Internal Atmospheric Variability, Pacific Meridional Mode & ENSO

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Contributions from

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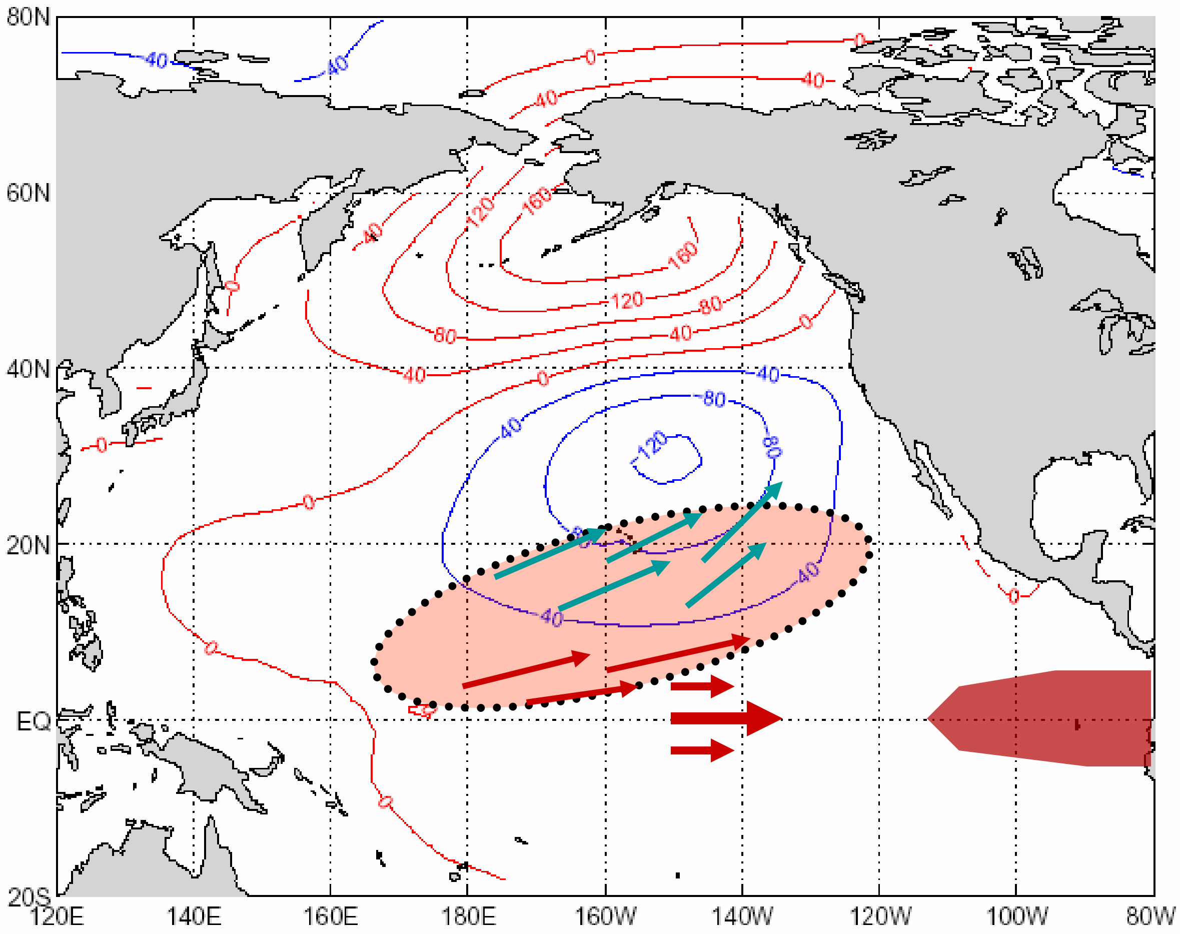
Seasonal Foot Printing Mechanism (Vimont et al.)



- NPO in NDJ (-1)

  ⇓
- Winds & Heat Flux

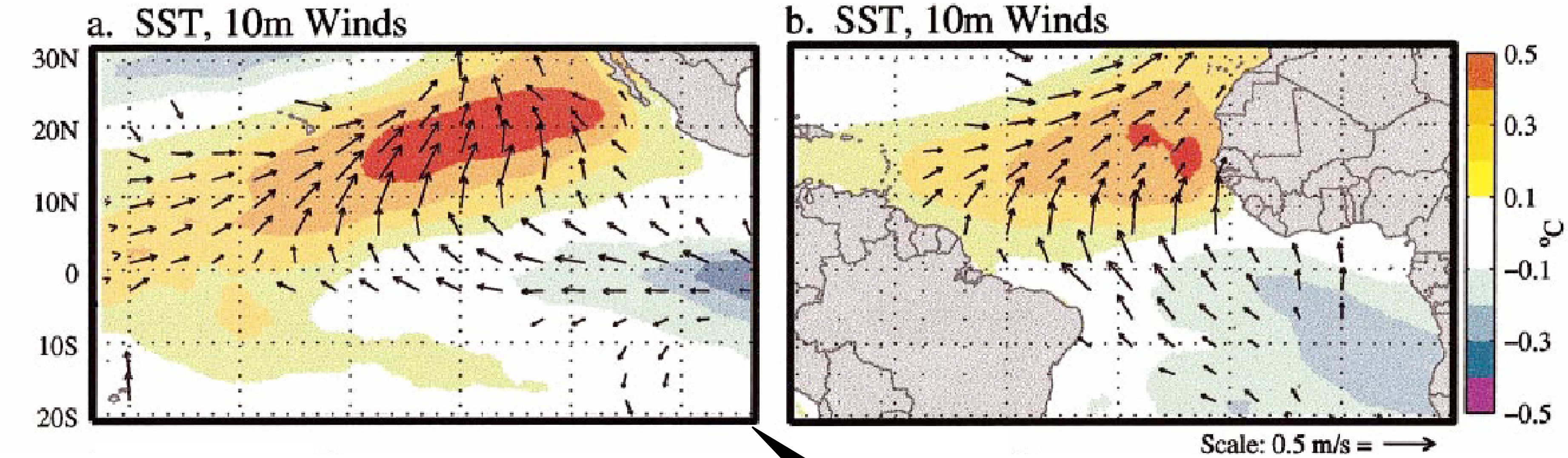
  ⇓
- SST in MAM (0)

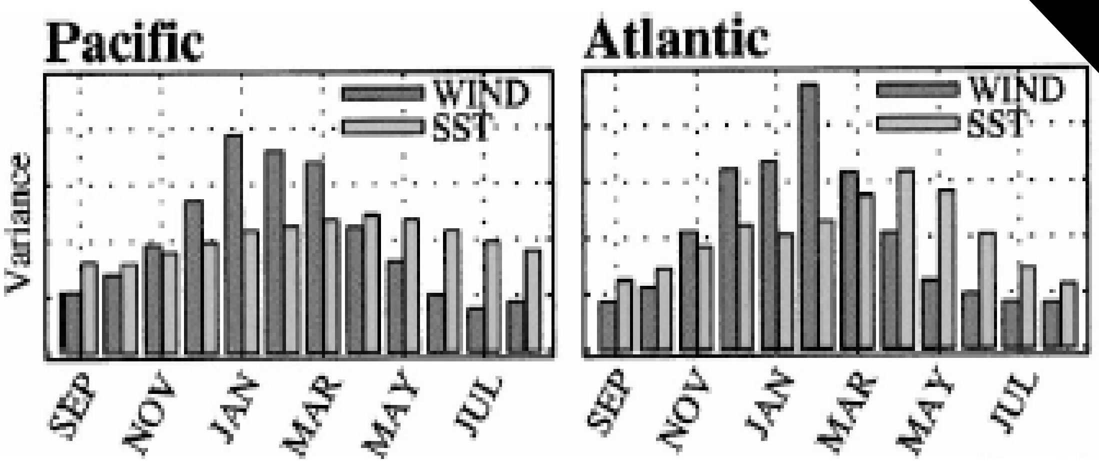
  ⇓
- Tropical Winds

  ⇓
- Bjerknes Feedback

  ⇓
- El Nino in NDJ(0)

Meridional Mode (MM)

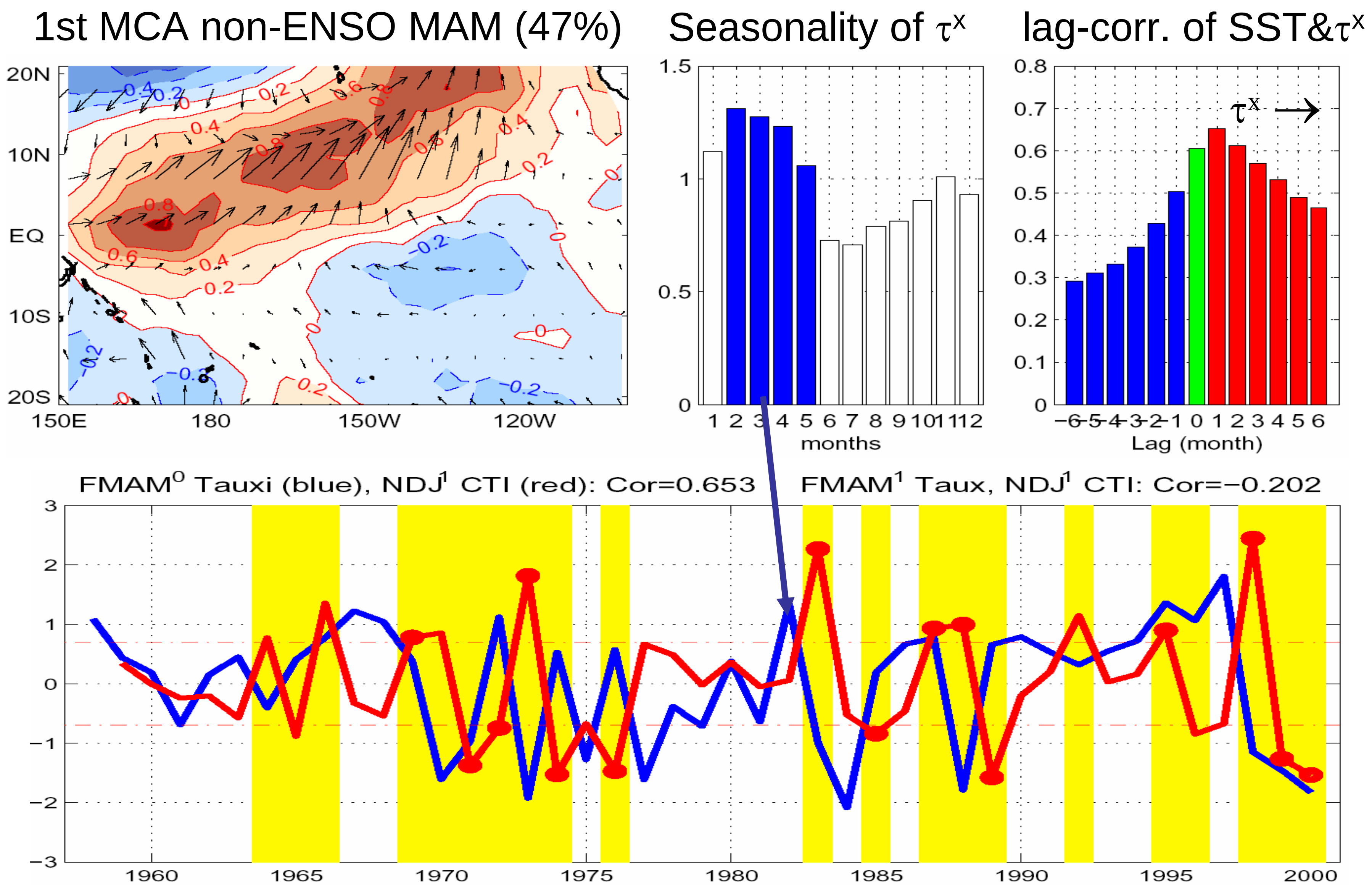




Chiang and Vimont (2004) postulate that "the MM is an effective conduit for extratropaL atmospheric influence on the tropics."

(Chiang&Vimont, 2004)

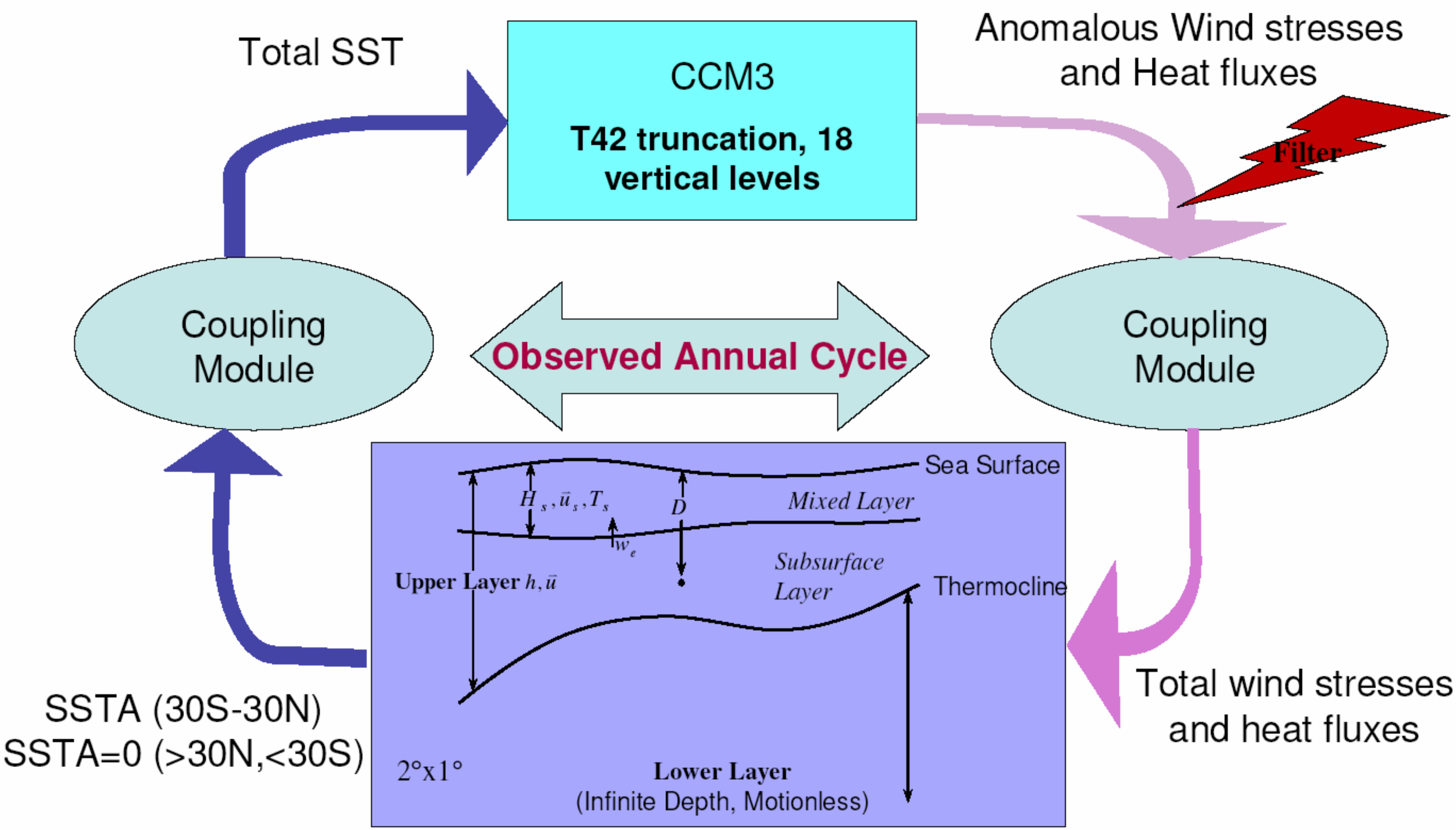
Pacific "Meridional Mode" → ENSO



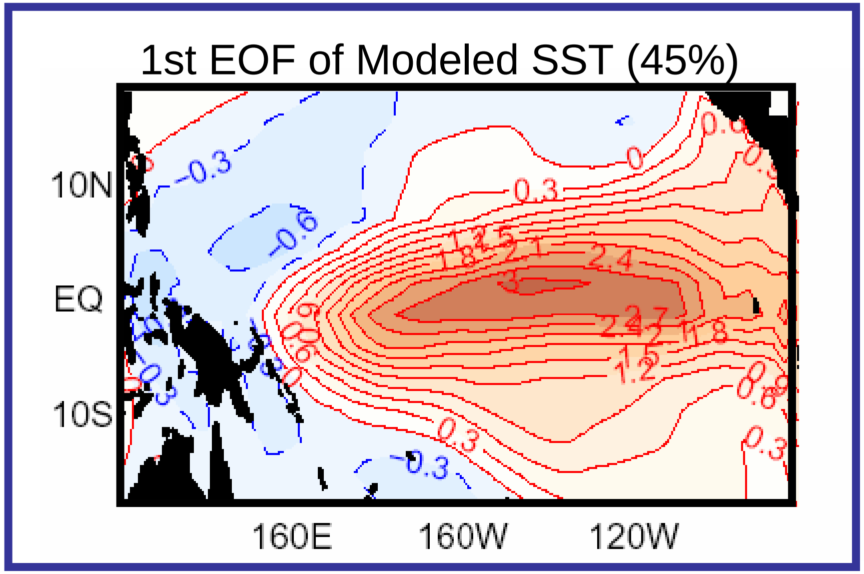
Remarks

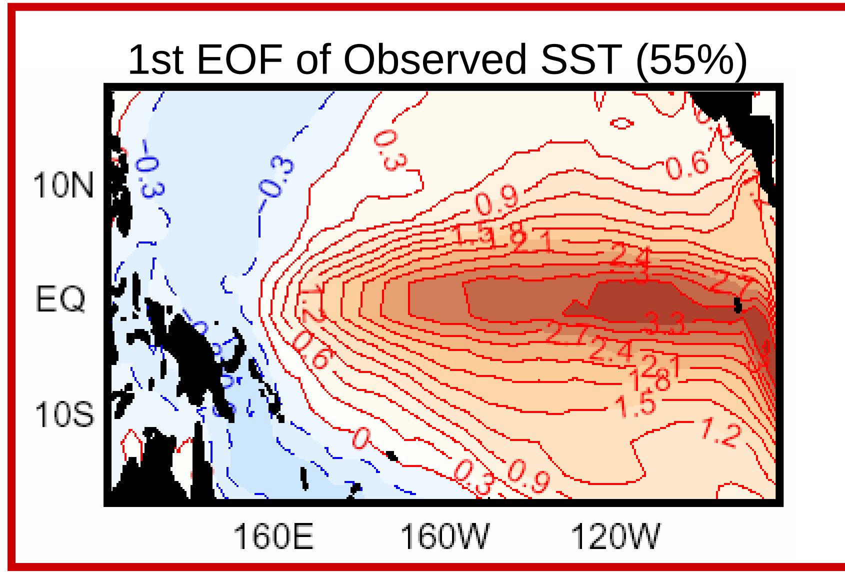
- The MM is not sensitive to analysis techniques and data sets (NCEP and ECMWF ERA 40), despite the limited record length (45 years).
- The NPO presents one major forcing mechanism to excite the MM, but other mechanisms may also exist.
- The relationship between the MM and ENSO appears to be more robust than the direct relationship between the NPO and ENSO.
- The MM related SST is most correlated with the southern lobe of the NPO, but not so much with the northern one.
- The NPO is not the most dominant mode in the north Pacific and explains less than 20% of the SLP variance in boreal winter.

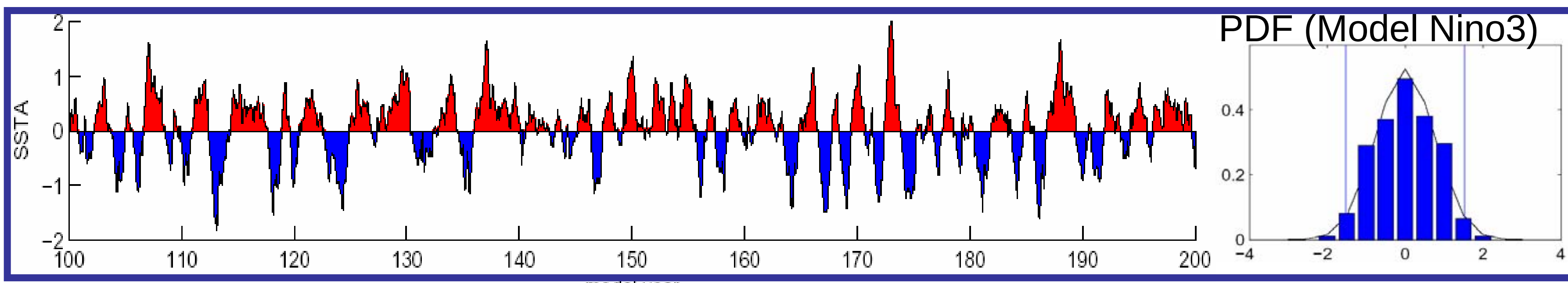
CCM3-RGO Coupled Model

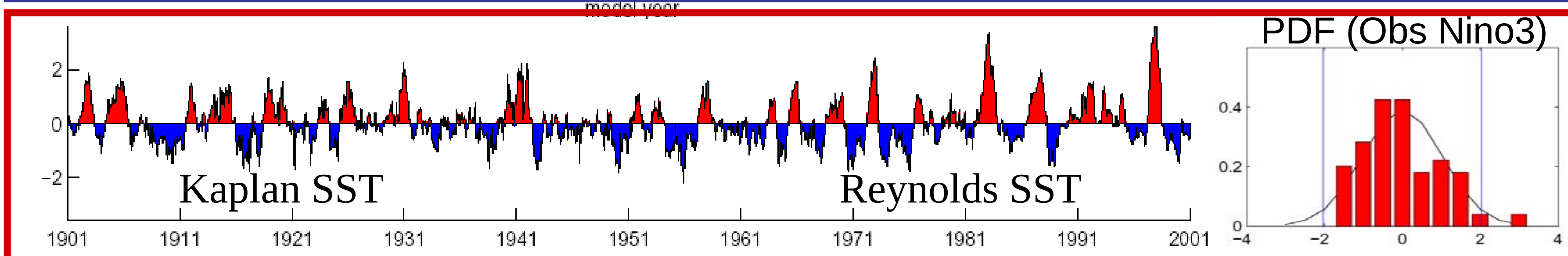


Simulated vs Observed ENSO

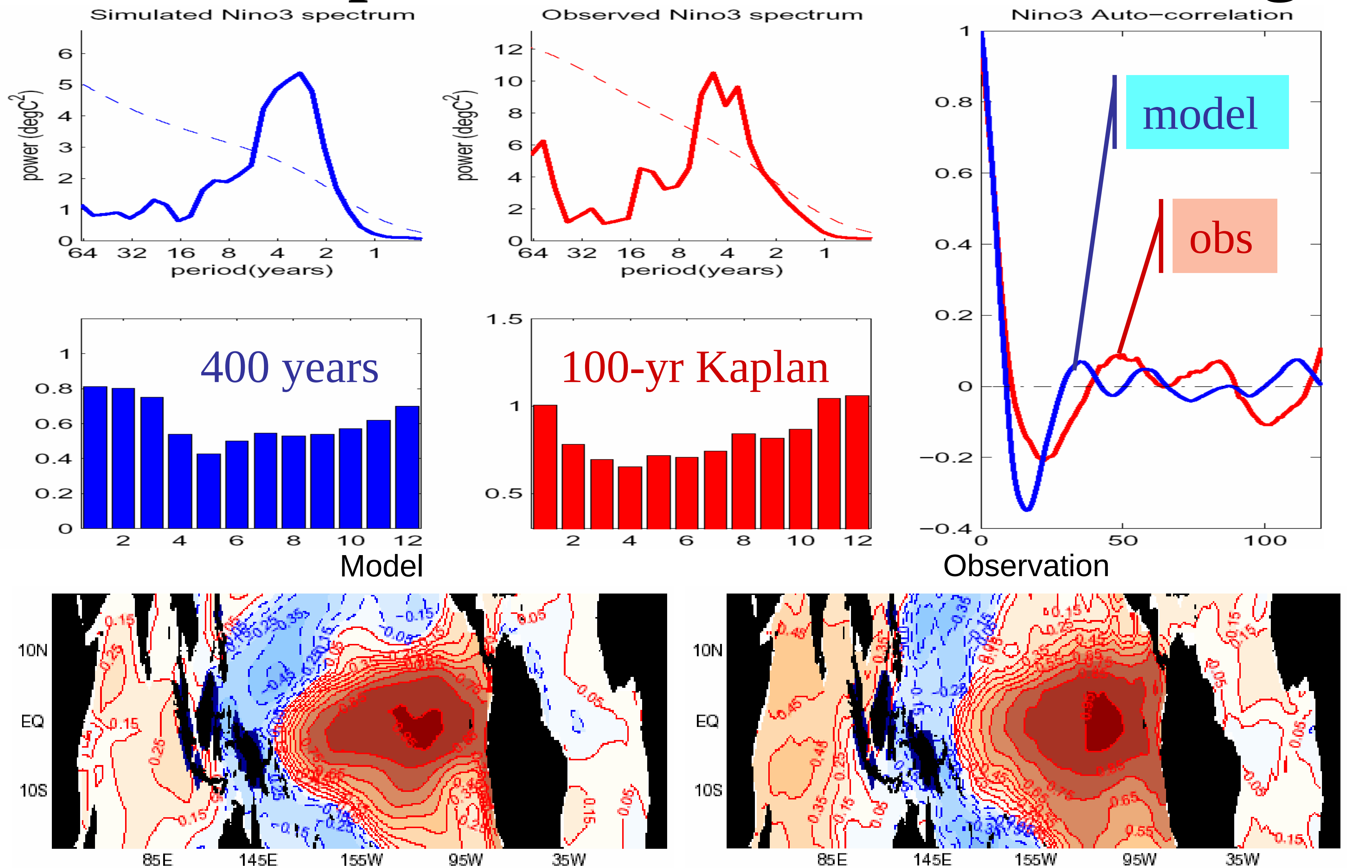






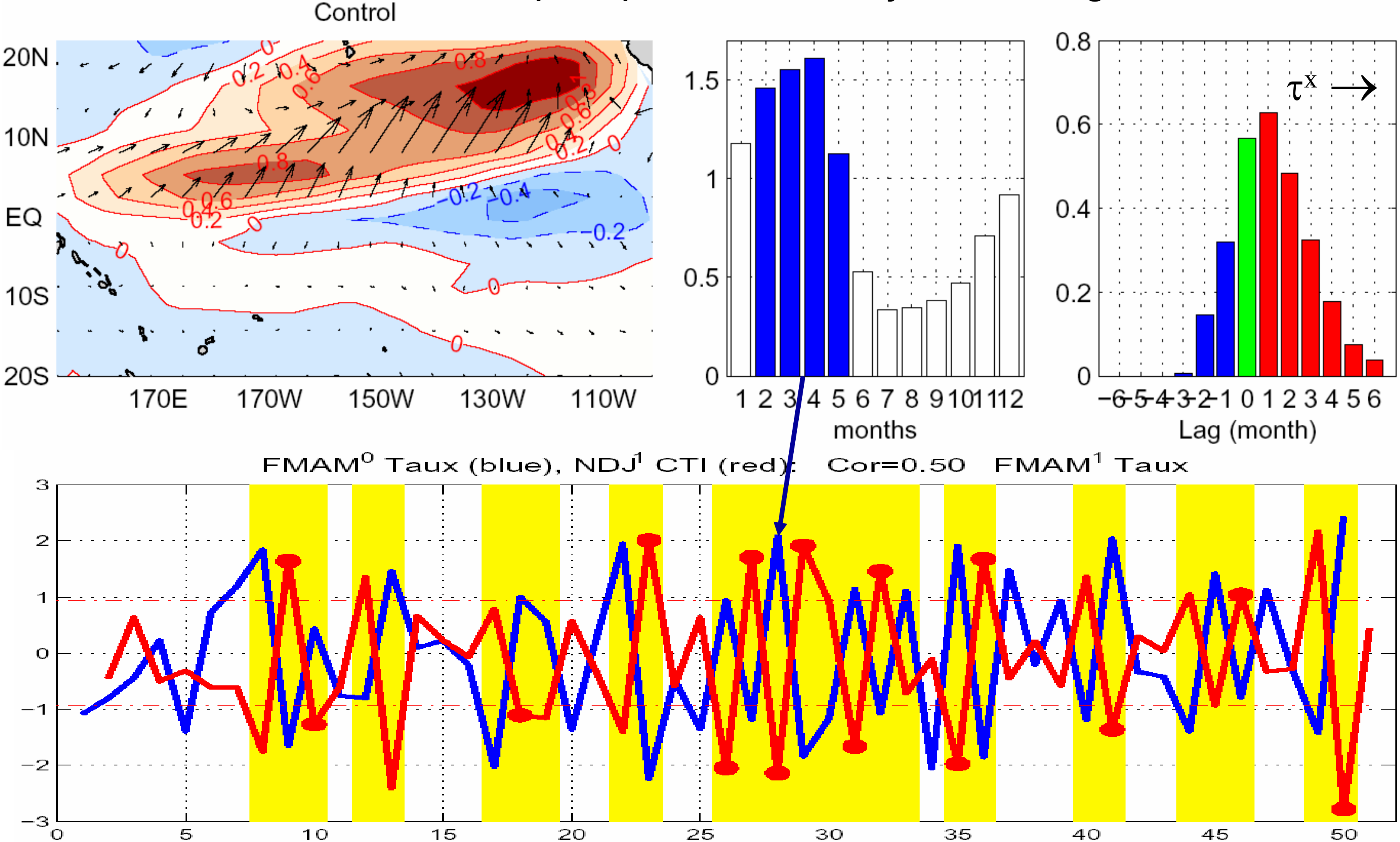


ENSO Spectrum and Phase-Locking



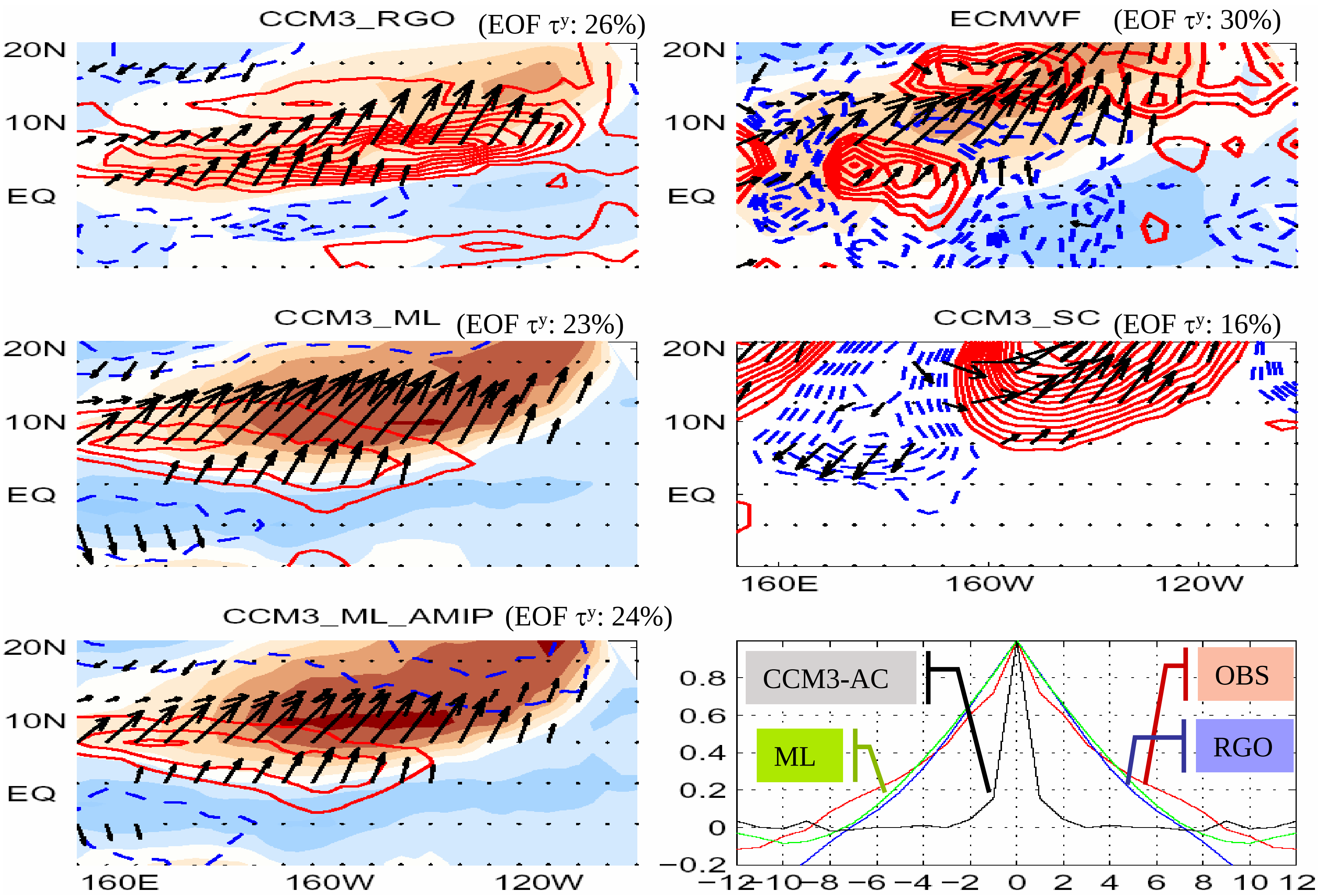
The MM in CCM3-RGO Simulation

1st MCA non-ENSO MAM (54%) Seasonality of τ^x lag-corr. of SST&τ^x

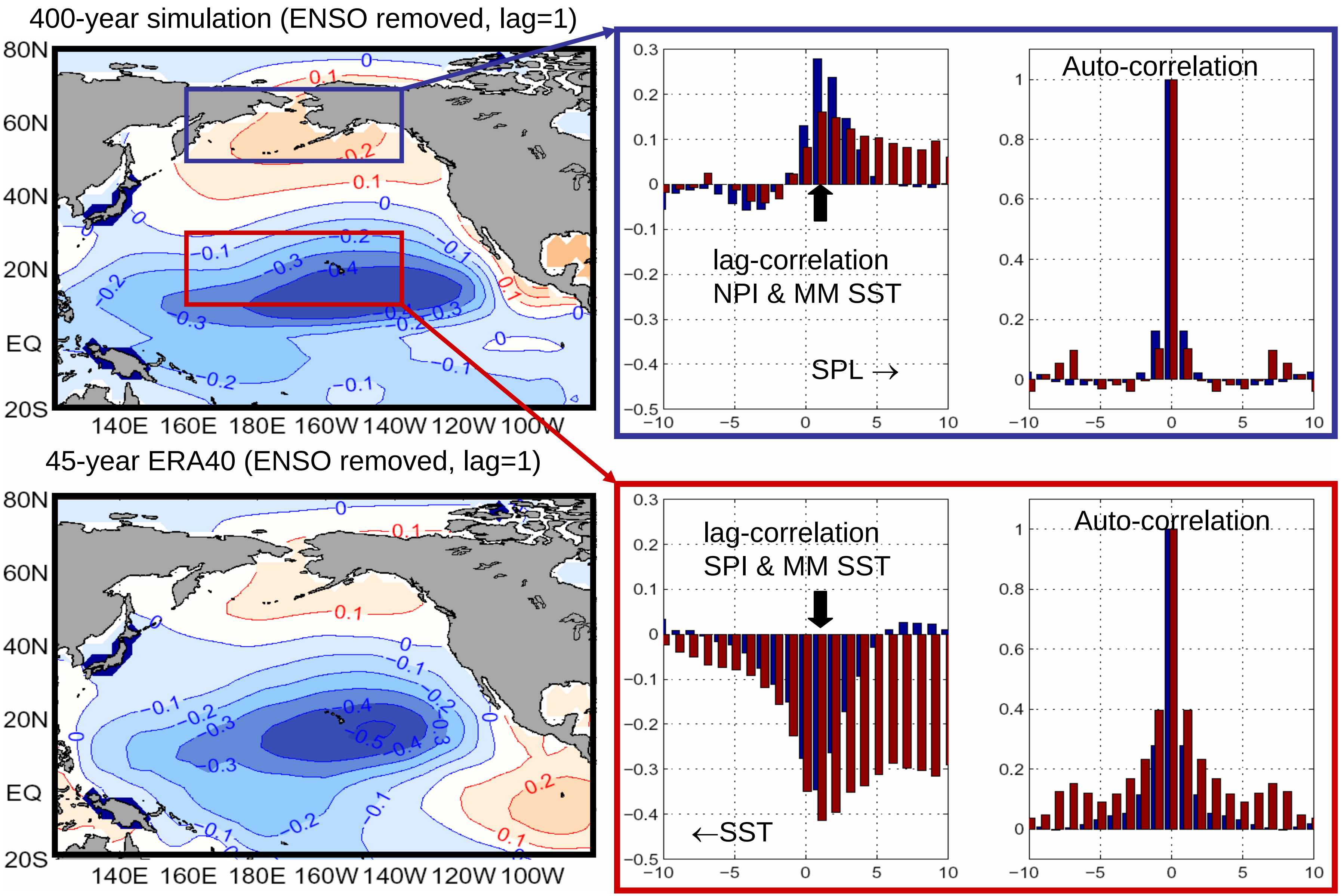


A sample from 400-year record

Thermodynamic Coupling in the MM



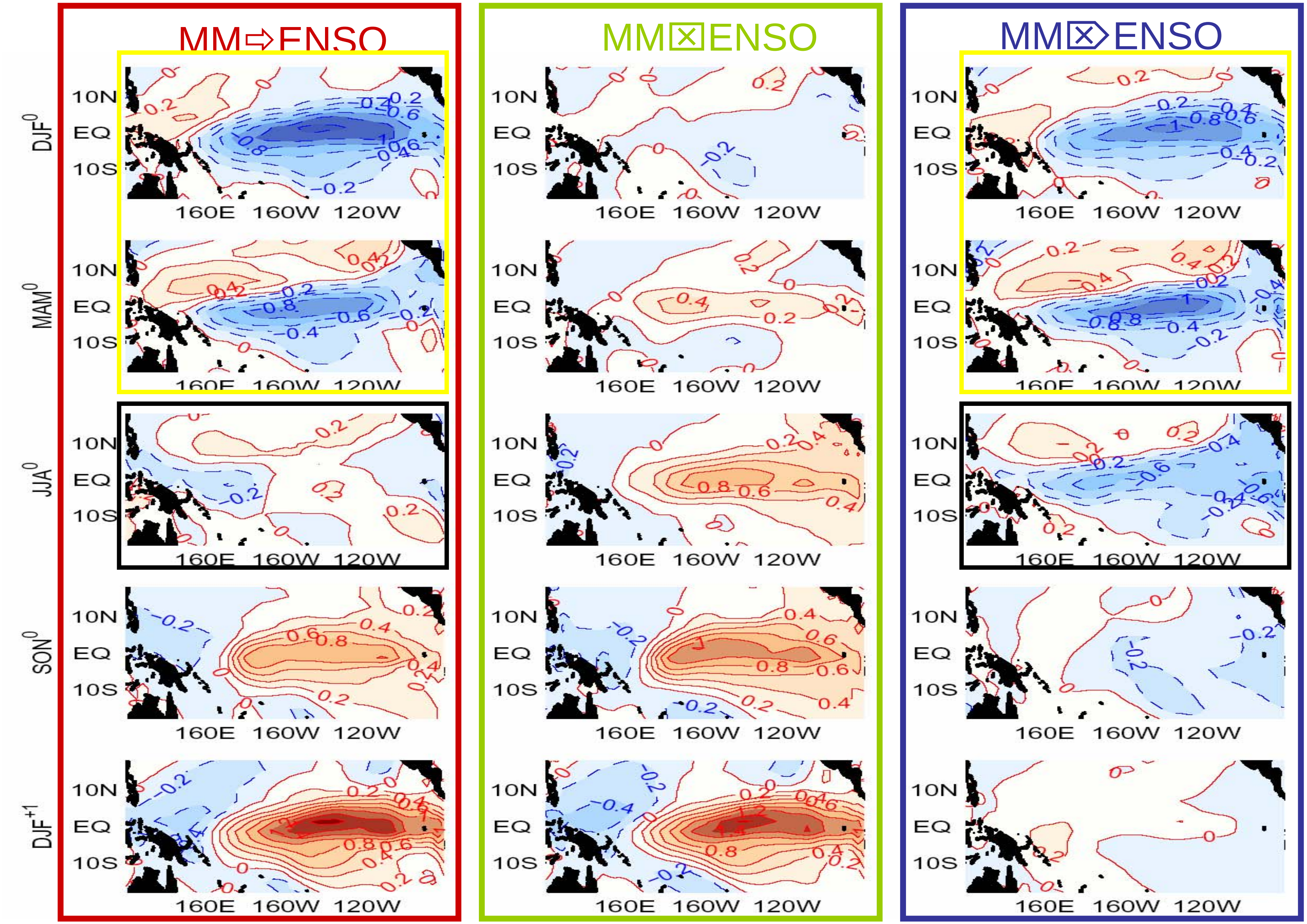
MM⇔NPO: Correlation of MM SST & SLP



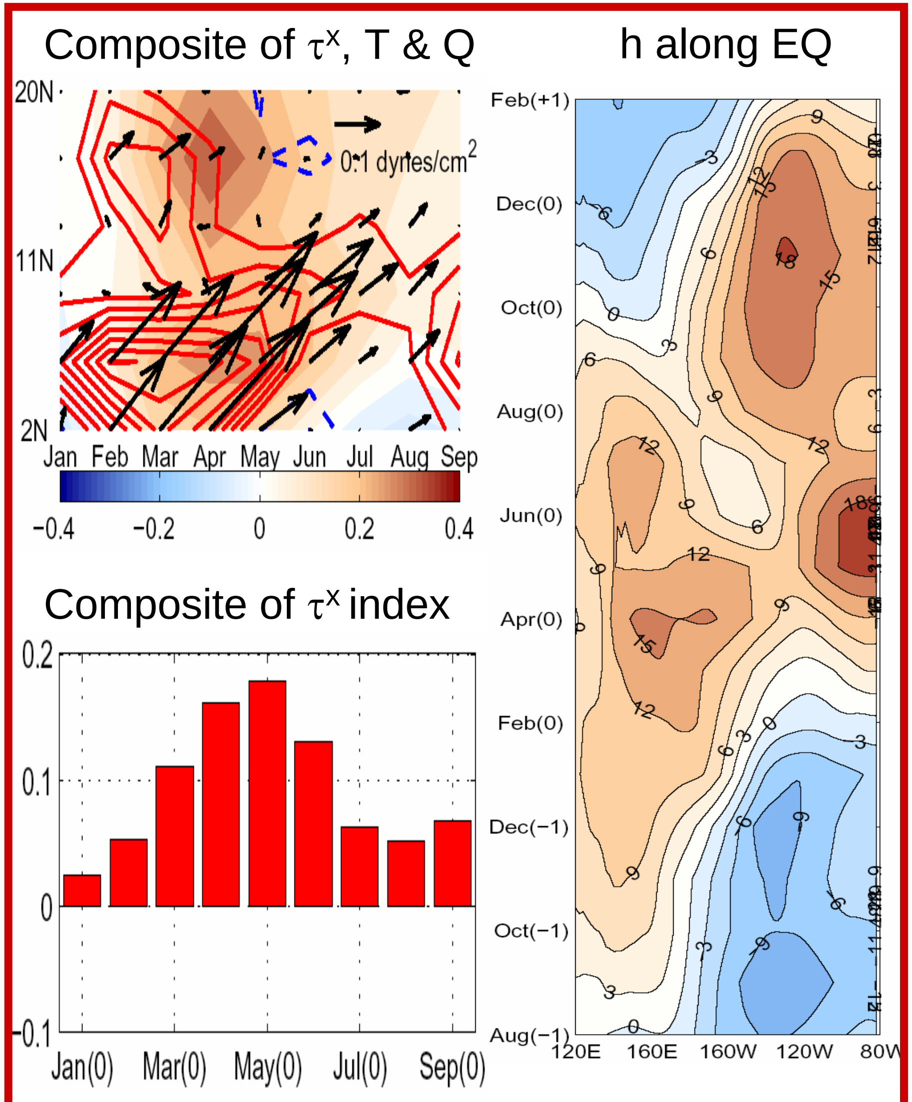
Remarks

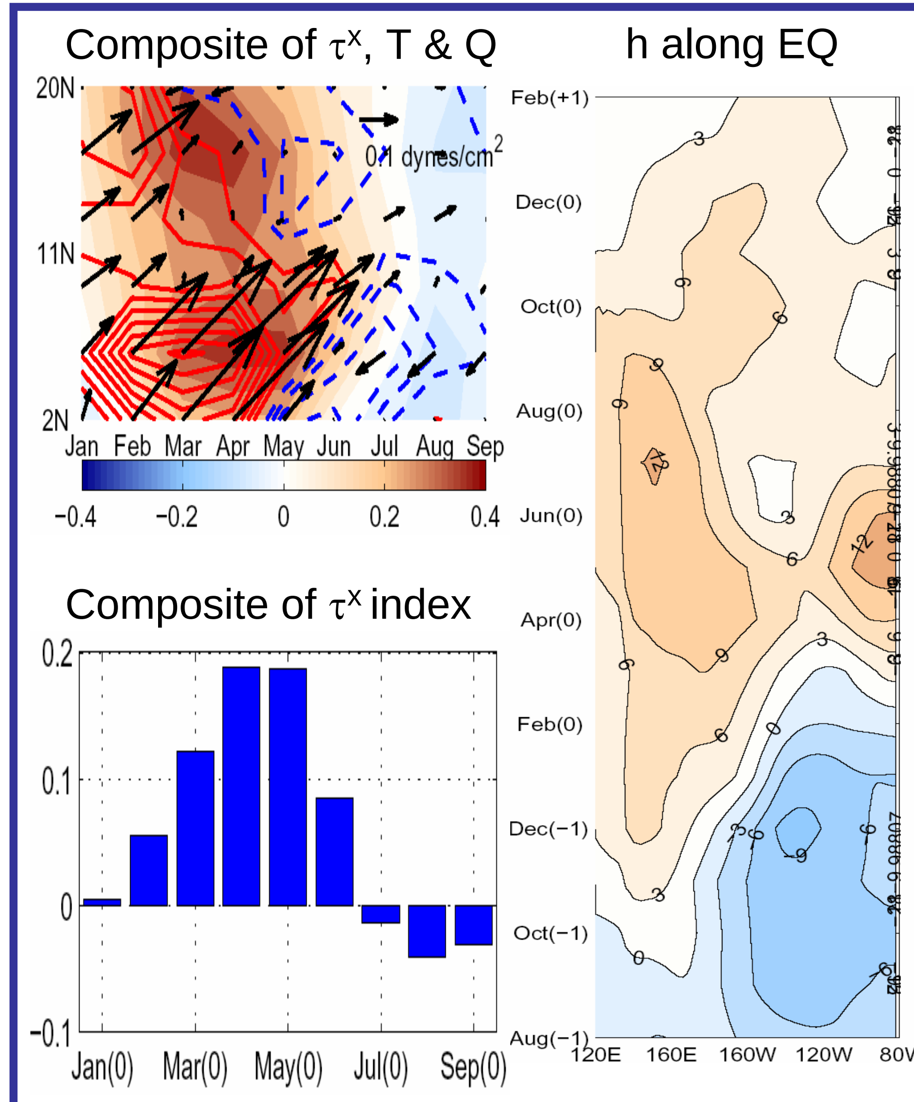
- The 400-year CCM3-RGO simulation gives a fairly realistic representation of ENSO variability except that 1) its amplitude is about 20% weaker; 2) its period is about one year shorter; 3) its seasonal phase-locking is one month later and 4) its PDF is less skewed than obs.
- The model also reproduces the observed MM with the exception of 1) the model MM explains more covariance; 2) it has a more symmetric lag-correlation and less persisted structure between SST & winds; suggesting stronger thermodynamic coupling in the model.
- As in the observed, there is a robust relation between the MM and ENSO in the model. About 66% of the simulated El Ninos are preceded by the MM. There is also a significant correlation between the southern component of the NPO and the MM with the NPO (SLP) leading the MM (SST) by one month.

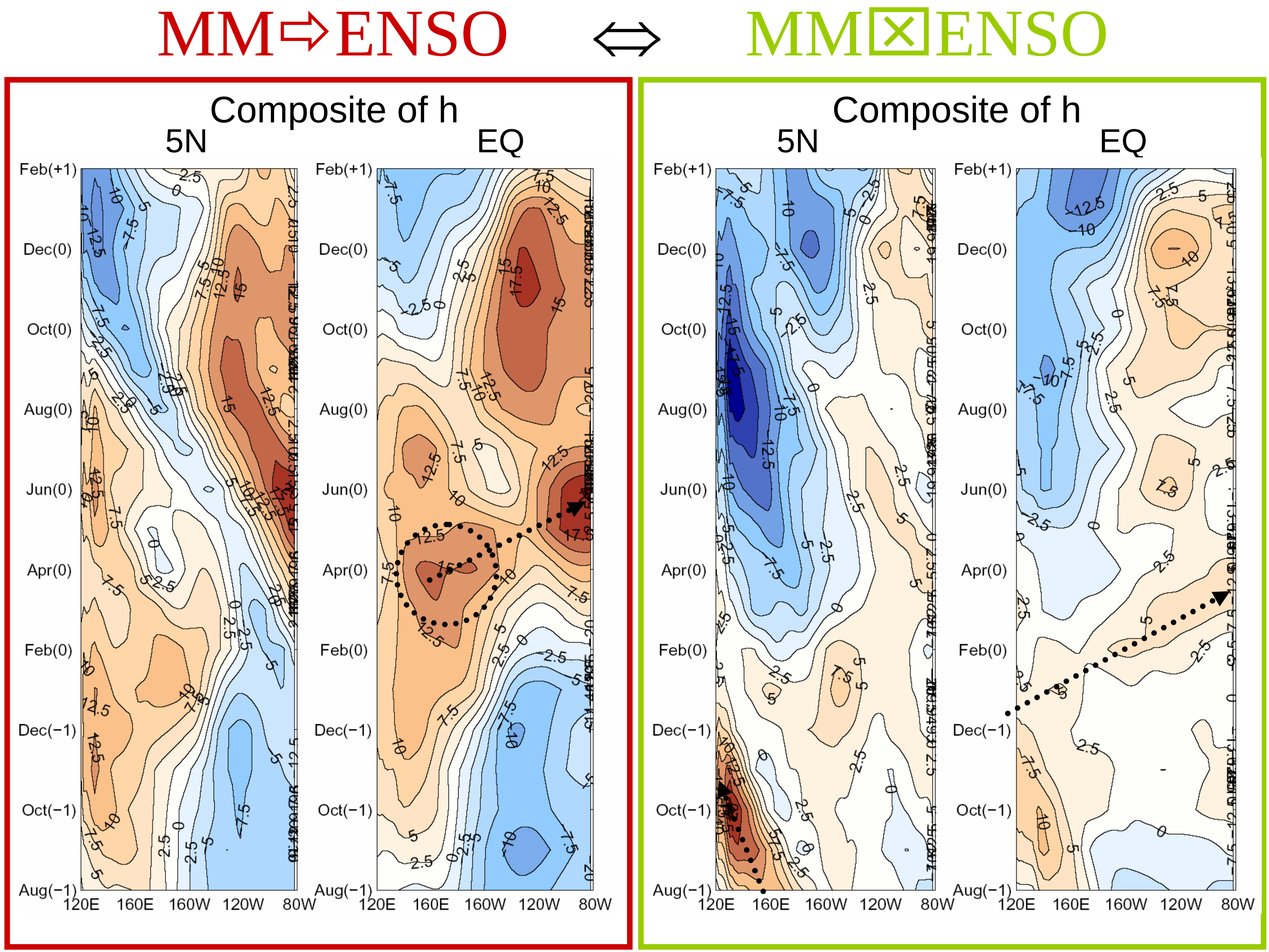
Classification of El Nino and MM events



MM⇨ENSO ⇔ MM ⇏ ENSO





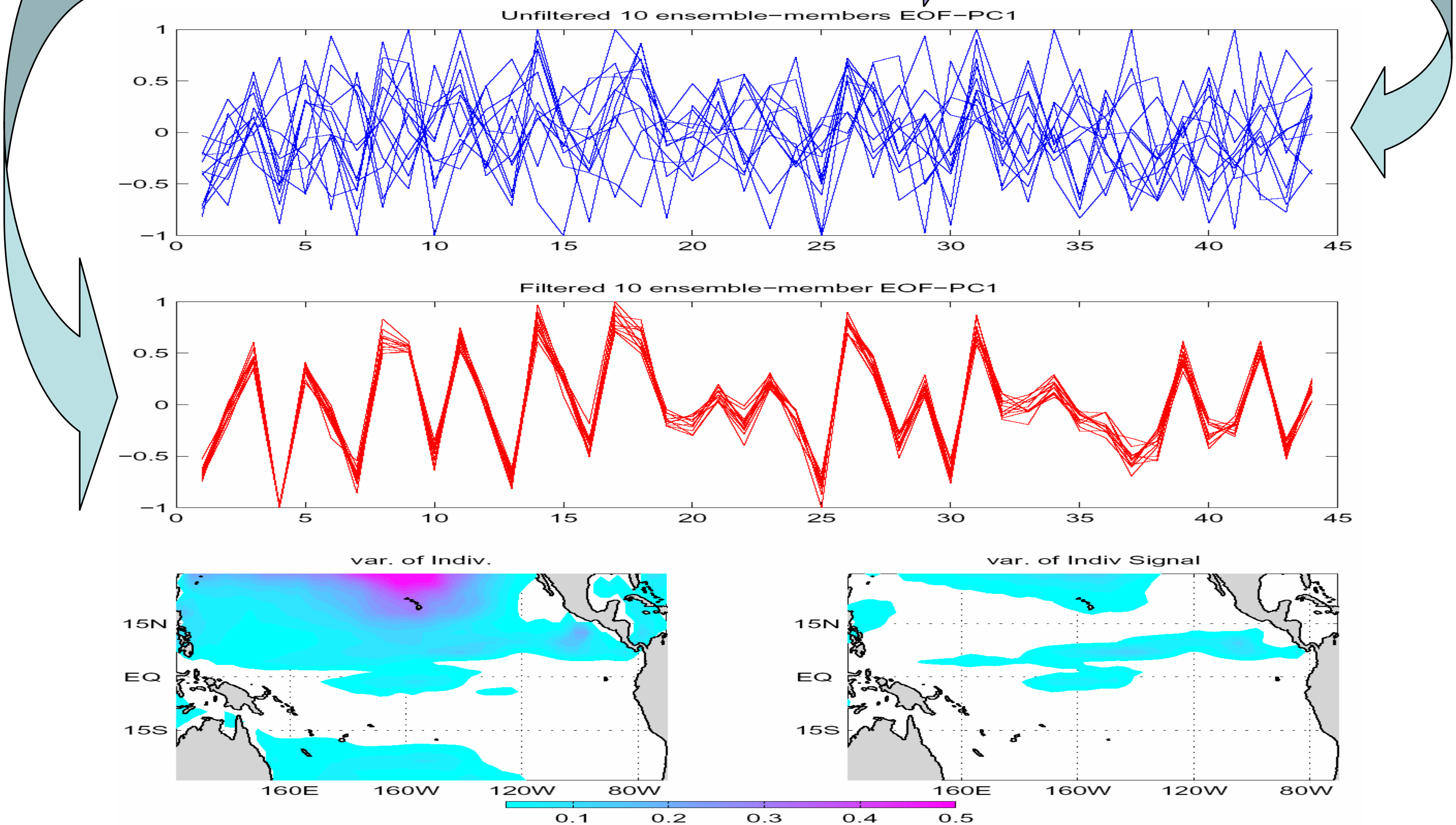

MM⇨ENSO
⇔
MM☒ENSO
Composite of h
5N
EQ
Feb(+1)
Dec(0)
Oct(0)
Aug(0)
Jun(0)
Apr(0)
Feb(0)
Dec(−1)
Oct(−1)
Aug(−1)
120E
160E
160W
120W
80W
Composite of h
5N
EQ

Remarks

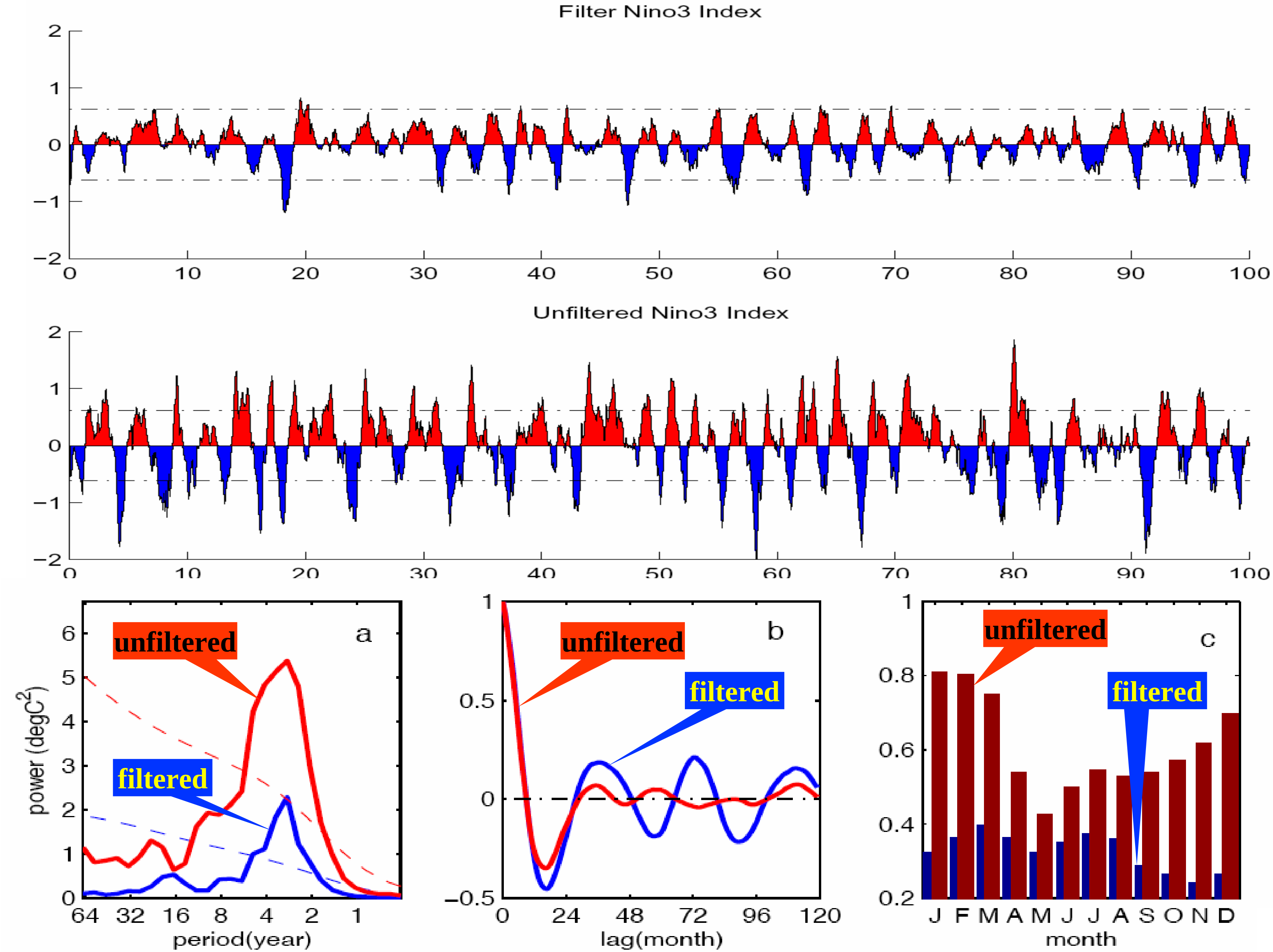
- The long CCM3-RGO simulation allows us to classify modeled MM and ENSO events into three groups: 1) MM⇨ENSO, 2) MM⌧ENSO, 3) MM ⌦ENSO.
- MM⇨ENSO: 65 El Nino events out of 99 identified over the 400-year data (66%). This group of El Ninos is preceeded by an anomaly just north of the equator that causes subsurface and surface warming in the eastern equatorial Pacific.
- MM⌧ENSO: 34 El Nino events out of 99 identified over the 400-year data (34%). This group of El Ninos is associated with a deepening of the thermocline in the western tropical Pacific, more in line with the delayed oscillator theory.
- MM ⌦ENSO: 46 MM events out of 111 identified over the 400-year data (41%). These MM events tend to have shorter duration than the other ones, and thus do not produce warming in the eastern equatorial Pacific.

Filtering Atmosphere Internal Variability

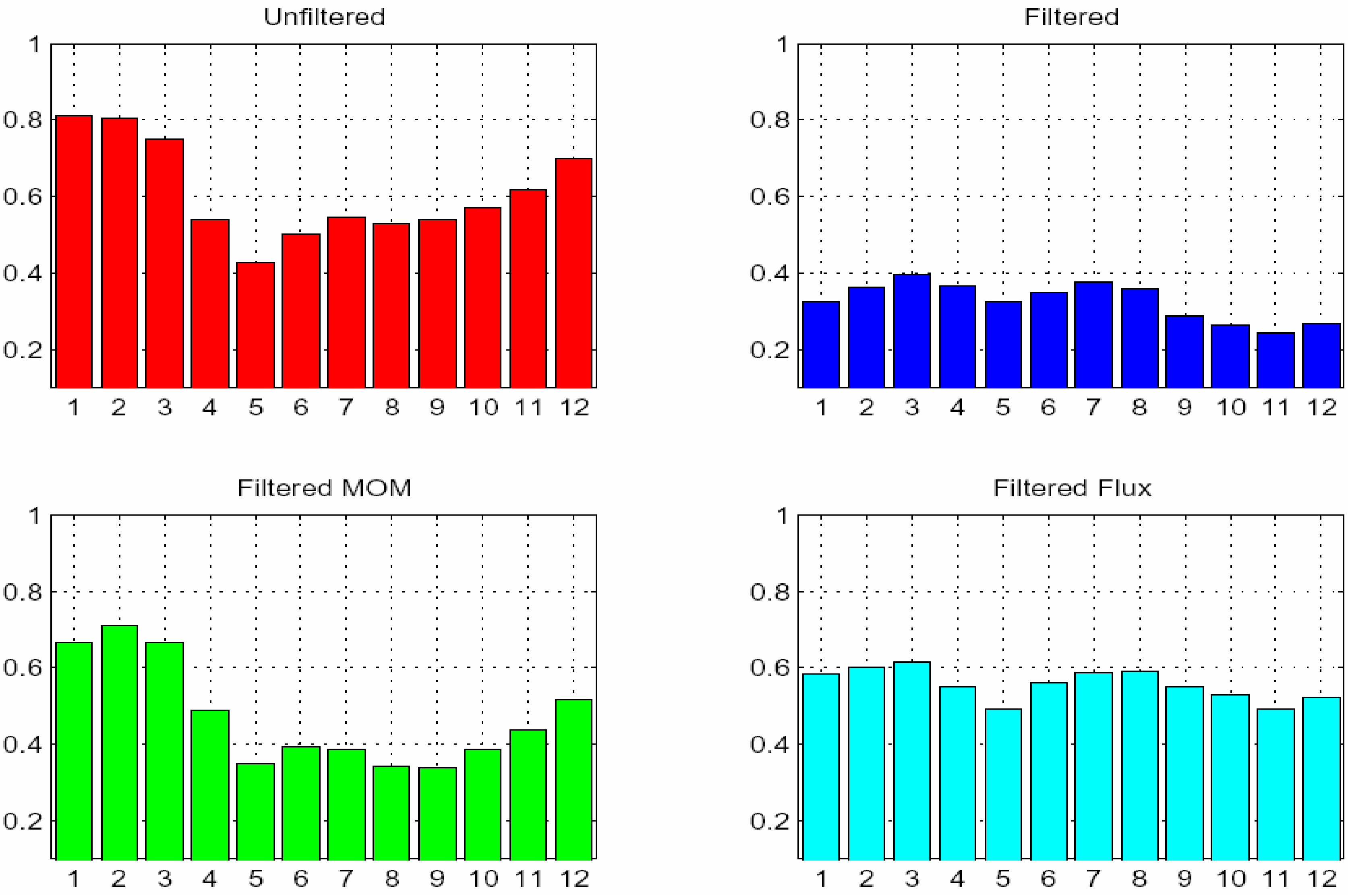
$$X_s = (I - C_n C_m^{-1}) X_i$$



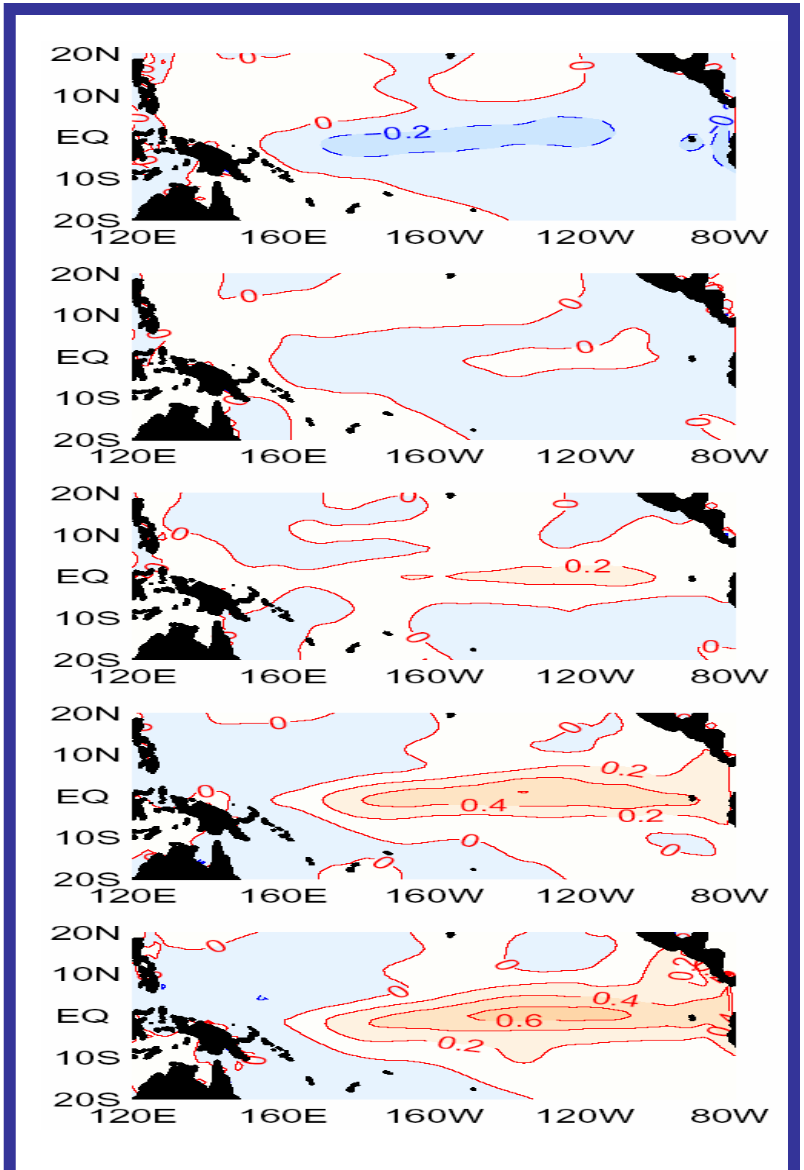
Filtered vs Unfiltered Experiment

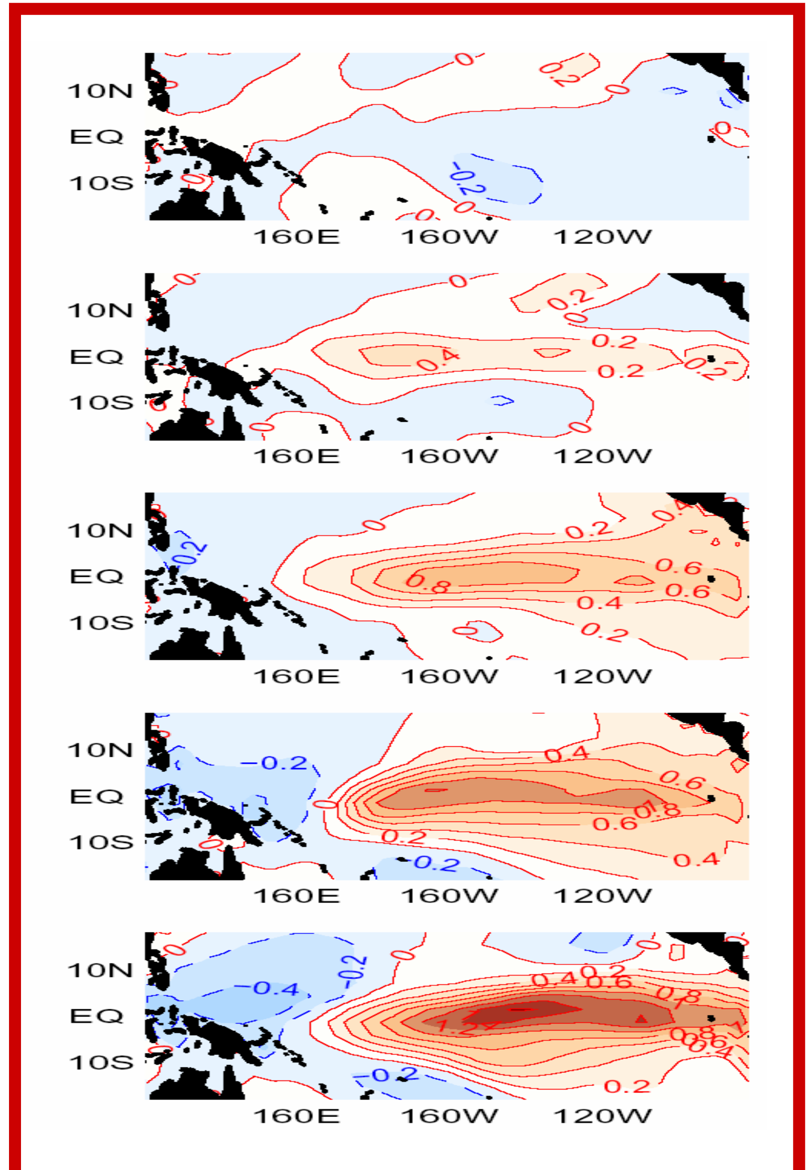


Filtered Momentum vs Heat Fluxes



Filtered & Unfiltered ENSO Composite

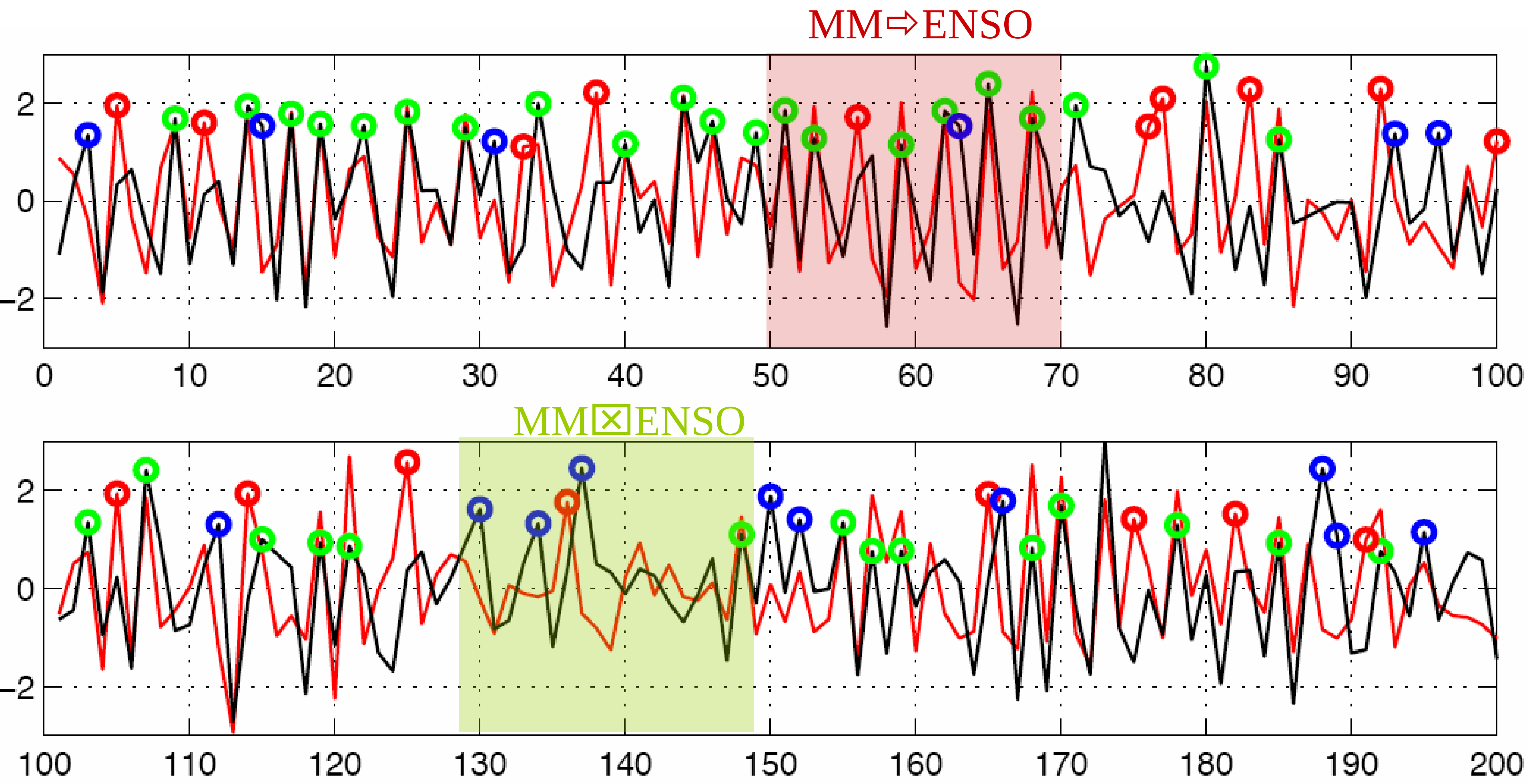




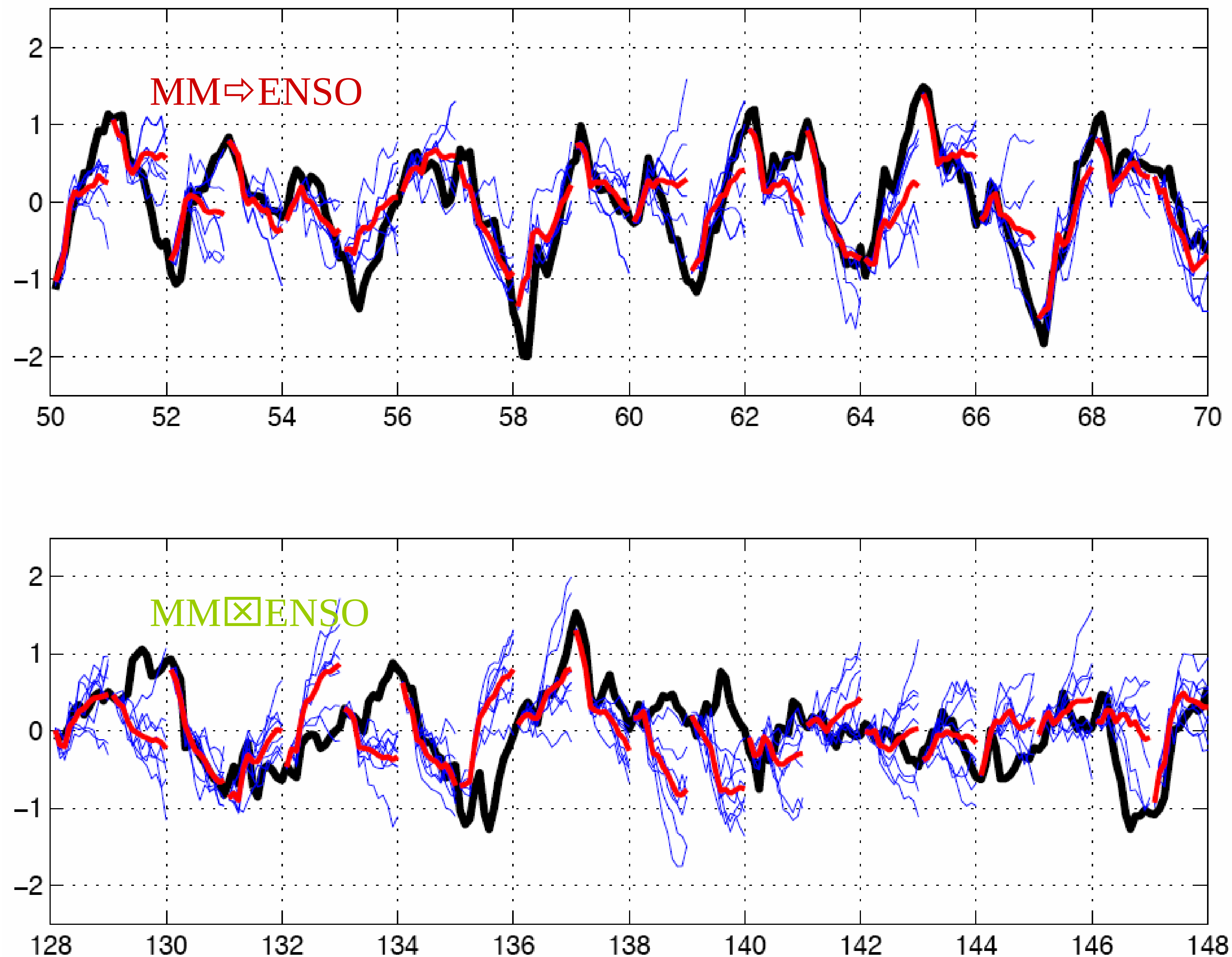
Remarks

- Reducing the effect of the atmospheric internal variability (“noise”) using a S/N filter yields 1) a substantially weakened ENSO variability; 2) altered seasonal phase-locking characteristics.
- Filtering “noise” in surface heat fluxes has a stronger impact on model ENS0 than filtering “noise” in momentum fluxes, particularly, on its seasonal phase-locking.
- Filtering “noise” does not remove the MM completely. This suggests that some of the MM variability may be driven by coupled dynamics.
- Filtering “noise” in surface heat fluxes does weaken the MM strength substantially. The correlation between the FMAM MM τ^x and DJF NINO3 is also reduced significantly from >0.5 to <0.2. Furthermore, the member of MM⇨ENSO events reduces to only 20%. This is consistent with the reasoning that heat flux “noise” $\rightarrow$ MM SST $\rightarrow$ MM Winds $\rightarrow$ ENSO.
- Caveats: 1) Linear assumption of the filtering technique; 2) Sensitivity to S/N filter construction.

Perfect Model Prediction Experiment

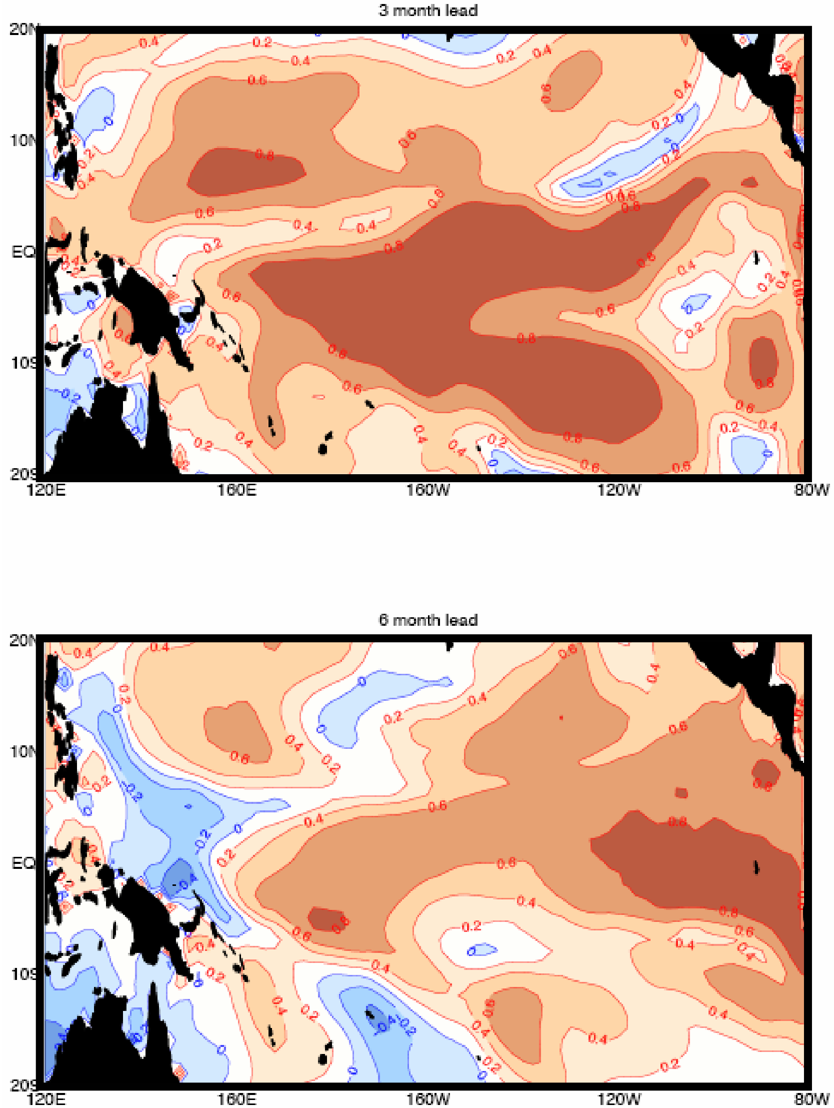


Ensemble of Forecasts

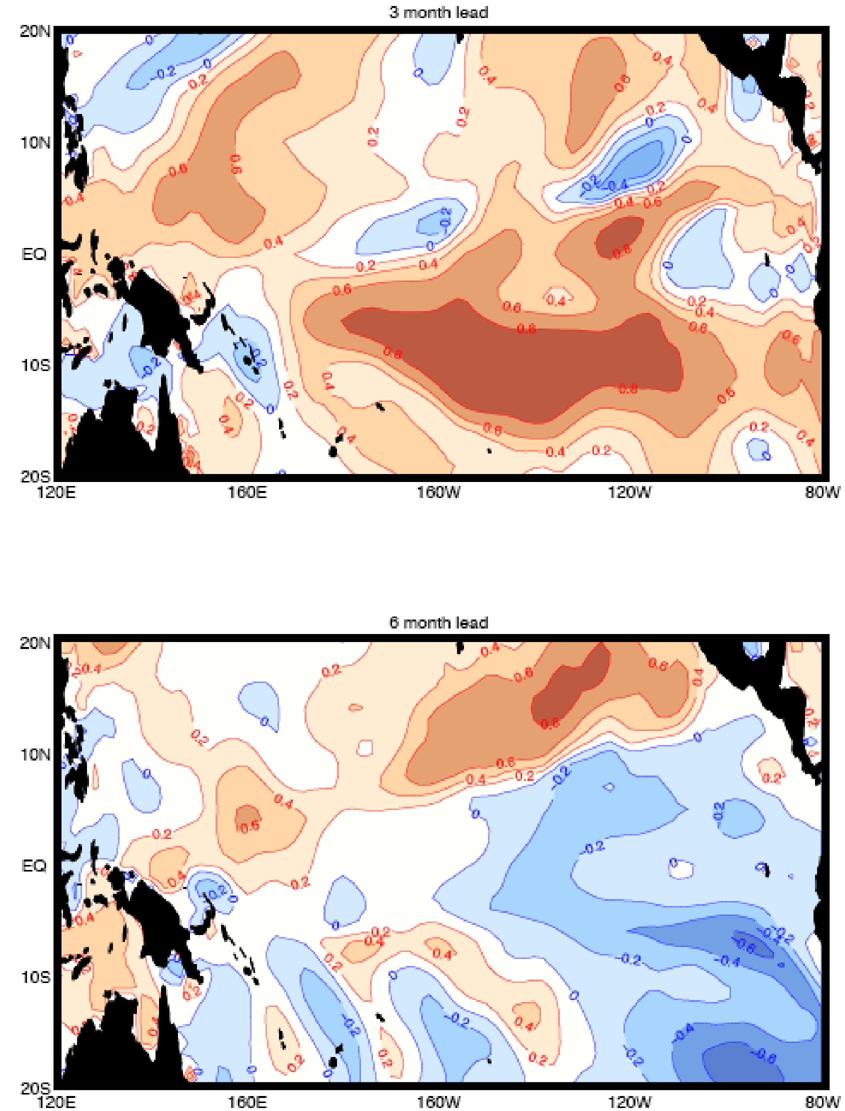


MM⇨ENSO ⇔ MM⊠ENSO

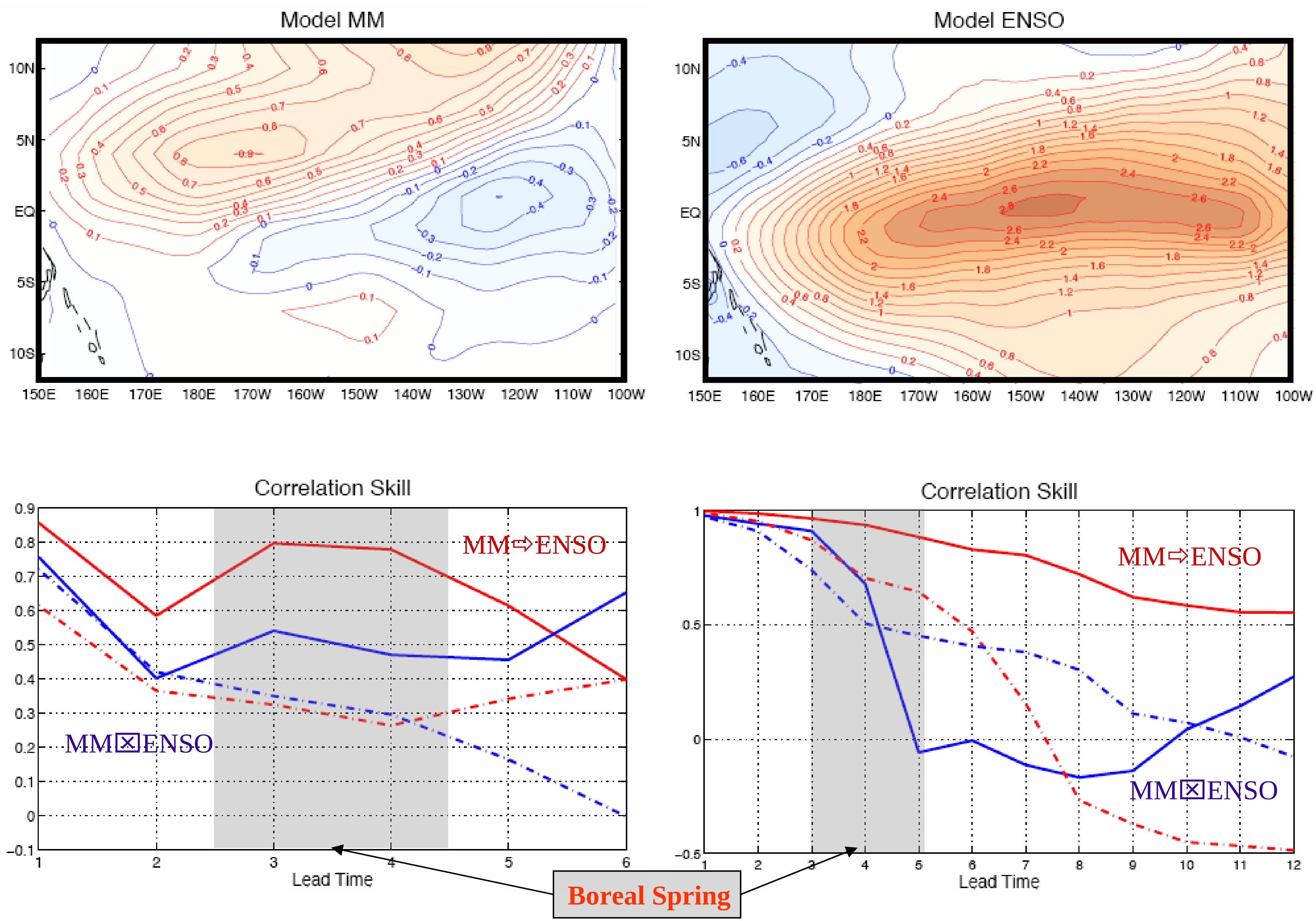
SST Correlation Score



SST Correlation Score



Skillful MM Forecast ⇒ Skillful ENSO Forecast



Summary

- The study confirms the existence of the meridional mode (MM) proposed by Chiang and Vimont (2004). It further shows that the MM can act as an important trigger for ENSO.
- Coupled model experiments suggest that 1) the MM is inherent to thermodynamic coupling in ITCZ latitudes, which enhances its persistence; 2) the long persistence of MM events is an important prerequisite for its effectiveness of as an ENSO trigger; 3) those ENSO events that are not associated with the MM tend to follow the delayed oscillator mechanism.
- Noise-filter experiments suggest that the MM variability is intimately linked to extratropical atmospheric internal variability. Suppressing the latter leads to a substantially weakened MM variability, and subsequently a much weakened ENSO. Furthermore, the MM conduit effect plays an important role in the seasonal phase-locking of ENSO.
- Prediction experiments suggest that the MM-ENSO relationship may have an impact on ENSO predictability. This leads to a conjecture that ENSO prediction may be improved if the MM could be predicted, particularly during the spring barrier.