SST ASSIMILATION WITH EnKF

Ziwang Deng and Youmin Tang

University of Northern British Columbia

May 28, 2007

Funded by the Canadian Foundation for Climate and Atmospheric Sciences

SST Assimilation-- Motivation

- **SST is a unique oceanic data starting from middle of the 19th century, which allows us to initialize ENSO hindcasts for a long period.**

- **The oceanic subsurface in-situ observations are sparse and sporadic compared with surface data (e.g., SST and altimetry) of satellite observations.**

Outline

- Data and Model
- Ensemble Kalman Filter for SST Assimilation
- Results
- Summary

Data and Model

<u>Data</u>

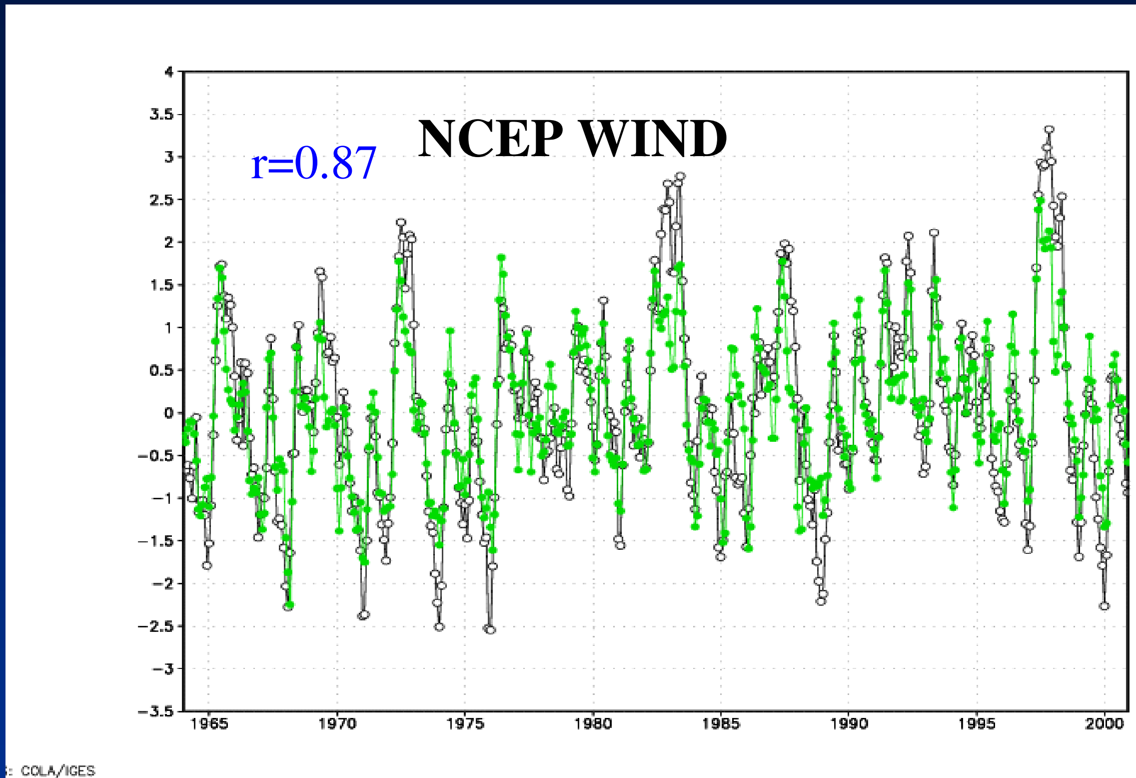
- **The tropical Pacific SST monthly, $2^o \times 2^o$ dataset for the period 1854-2002(ERSST.v2, Smith and Reynolds, 2004).**
- **The NCEP-NCAR reanalysis 10 meter wind speed dataset for the period from 1948-2002 (Kistler et al. 2001).**
- **FSU pseudo wind stress from 1964 – 2002.**

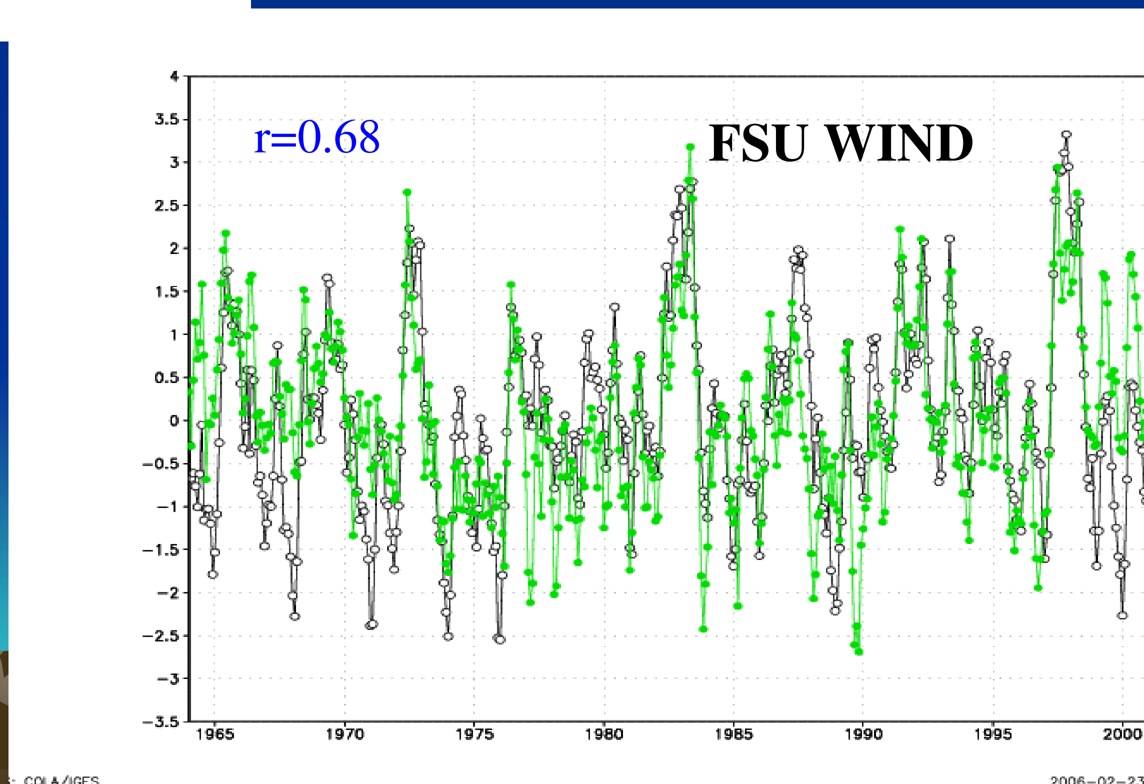
Ocean model – OPA9.1 OGCM

- **31 levels in the vertical direction with 17 concentrated in the top 250m of the ocean.**
- **Model domain: 30N - 30S and 120E - 70W.**
- **Resolution: 2 degree in the zonal direction; in the meridional direction, the resolution is 0.5 degree within 5 degree of the equator, smoothly increasing up to 2.0 degree at 30N and 30S.**
- **Time step is 1.5 hours.**

Atmospheric model

SVD statistical model, built with cross-validation scheme.


r=0.87
NCEP WIND
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1965
1970
1975
1980
1985
1990
1995
2000
: COLA/IGES


r=0.68
FSU WIND
4
3.5
3
2.5
2
1.5
1
0.5
0
−0.5
−1
−1.5
−2
−2.5
−3
−3.5
1965
1970
1975
1980
1985
1990
1995
2000
: COLA/IGES
2006-02-23-

X^a

Ensemble Kalman Filter (EnKF)

$$\mathbf{X^a = X + P_e H^T (H P_e H^T + R_e)^{-1} (D - HX)} \qquad (1)$$

X^a----analysis (sea temperature at 17 levels)

X --- first guess (sea temperature at 17 levels)

H --- observation operator

D --- SST observations (sea temperature anomaly at level 1)

R_e -- the observation error covariance matrix

P_e-- the ensemble covariance matrix

$$\mathbf{X^a}_j = \mathbf{X}_j + (\mathbf{C}_{j,1}\mathbf{C}_{1,1}{}^{-1})\{(\mathbf{C}_{1,1}\mathbf{H}_1{}^T)(\mathbf{H}_1\mathbf{C}_{1,1}\mathbf{H}_1{}^T + \mathbf{R}_e)^{-1}(\mathbf{D} - \mathbf{H}_1\mathbf{X}_1)\} \qquad (4)$$

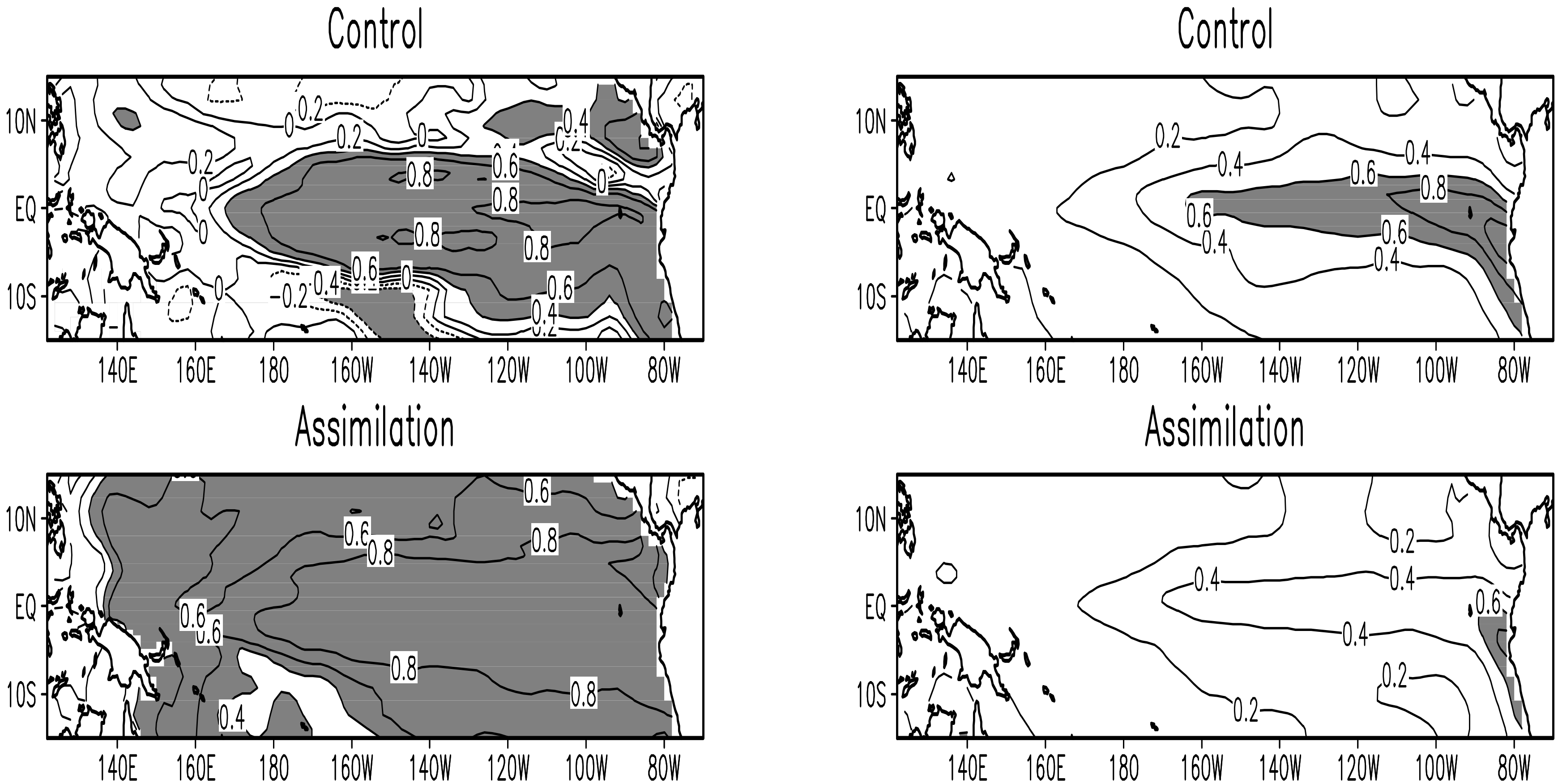
$$= \mathbf{X}_j + \mathbf{B}_j\mathbf{K}_1(\mathbf{D} - \mathbf{H}_1\mathbf{X}_1)$$

$$\mathbf{X^a}_j - \mathbf{X}_j = \mathbf{B}_j(\mathbf{X}_1^a - \mathbf{X}_1) \qquad (5)$$

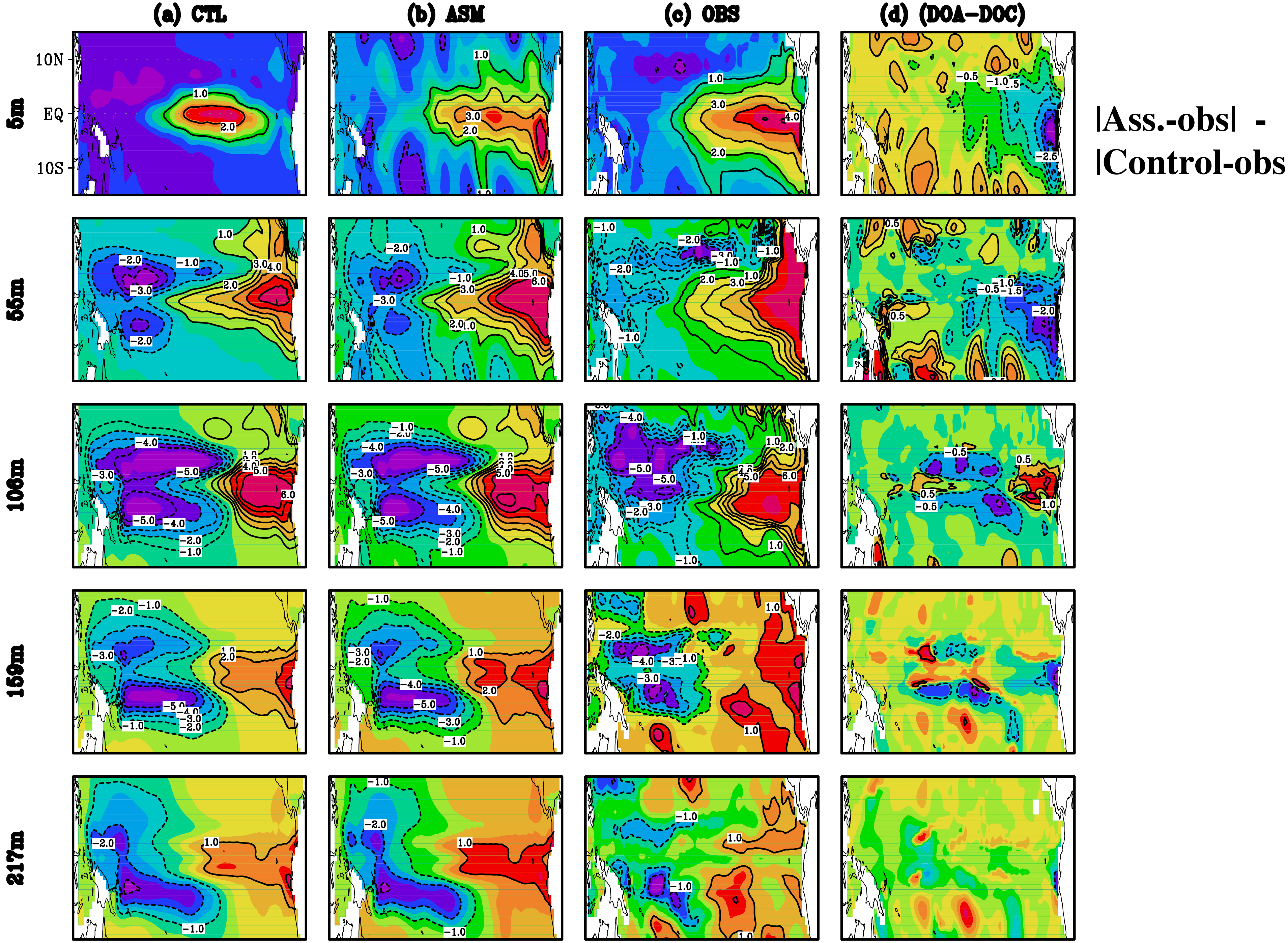
$$\mathbf{B}_j = \mathbf{C}_{j,1}\mathbf{C}_{1,1}{}^{-1}$$

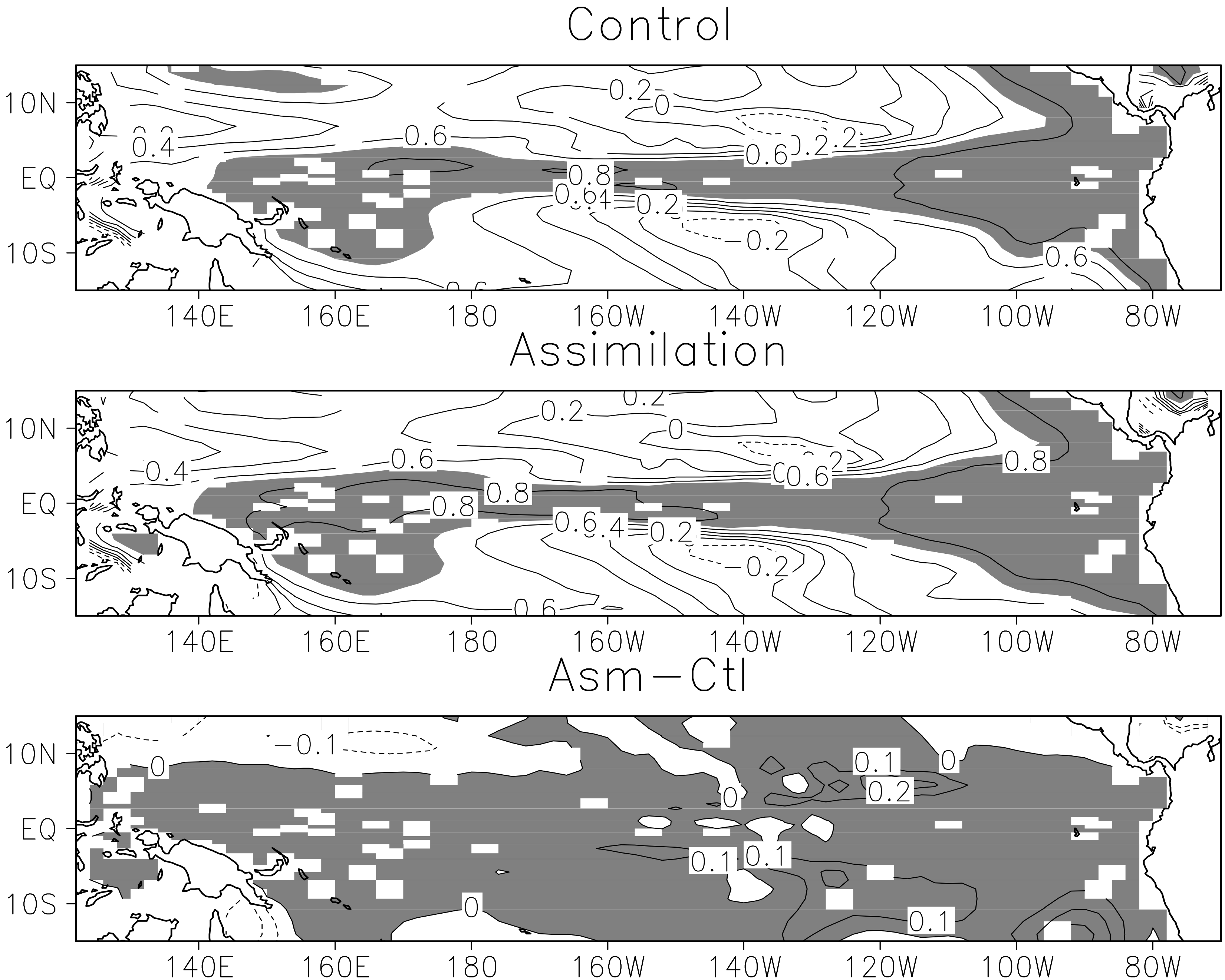
The assimilation was performed every 5 days.

The initial perturbation is a smooth pseudo random field considering the spatial coherence, with the mean equal to zero and variance equal to one (Evensen, 2003; Ocean Dynamics).

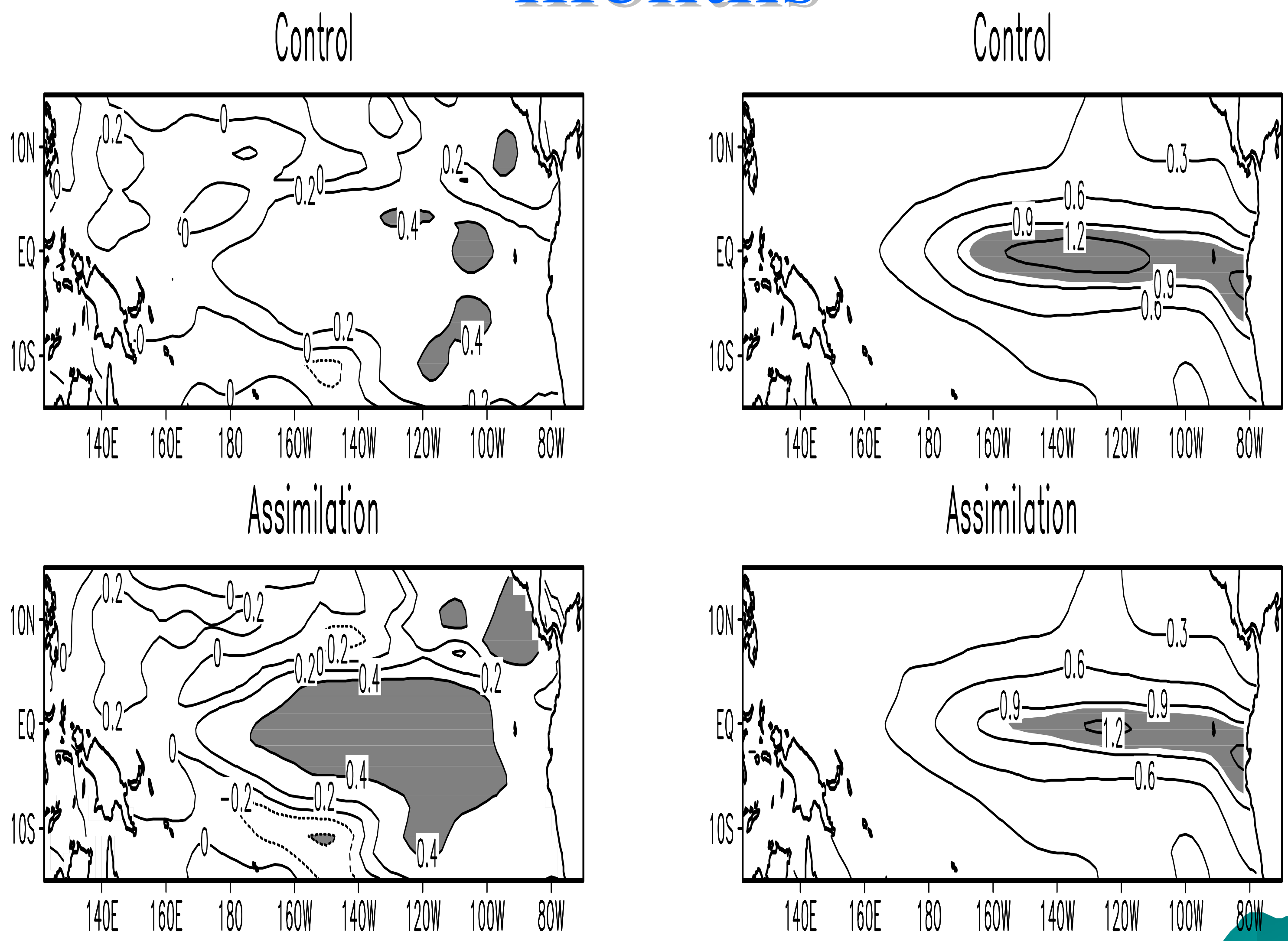


Anomaly Correlations (right) and rmse (left) of observed and modeled SSTA (from the control and assimilation experiment) for the period from Jan 1881-Dec 2000. The areas with correlation over 0.5 and RMSE over 0.6□ are shaded.

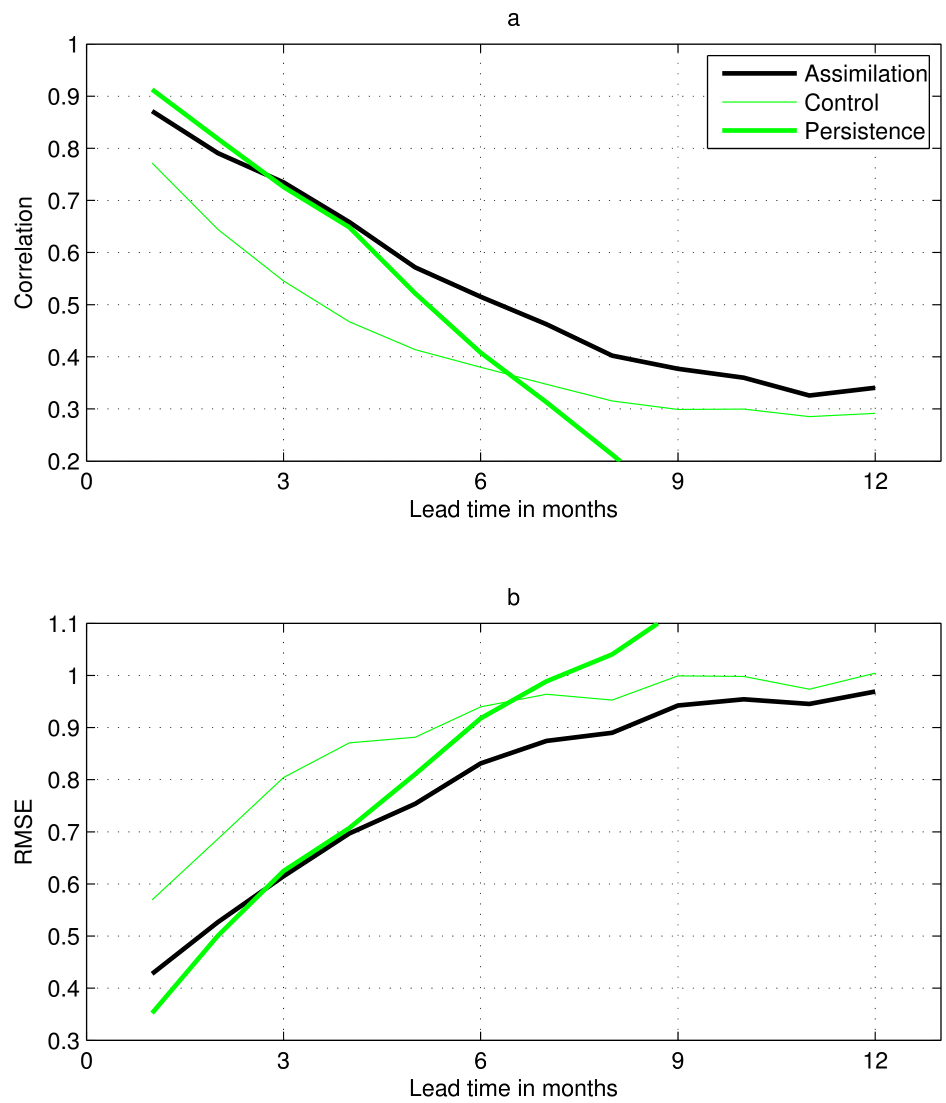

(a) CTL
(b) ASM
(c) OBS
(d) (DOA-DOC)
5m
55m
106m
159m
217m
10N
EQ
10S
|Ass.-obs| -
|Control-obs|

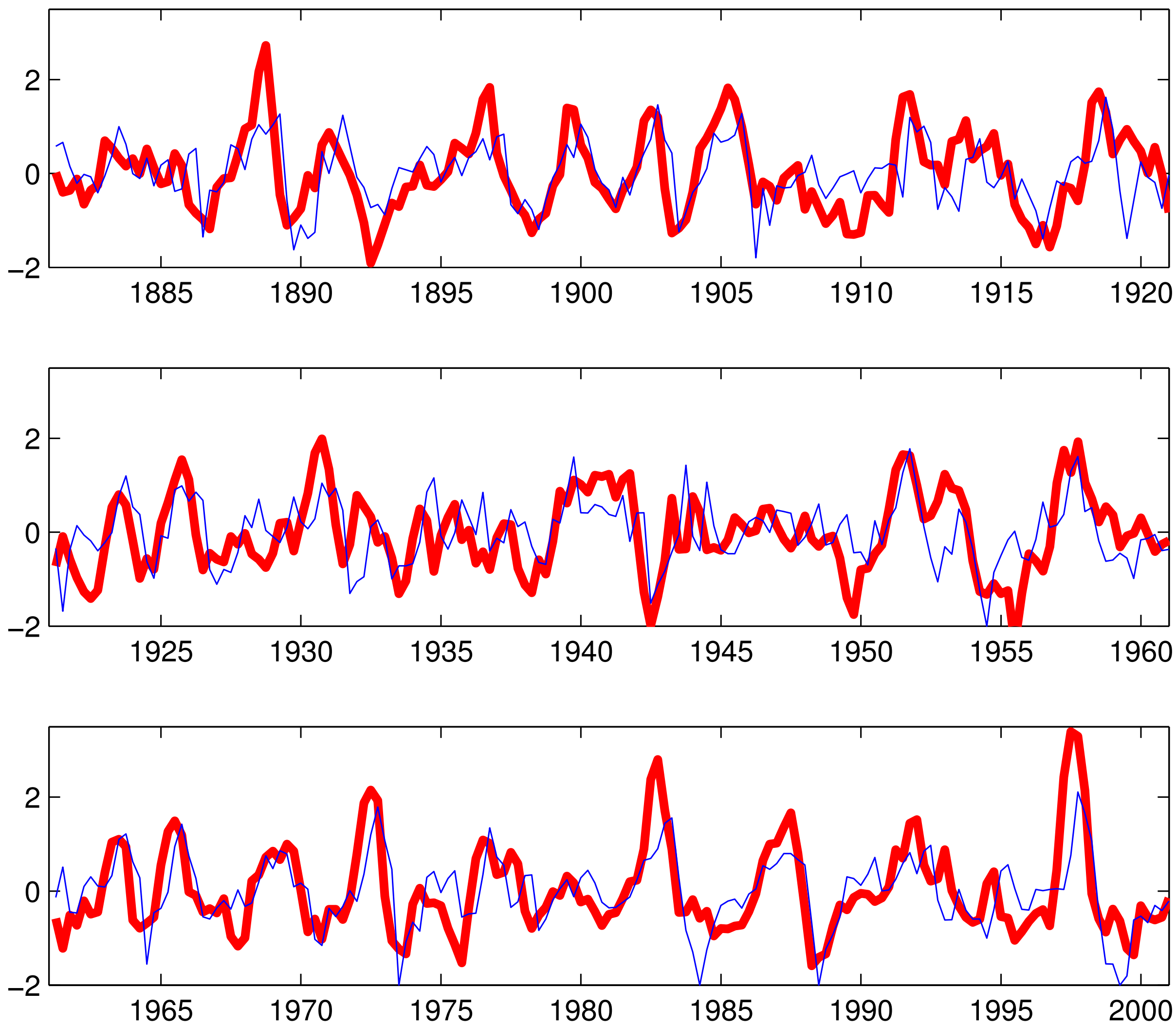

Control
Assimilation
Asm−Ctl
10N
EQ
10S
140E
160E
180
160W
140W
120W
100W
80W

Prediction skill at the lead time of 6 months



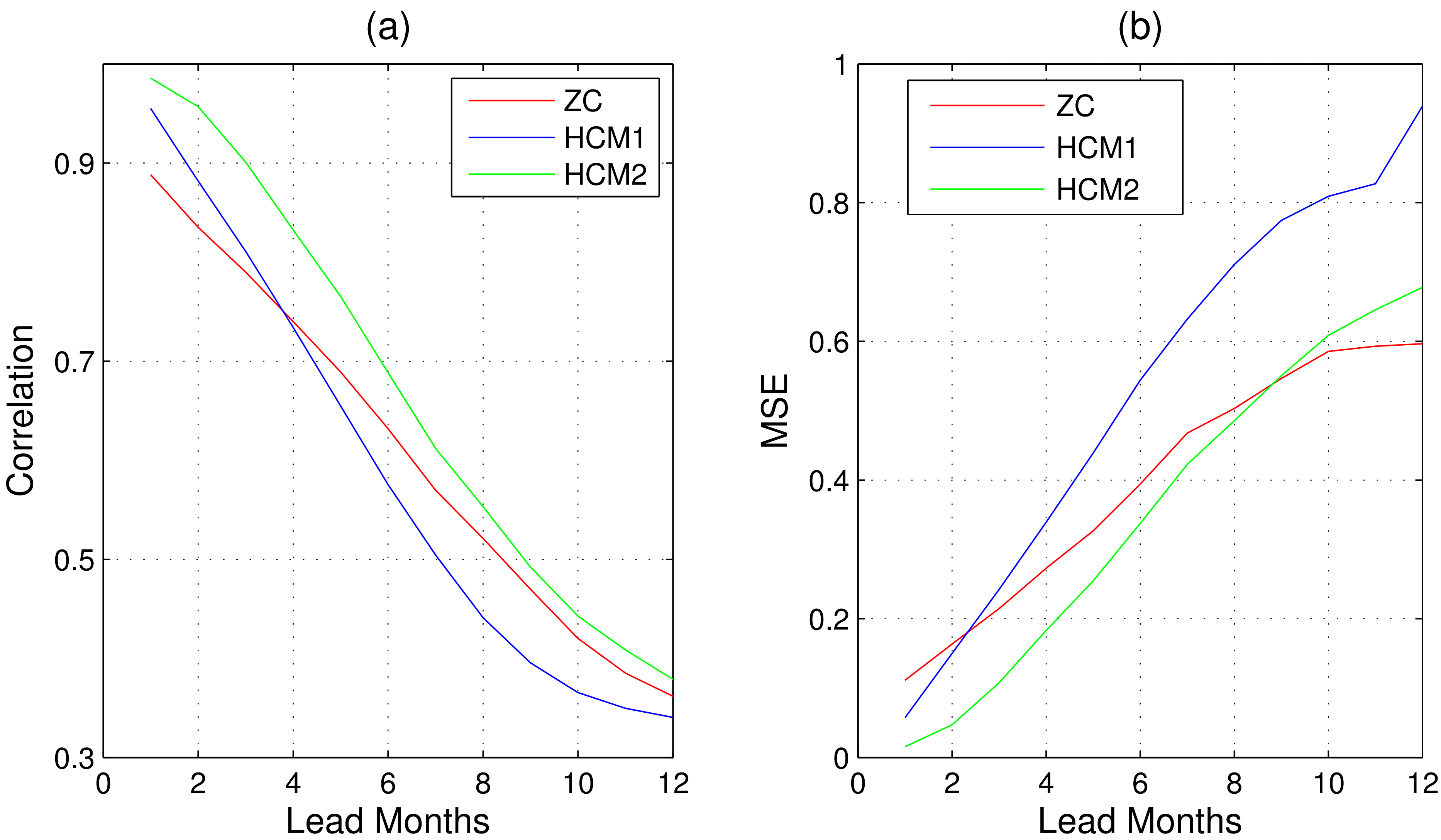
Prediction skill for the last 120 years, as a function of lead time





The predicted Nino3.4 SSTA at the lead time of 6 months against the observation.

Correlations and MSEs between observed and predicted Nino3.4 SSTA index as a function of lead time for the three models for 120-yr period from 1881-2000.



Conclusions

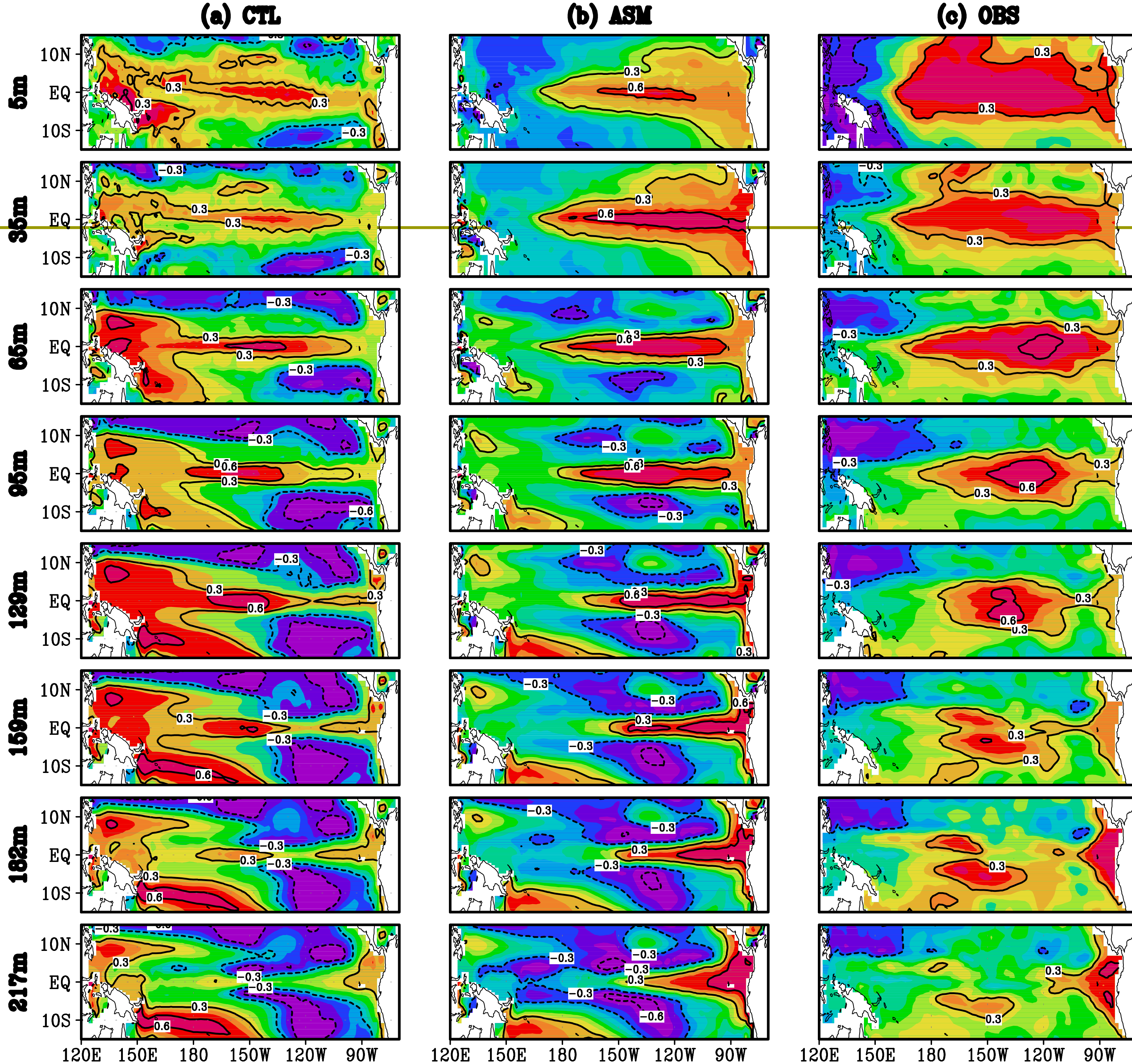
- EnKF can automatically transfer the correction in SST into the subsurface, which is not available for other assimilation algorithms. As such, the assimilation of SST leads to moderate improvement in subsurface temperature.

- The assimilation of SST with EnKF improves the long-term hindcast skill of ENSO for the last 120 years.

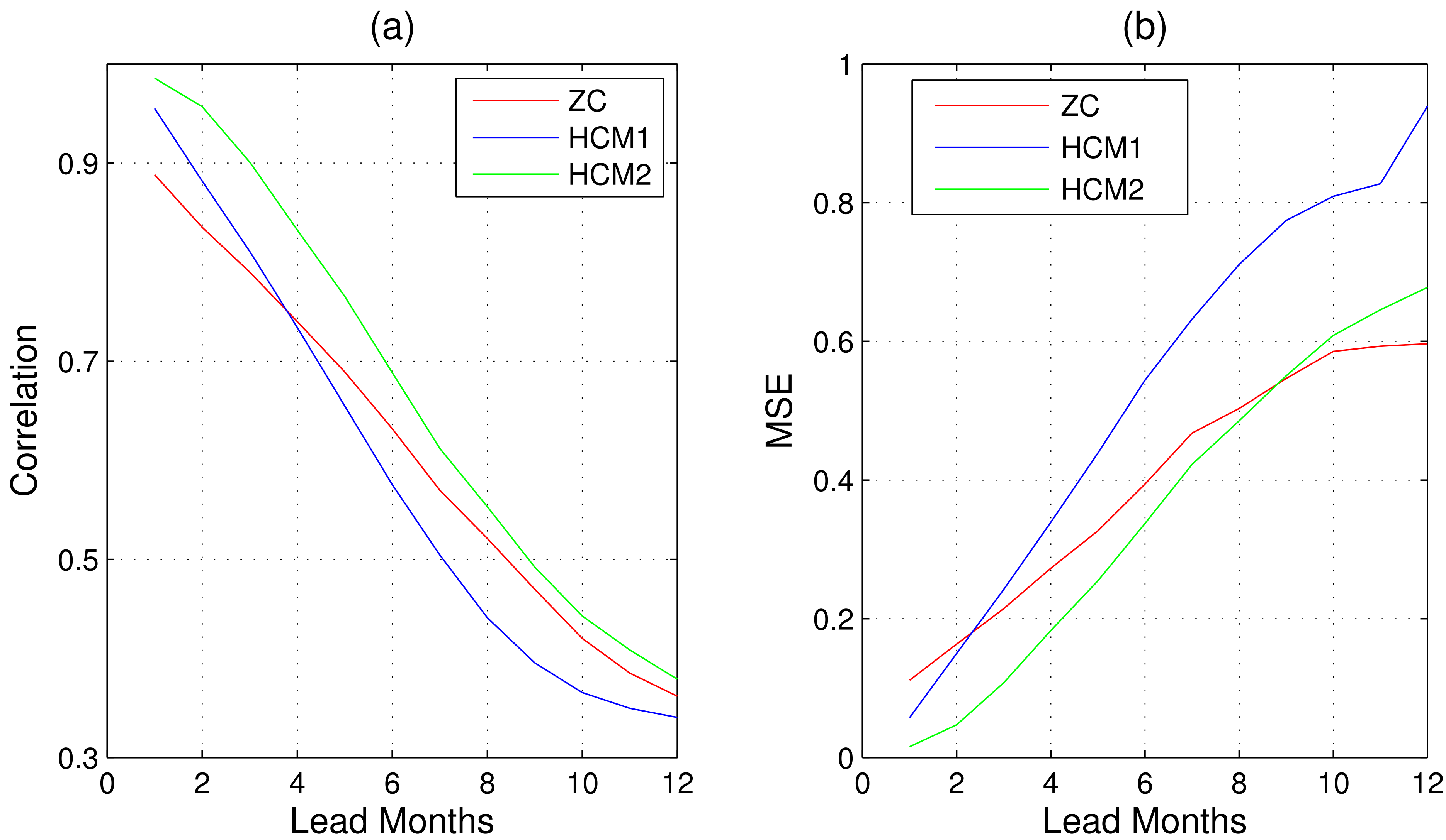
Future work

- Joint-assimilation experiments for coupled models, as proposed in I 2.2. We are expecting coupled models, or GEM atmospheric model.

- The study of predictability and prediction verification using ensemble predictions, as proposed in II3.2, II3.3. We are expecting some collaborations with the PIs of these sections.


(a) CTL
(b) ASM
(c) OBS
5m
35m
65m
95m
129m
159m
182m
217m
10N
EQ
10S
120E
150E
180
150W
120W
90W

Correlations and MSEs between observed and predicted Nino3.4 SSTA index as a function of lead time for the three models for 120-yr period from 1881-2000.



The state vector analysis X^a and the first guess can be written as:

$$X^a = \begin{pmatrix} X_1^a \\ X_2^a \\ \cdots \\ X_j^a \\ \cdots \\ X_{17}^a \end{pmatrix} \qquad X = \begin{pmatrix} X_1 \\ X_2 \\ \cdots \\ X_j \\ \cdots \\ X_{17} \end{pmatrix}$$

X_j^a ---Analysis at level *j*

X_j ---First guess at level *j*

$$H = \left[H_1, H_2, \ldots, H_{17}\right] \qquad (2)$$

$SST^{obs} = H_1(SST^{\text{mod}el})$, a bilinear interpolation operator.

$SST^{obs} = H_j(T_j^{\mathbf{mod}\,el})$ j=2,3,…17.

H_j is assumed to be zero matrix.

Pe can be written as a block matrix in term of level (the subscripts)

$$\mathbf{P_e} = \begin{bmatrix} C_{1,1} & C_{1,2} & \cdots & C_{1,(m-1)} & C_{1,m} \\ C_{2,1} & C_{2,2} & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ C_{m-1,1} & \cdots & \cdots & C_{m-1,m-1} & C_{m-1,m} \\ C_{m,1} & C_{m,1} & \cdots & C_{m,m-1} & C_{m,m} \end{bmatrix} \qquad (3)$$