Prediction skills of ENSO and the East Asian Winter Monsoon in the BCC_CSM1.1m model

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ENSO predictability

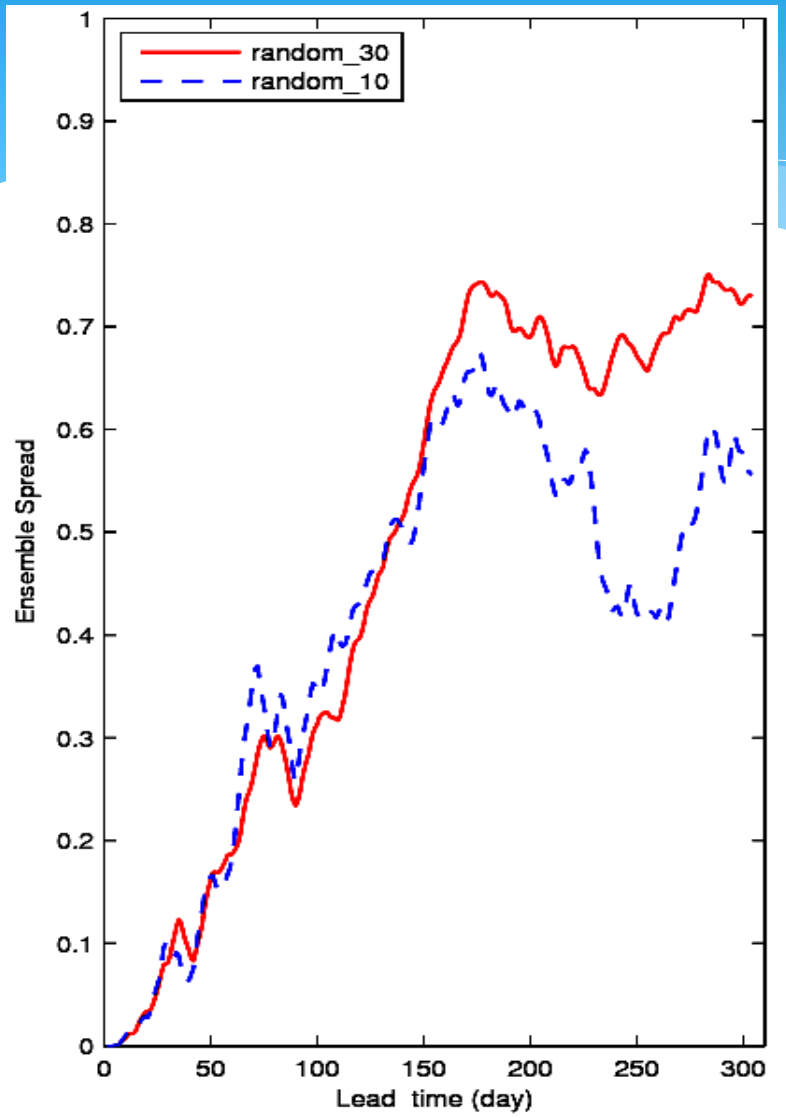
- ENSO is one key source of predictability for seasonal forecast

- Significant progress has been made, many models have reached a correlation skill of 0.8 for ENSO predictions at 6 months (Jin et al. 2008).

- The loss of ENSO predictability depends on:
  i) Uncertainty in initial conditions
  ii) Stochastic atmospheric noise
  iii) Model errors

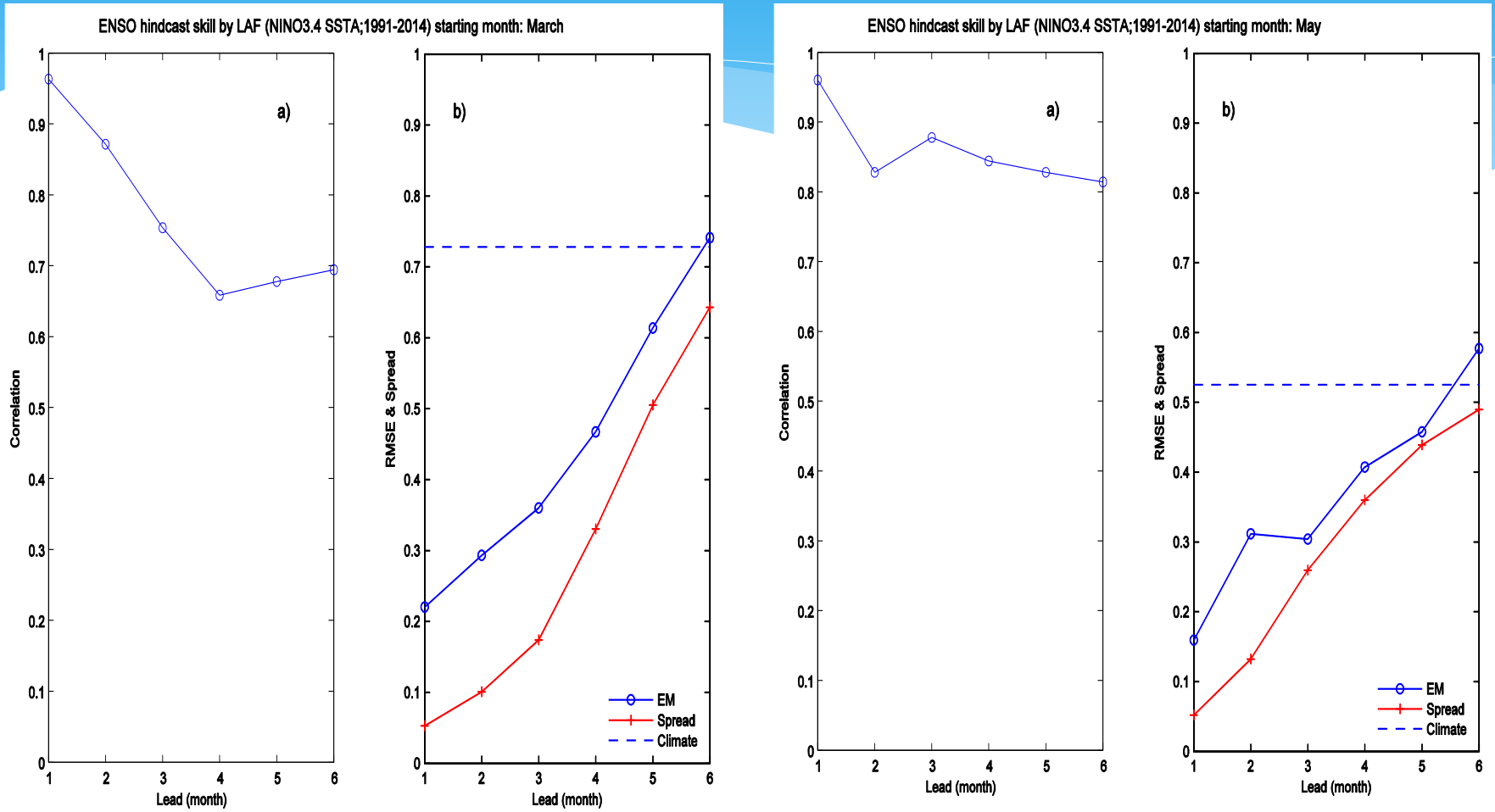
BCC model is very sensitive to initial SST condition

(random perturbation, magnitude 1.E-8)



1. Ensemble spread grows significantly when model running forward from 1 to 6 months lead time (NINO3.4 SST)
2. At 6 months lead time ensemble spread closes to its saturation value (the climate standard deviation of NINO3.4, ~0.75),suggesting that ENSO predictability is about 6 months for the BCC model.
3. The spread of 10 members is close to that of 30 members, suggesting that 10 member is sufficient to represent the initial uncertainty.

Using 15 members LAF initial perturbation method, ENSO prediction skill of the BCC model in 1991-2014, starting from March and May respectively.



Question: How to improve ENSO prediction skill of the BCC model and construct a reliable ENSO ensemble prediction system?

Requires better initial perturbation method & Ensemble verification.

Singular Vector initial perturbation method

* SV is the optimal linear initial perturbation method.
* The standard SV method requires a TLM and an adjoint model, which are difficult to construct for a large and complex climate system model.
* SV from weather model could not be applied in climate time scales, because weather noises can cover climate signals.
* In this study, a statistical SV method proposed by Kleemen (2003) will be applied in BCC model.

The procedure to calculate the Singular vector (SV) for the BCC model

1) Calculate the correlation-EOF modes by using the normalized long-term historical model initial SST dataset. The leading three correlation–EOF modes denote as E_i (i= l, 2, 3). Note E_i has the dimension of $m \times 1$. m is the spatial grid number of the ocean model.

2) An ensemble of 30 predictions with lead time of 6 months is constructed by randomly perturbing the initial SST field with 30 "small" random patterns (A white-noise pattern in space with amplitude around 1E-8 ° C). The ensemble mean of SSTA at lead time of 6 months is denoted by Ψ_0.

3) Each of the leading three correlation–EOF modes E_i of SST are added in turn to the initial condition described in 2) and a new ensemble of 30 predictions is obtained. The corresponding ensemble means are denoted by Ψ_i.

4) Calculate SV using $\Psi 0, \Psi 1, \Psi 2, \Psi 3$ as follows.

$$R_{m\times m} \times E_{m\times 3} \approx \delta\Psi_{m\times 3} = \begin{pmatrix} \overline{\Psi_1}(t) - \overline{\Psi_0}(t) \\ \overline{\Psi_2}(t) - \overline{\Psi_0}(t) \\ \overline{\Psi_3}(t) - \overline{\Psi_0}(t) \end{pmatrix} \longrightarrow R_{m\times m} \approx \delta\Psi_{m\times 3} \times E'_{m\times 3} = U_{m\times m}\Lambda_{m\times m}V'_{m\times m}$$

$$SV_{m\times m} = V_{m\times m}$$

$$FP_{m\times m} = U_{m\times m}\Lambda_{m\times m} = R_{m\times m} \times V_{m\times m}$$

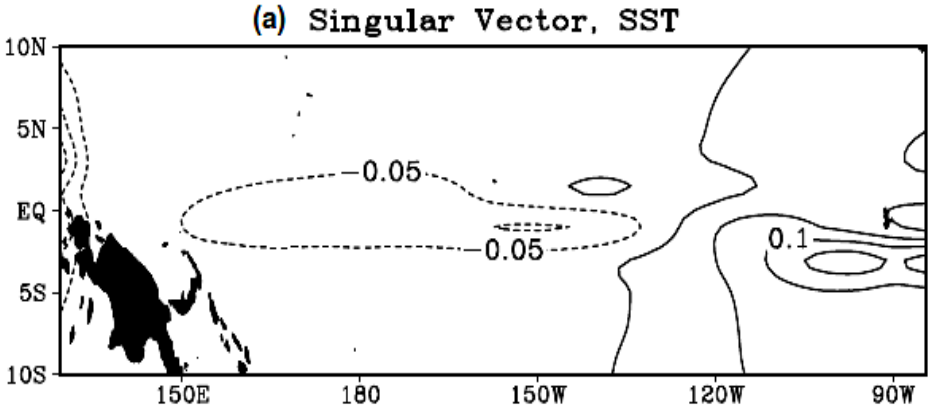
Examine the SV method by the Zebiak Cane model

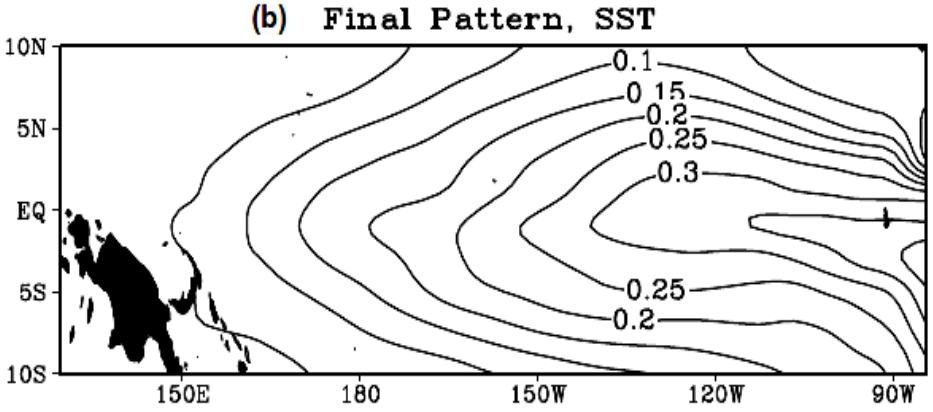
using the standard method and the statistical method

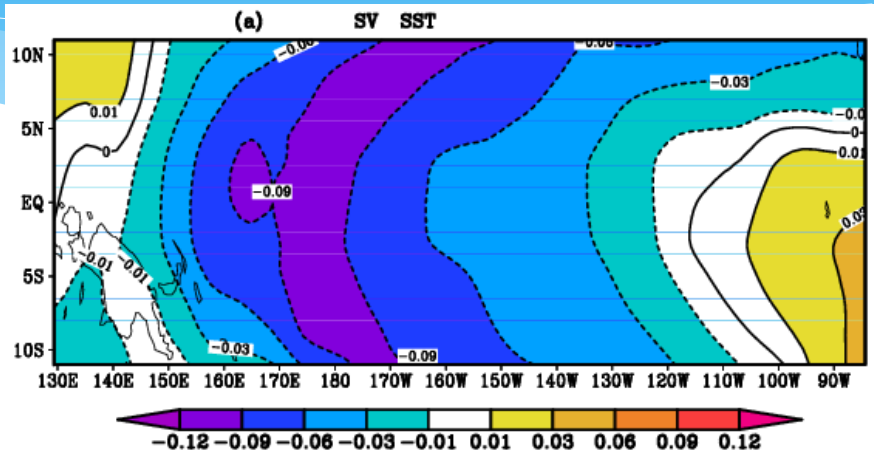
TLM

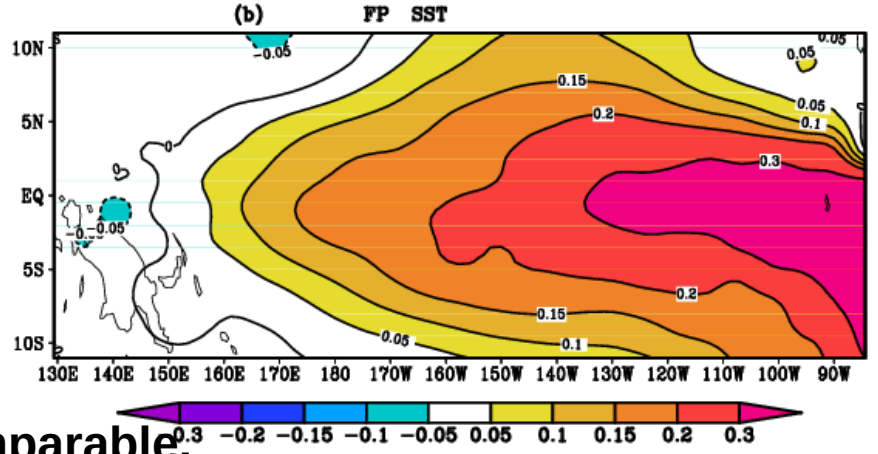
SV & Final pattern (Cheng et al. 2010)

Statistical method: SV&FP





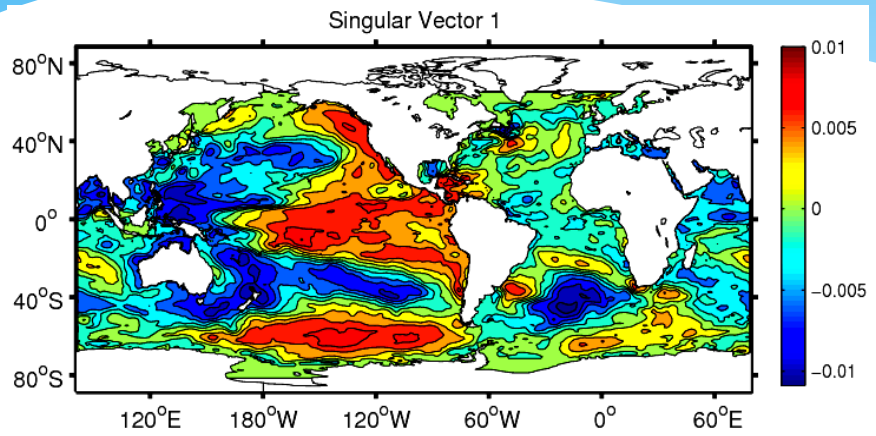


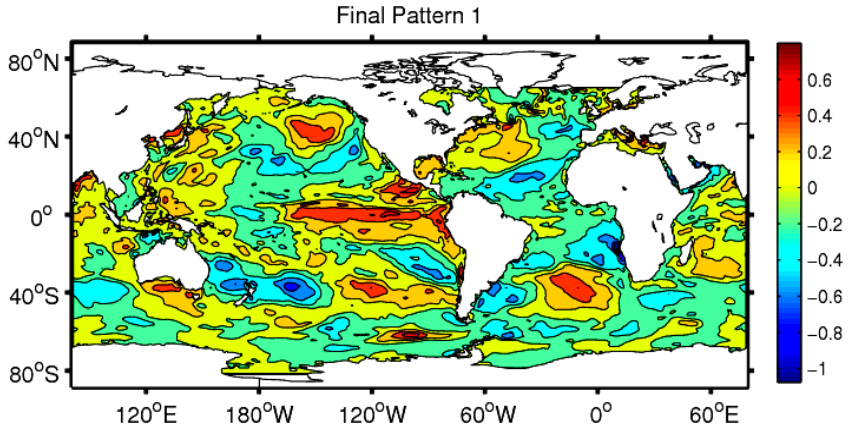


SV and Final Pattern are comparable.

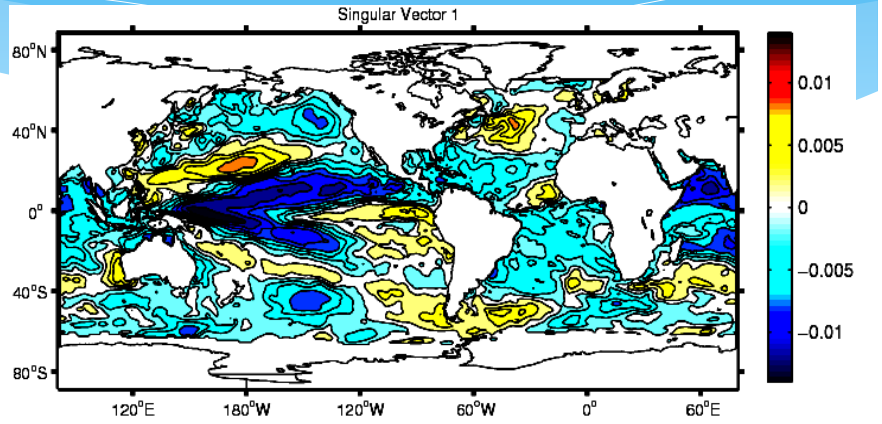
SV and Final Pattern for BCC_CSM1.1m, starting from March, May respectively

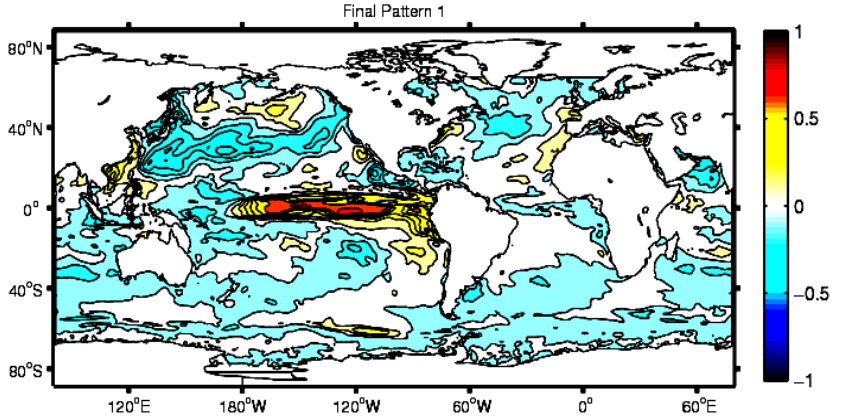
March





May

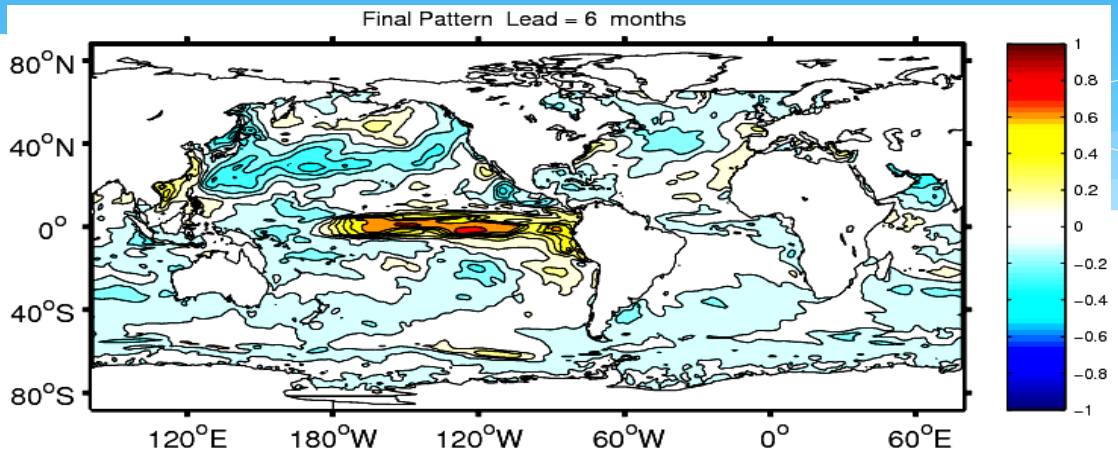




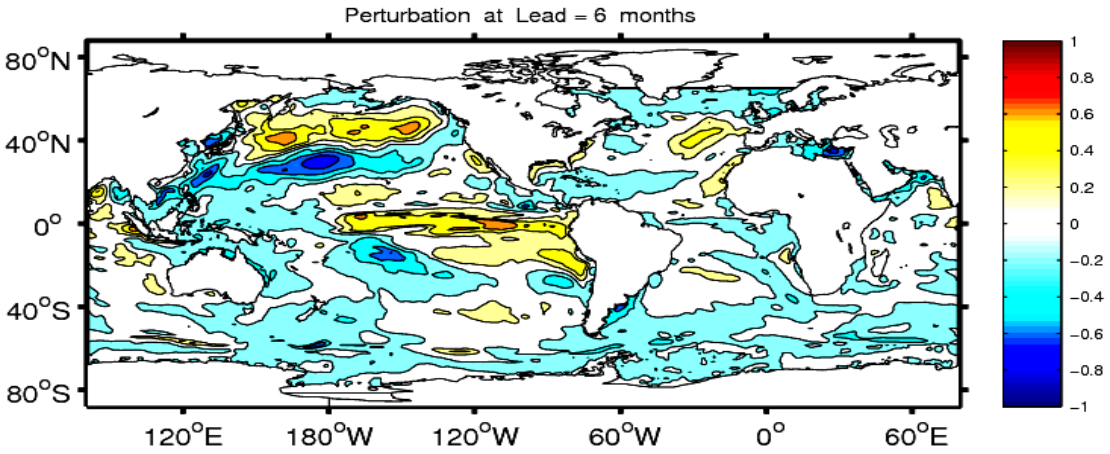
Verification the SV method by comparing the Final Pattern and Perturbation Growth pattern

Starting from May 1

FP at 6 months lead from SV method



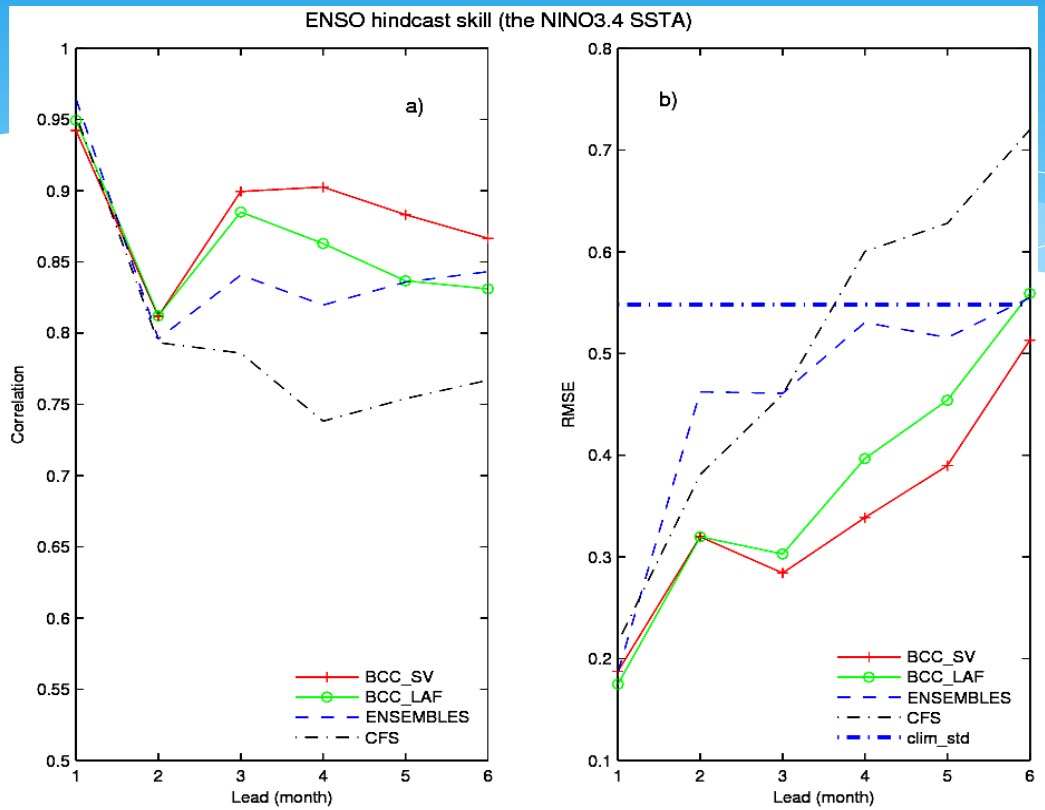
Perturbation growth at 6 months lead, using SV as initial perturbation



ENSO Hindcast Skills (1991-2005)

The Nino3.4 SSTA

Starting time: May 1



ENSEMBLES: 54 members

CFS: 15 members

BCC(LAF): 15 members

BCC(SV): 8 members

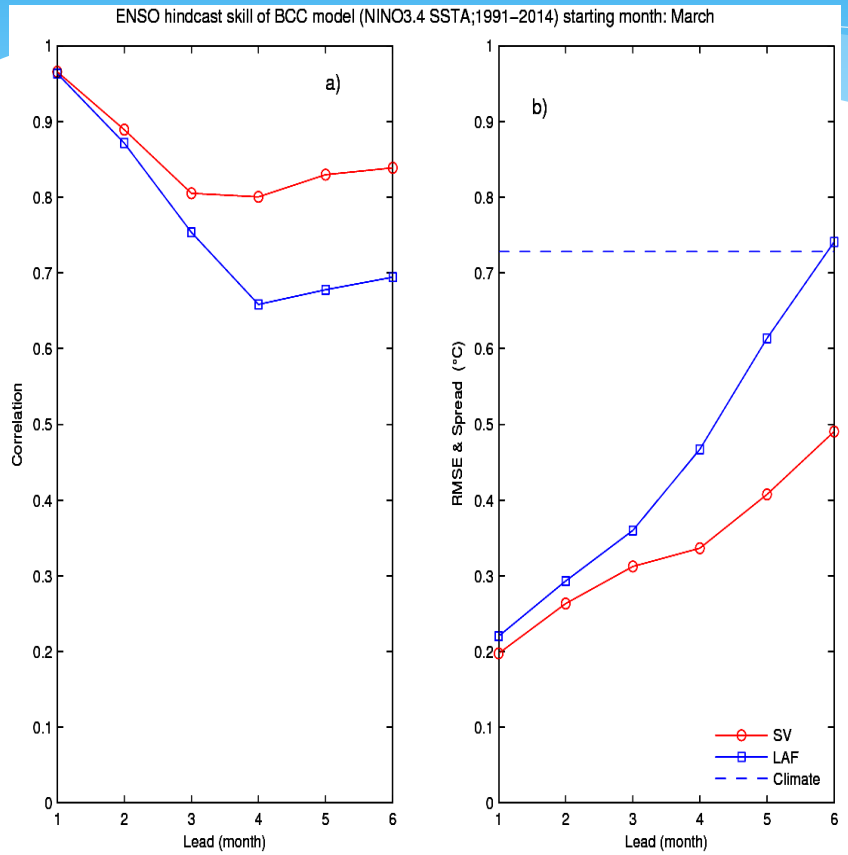
Left panel：correlation，Right panel ：RMSE

BCC SV（red line）
BCC LAF （green line）
ENSEMBLES（blue dashed line）
CFS（black dashed line）

ENSO Hindcast skill 1991-2014

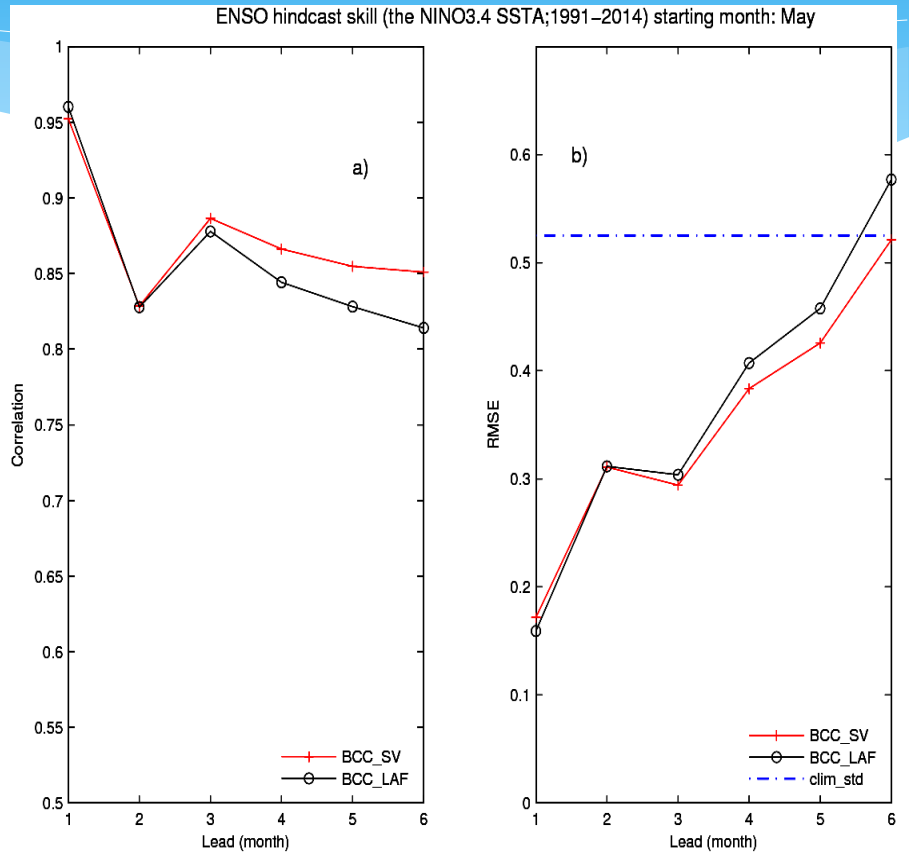
Starting time: March

Correlation RMSE

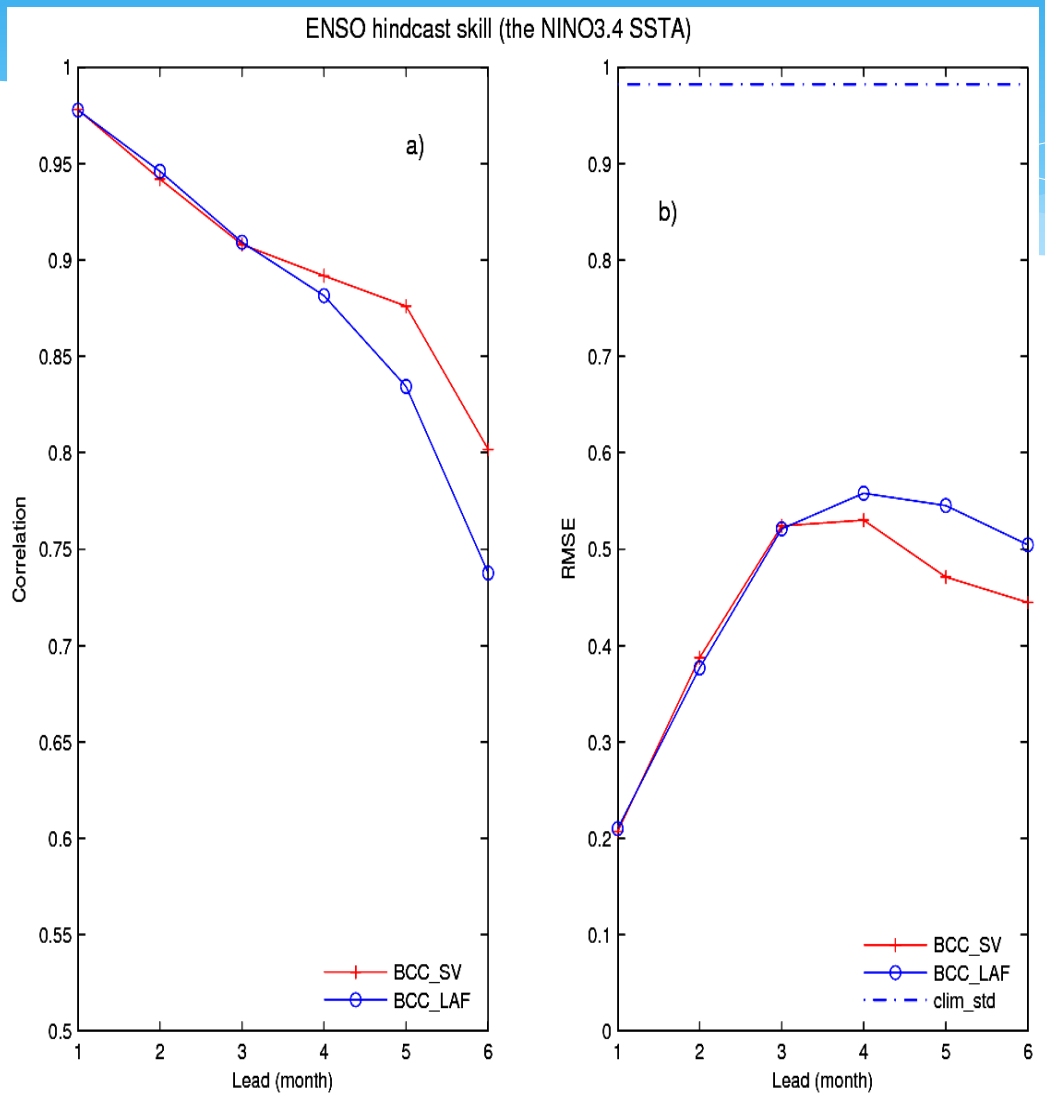


Starting time: May

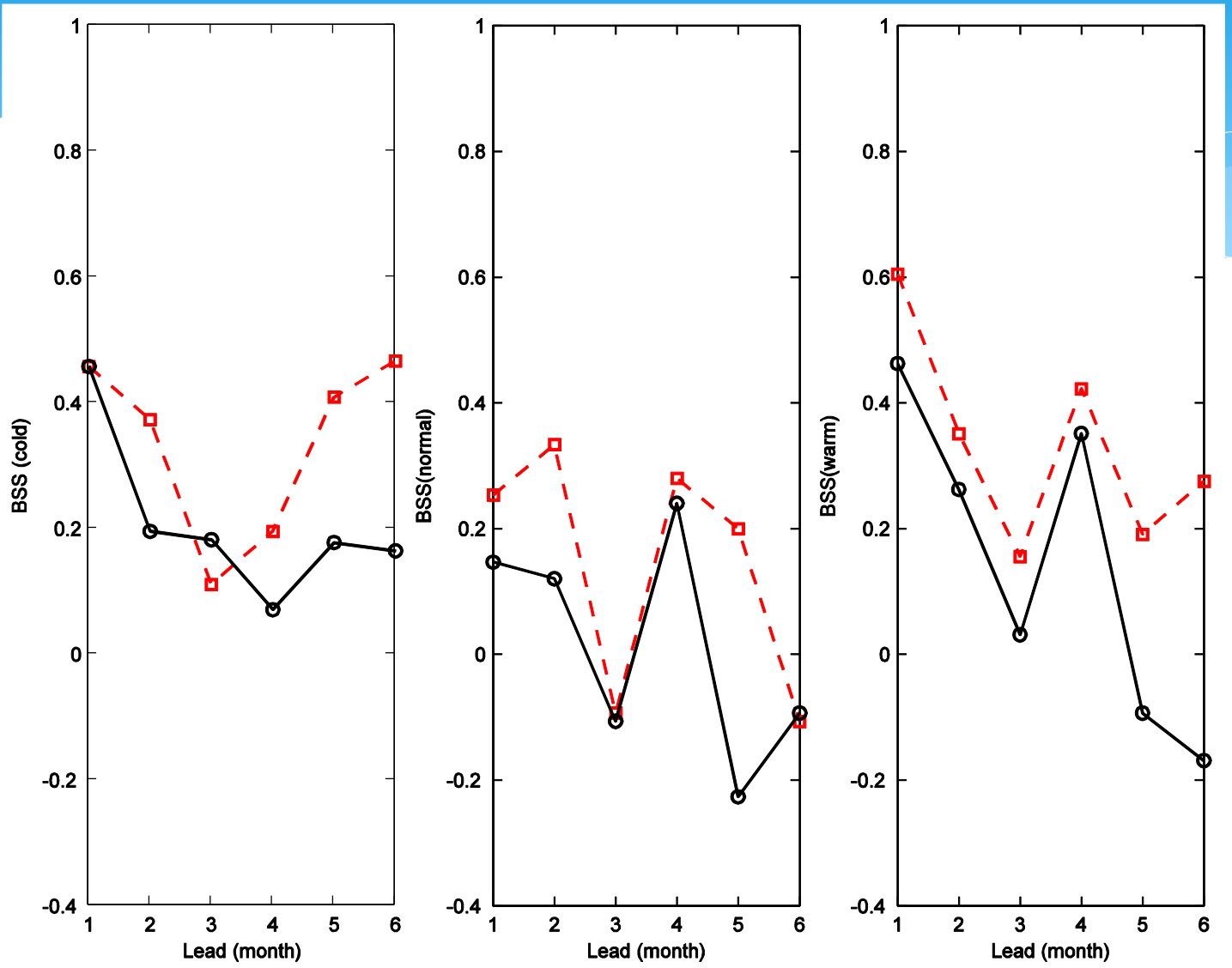
Correlation RMSE



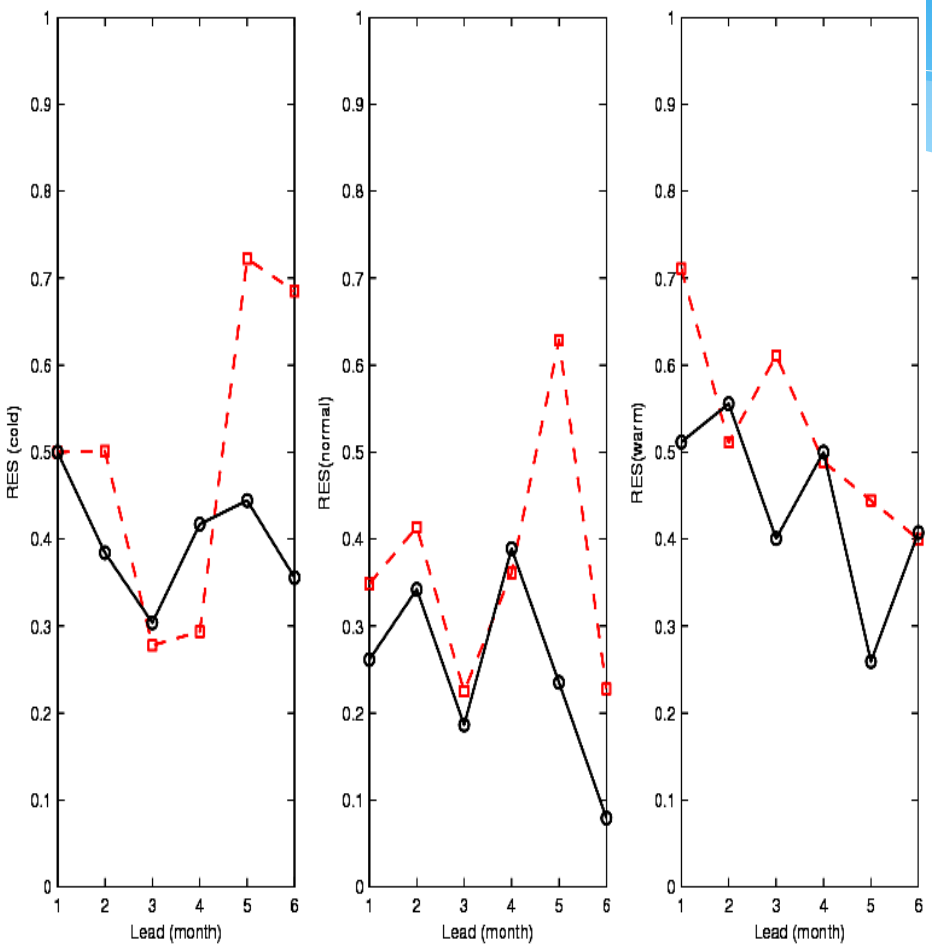
Starting time: Oct.



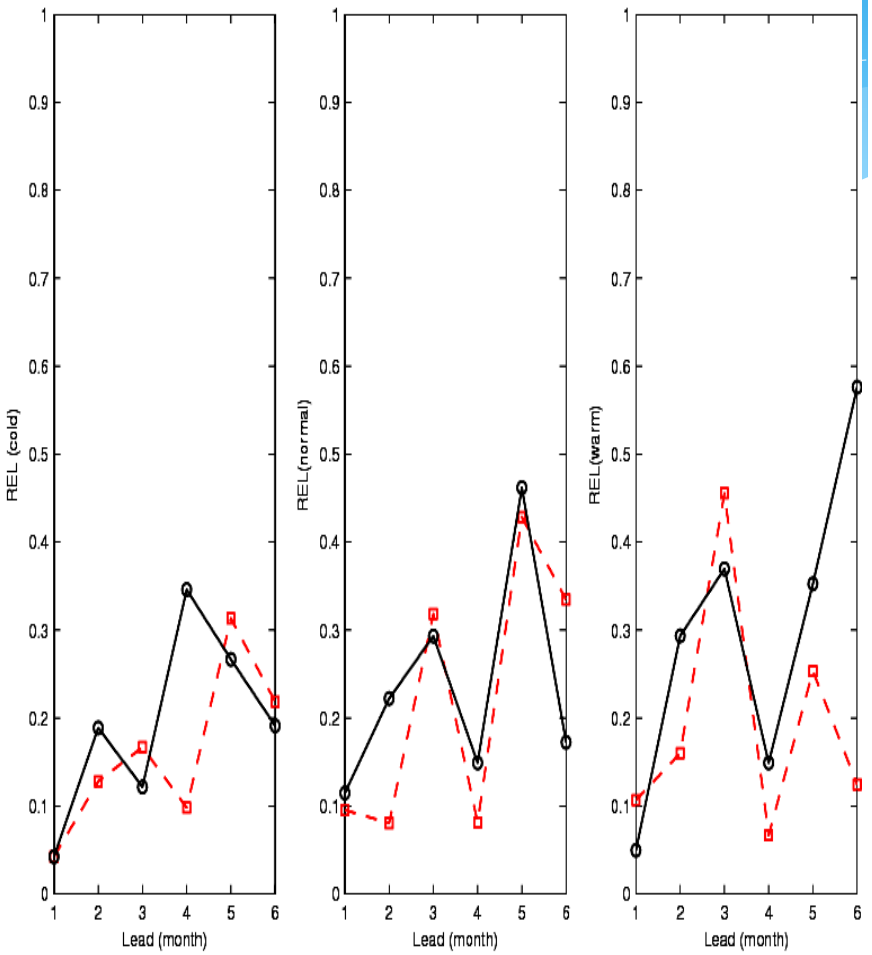
Brier Skill Score (BSS), March



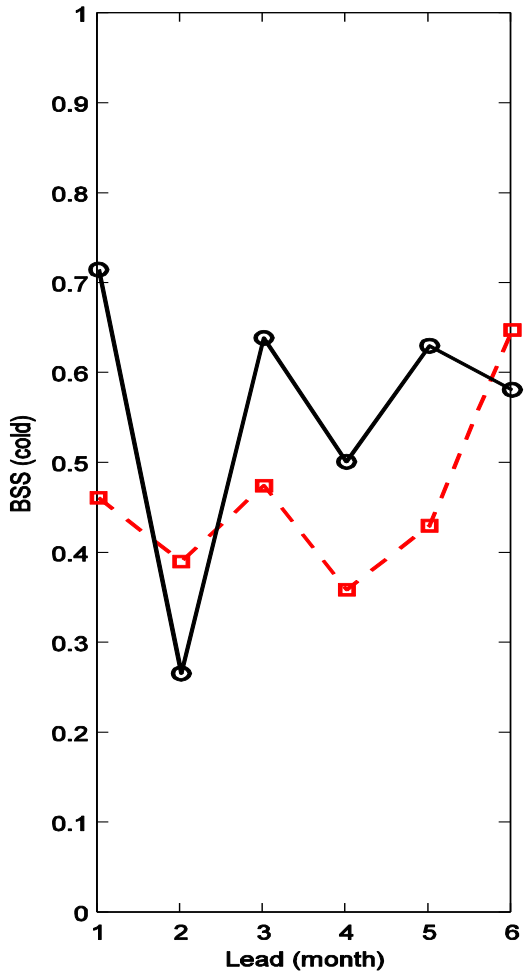
RES, March

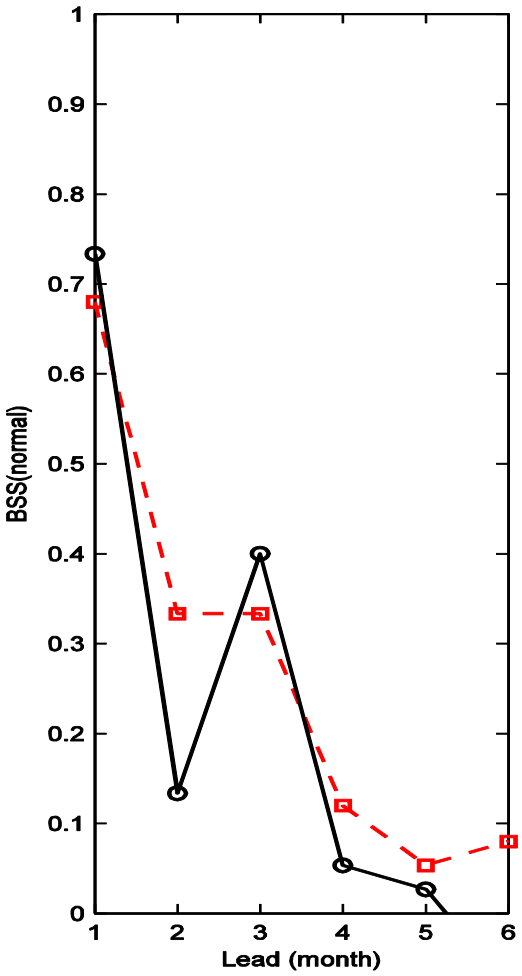


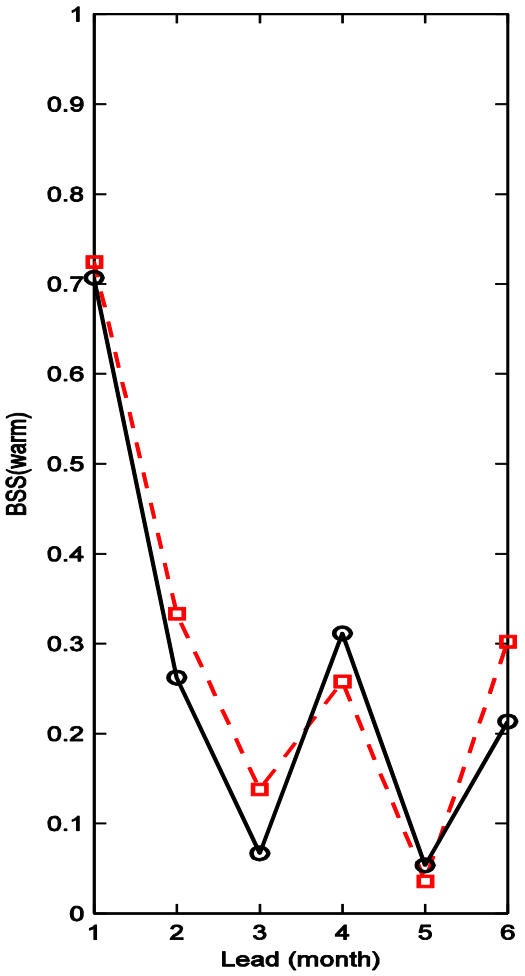
REL, March



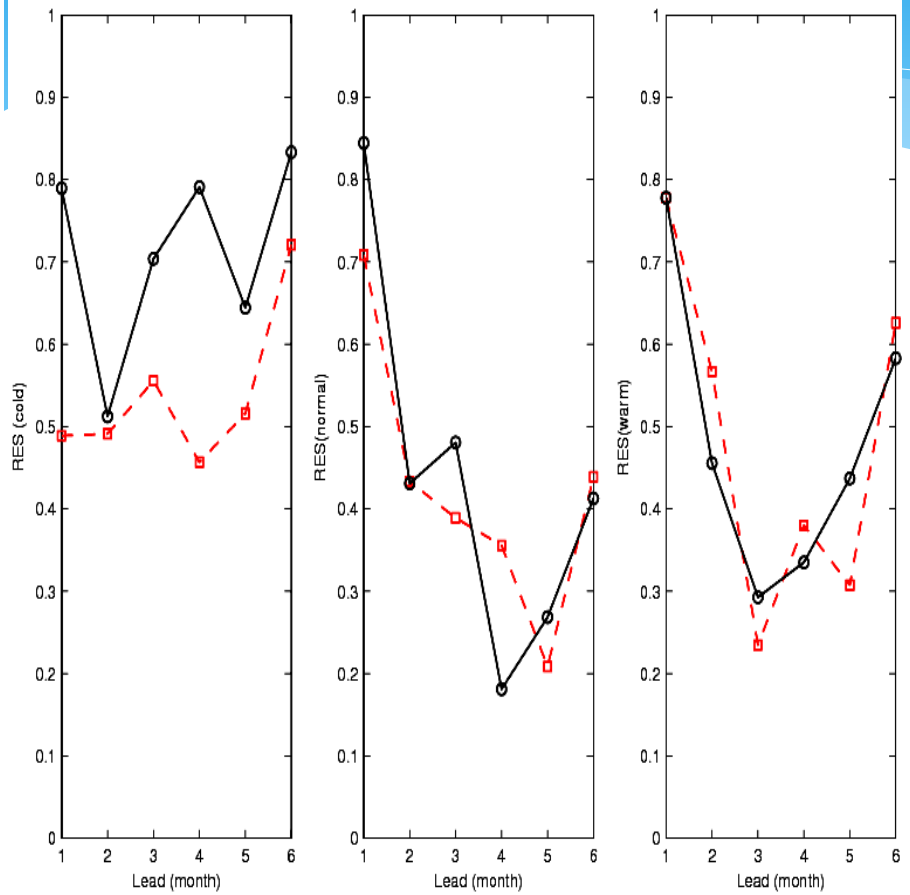
BSS, May


BSS (cold)
Lead (month)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6

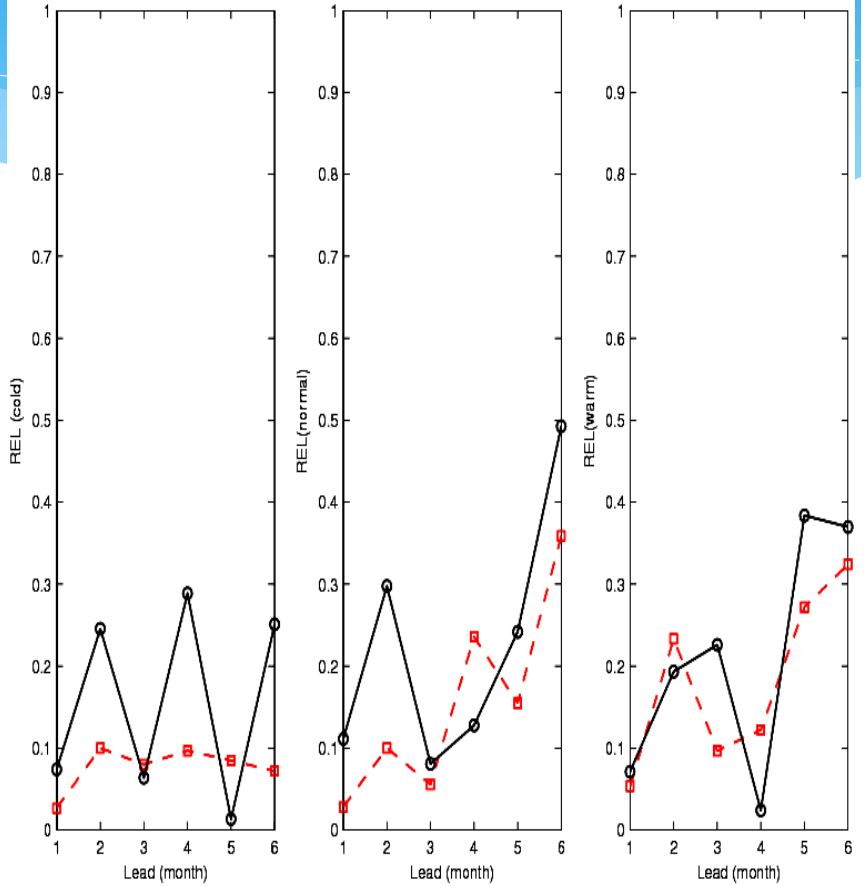

BSS(normal)
Lead (month)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6


BSS(warm)
Lead (month)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1
2
3
4
5
6

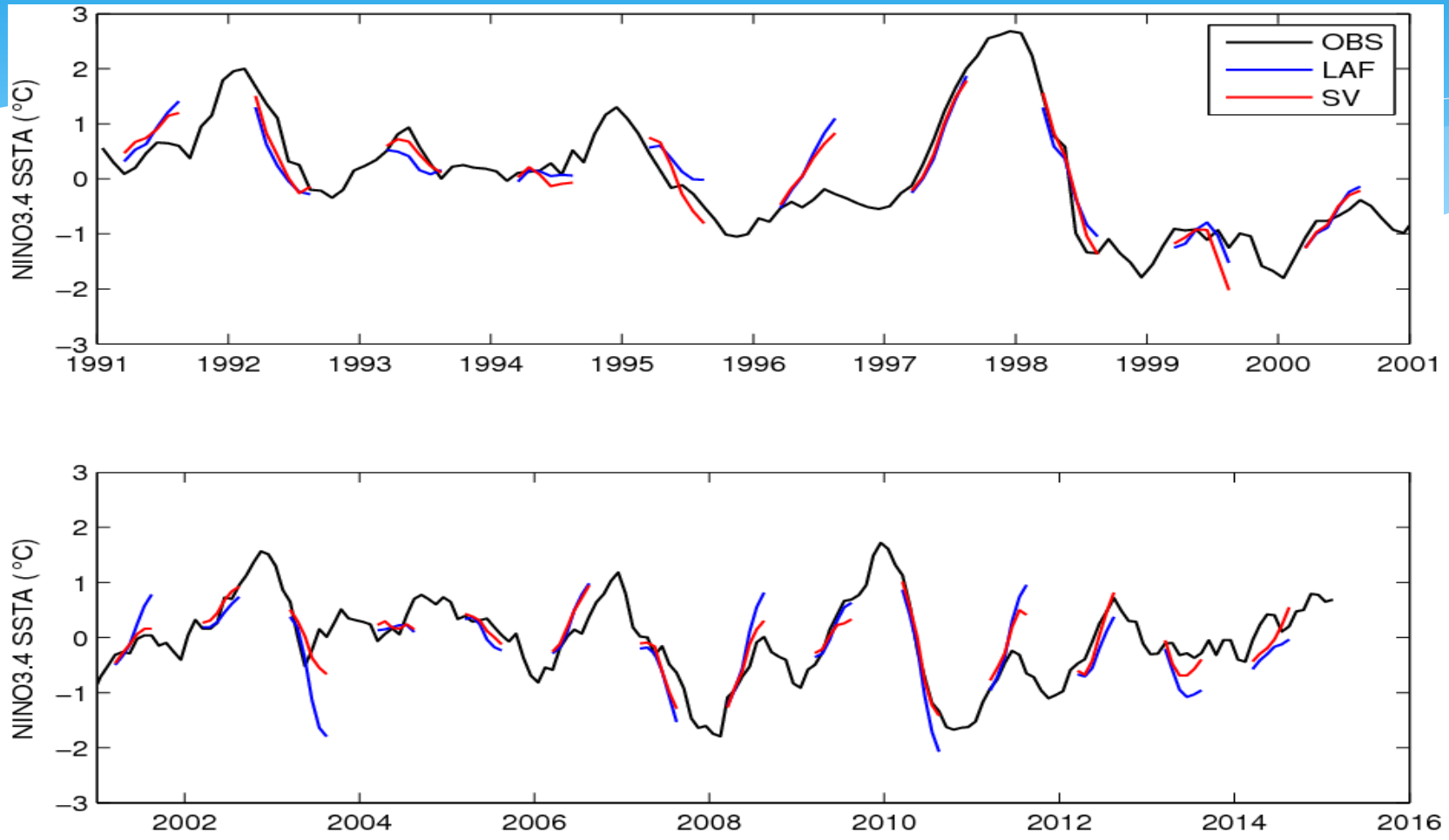
RES, May



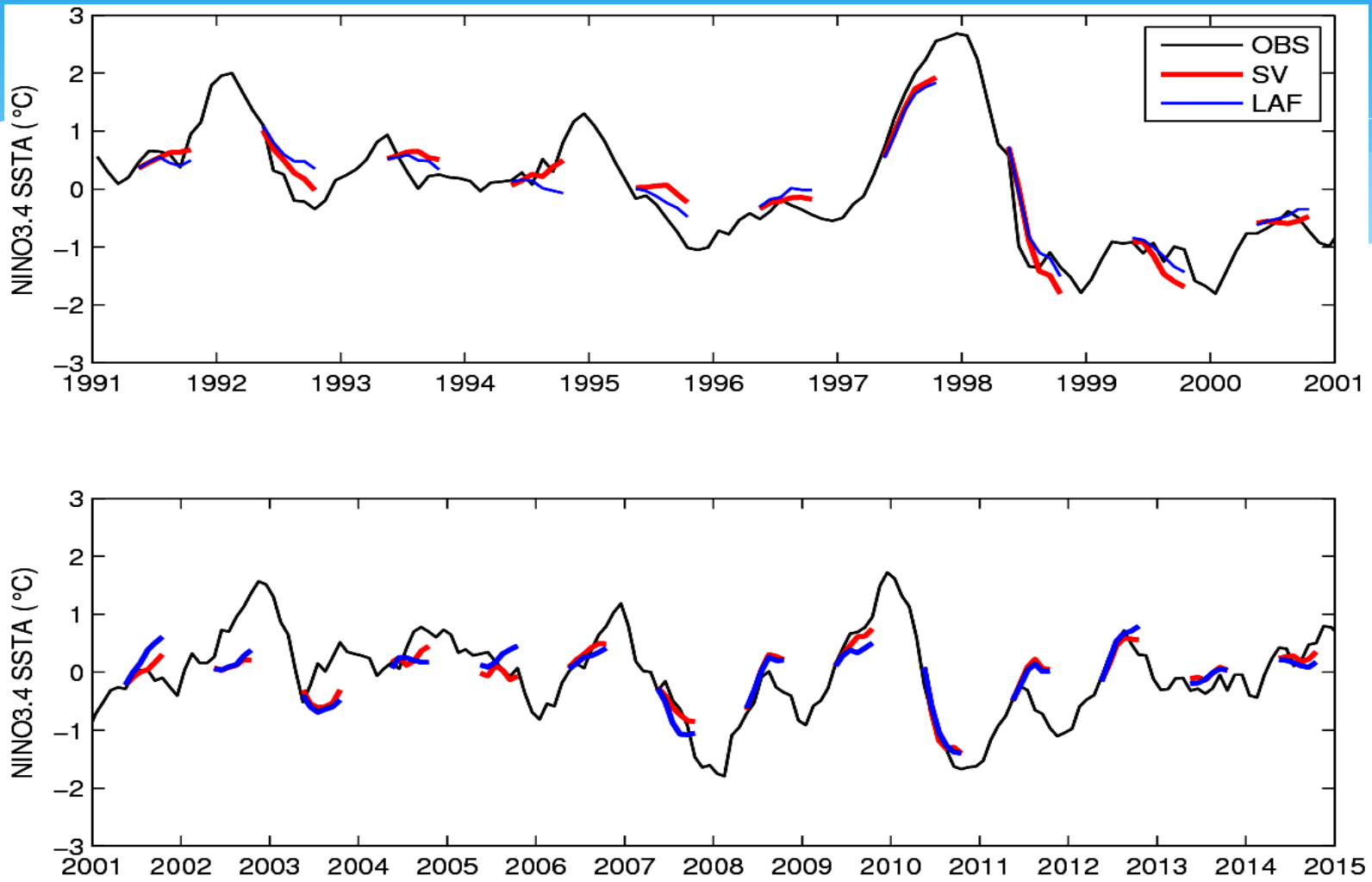
REL, May



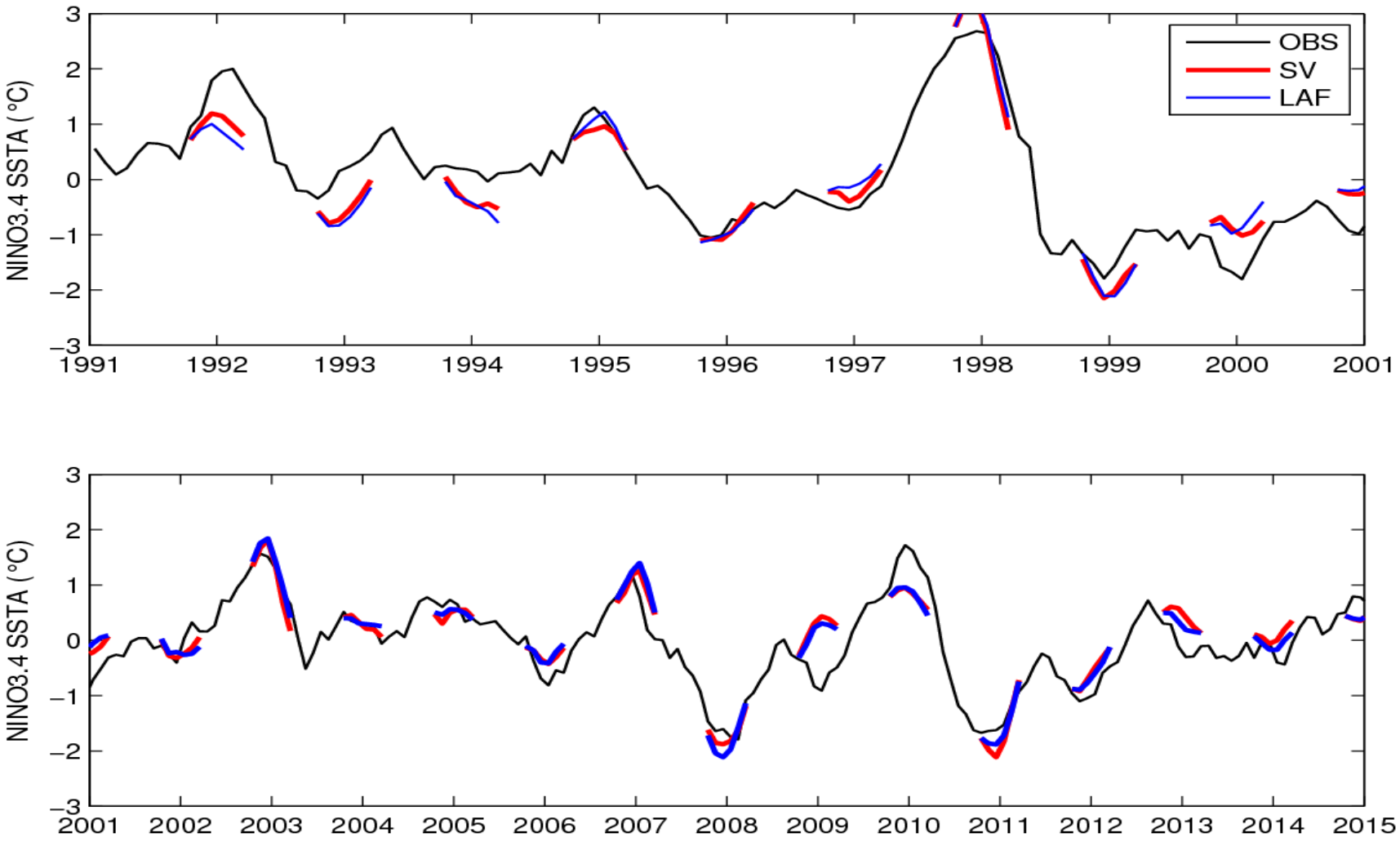
BCC_CSM1.1m,1991-2014， March



BCC_CSM1.1m,1991-2014， May



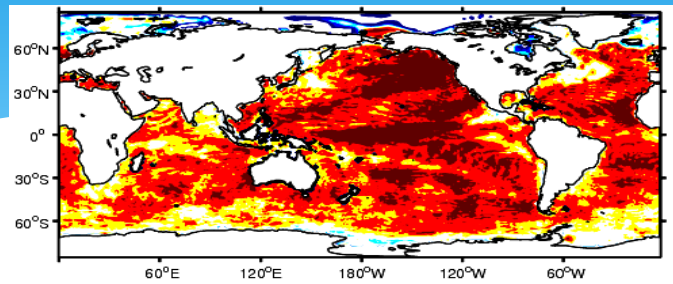
BCC_CSM1.1m,1991-2014，Oct.

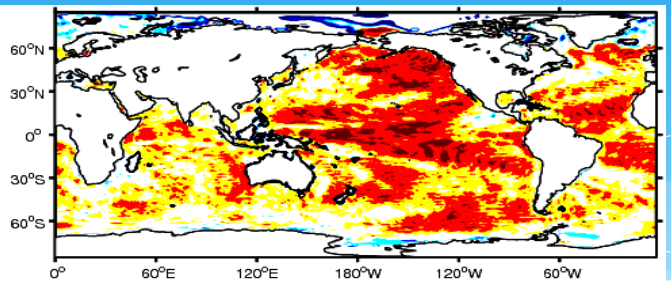


BCC, SSTA Correlation Skill (1991-2014),March

Mar.

Lead=1 month



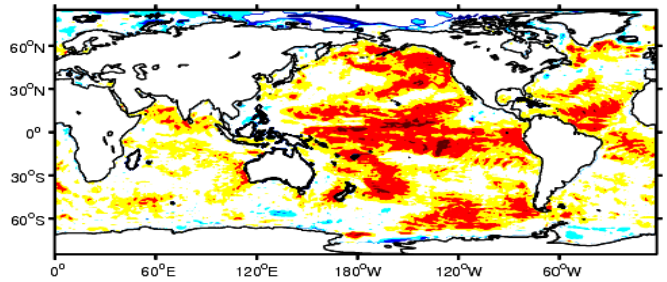


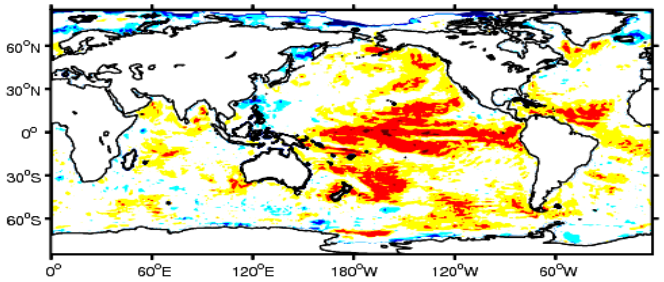
May

Lead=2 months

Jun.

Lead=3 months



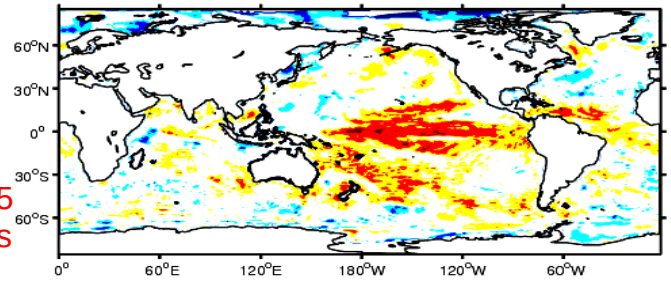


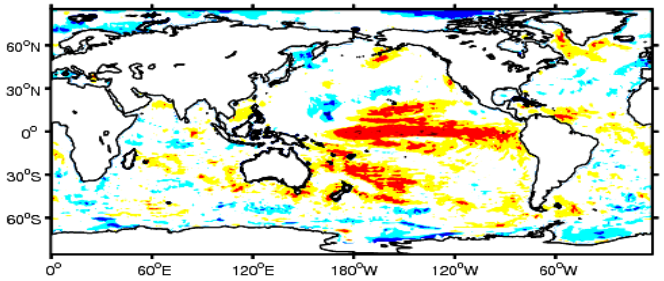
Jul.

Lead=4 months

Aug.

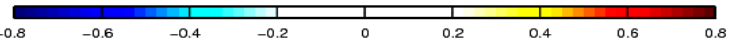
Lead=5 months





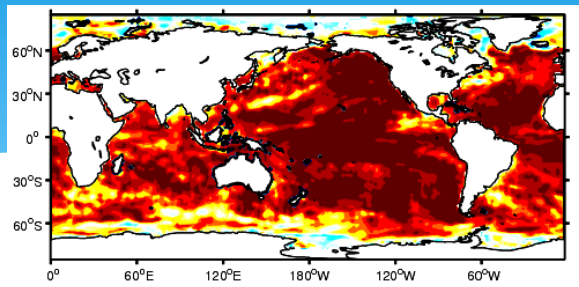
Sep.

Lead=6 months

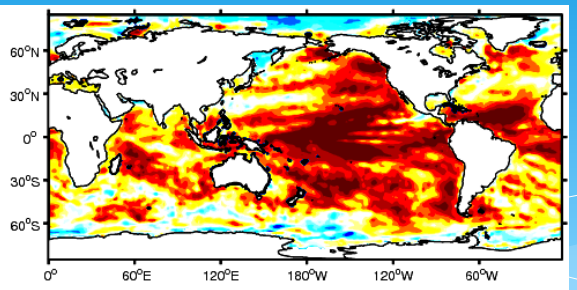


BCC, SSTA Correlation Skill (1991-2014),May

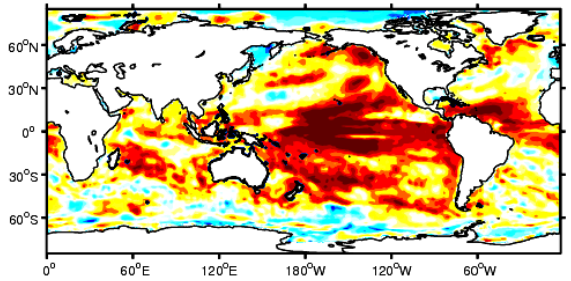
May
Lead=1 month



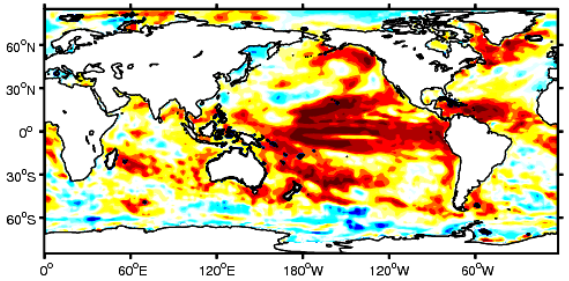
Jun.
Lead=2 months



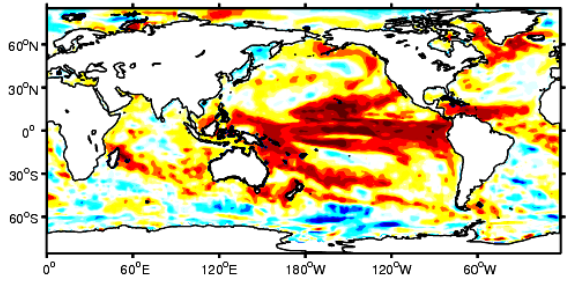
Jul.
Lead=3 months



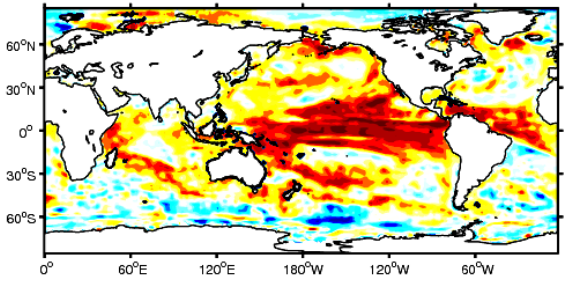
Aug.
Lead=4 months

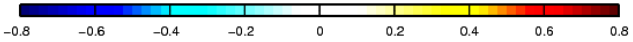


Sep.
Lead=5 months



Oct.
Lead=6 months

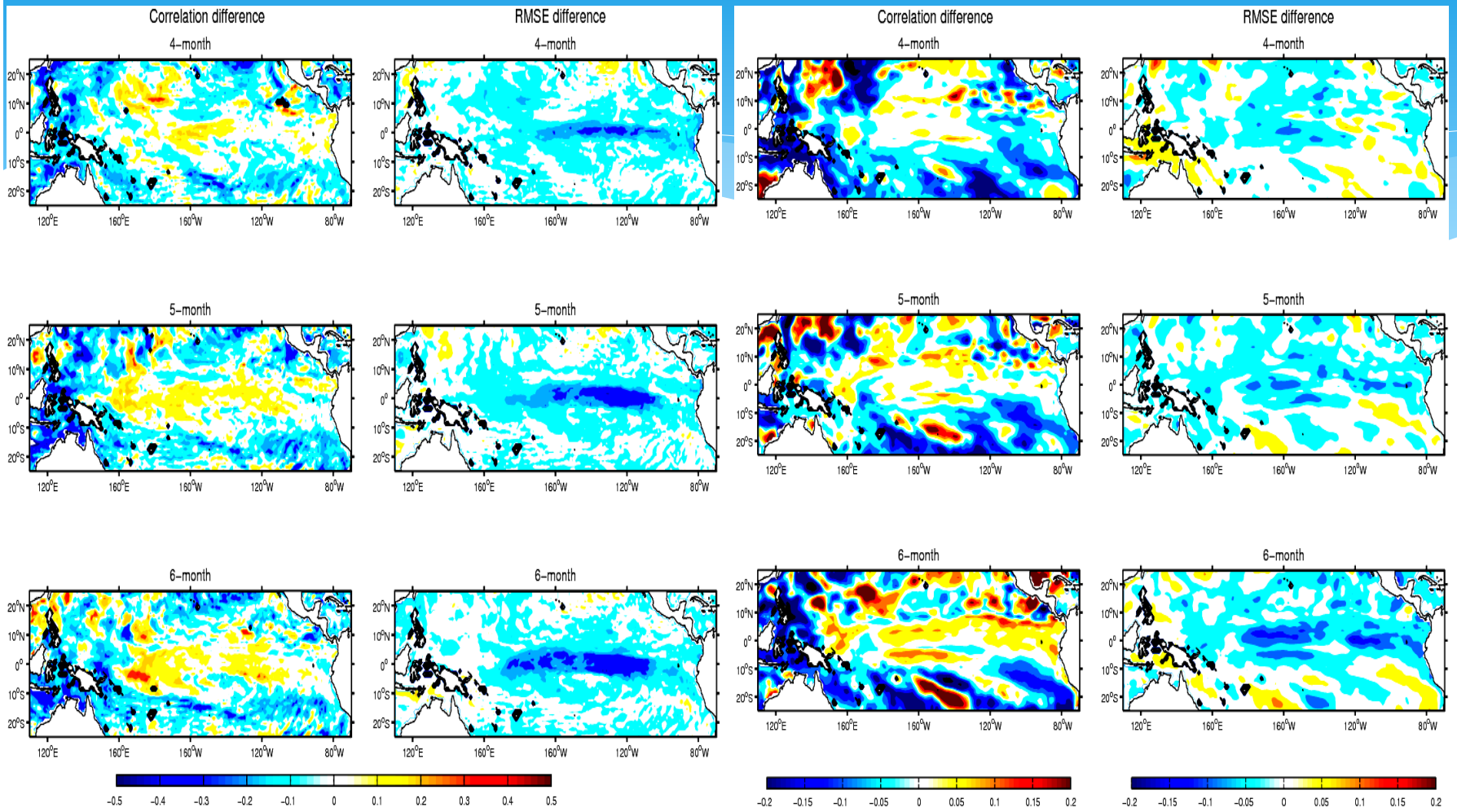




Correlation and RMSE Difference Between SV and LAF

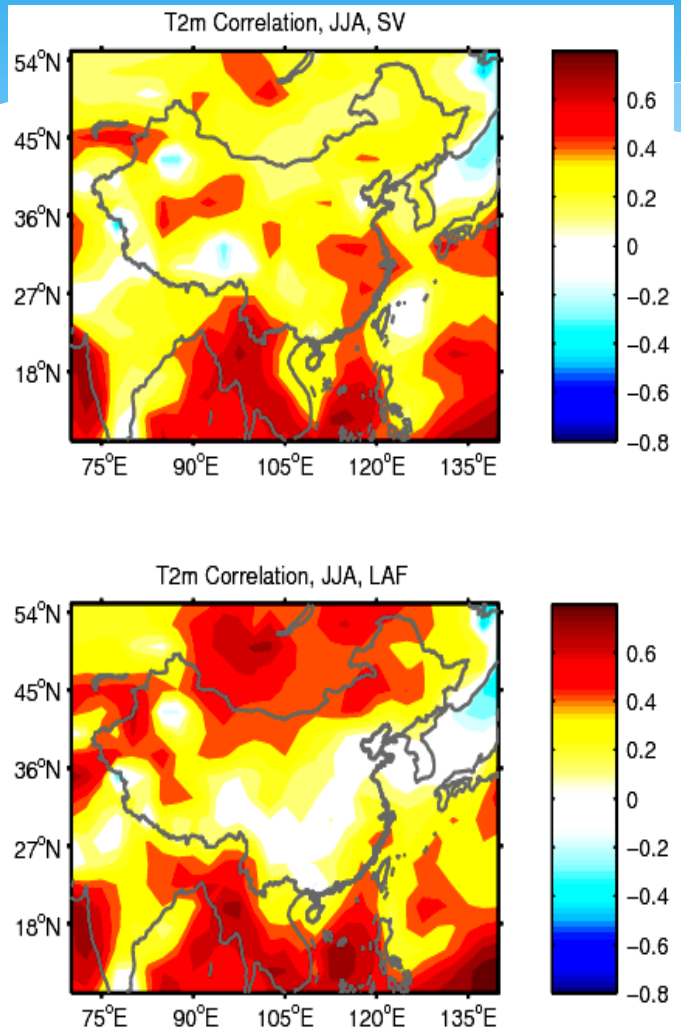
at lead time from 4 to 6 months

Starting time: March **May**



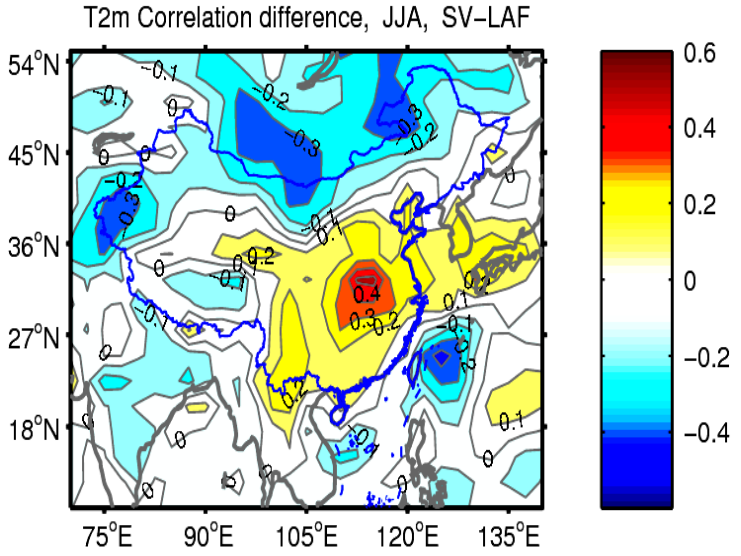
Correlation and RMSE skills improved at the NINO3.4 region

2m air temperature correlation skill is improved over China in summer JJA

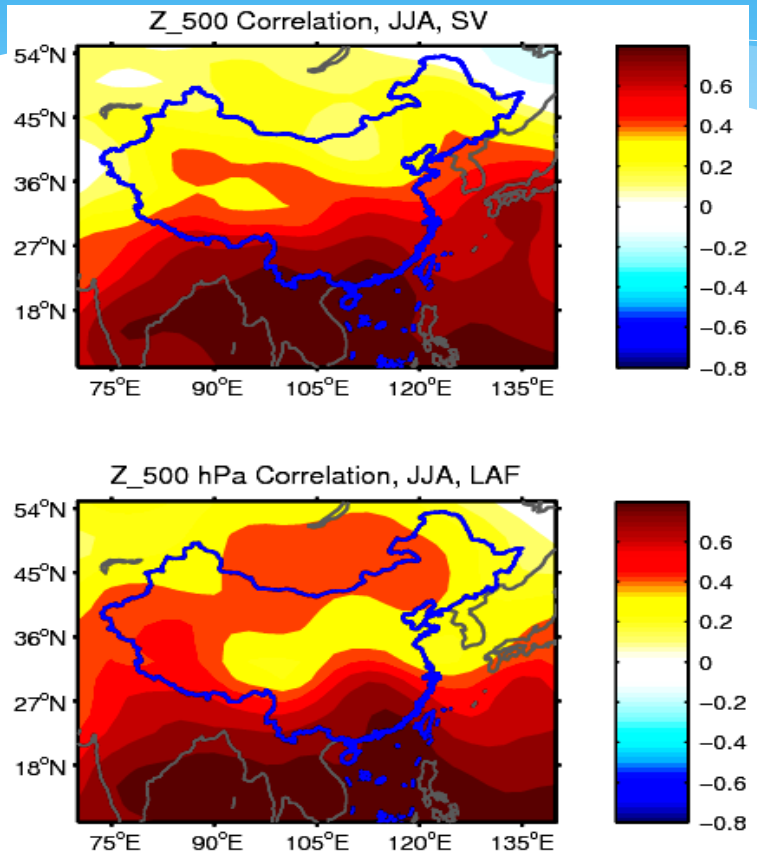


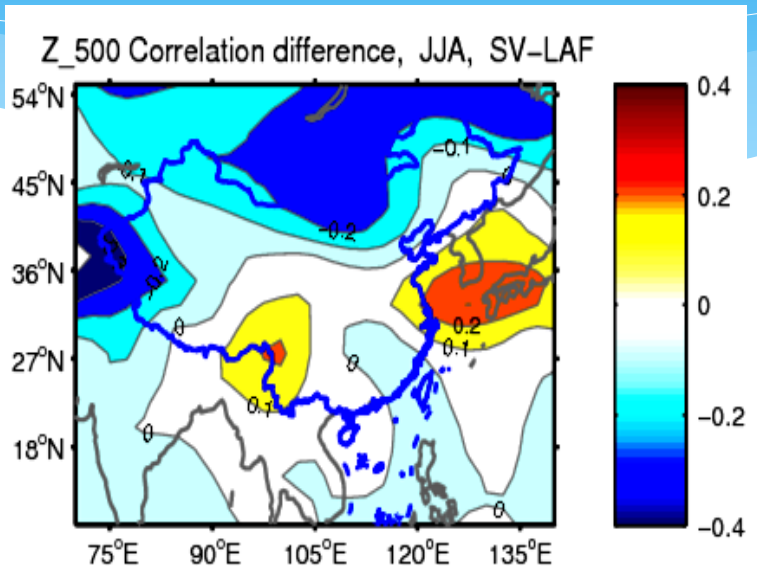
1991-2014,

starting time: May



500hPa Height, correlation skill is improved in east China and southwest China in summer JJA





BCC Model prediction Scheme

Model：Climate coupled model, BCC_CSM1.1m ,

Resolution of Atm: T106（~110 km）; Tropical ocean : 30 km.

Initial data：

Atm：NCEP daily reanalysis（Air Temp., winds, SLP）

Ocean：NCEP_GODAS monthly、Pentad reanalysis

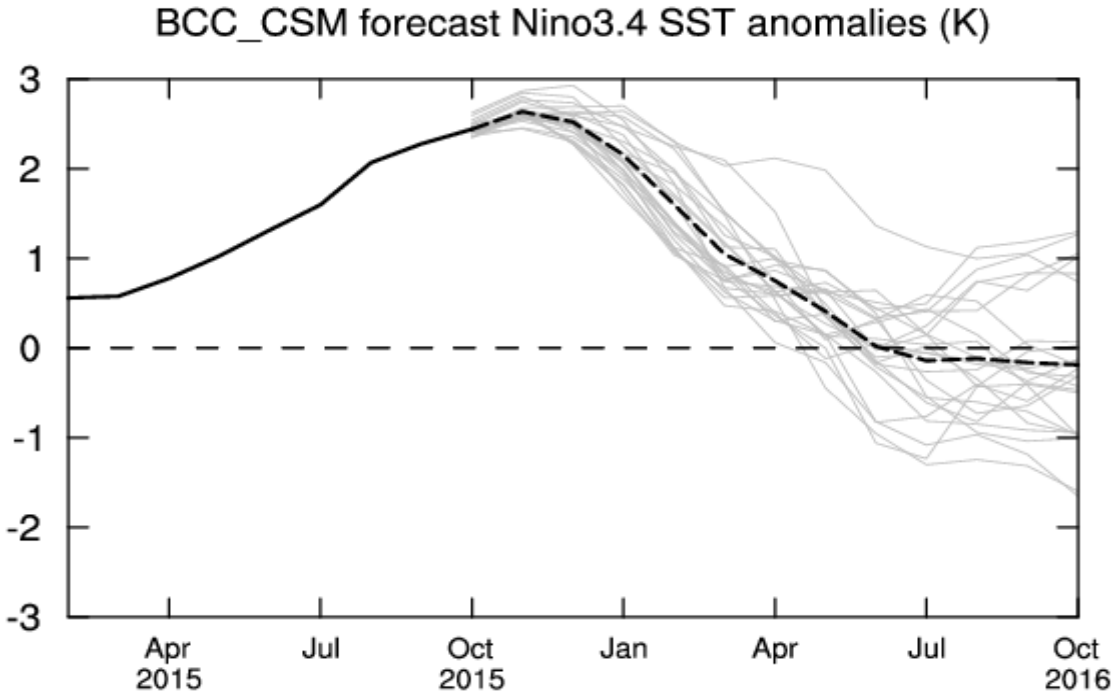
Ensemble Members：24（15 LAF+9 SV）

Prediction range：13 months（from 2015.10.1~2016. 10.31）

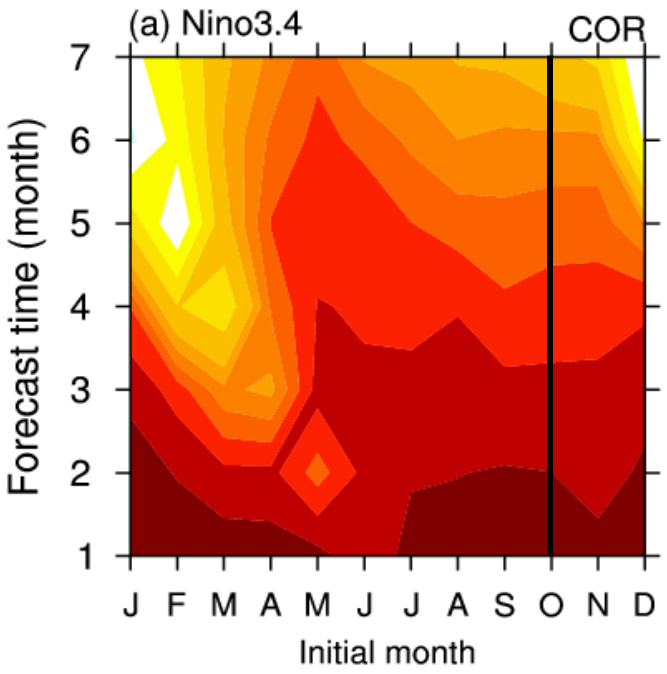
Hindcast time period： 1991~2010

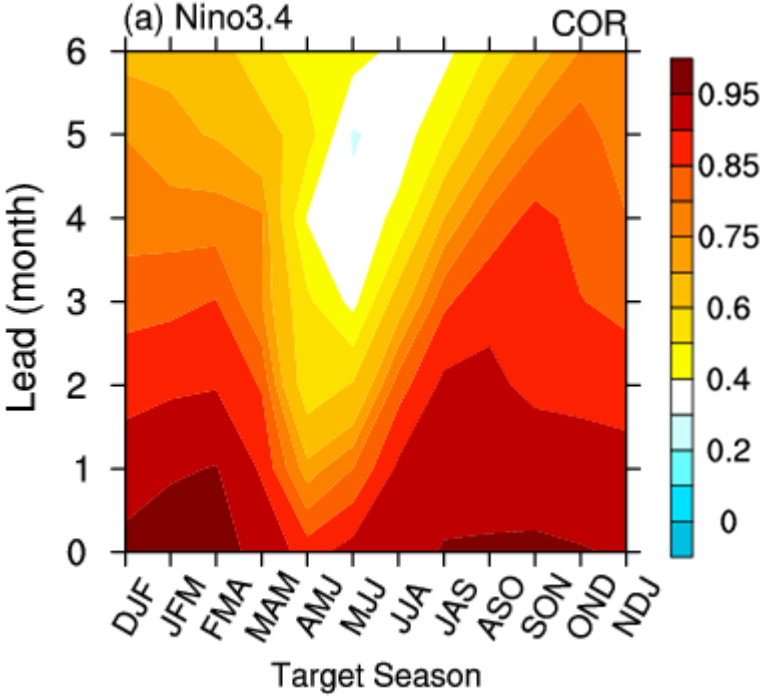
Operational starting date2014 Dec.

Nino 3.4 SSTA index

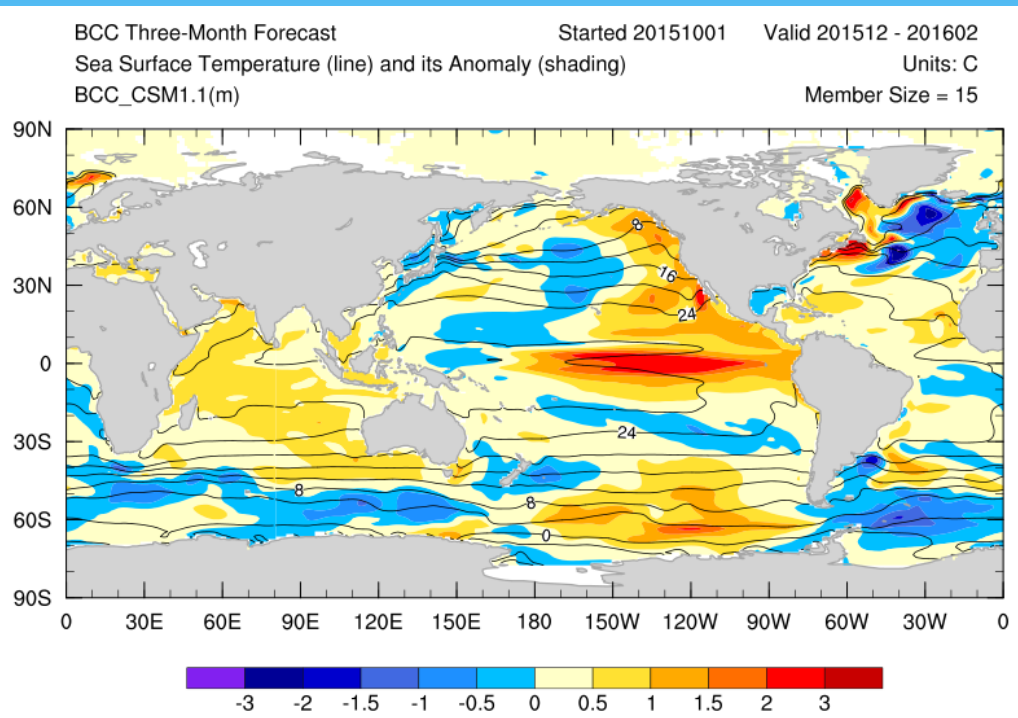


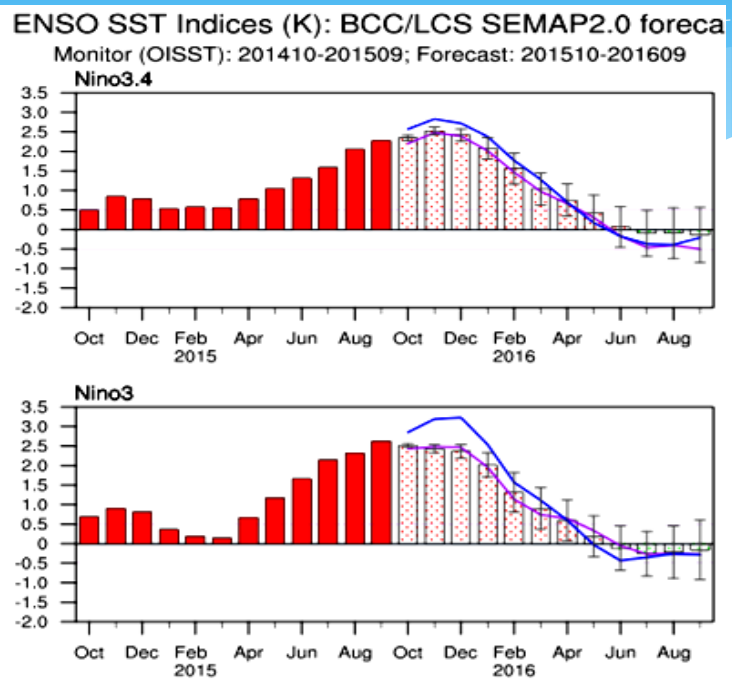
Hindcast skill of ENSO





ENSO (Dec. 2015 - Feb. 2016)





El Nino mature phase in the Middle & East tropical Pacific Ocean

SSTA Nino index

(Provided by BCC opening research Lab., Oct. 2015)

Summary

* ENSO hindcast for 1991-2014 are conducted by BCC_CSM1.1m using SV initial perturbation method.
* Compared with LAF method, ENSO prediction skills are improved significantly for hindcasts starting from March and May respectively.
* Correlation skill for 2m air temperature and 500hPa height are improved over the most areas of China in summer.