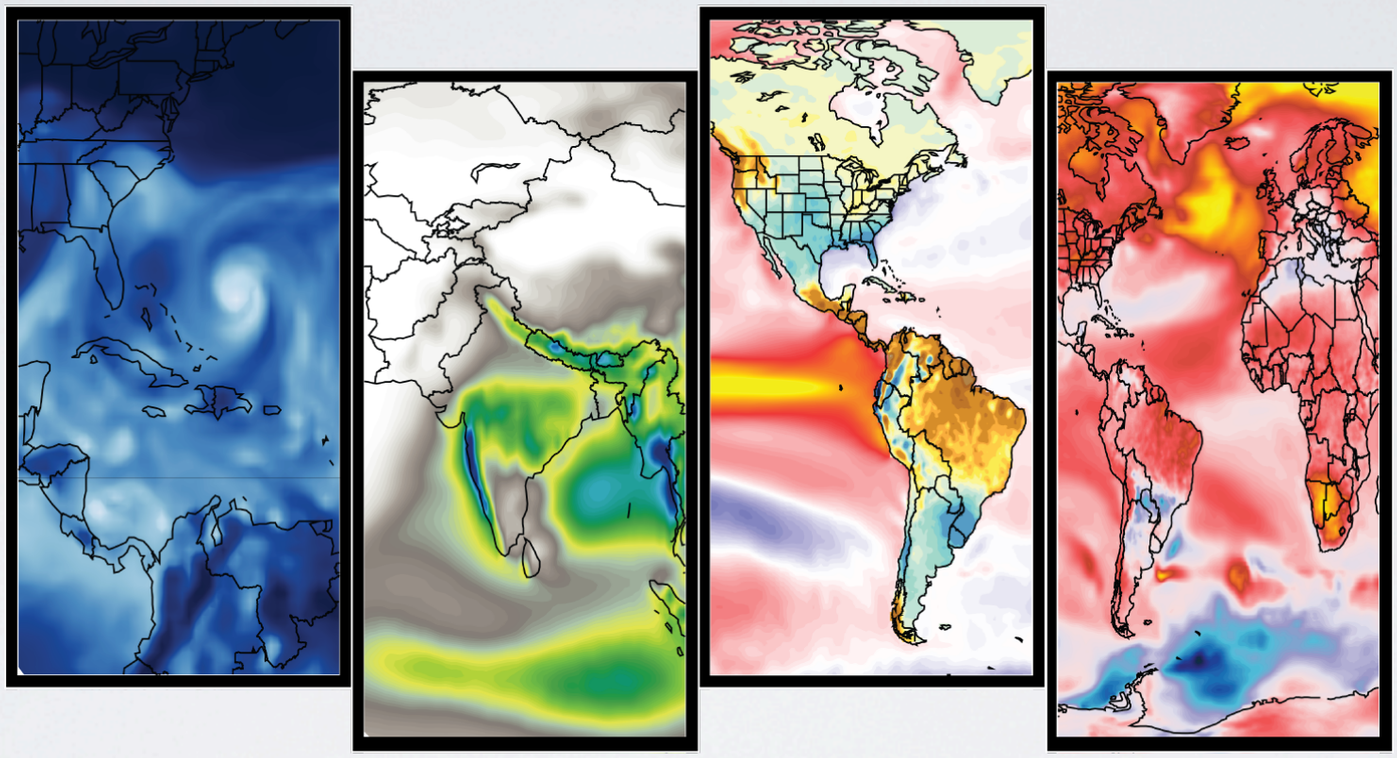
Impact of Model Resolution and Mean State Errors on ENSO

NOAA/GFDL Climate Variations and Predictability Group



Hypothesis: Enhanced resolution & corrected large-scale climate improve simulation and prediction of regional climate & extremes.

Goal: Build tools to understand and predict intraseasonal to multi-decadal variations in large-scale climate, and regional climate and extremes

Vary atmospheric and oceanic resolution within same model family

	2°x2.5° L24 (LM2)	50k (cubed-sphere) L32 (LM3)	25km (cubed-sphere) L32 (LM3)
1° L50 MOM5 (1/3° merid. near Eq.)	CM2.1 *(Delworth et al. 2006)* *(cost ~ 1/12)*	FLOR *(Vecchi et al. 2014)* *(cost = 1)*	HiFLOR *(Murakami et al. 2015)* *(cost ~ 6)*
0.25° L50 MOM5		CM2.5 *(Delworth et al. 2012)* *(cost ~ 2.5)*	
0.1° L50 MOM5		CM2.6 *(Delworth et al. 2012)* *(cost ~ 20)*	

Flux adjustment to correct systematic errors

- **Hypothesis:** Systematic errors in large-scale climate (SST, τ) degrade simulation and prediction.

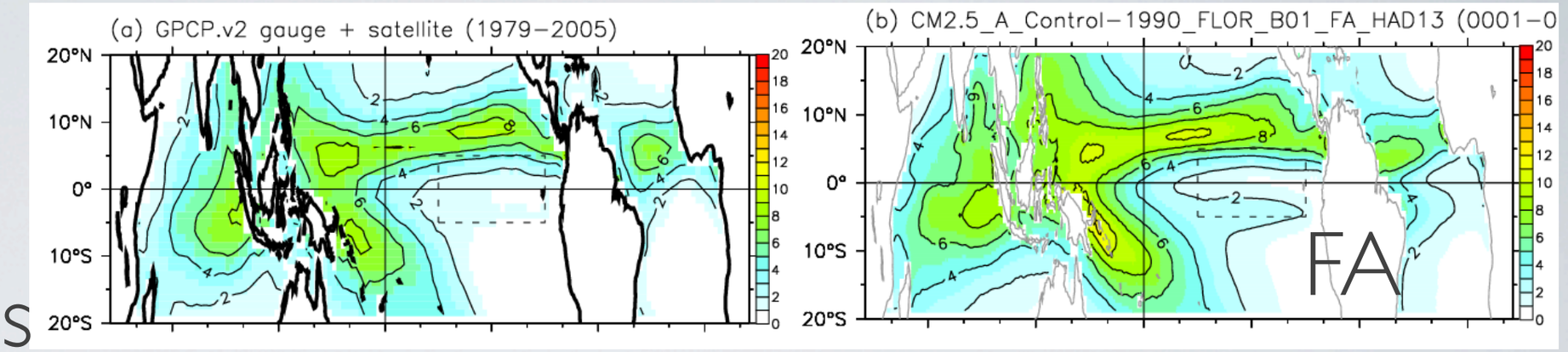
- **Methodology:** FA version of FLOR with climatological (once computed, independent of model state) adjustment to momentum, freshwater and enthalpy fluxes to ocean.

  Repeat simulations and predictions with FLOR-FA, compare to FLOR.

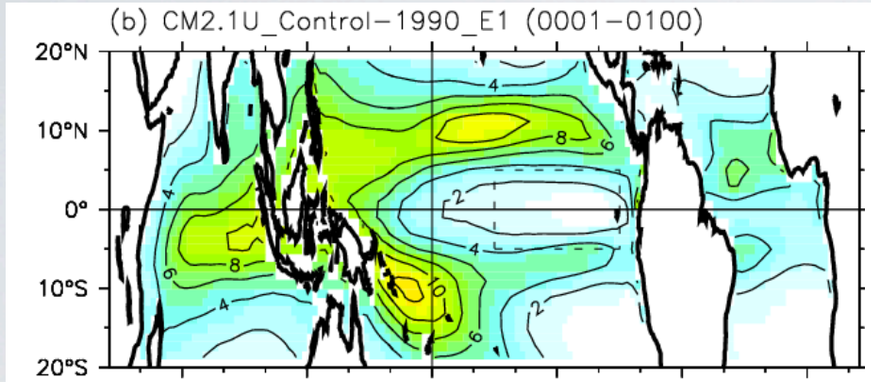
Vecchi et al. (2014, J. Climate)

Annual-mean Precipitation

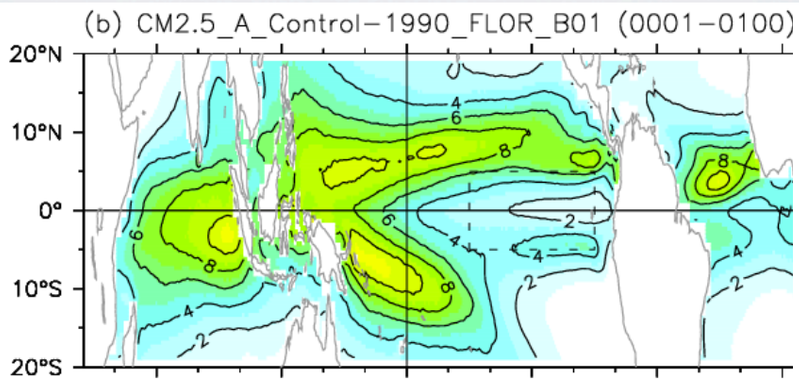
Obs



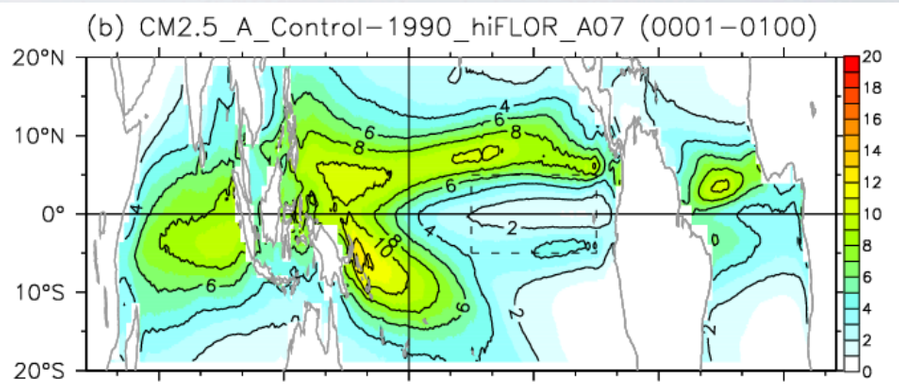
200km Atm.

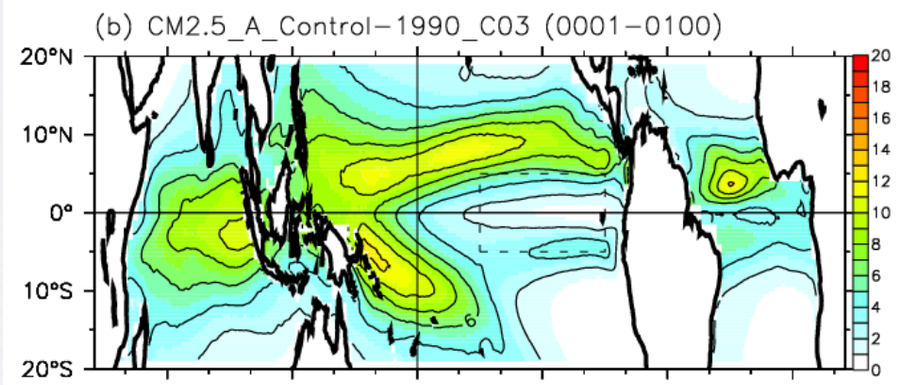


50km Atm.

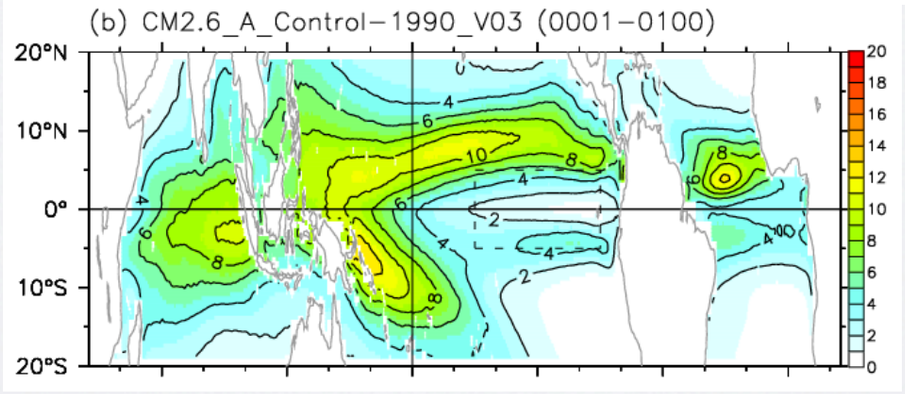


25km Atm.





0.25° Ocn.

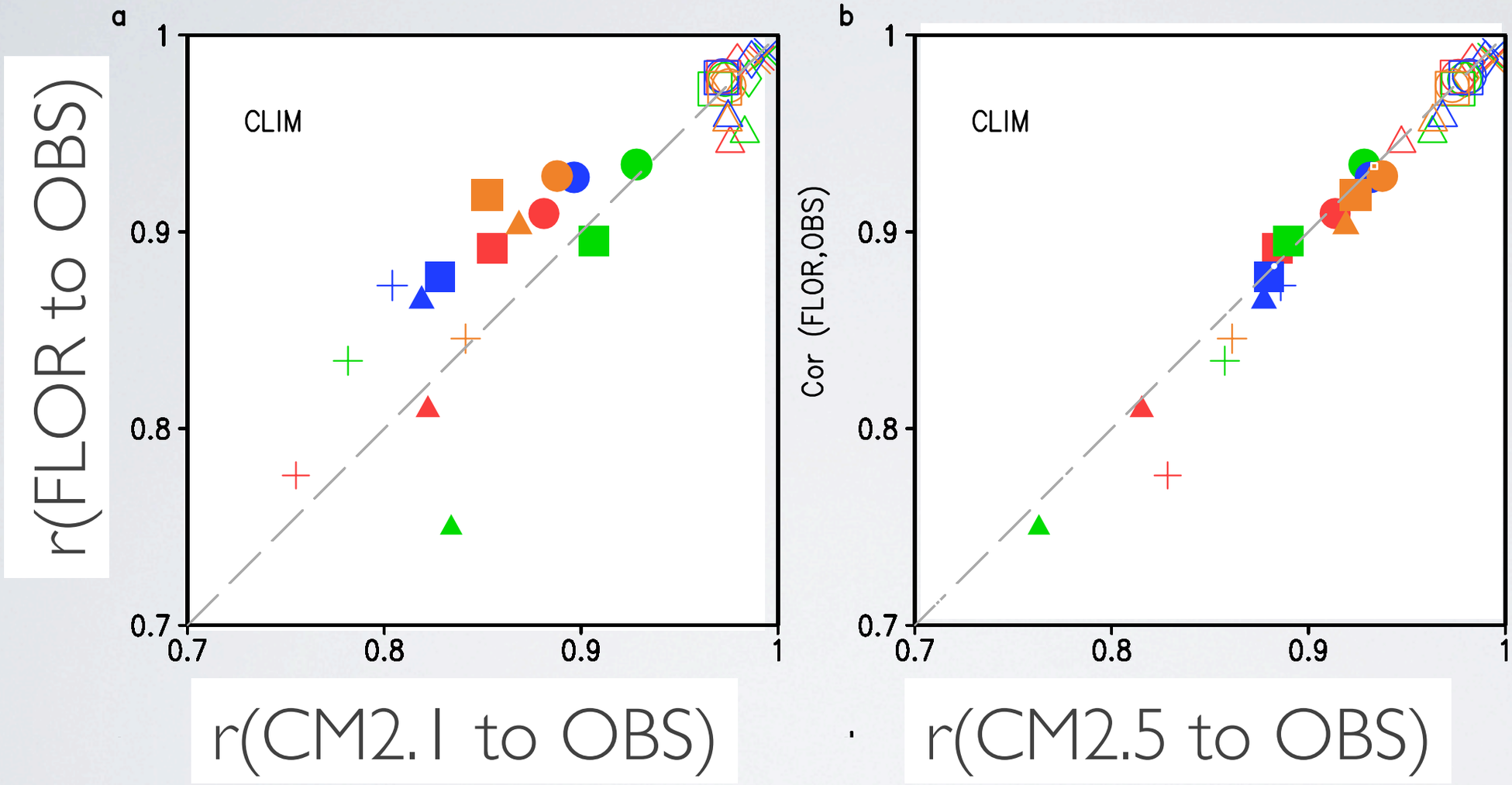


0.1° Ocn.

Enhanced atmos./land resolution crucial to improving near-surface climate simulation

~5xAtmos Res.

4xOcean Res.



Spatial Correlation Of Mean

Figure: Lakshmi Krishnamurthy

Jia et al. (2015, J. Clim.)

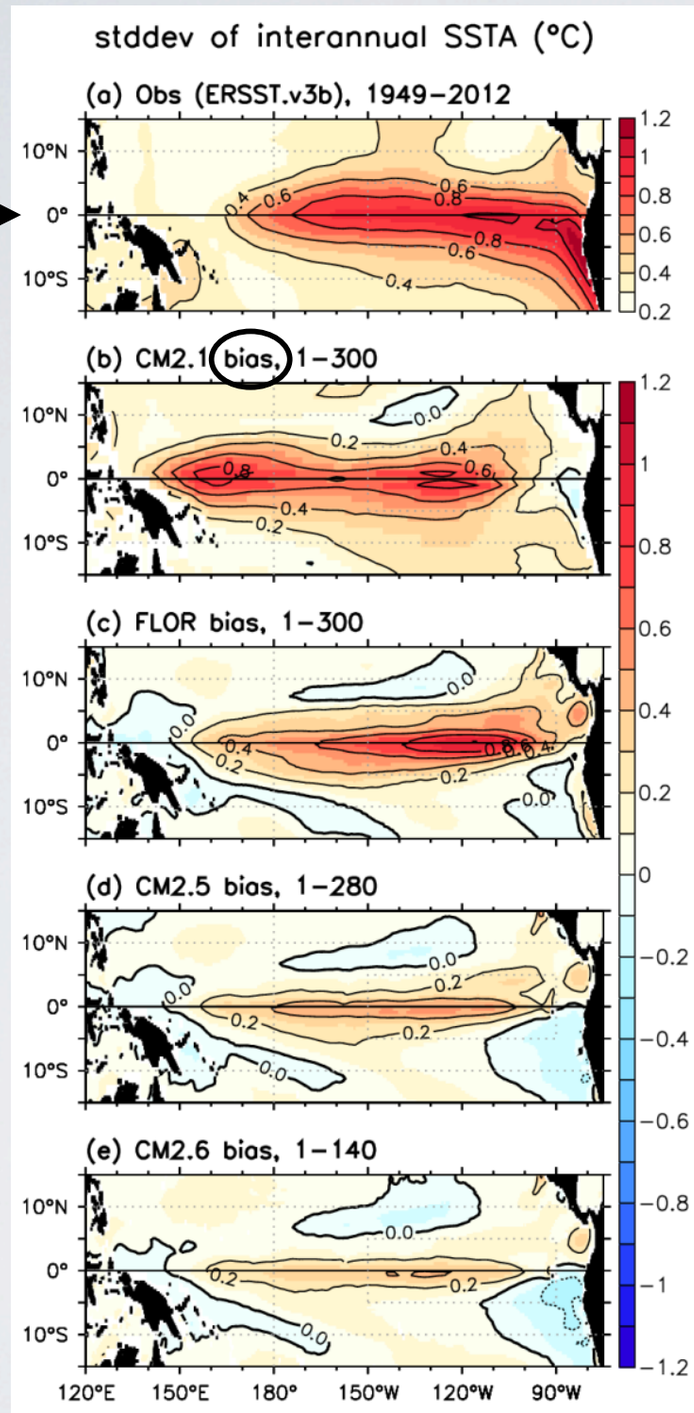
ENSO improvements with increasing resolution

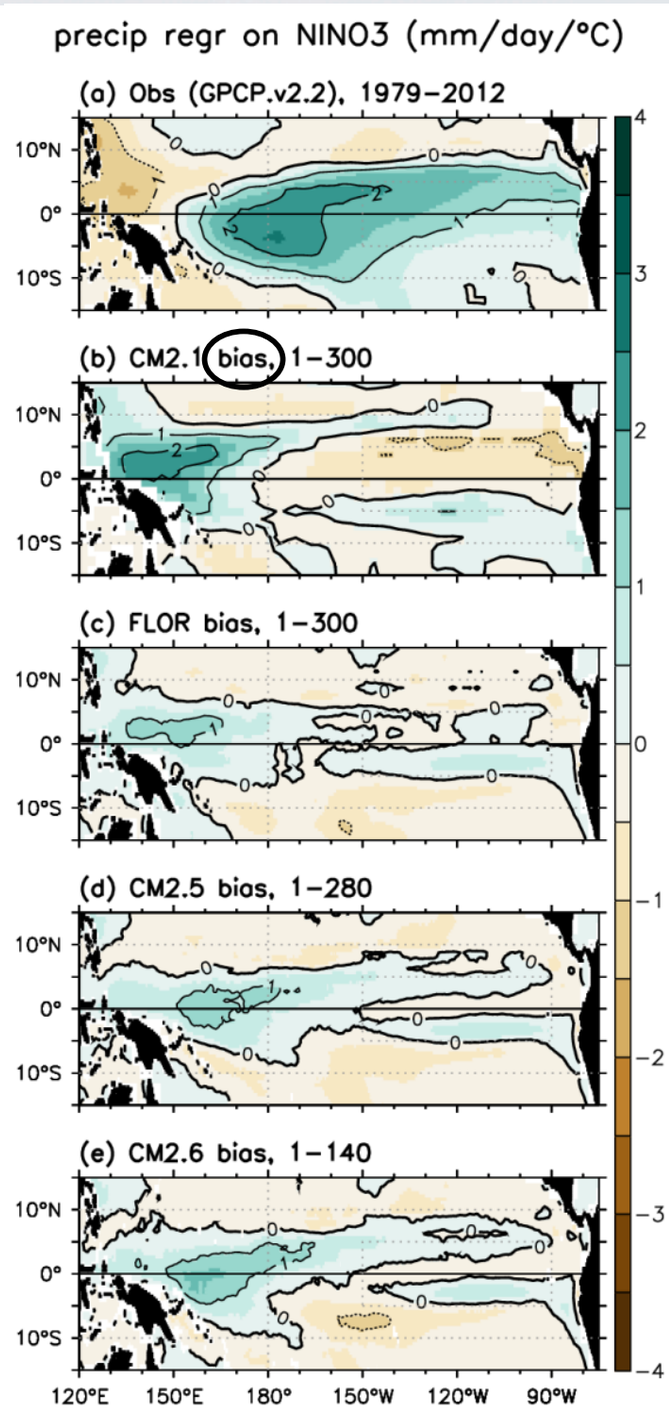
OBS →

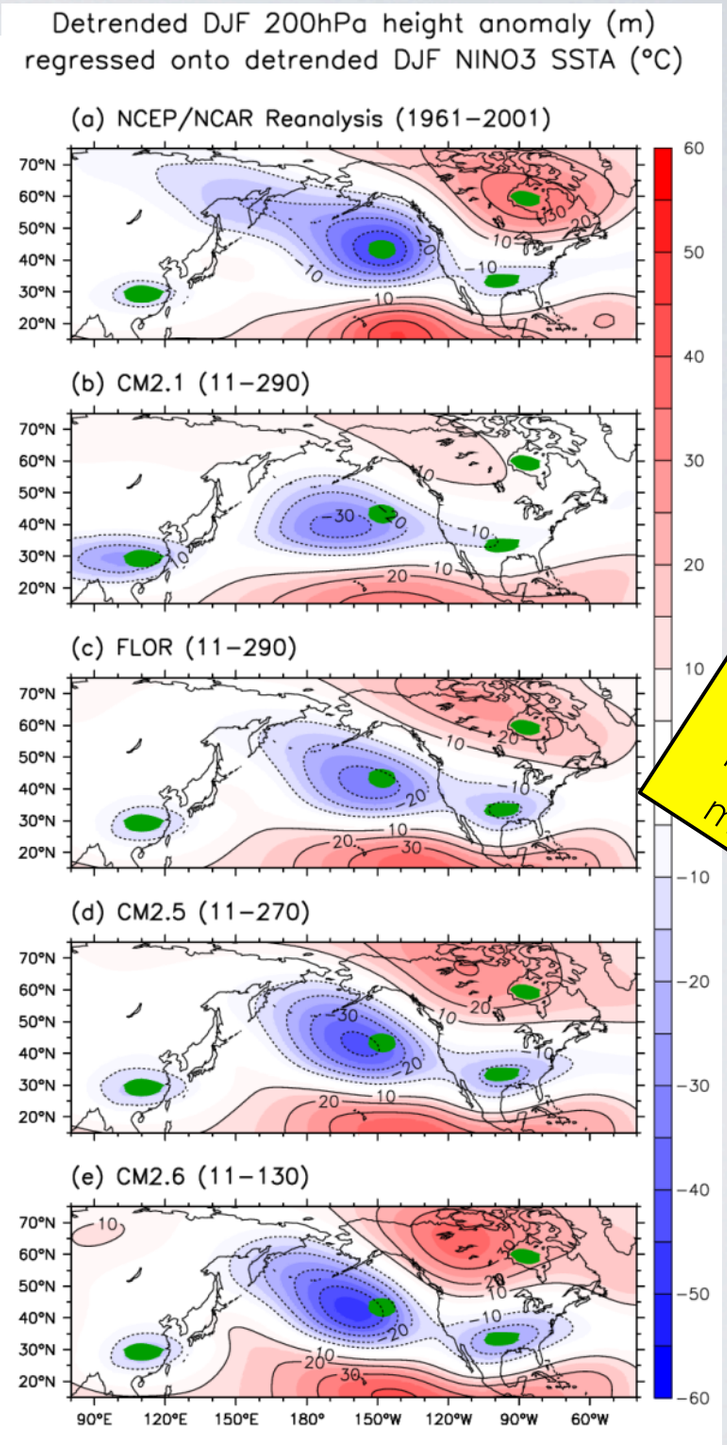
5x atm

4x ocn

2.5x ocn



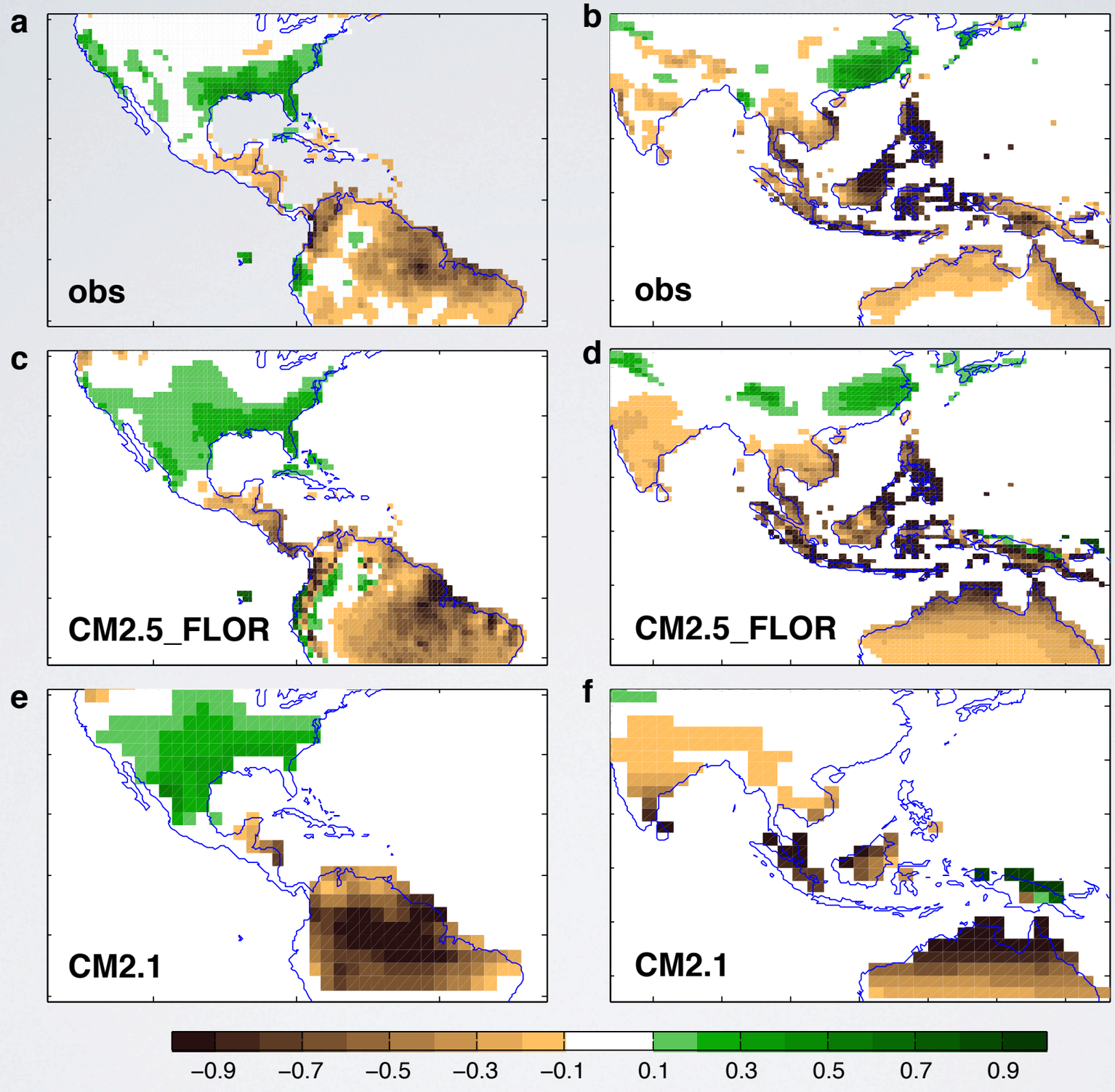




new forecast model

Delworth et al. (2012); Vecchi et al. (JC 2014); Jia et al. (JC 2015); Wittenberg et al. (in prep)

ENSO rainfall pattern improved in FLOR (prediction skill up too)



Most predictable precip pattern (mm/day) (Jia et al. 2014, J. Clim.)

Structure of ENSO improves in FA, as does its phase-locking

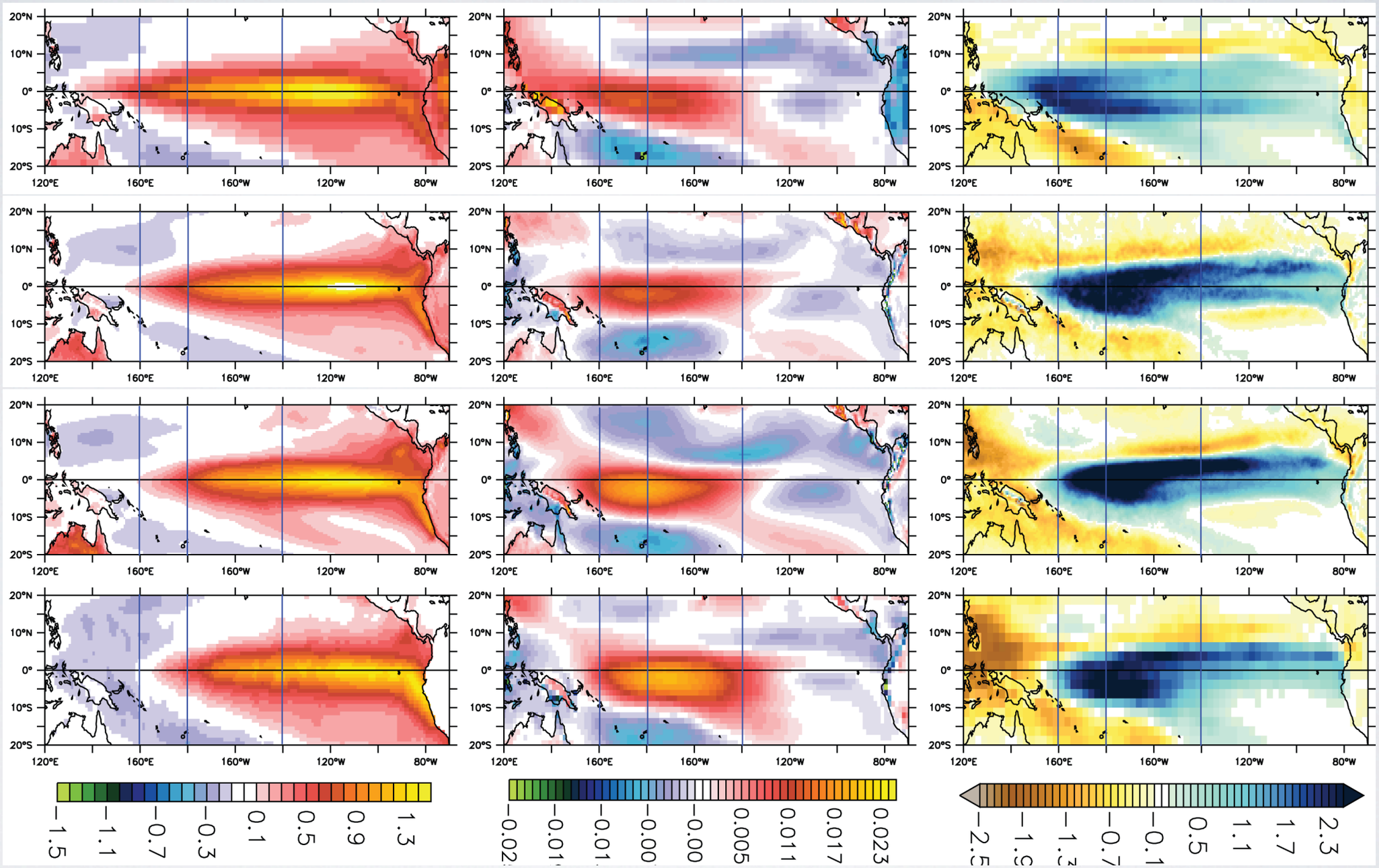
Regression on NIÑO3 SSTA

CM2.1

FLOR

FLOR-FA

OBS

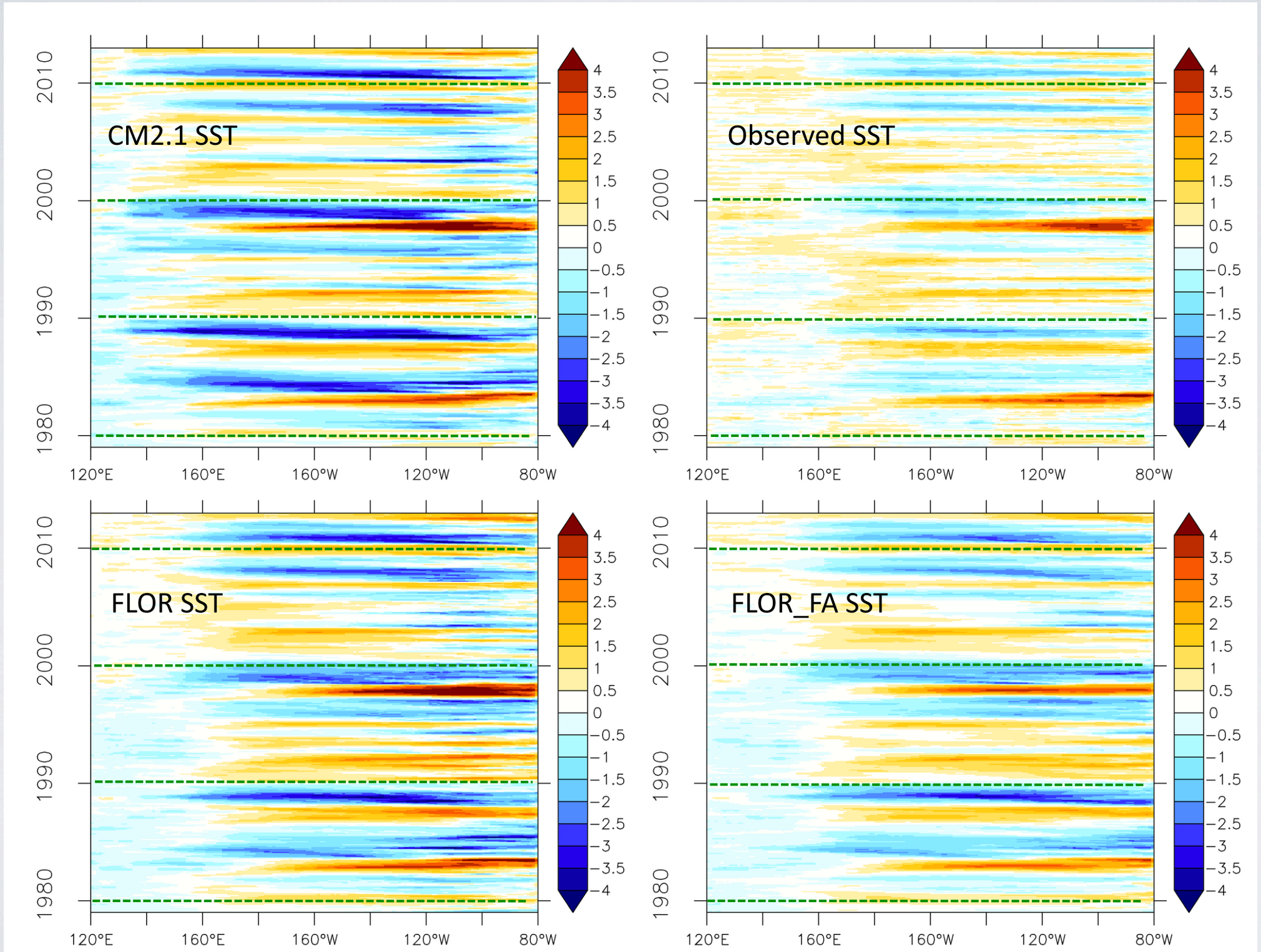


SST

Zonal Stress

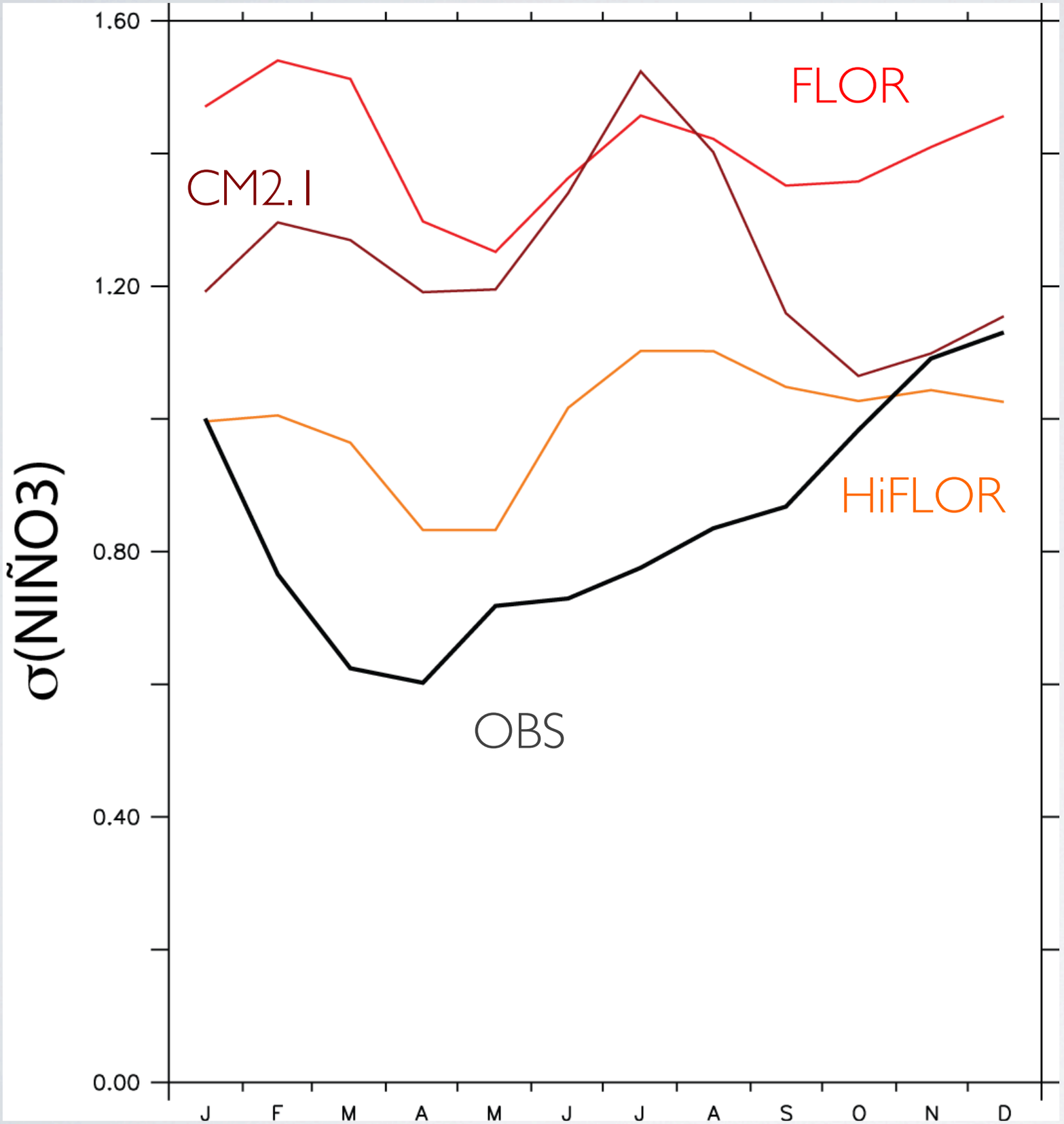
Precip.

Response of coupled model to historical τ better in FA here: Eq.Pac. SSTA (also *e.g.* N. Amer. Precip)



Delworth et al. (2015, J. Climate, in press)

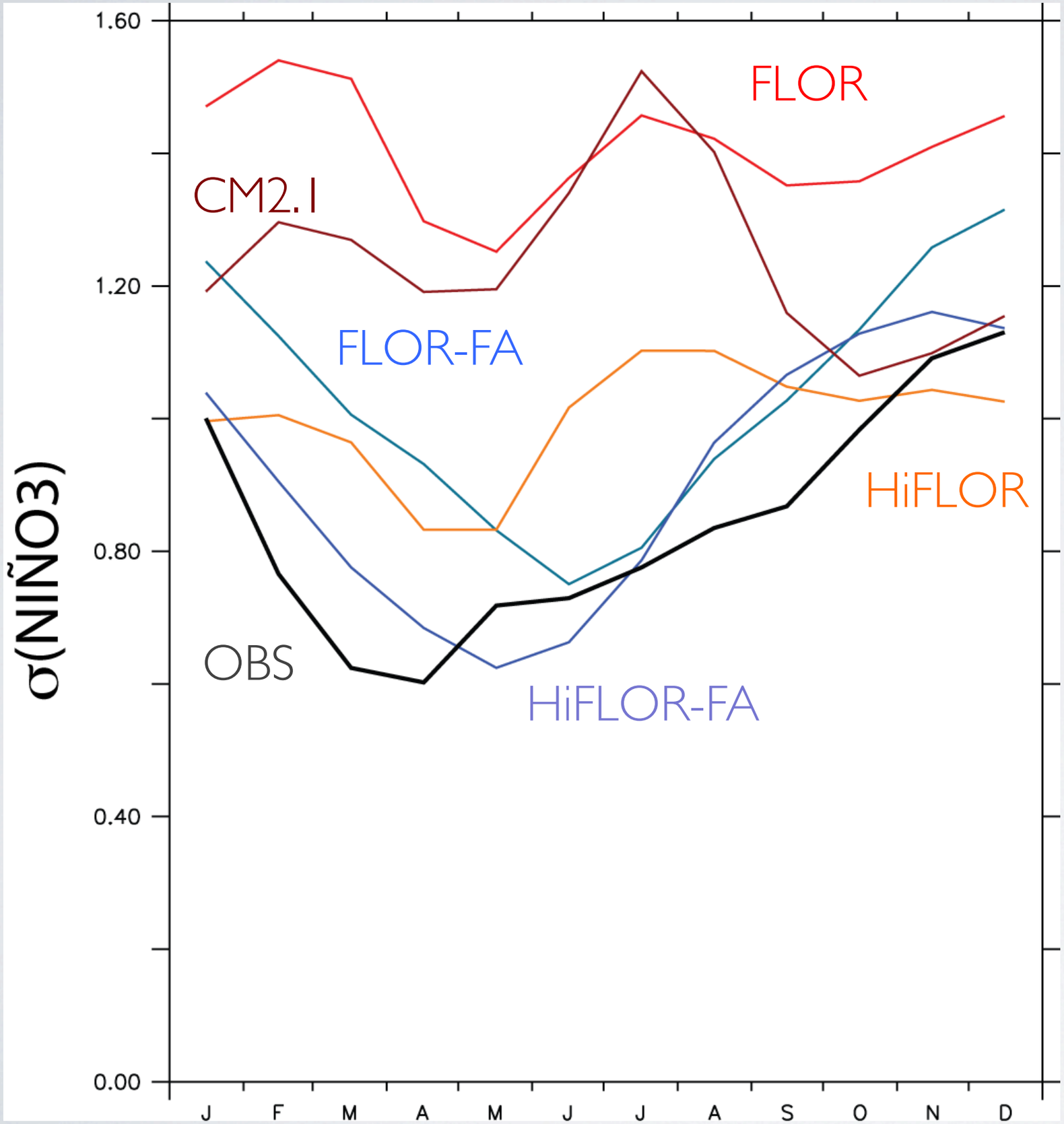
Atmospheric resolution and ENSO phase locking



Resolution alone does not fix phase locking.

Similar for ocean resolution increases.

Atmospheric resolution/FA and ENSO phase locking



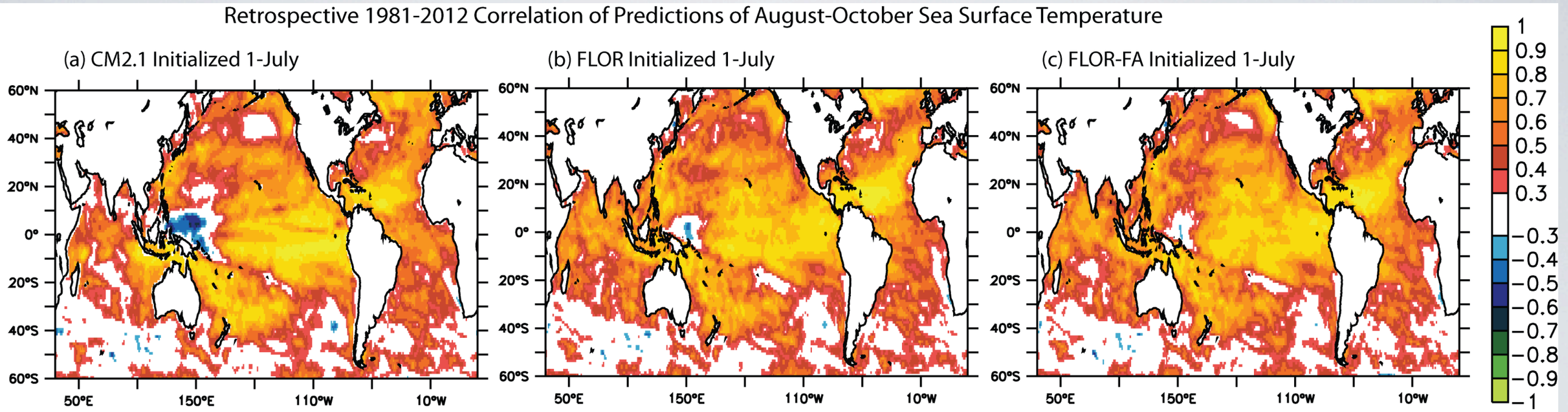
Hi-res + FA "best"

Appears in part related to onset.

Seasonality of WWEs improved…

Thought after Dietmar's and Gaby's talks: is it in part clouds?

Retrospective predictions of ASO SST no worse in FLOR-FA than FLOR – both somewhat better than CM2.1



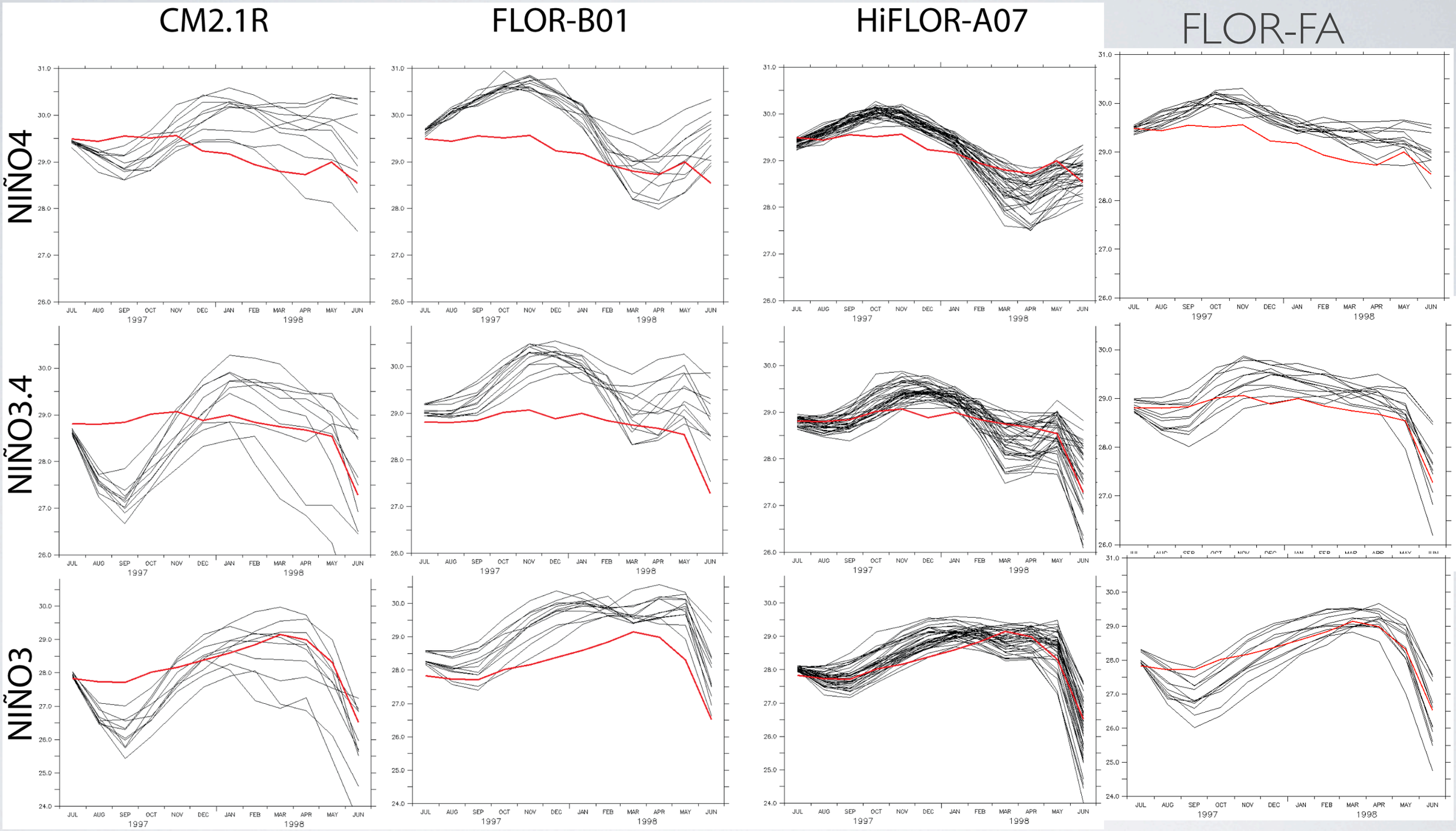
CM2.1 FLOR FLOR-FA

1981-2012 correl. of Aug-Oct SSTA predictions

Predictions of seasonal hurricane activity greatly improved by FA

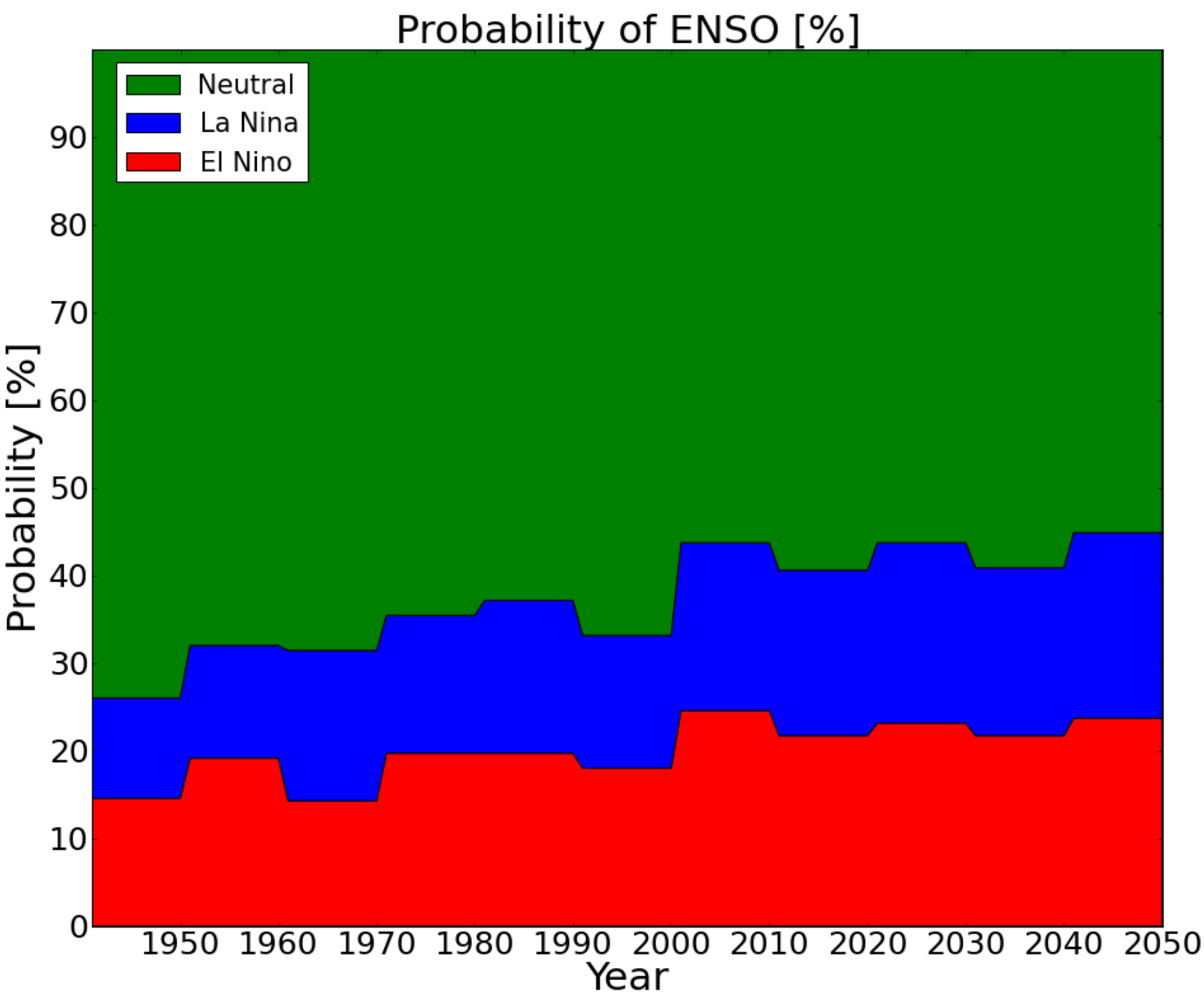
Vecchi et al. (2014)

Test reforecasts of 1997 El Niño



10 ens. 12 ens. 36 ens. 12 ens.

Historically and near-term: ENSO becomes more active in FA-FLOR



Large-ensemble : 350-yr sample for each 10-yr epoch

Summary

- Parallel free and FA versions for understanding, prediction and projection.

- Increasing atmospheric resolution improves simulation of mean climate and structure of ENSO – and teleconnections

- Increasing oceanic resolution improves amplitude of ENSO

- Artificially correcting biases in SST and stress improves:
  - Simulation of mean climate (non-SST variables).
  - ENSO amplitude, phase locking and teleconnections.
  - Predictions of regional climate and extremes (e.g., regional TC activity)
  - Reduces drift/shock
  - Nonlinearity of atmospheric ENSO response (Kit's talk tomorrow)

References

Choi, K.-Y., G.A. Vecchi and A.T. Wittenberg (2013): A mechanism for ENSO asymmetry. *J. Climate* doi: 10.1175/JCLI-D-13-00045.1.

Delworth, T.R., and Coauthors, 2006: GFDL's CM2 global coupled climate models. Part I: Formulation and simulation characteristics. J. Climate, 19, 643–674, doi:10.1175/JCLI3629.1.

Delworth, T.R., A. Rosati, W. Anderson, A.J. Adcroft, V. Balaji, R. Benson, K. Dixon, S.M. Griffies, H.-C. Lee, R.C. Pacanowski, G.A. Vecchi, A.T. Wittenberg, F. Zeng, and R. Zhang (2012): Simulated climate and climate change in the GFDL CM2.5 high-resolution coupled climate model. *J. Climate.* doi:10.1175/JCLI-D-11-00316.1

Delworth, T.L., F. Zheng, A. Rosati, G.A. Vecchi, and A.T. Wittenberg (2015): A link between the hiatus in global warming and North American drought. *J. Climate (in press).*

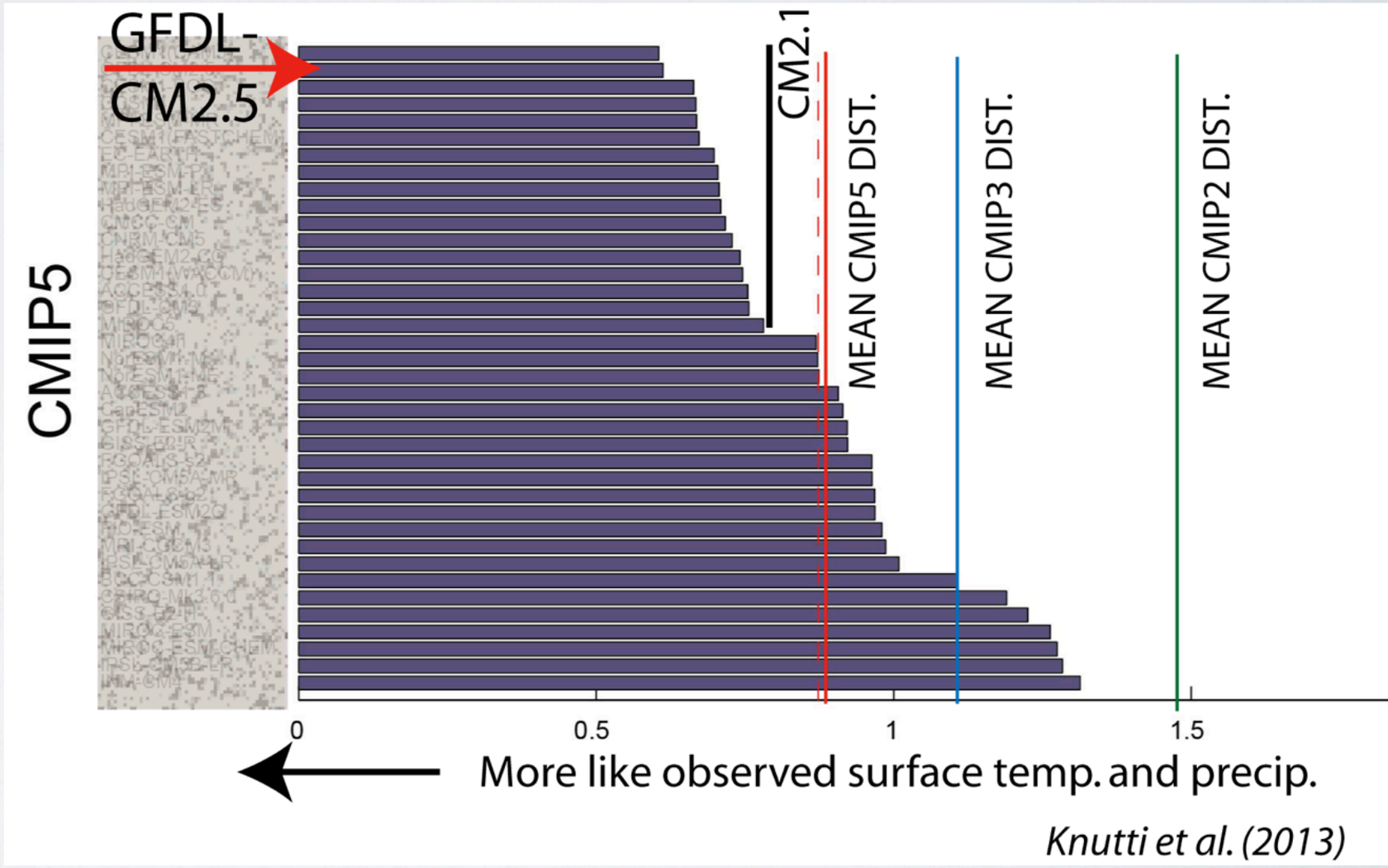
Jia, L. and coauthors (2015): Improved Seasonal Prediction Skill of Land Temperature and Precipitation in a GFDL High-Resolution Climate Model, *J. Climate (in press)*.

Vecchi, G.A., and coauthors (2014): On the prediction of regional tropical cyclone activity. *J. Climate, doi:10.1175/JCLI-D-14-00158.1*

CM2.5 produces one of best global surface climate simulations of present model generation: we're flux adjusting a 'good' model

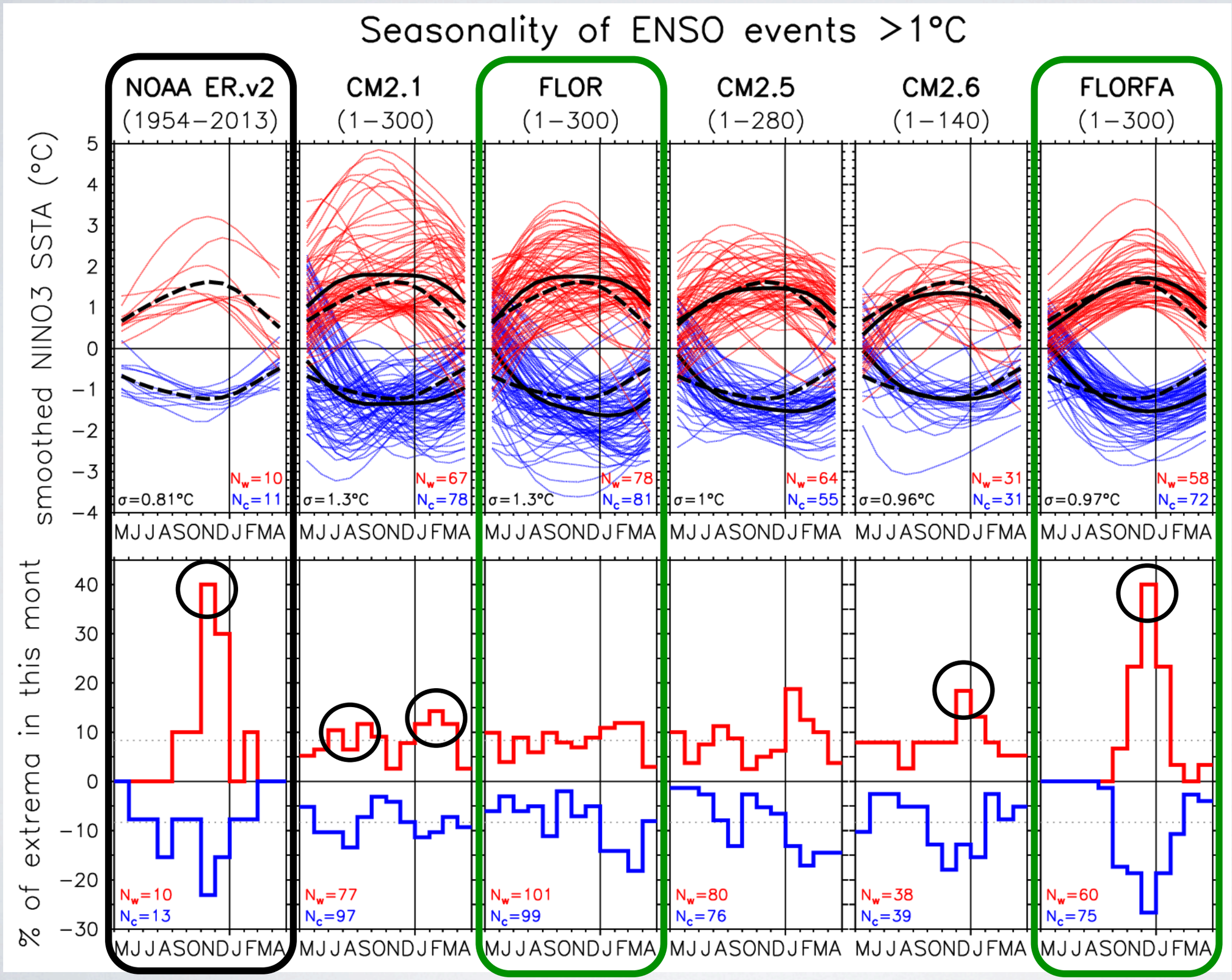
CM2.1: 2° atmos/land; 1° ocean/ice, LM2
CM2.5: 50km atmos/land; 0.25° ocean/ice, LM3

Faster computer (GAEA) allows improved resolution that translates into significantly reduced biases in CM2.5 relative to CM2.1



Knutti et al. (2013)

Seasonal synchronization of ENSO events



Obs events peak in Nov/Dec.

Coarse-res CM2.1 was *semiannually* synchronized!

Some improvements with increased atmos/ ocean resolution, but...

Flux adjustment gives **major improvements**, due to improved SST/ precip/wind, upwelling, and thermocline depth climatologies.