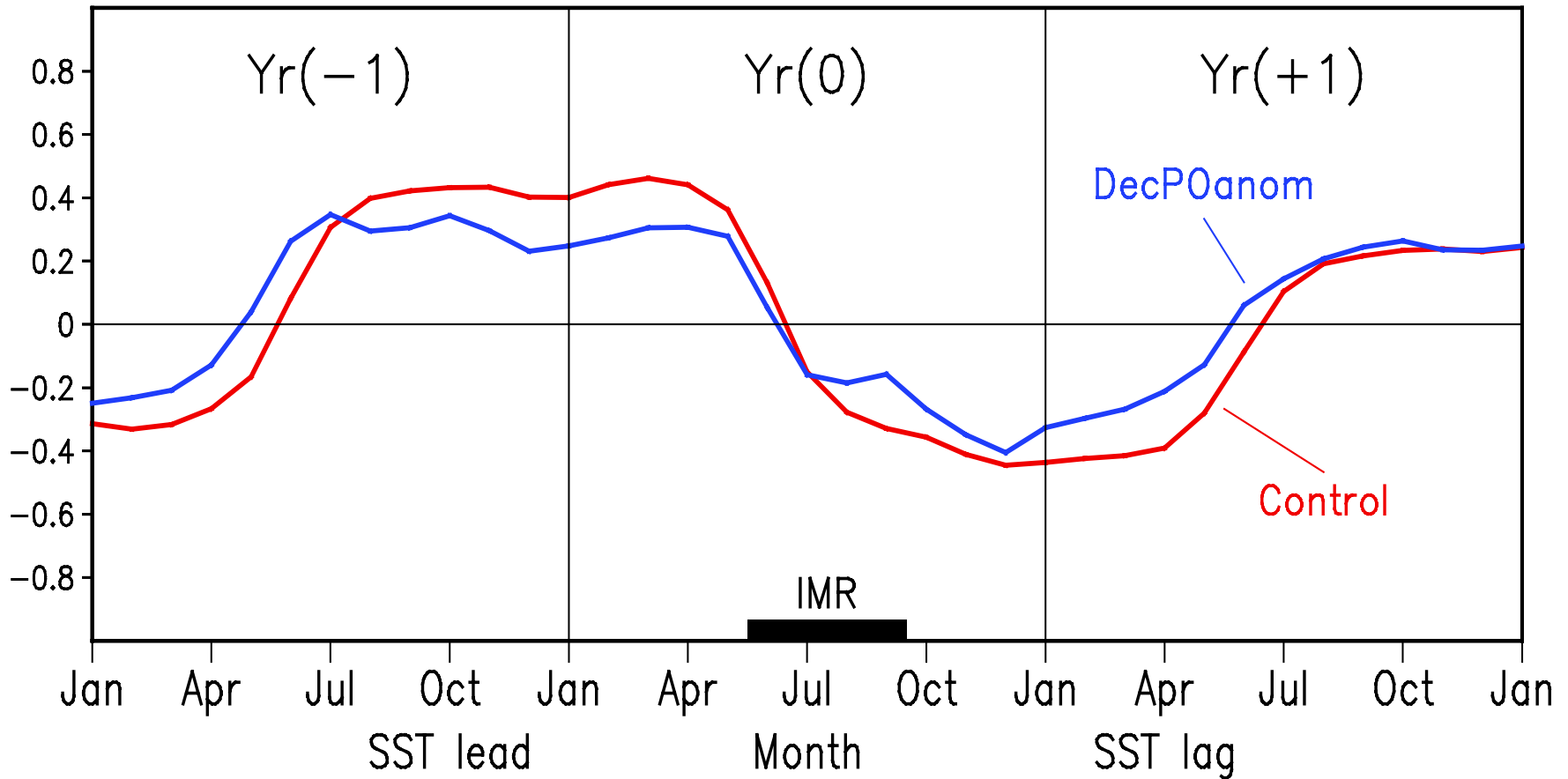
Regional Coupling Experiments

- **Specify Indian Ocean Coupled Model
Climatology – Decoupled Indian Ocean**
- **Specify Indian Ocean Coupled Model
Anomalies – Forced Indian Ocean**
- *Specify Pacific Ocean Coupled Model
Climatology – Decoupled Pacific Ocean*
- **Specify Pacific Ocean Coupled Model
Anomalies – Forced Pacific Ocean**

JJAS IMR lag-cor with monthly NINO3.4 SST (COLA Model)



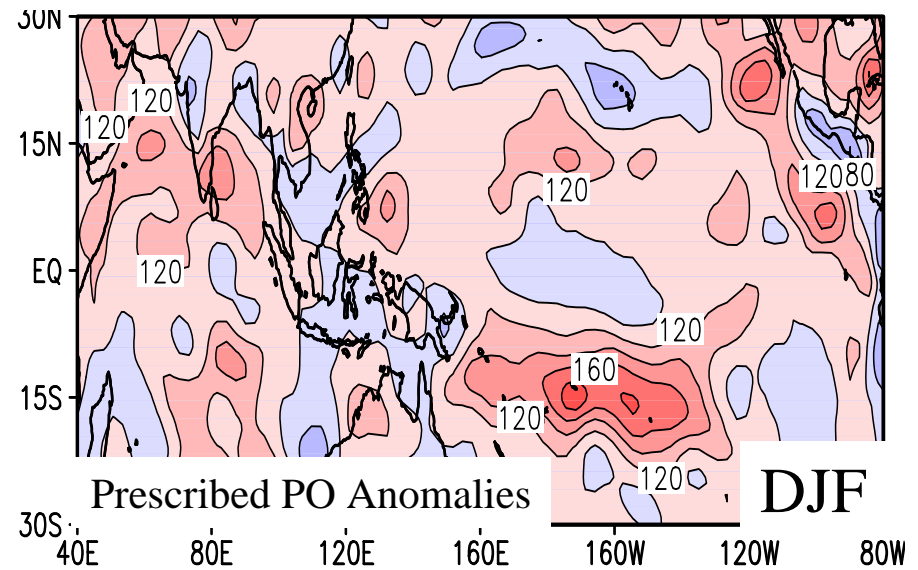
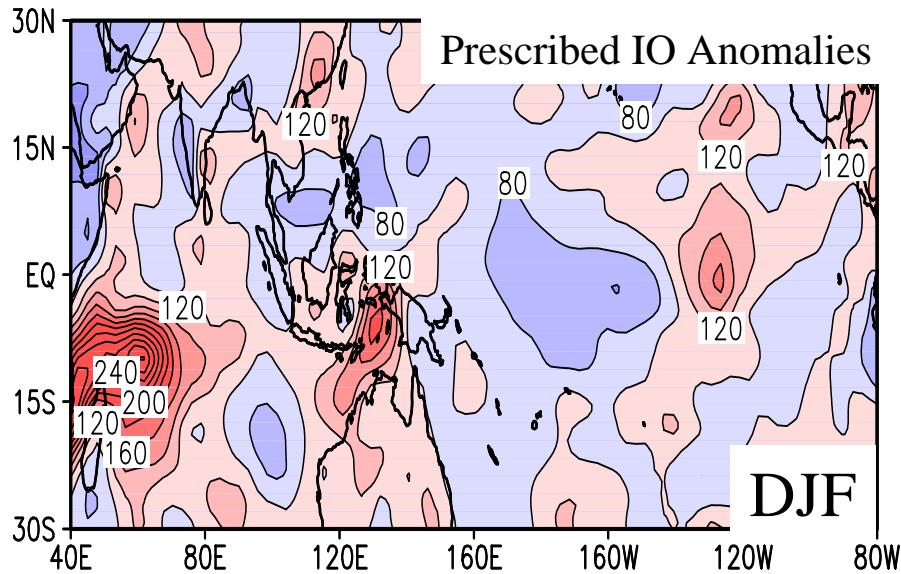
JJAS IMR lag-cor with monthly NINO3.4 SST (COLA Model)



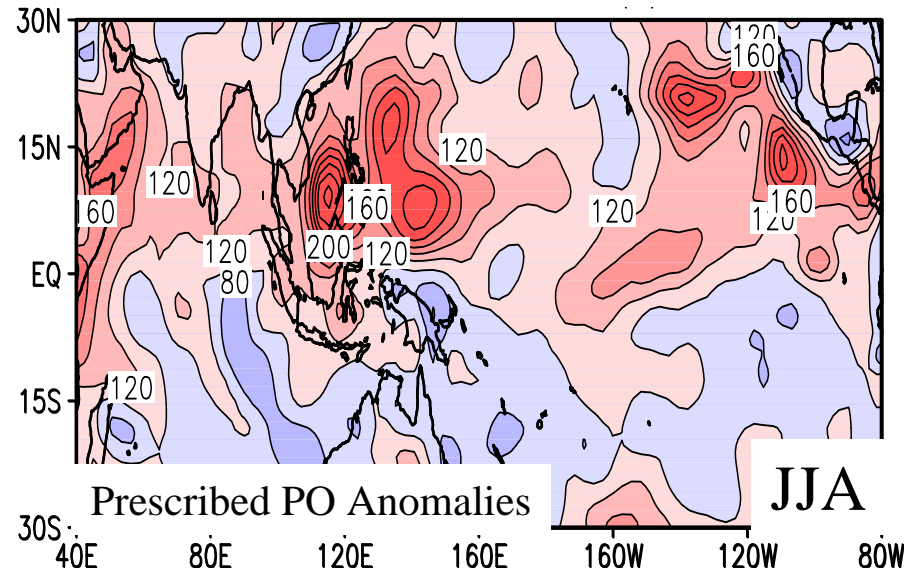
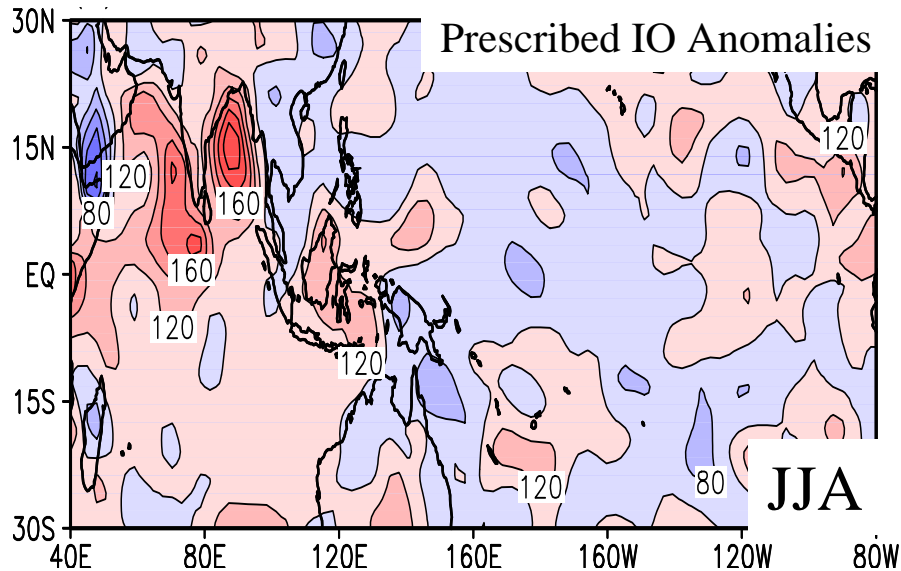
But, Coupled Interactions in the Indian Ocean Still Required!

- Prescribing Global SSTs (even from the CGCM)
Fails to Capture Monsoon-Global SSTA
Teleconnection
- Regional Coupling Experiments:
 - Prescribed Pacific and Coupled Indian Ocean
Re-Captures the Monsoon-SST Co-Variability
- How Do the Coupled Feedbacks Impact the
Variability?
 - Changes in Variability over Warm Oceans
- Ocean Forcing Atmosphere vs. Atmosphere
Forcing Ocean
 - Relationship Between Local SST, SST
Tendency, Latent Heat Flux and Rainfall

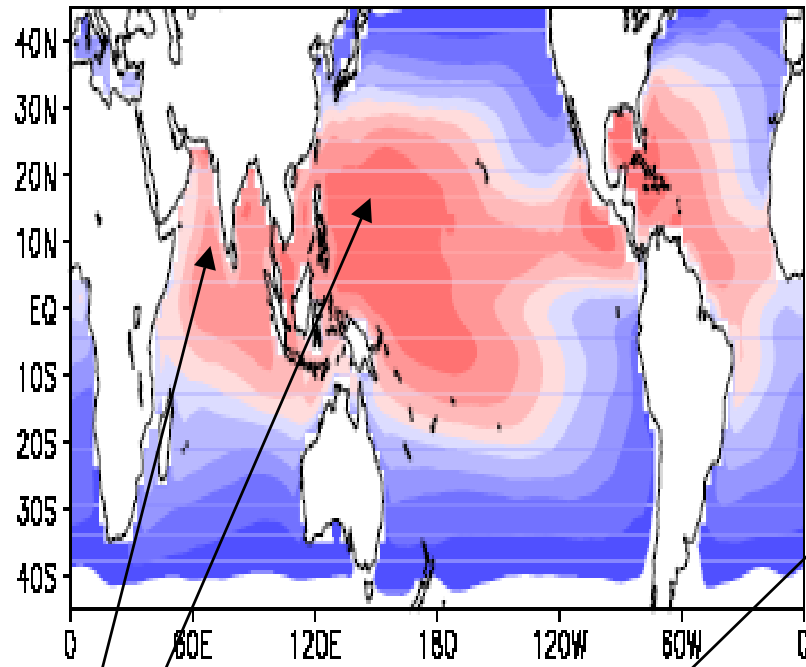
Precipitation Variance Ratios: Regional/Control



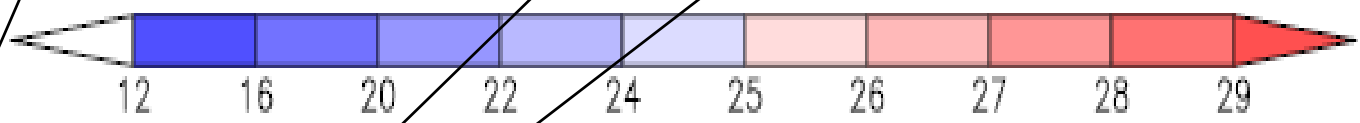
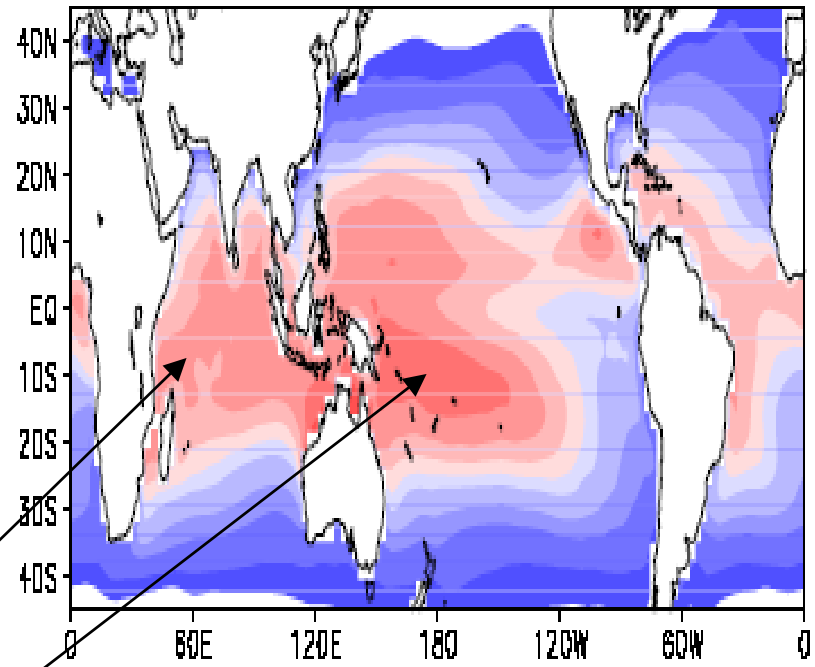
Precipitation Variance *Increases* with Prescribed SST



JJAS Tsfc (COLA Anomaly Coupled Model)



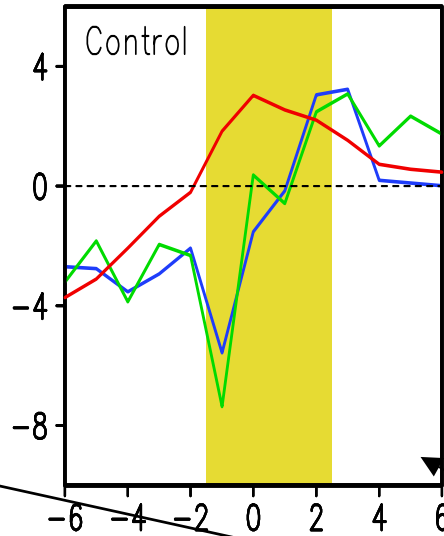
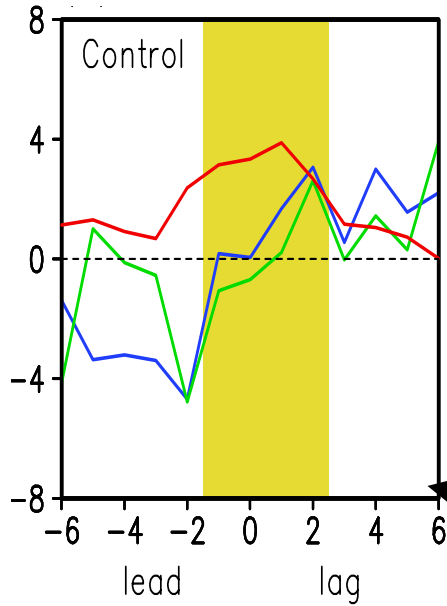
DJF Tsfc (COLA Anomaly Coupled Model)



Warm Oceans

North IO

West North Pac



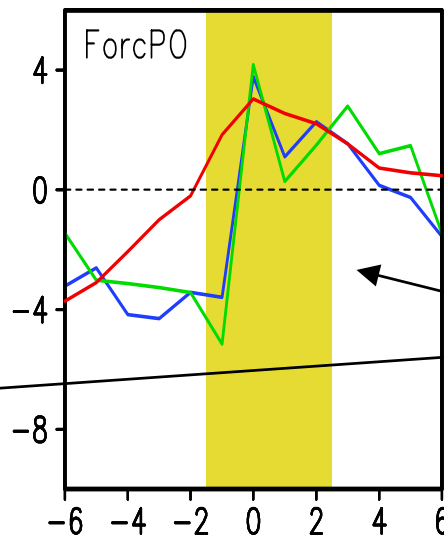
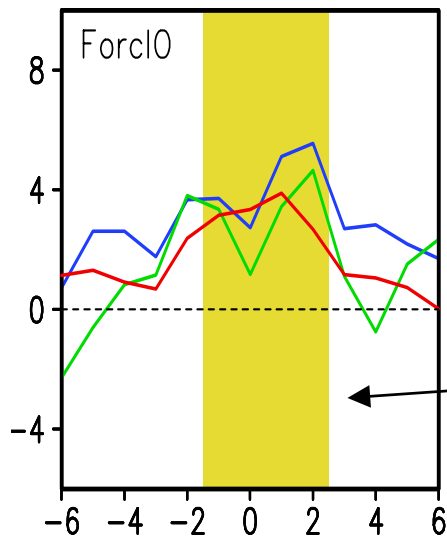
Local Lag-Lead Regression
Between SST and:

Precipitation

Latent Heat Flux

SST

Coupled Model



Regionally Prescribed SST

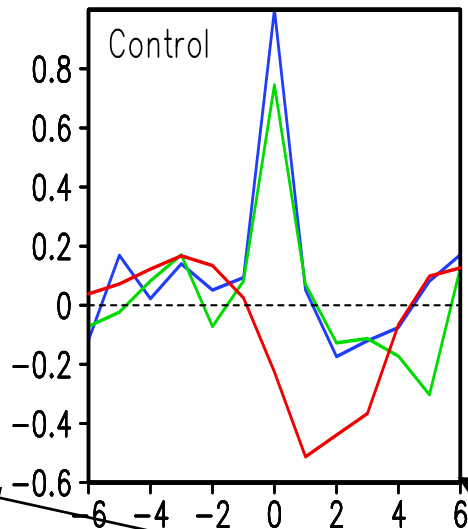
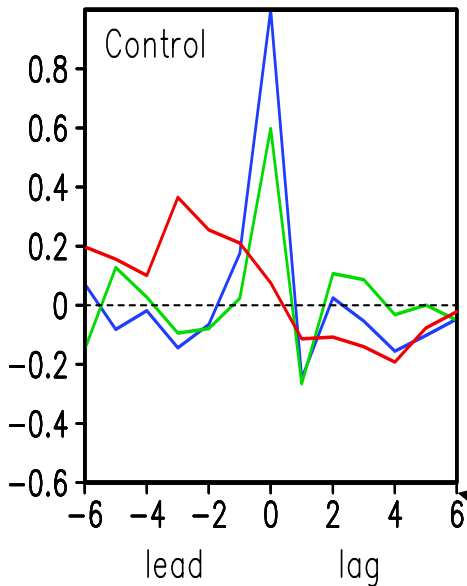
— p*10

— lhf

— sst*20

North IO

West North Pac



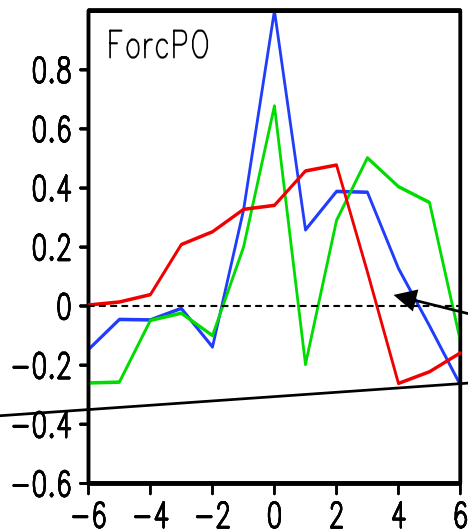
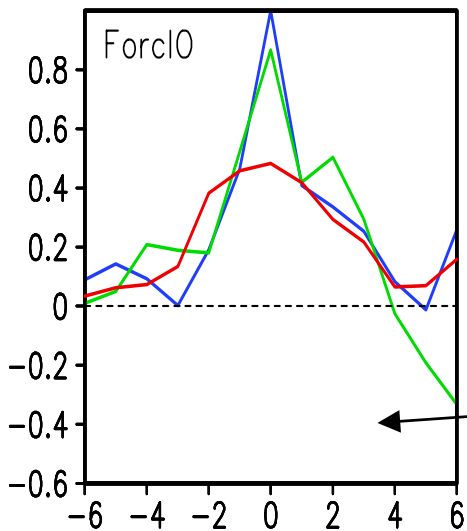
Local Lag-Lead Correlation
Between Precipitation and:

Precipitation

Latent Heat Flux

SST

Coupled Model



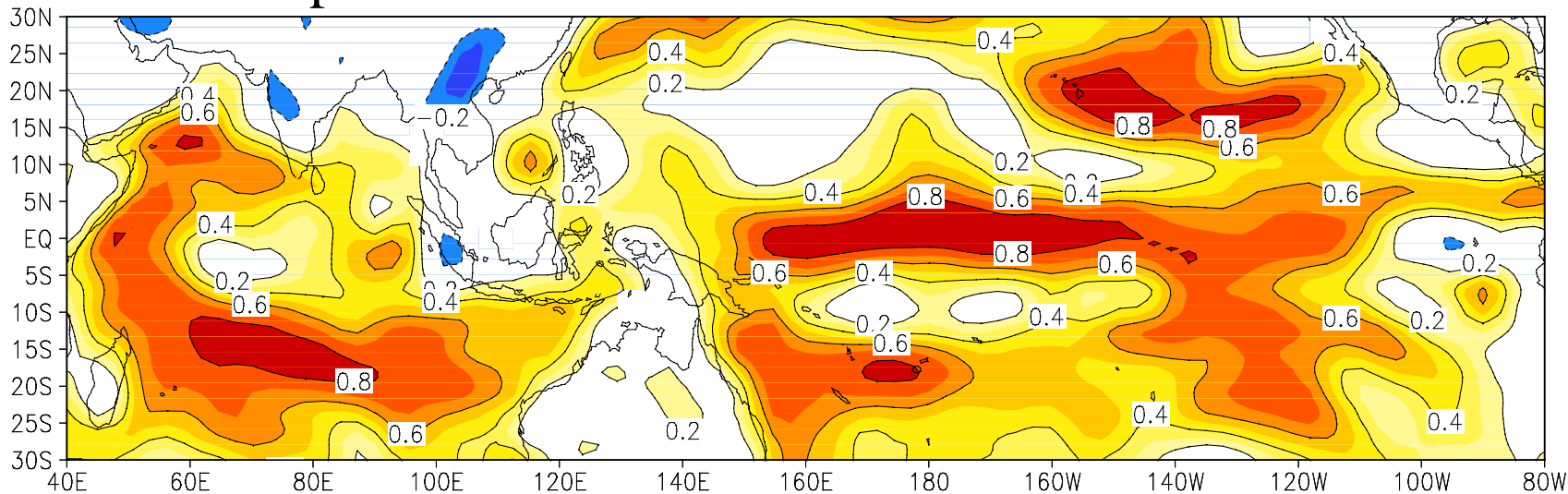
Regionally Prescribed SST

p

lhf

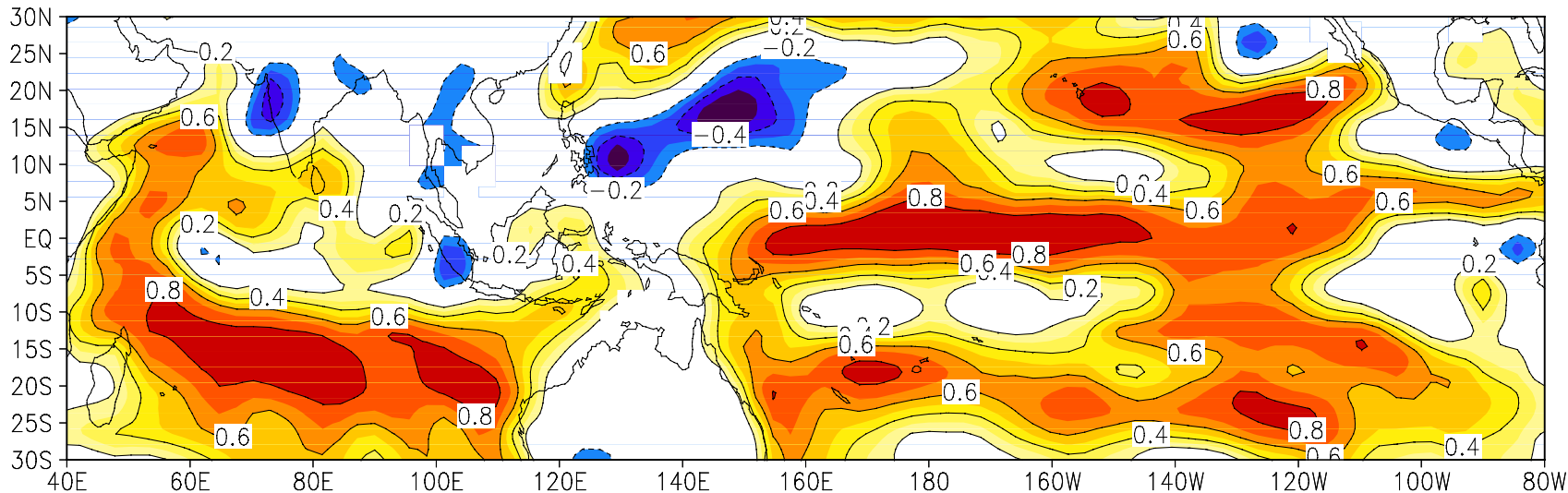
sst

JJAS Precipitation – SST Local Correlation: Perfect AMIP

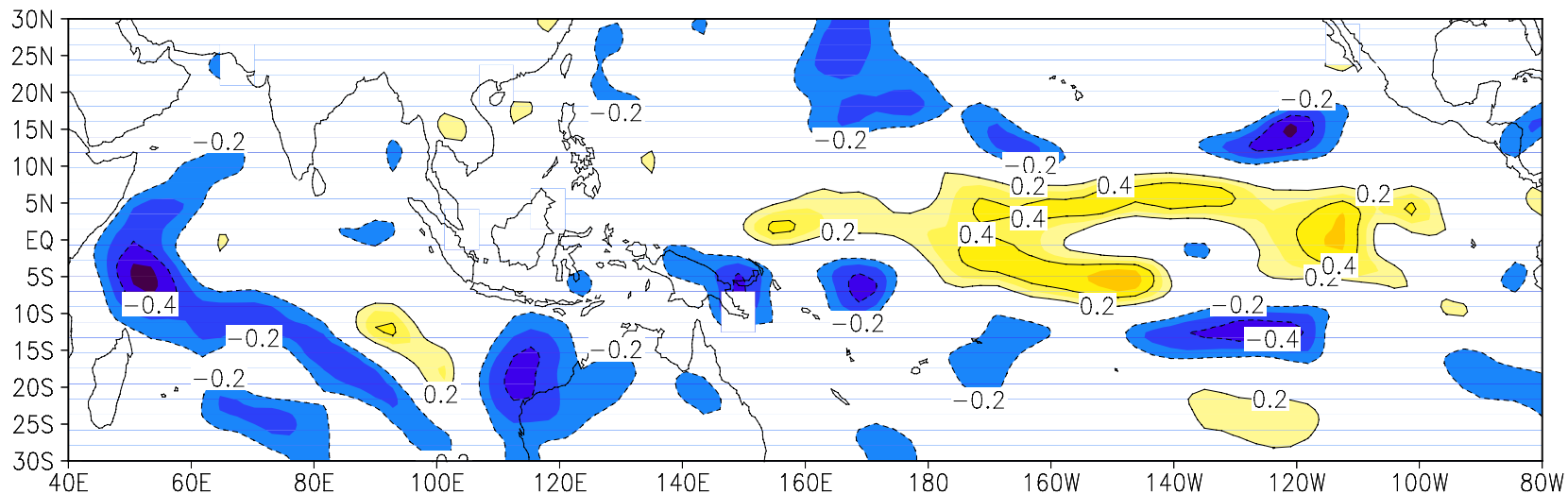


Overlapping 50-Year Period

JJAS Precipitation – SST Local Correlation: Coupled Model

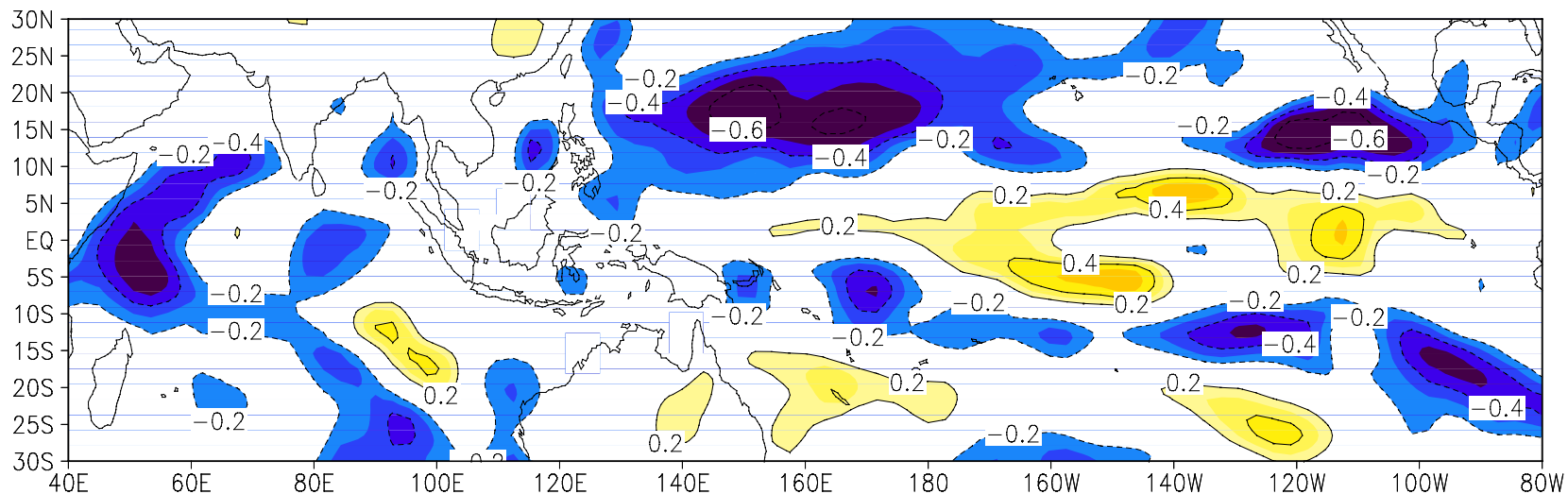


JJAS Precipitation – SST Tendency Local Correlation: Perfect AMIP

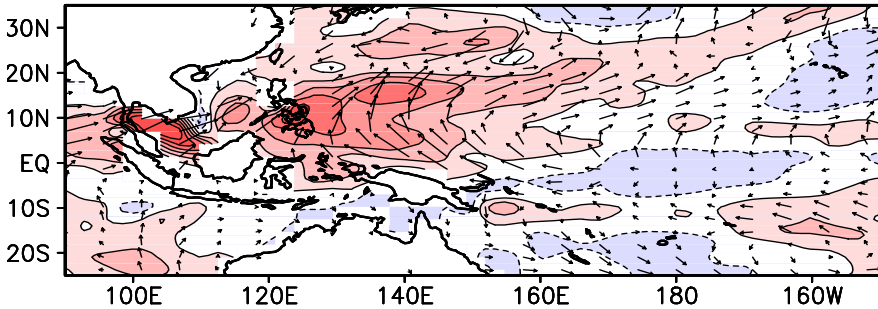


Overlapping 50-Year Period

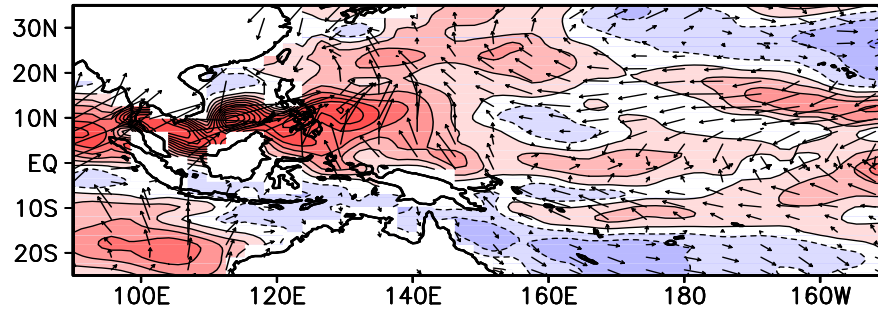
JJAS Precipitation – SST Tendency Local Correlation: Coupled Model



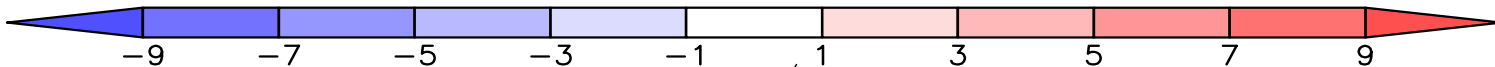
lhf&wind (Control)



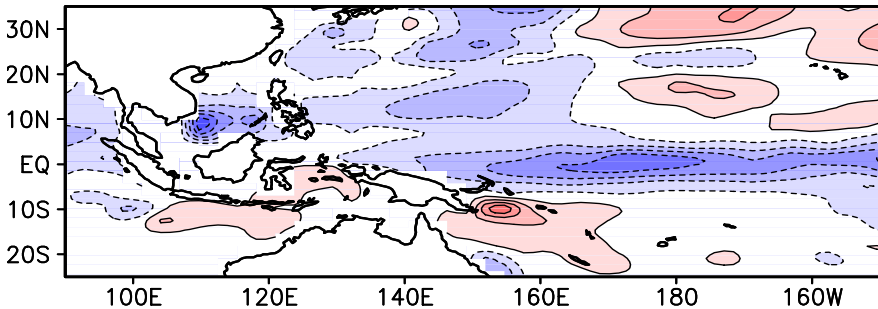
Simultaneous Regression wrt Jul WNP P



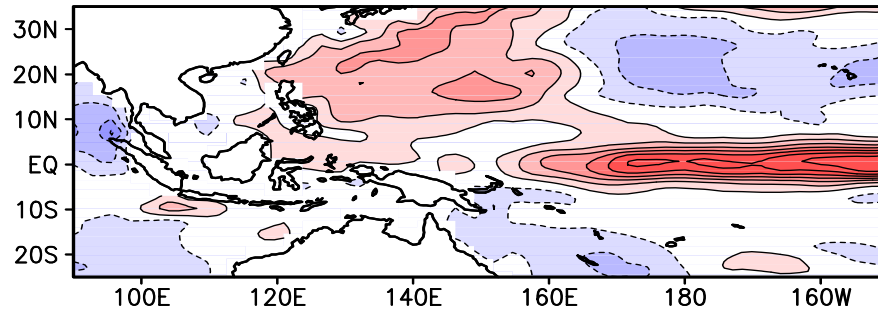
lhf&wind (ForcPO)



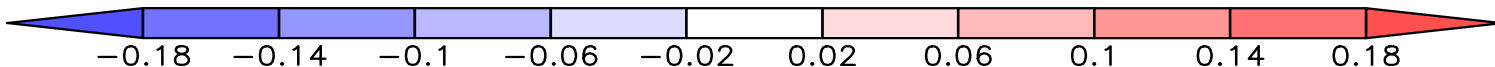
tcas (Control)



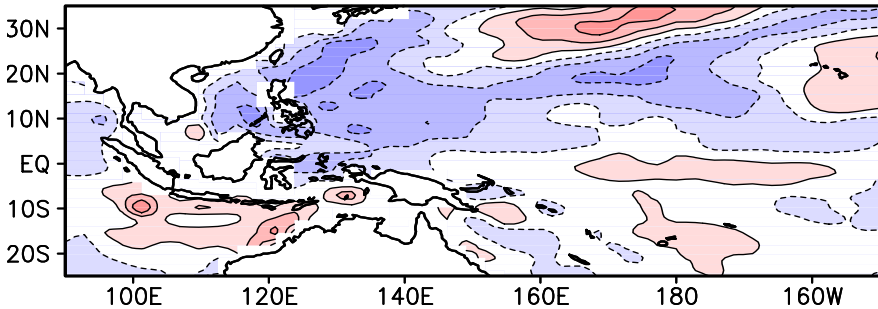
tcas (ForcPO)



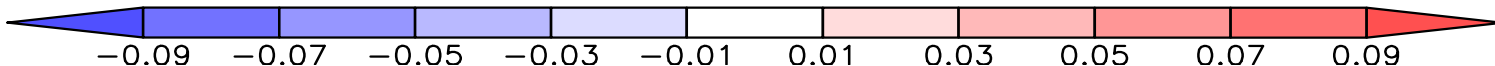
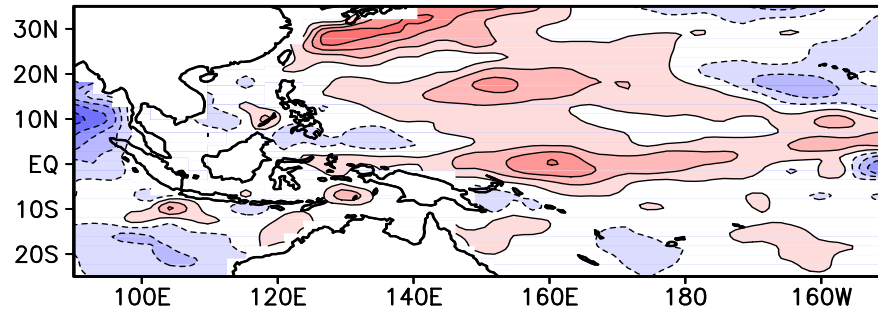
1m/s



tcas tendency (Control)

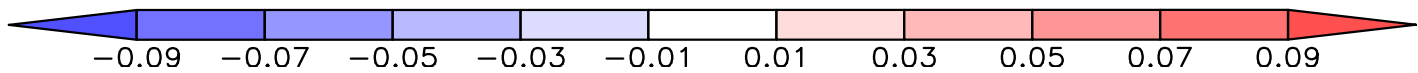
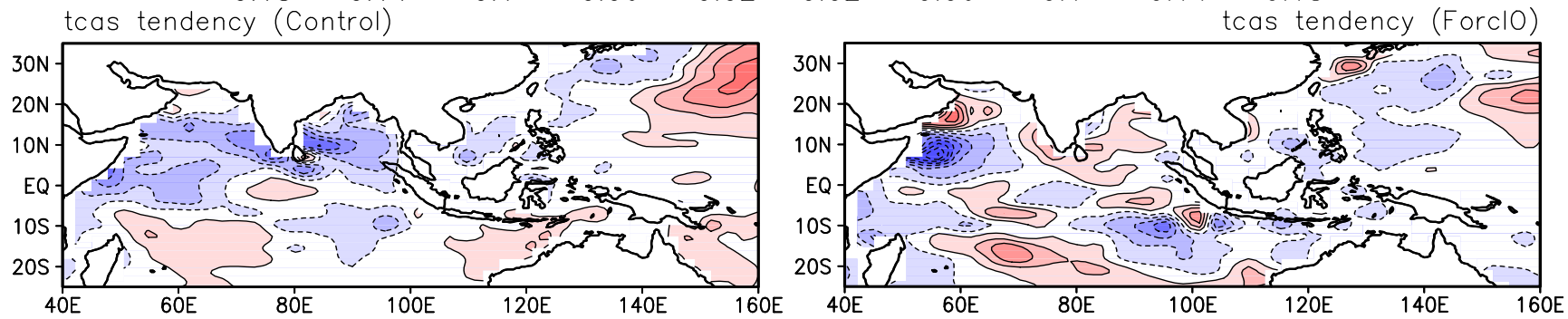
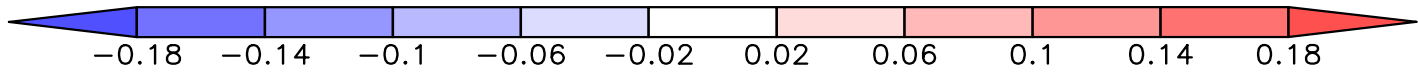
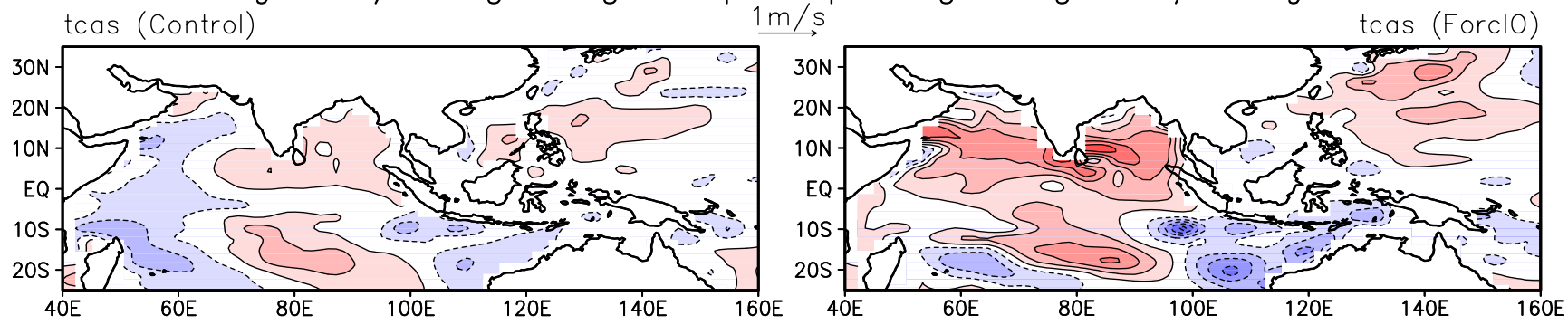
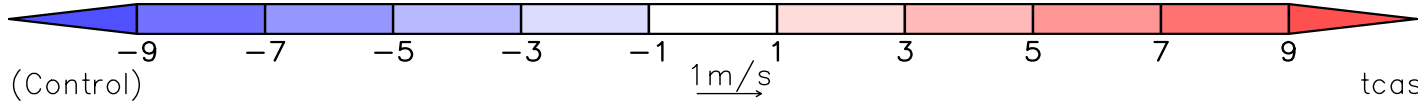
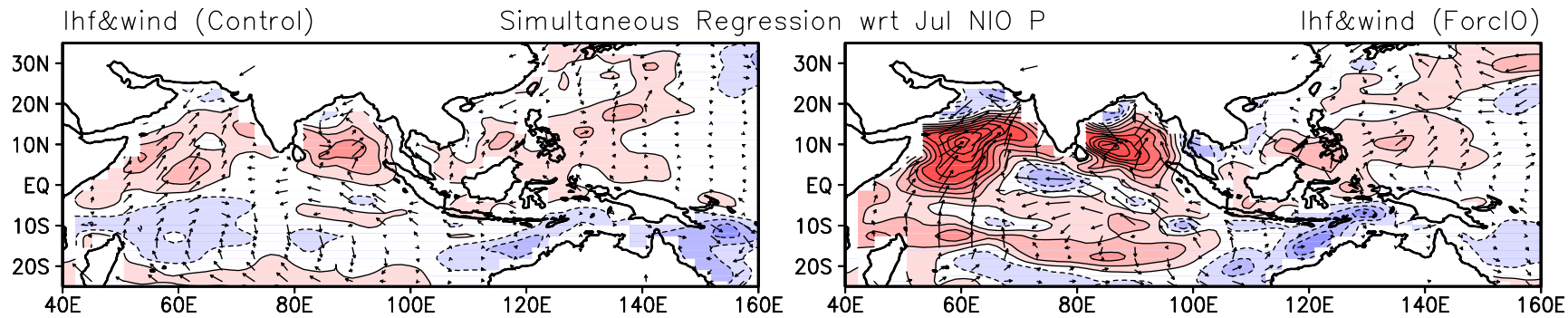


tcas tendency (ForcPO)



Coupled Simulation

Prescribed Pacific SST



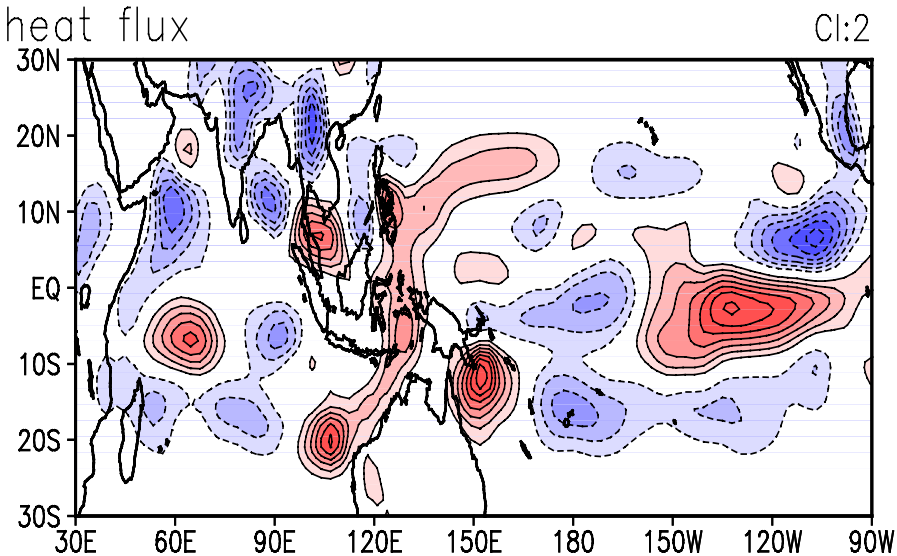
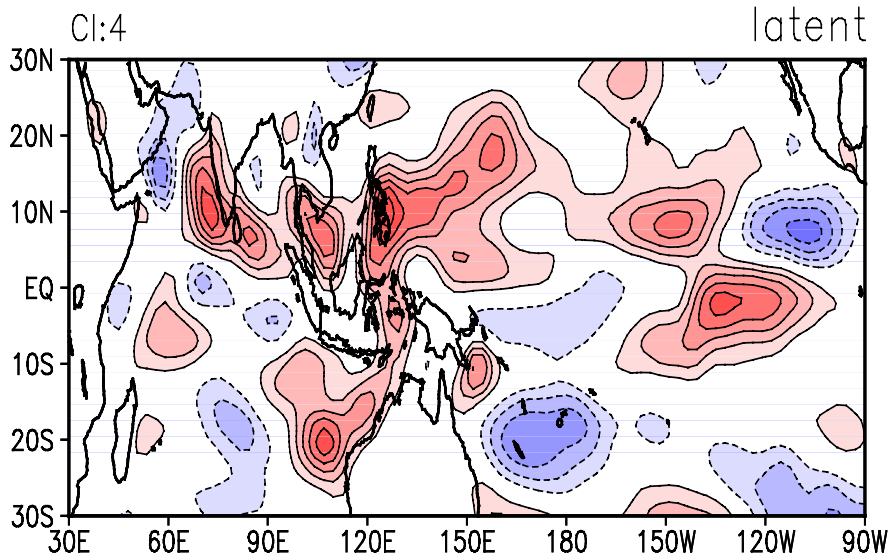
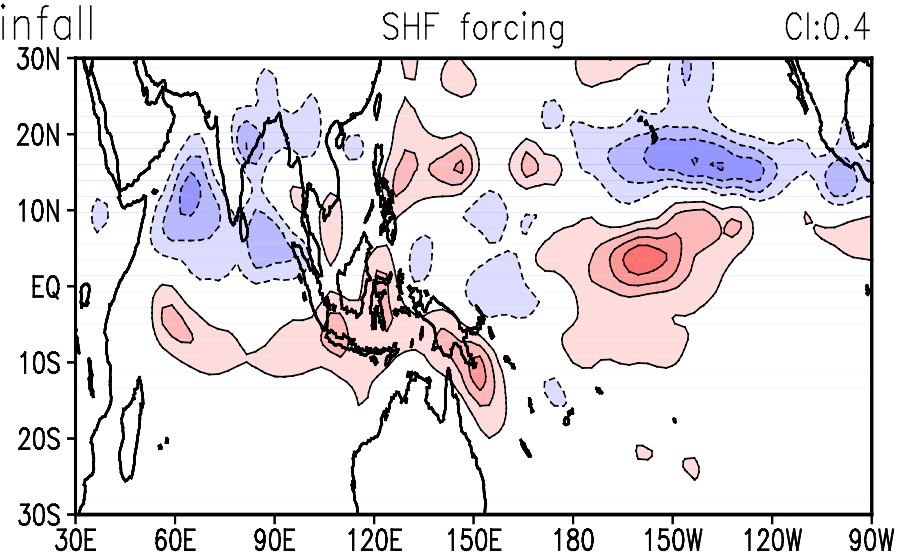
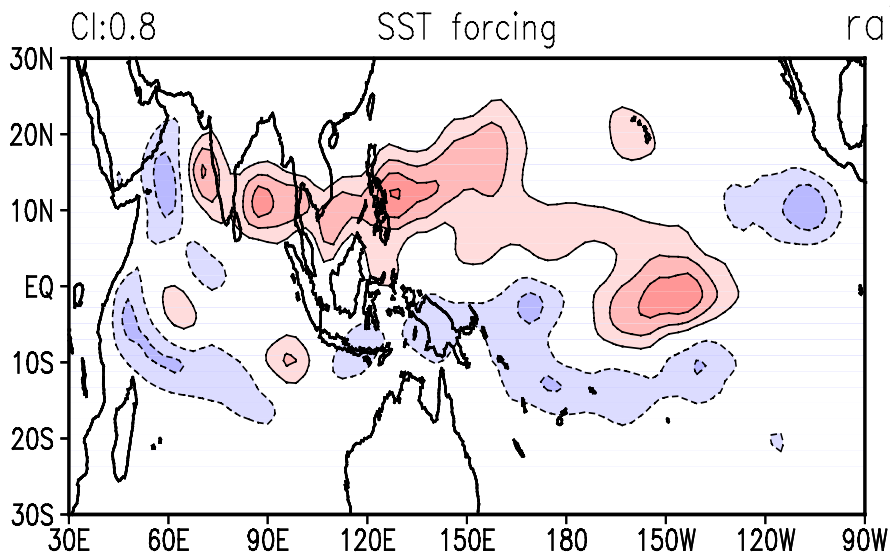
Coupled Simulation

Prescribed Indian SST

Warm Ocean Coupled Feedbacks

- Prescribed SSTs
 - Heat Fluxes are Inconsistent with SST
 - Modifies Phase Relationships between SST and Precipitation (Heat Flux)
 - Increases local Variability
 - Interferes (Modifies) with Competition between Local and Remote Influences on Co-Variability (i.e., ENSO-Monsoon)
- Prescribed Heat Fluxes
 - Atmospheric Circulation and Fluxes Inconsistent
 - But SST and Heat Fluxes are Consistent

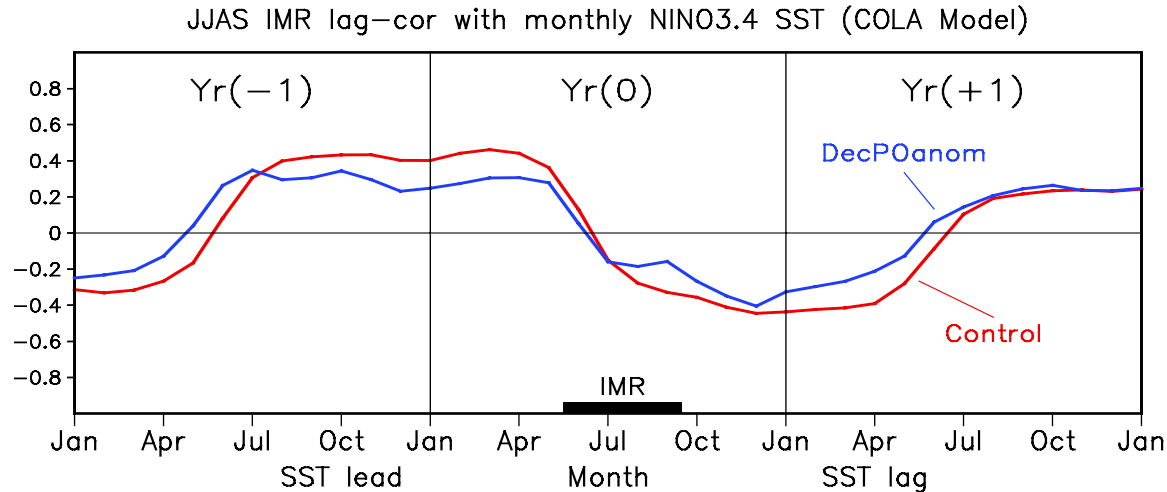
AGCM response 10-ensemble mean



Prescribed SST Forcing

Prescribed Heat Flux Forcing

Conclusions and Proposal



- Warm Tropical Ocean Coupled Air-Sea Interactions Essential for Atmosphere Ocean Co-Variability (Indian Ocean, West Pac)
 - Modifies Competition between Remote and Local Influences
 - Surface Heat Flux Boundary Condition Re-Captures Some of the Co-Variability
- East Tropical Pacific SST Forced Response is Reasonable
- Proposed Coupled Tier-2 Prediction Experiment
 - Use Prescribed (but Predicted) SSTA in East Pacific and Coupled Model (Mixed-Layer or OGCM) Elsewhere