PICES 2009 annual meeting
W8 – POC workshop

Influence of reducing weather noise on ENSO prediction

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2009-10-24

Weather Noise and ENSO Predictability

Variability of the atmosphere in a coupled climate system:

- **Coupling signal**: response to SST, predictable part
- **Noise:** atmospheric internal variability, also called "weather noise". Stochastic, unpredictable part

Stochastic noise forcing affects ENSO predictability:

- Sustain the ENSO cycle, excite ENSO events *(Penland and Sardeshmukh, 1995; Flügel and Chang,1996)*
  - ✓ West Wind Burst *(Vecchi et al., 2006)*
  - ✓ via Meridional Mode *(Vimont et al., 2004; Chang et al., 2007)*
- Cause irregularity of ENSO, and lower its predictability *(Fedorov et al,2003; Kirtman and Shopf, 1998)*

Remove weather noise in prediction?

ENSO: stochastically forced linear system

$$\frac{\partial T}{\partial t} + \lambda T = \underline{\eta(t)}$$

white noise forcing

Predictability of a nonnormal system may depend on the structure of noise forcing *(Chang et al., 2004).*

For the present climate models, simulation of weather noise is far from perfect. Weather noise is basically an unpredictable part.

Erroneous simulation of noise forcing may obscure the coupling signal, and degrade prediction skill of the model. Therefore,

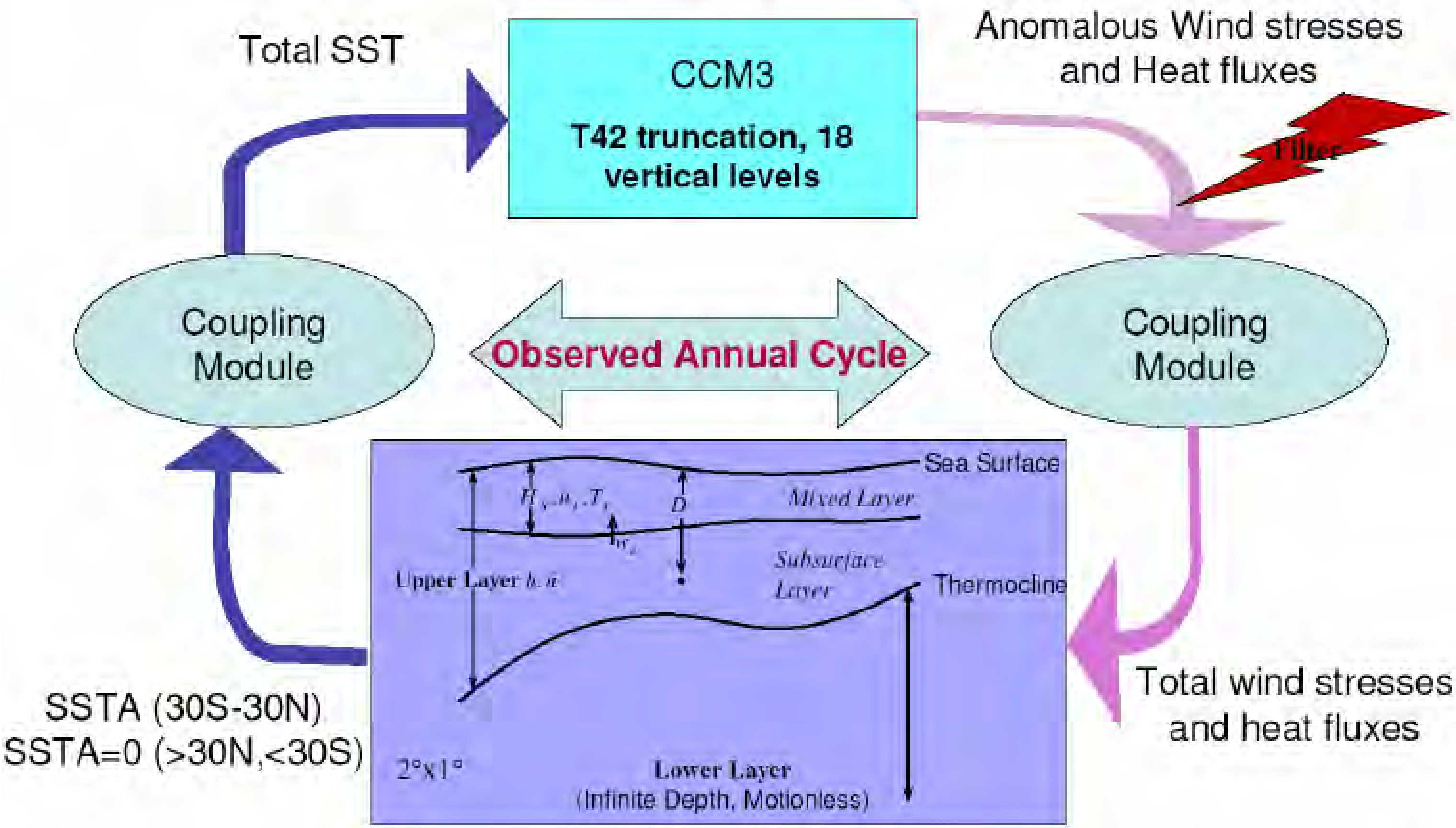
Our hypothesis is that, reducing weather noise in the coupled model, and focusing on the predictable part, may enhance the prediction of coupling signal.

→ We introduce a noise filter to our coupled model, in order to investigate the influence of reducing weather noise on ENSO prediction.

CCM3 - RGO coupled model

- Atmosphere：CCM3.3.6, an AGCM developed by NCAR
  - Global spectral model
  - T42 truncation（roughly 2.8º×2.8º）, 18 vertical levels
  - Integration time step is 20min
- Ocean：Zebiak-Cane type of 1－1/2 layer reduced gravity ocean model（RGO）
  - Covers global tropical ocean from 30ºS to 30ºN, horizontal resolution is 2º latitudes ×1º longitude
  - Improved parameterization of subsurface temperature
  - Integration time step is 3hr
- Coupling strategy: anomaly couple
  - AGCM provides wind stress, heat flux and solar radiation
  - RGO provides SST
  - Weather noise is filtered before coupling

CCM3-RGO Coupled Model



ZC type of RGO

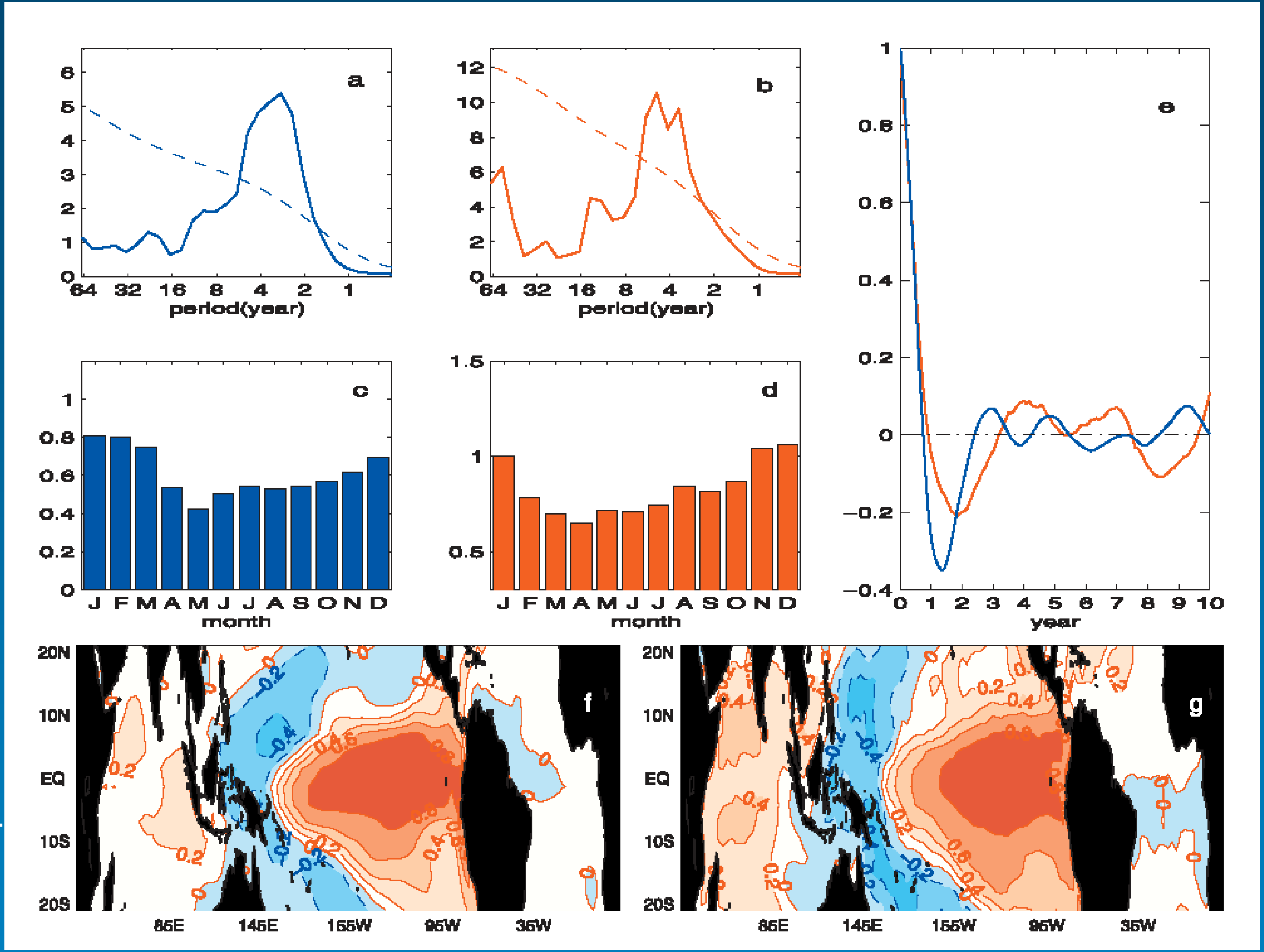
(Chang et al., 2007)

Model validation: ENSO simulation with CCM3 - RGO

Nino3 Power spectrum

Nino3 SST Standard deviation

Correlation Coefficient between SST and Nino3



Nino3 SST Auto-correlation

Red-observation ; Blue- model

(Chang et al., 2007)

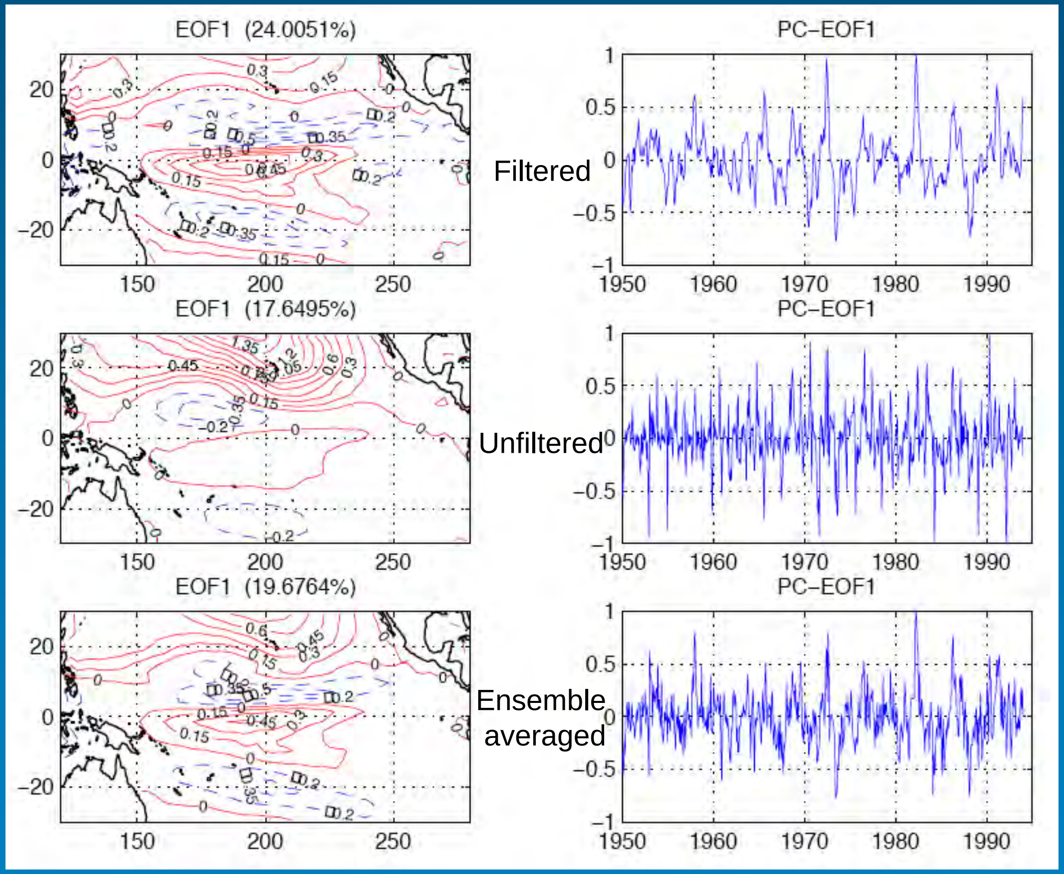
Design of Noise Filter

Procedure:

- Performing an ensemble of AMIP runs forced with multiyear SST observations.
- Formulating ensemble mean covariance matrix Cm and noise covariance matrix Cn.
- Estimating "true" SST forced response using a s/n optimization procedure:

$$\mathbf{X}_S = (\mathbf{C}_M - \frac{1}{m}\mathbf{C}_N)\mathbf{C}_M{}^{-1}\mathbf{X}_M = (\mathbf{I} - \frac{1}{m}\mathbf{C}_N\mathbf{C}_M{}^{-1})\mathbf{X}_M$$

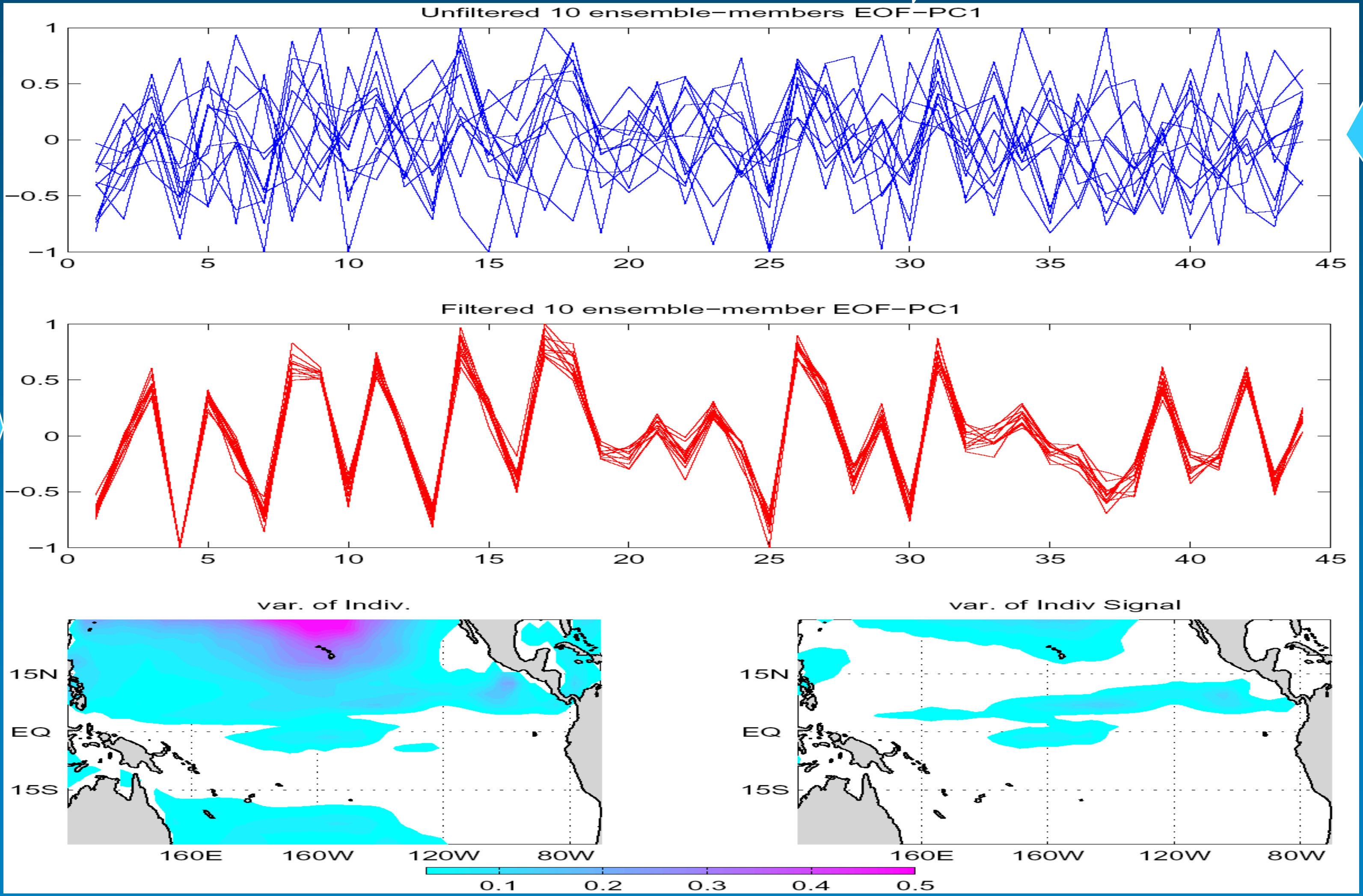
Results：



（Chang et al., 2007; Zhang et al, 2008)

Effects of filtering noise in wind stress

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



(Zhang et al., 2008)

Prediction Experiments

Stand-alone IC:

Atmospheric initial condition: CCM3-AMIP + Reynold’s SST
Oceanic initial condition: ERA-40 winds + Reynold’s SST
Ensemble size: 6x 4season(1/1, 4/1, 7/1, 10/1) x 20 yr(1981-2000)
Experiments: 1) **standard**, 2) **noise-filtered**

Coupled IC:

Atmospheric & oceanic initial condition:
CCM3-RGO coupled model + Reynold’s SST
Ensemble size: same
Experiment: 3) **noise-filtered/cpIC**
(filtering noise in both wind and heat fluxes)

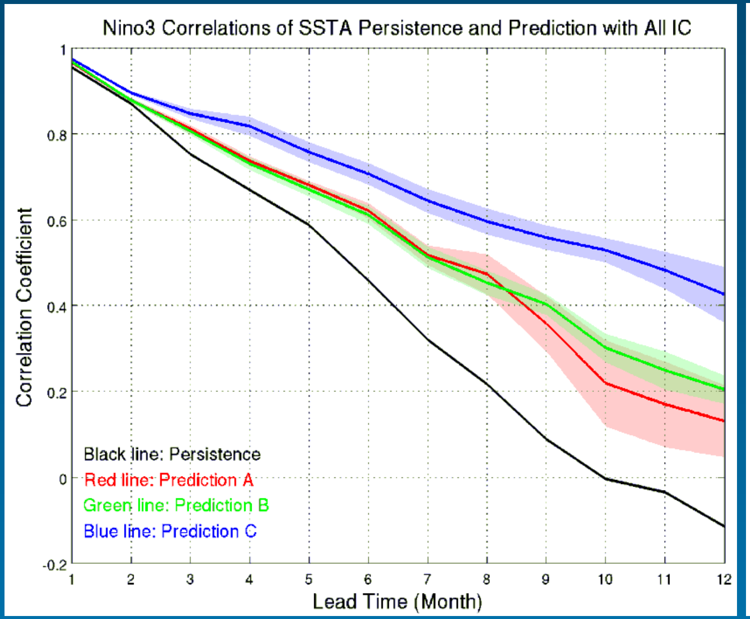
for further comparison:

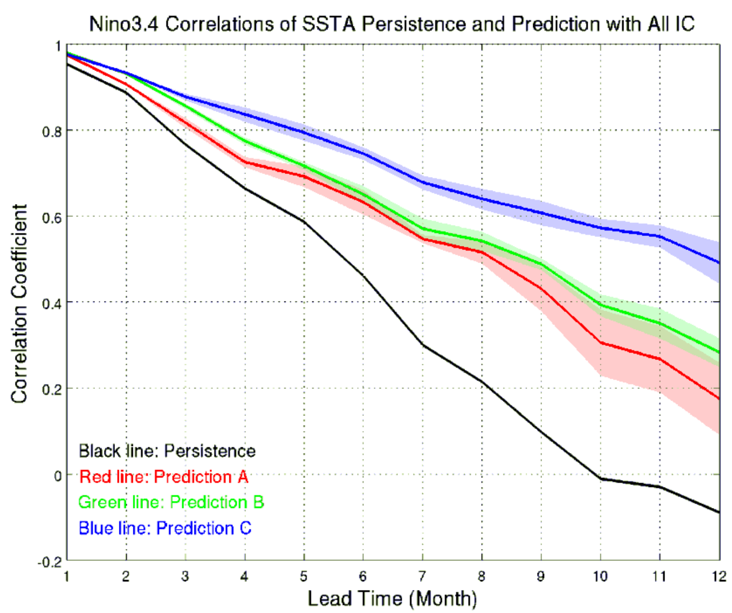
3-1) non-filter
3-2) wind-filtered
3-3) flux-filtered

ENSO prediction results

Anomaly Correlation Coefficient（ACC）:

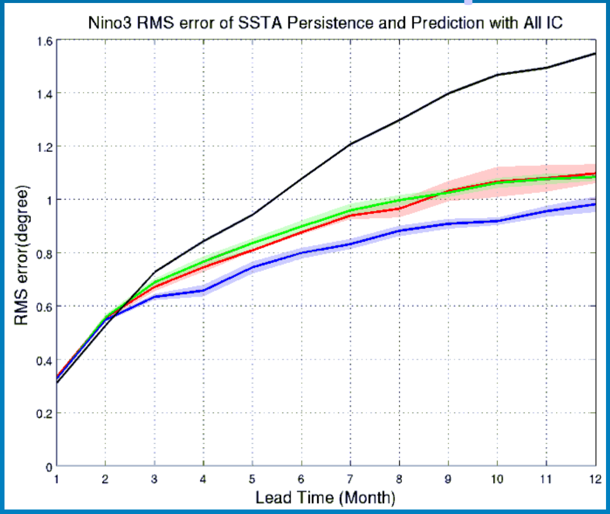
Nino3 **Nino3.4**

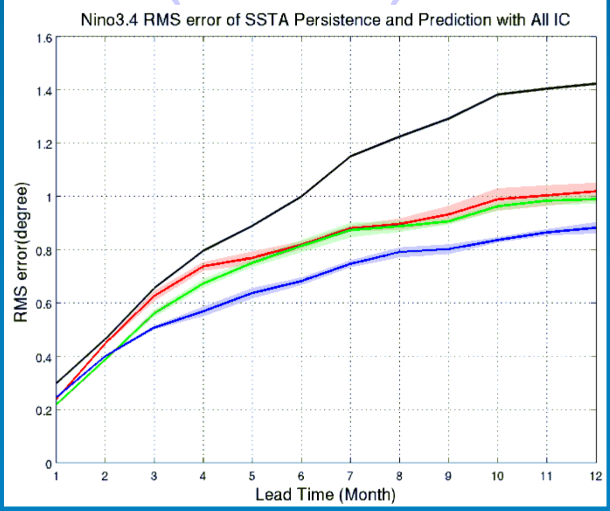




Red: standard exp.
Green: noise-filtered
Blue: noise-filtered/cpIC
Black: Persistence
Shadow: ensemble spread

Root-mean-square error（RMSE）:

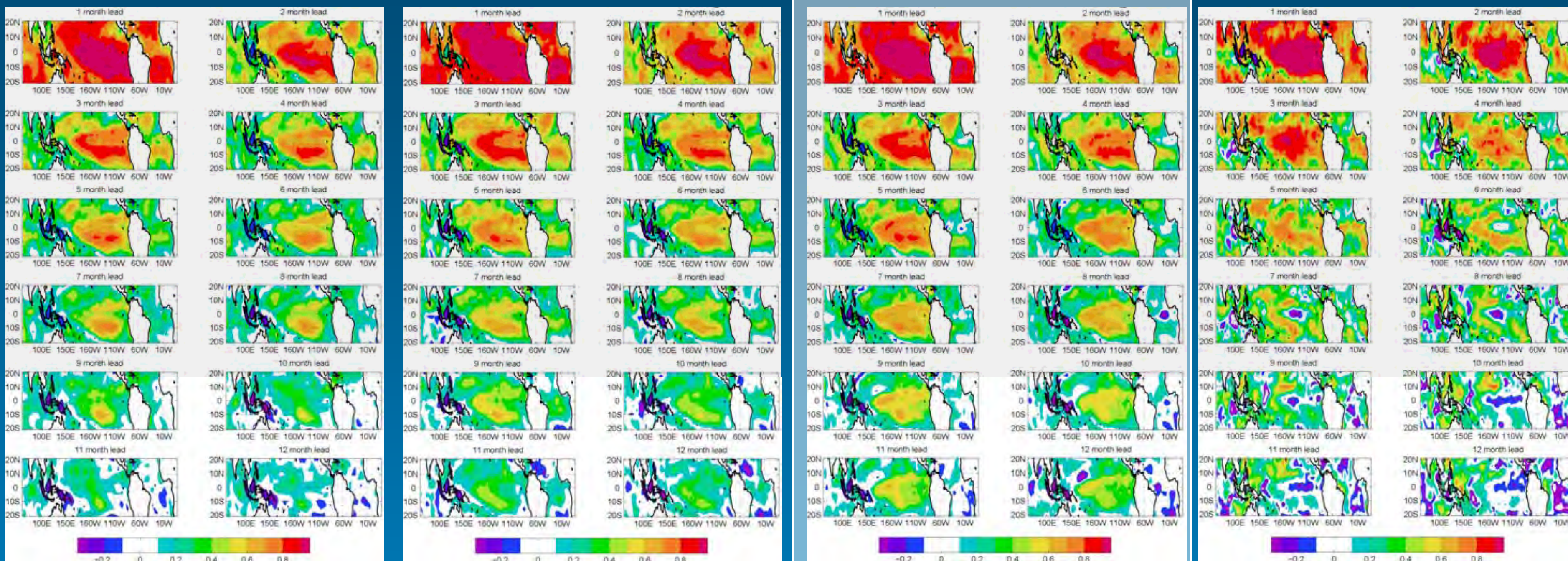




- ✓ The noise-filtered /cpIC exp. shows improved forecast skill
- ✓ Filtering weather noise narrows down the ensemble spread

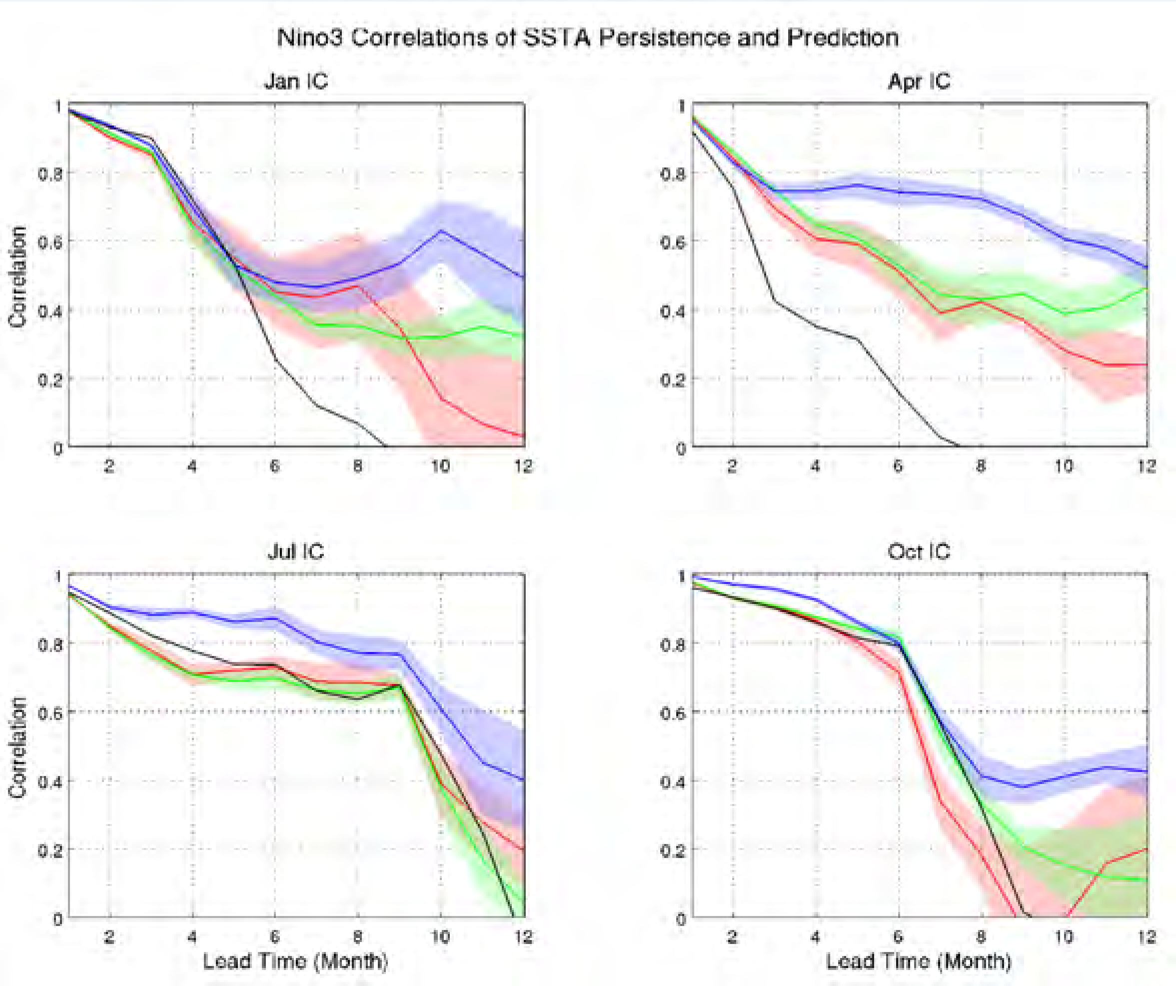
Spatial distribution of ACC：

Standard | Noise-filtered | Noise-filtered /cpIC | Persistence



- ✓Forecast kill of all experiments in tropical Pacific are above persistence
- ✓The noise-filtered /cpIC exp. shows improved 3-4 season forecast skills at cold tongue
- ✓Flitering weather noise improves forecast skill at ITCZ (10N) and south tropical Atlantic

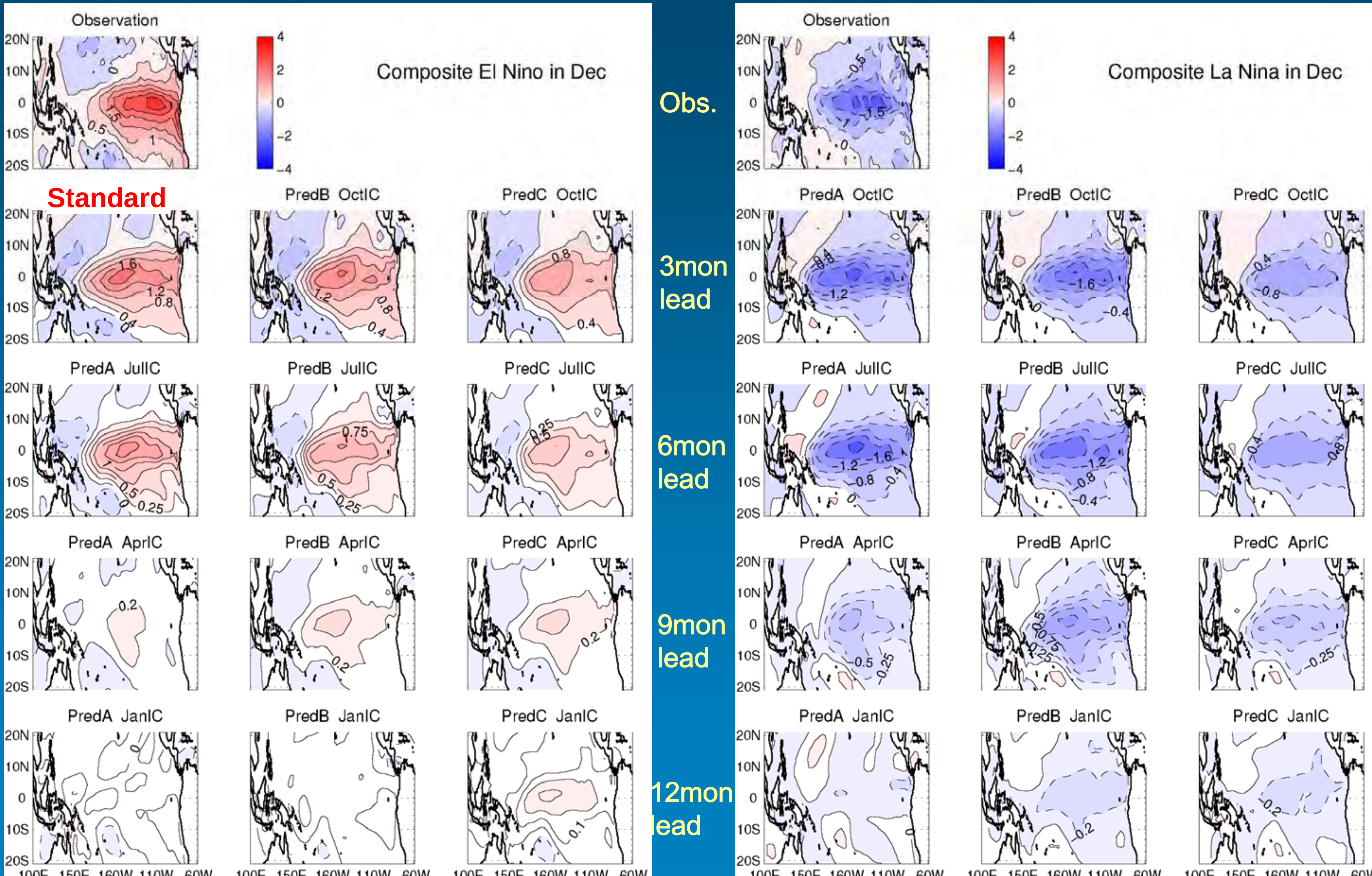
Seasonal difference in ENSO prediction



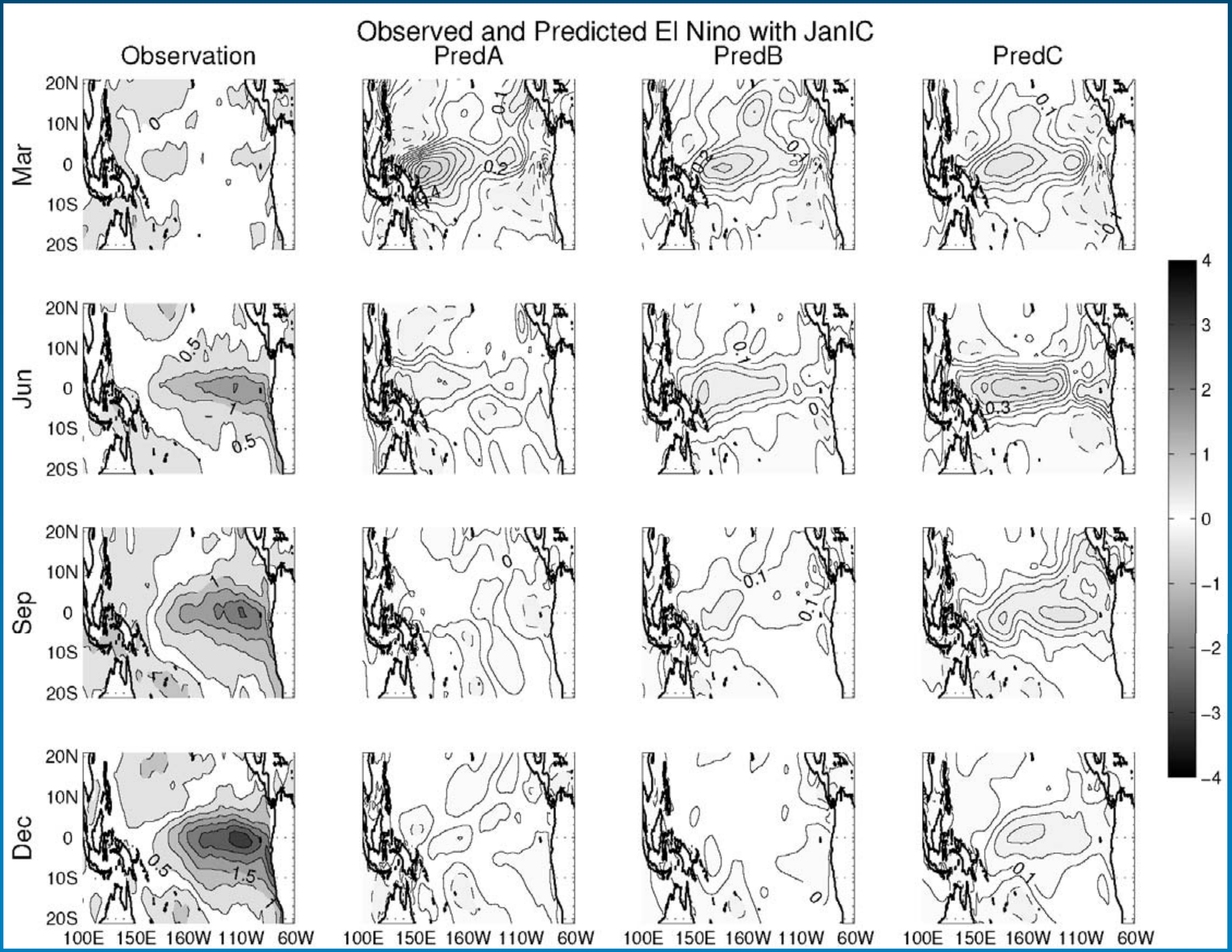
✓Strong season- dependence, influenced by the “spring predictability barrier” (SPB)

✓Noise-filtered/cpIC exp. Effectively overcome “initial shock”

Simulation of the Pacific cold tongue in strong ENSO events

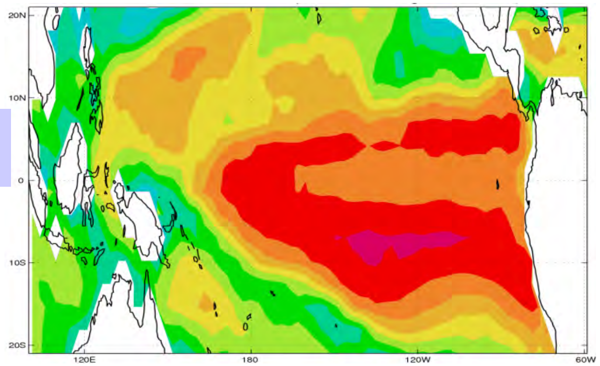


Composition of predicted El Nino events initialized from January

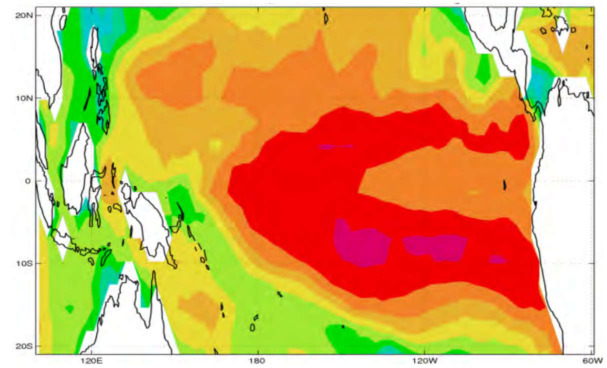


Comparison with other ENSO forecast models

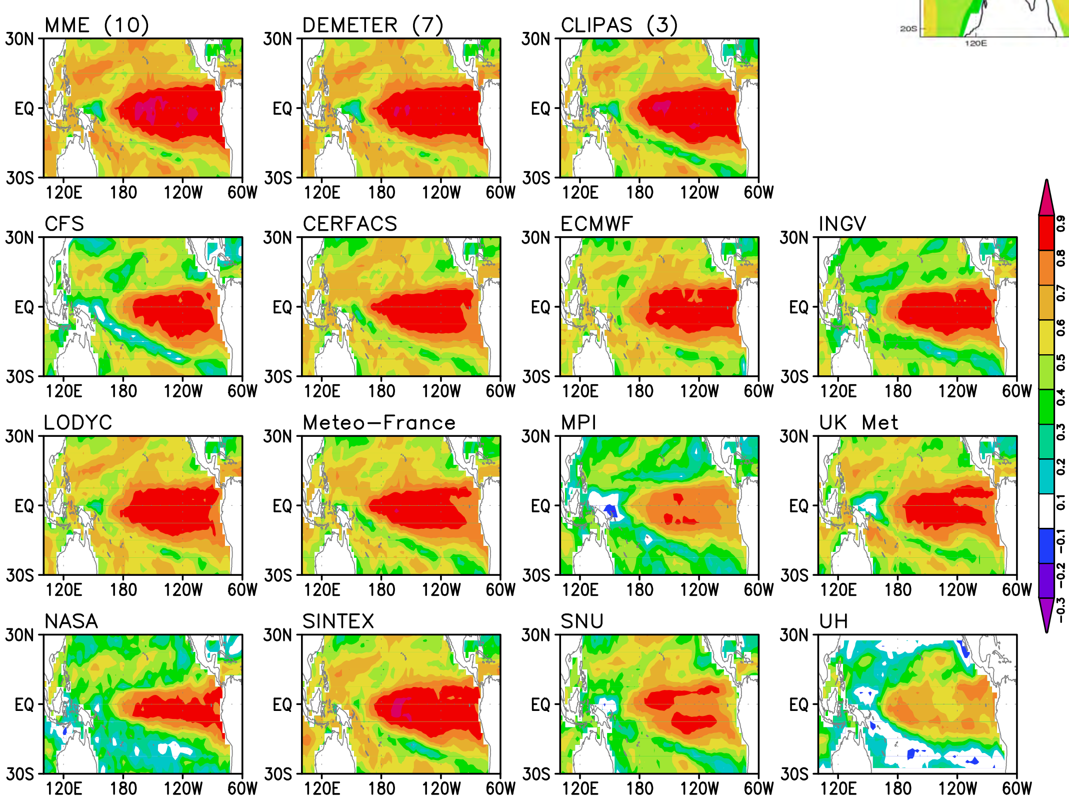
Standard



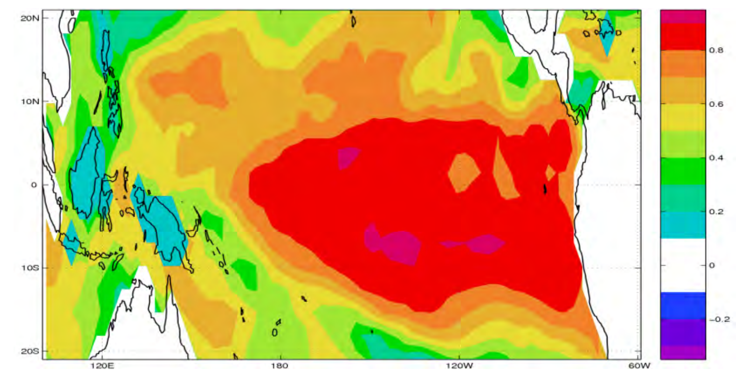
Noise-filtered



ACC of first season prediction :



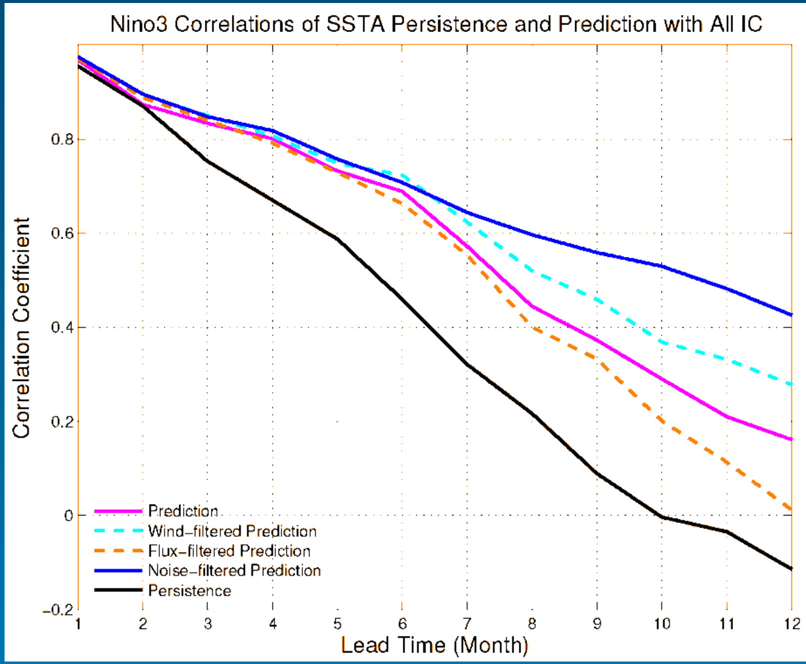
Noise-filtered/cpIC



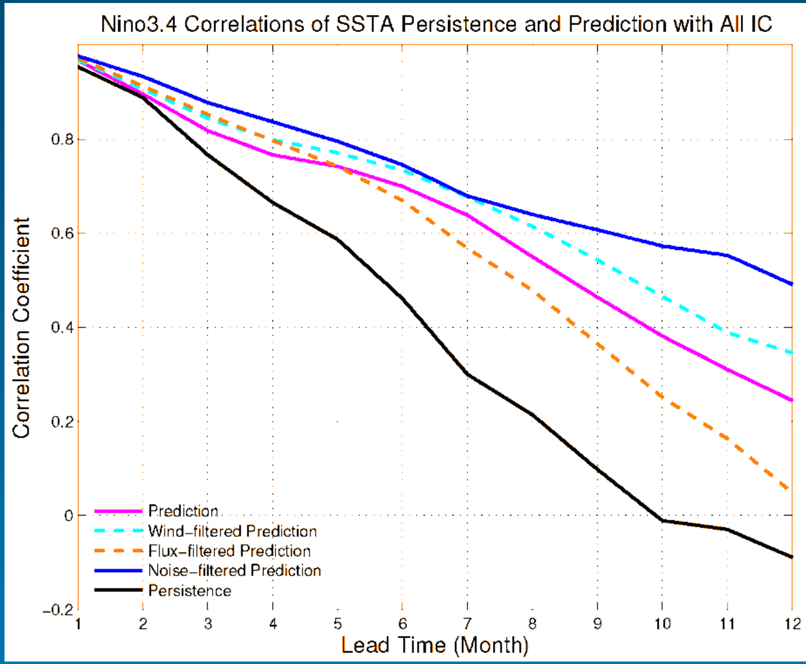
Further analyses on how the filter take effect

ACC：

Nino3



Nino3.4



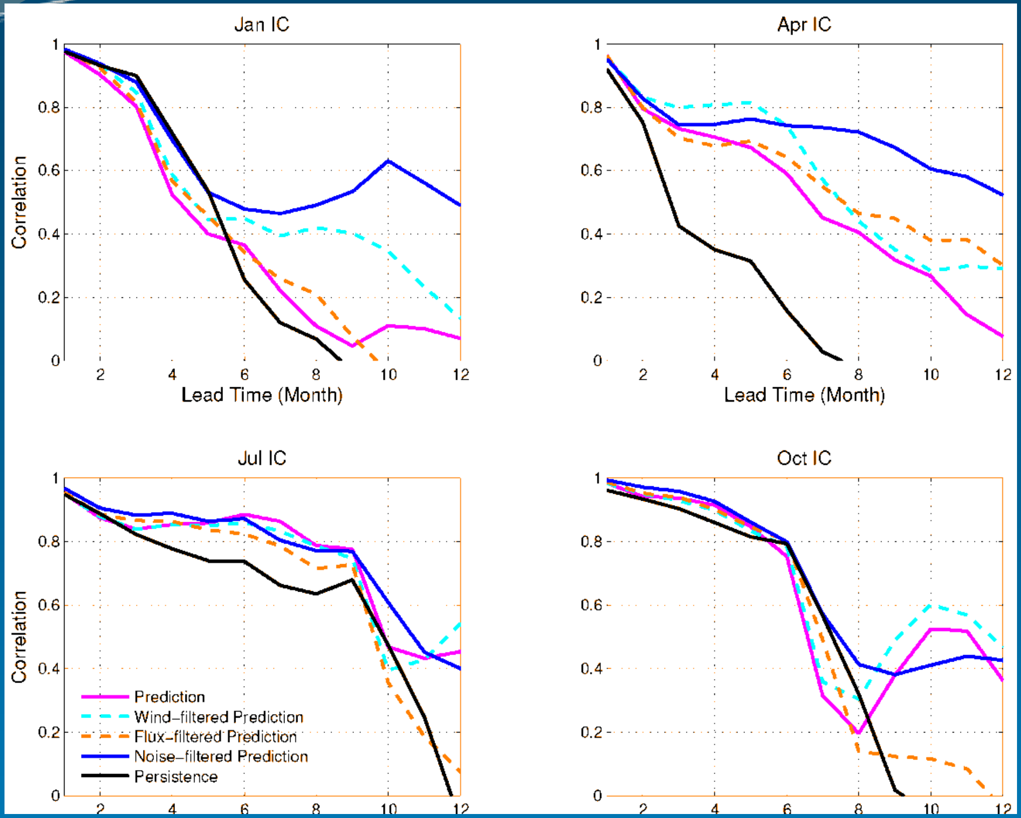
✓ICs are very important to prediction of 1-2 seasons

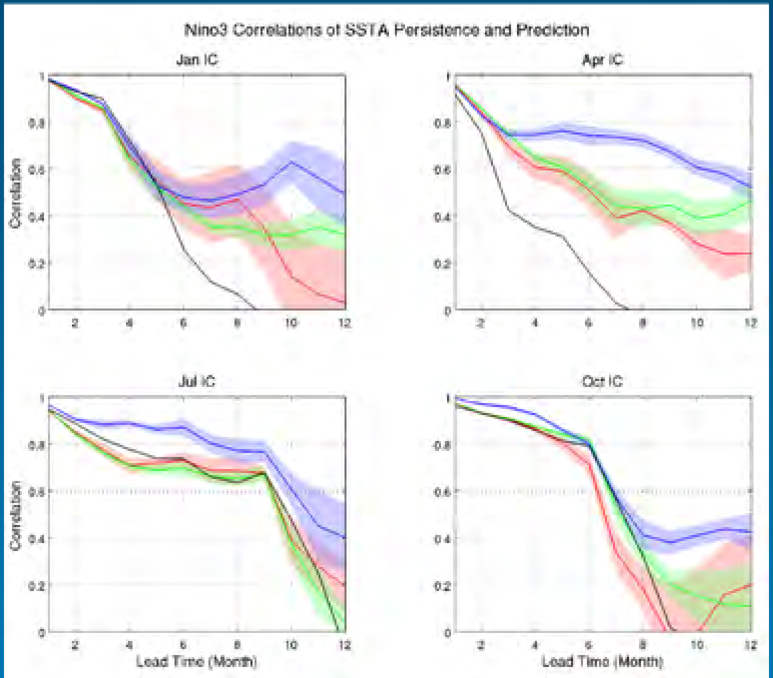
✓Filtering noise in wind stress takes more effect than filtering noise in heat-flux

Blue：noise-filtered/cpIC
Magenta：non-filter
Cyan：wind-filtered
Orange：flux-filtered
(all with same IC)

ACC for different seasons：

Blue：noise-filtered/cpIC
Magenta：non-filter
Cyan：wind-filtered
Orange：flux-filtered

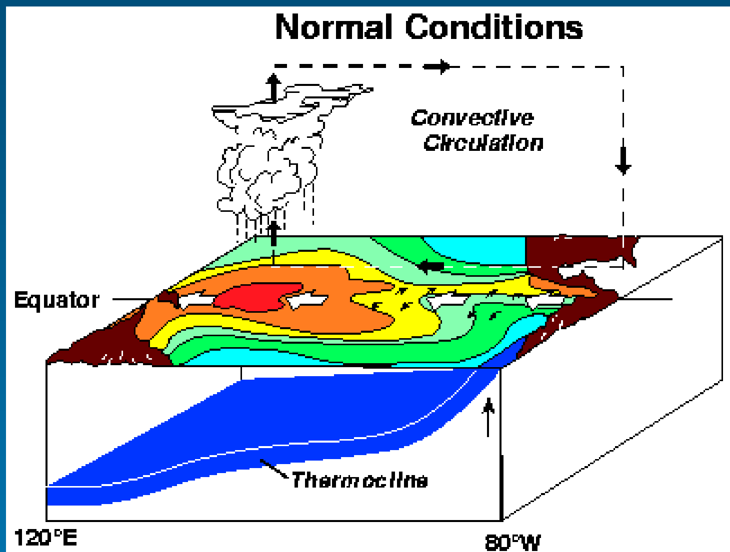


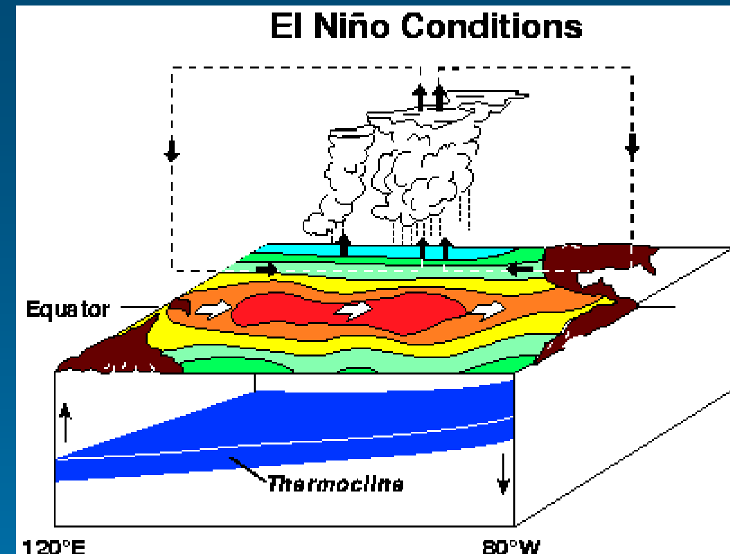


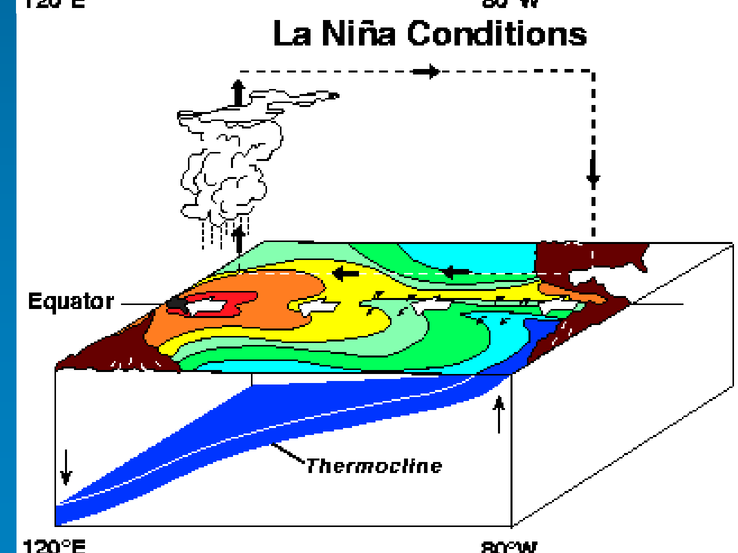
✓Winter and spring forecast are greatly influenced by weather noise. Filtering weather noise, especially in wind-stress, alleviate drop of forecast skill caused by SPB.

✓Forecasts that begins from summer and fall is easily influenced by initial conditions.

Why wind stress? Bjerknes feedback







Reducing weather noise may boost the signal-to-noise and improves the model's response to Bjerknes feedbacks between wind stress, thermocline and SST, resulting in an enhanced ENSO forecast skill.

(http://www.pmel.noaa.gov/tao/elnino/nino_normal.html)

Summary

- Suppressing weather noise leads to a general improvement in model forecast skills. With appropriate initial conditions, reducing weather noise can alleviate drop of ENSO forecast skill caused by the so called “spring predictability barrier”, and help maintaining considerably high skill in 3-4 leading seasons.
- the improved ENSO forecast skill is mainly attributed to reducing weather noise in wind stresses, which may take effect by boosting the SNR and improves the model’s response to Bjerknes feedbacks.

Weather Noise and ENSO Predictability

Thanks !

Questions and discussions are welcome !