Stratospheric Influence on Predictability Enhancement in Late Winter

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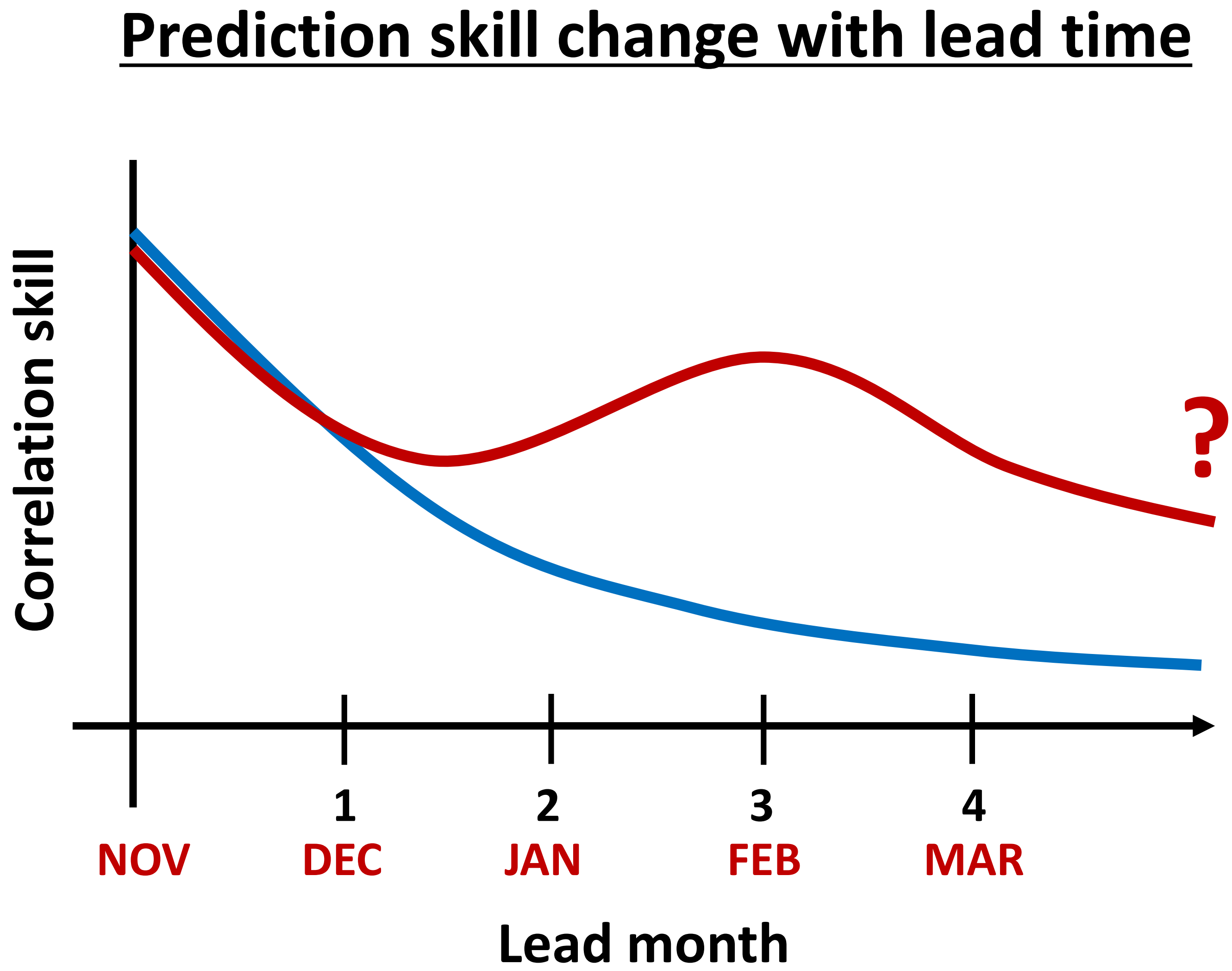
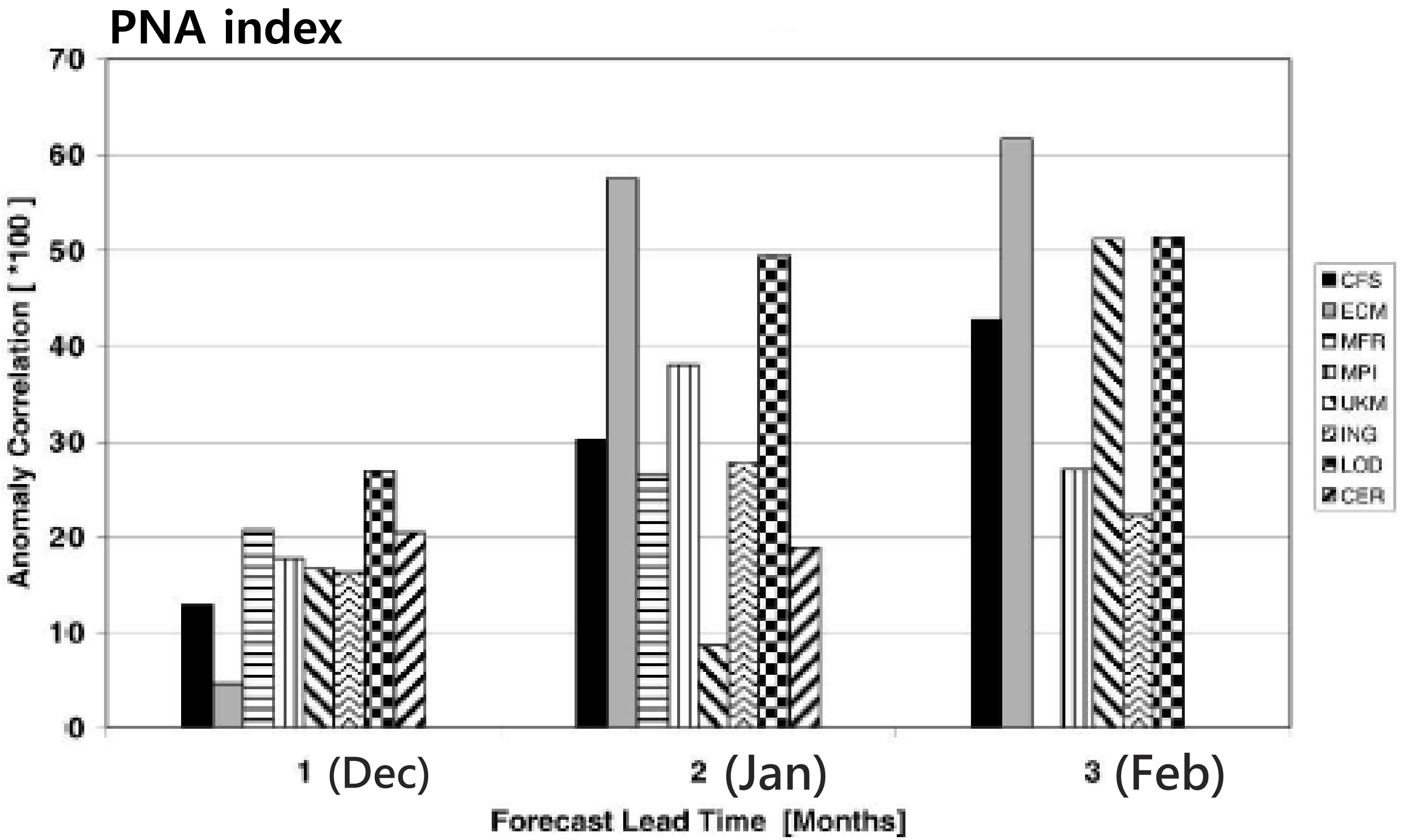
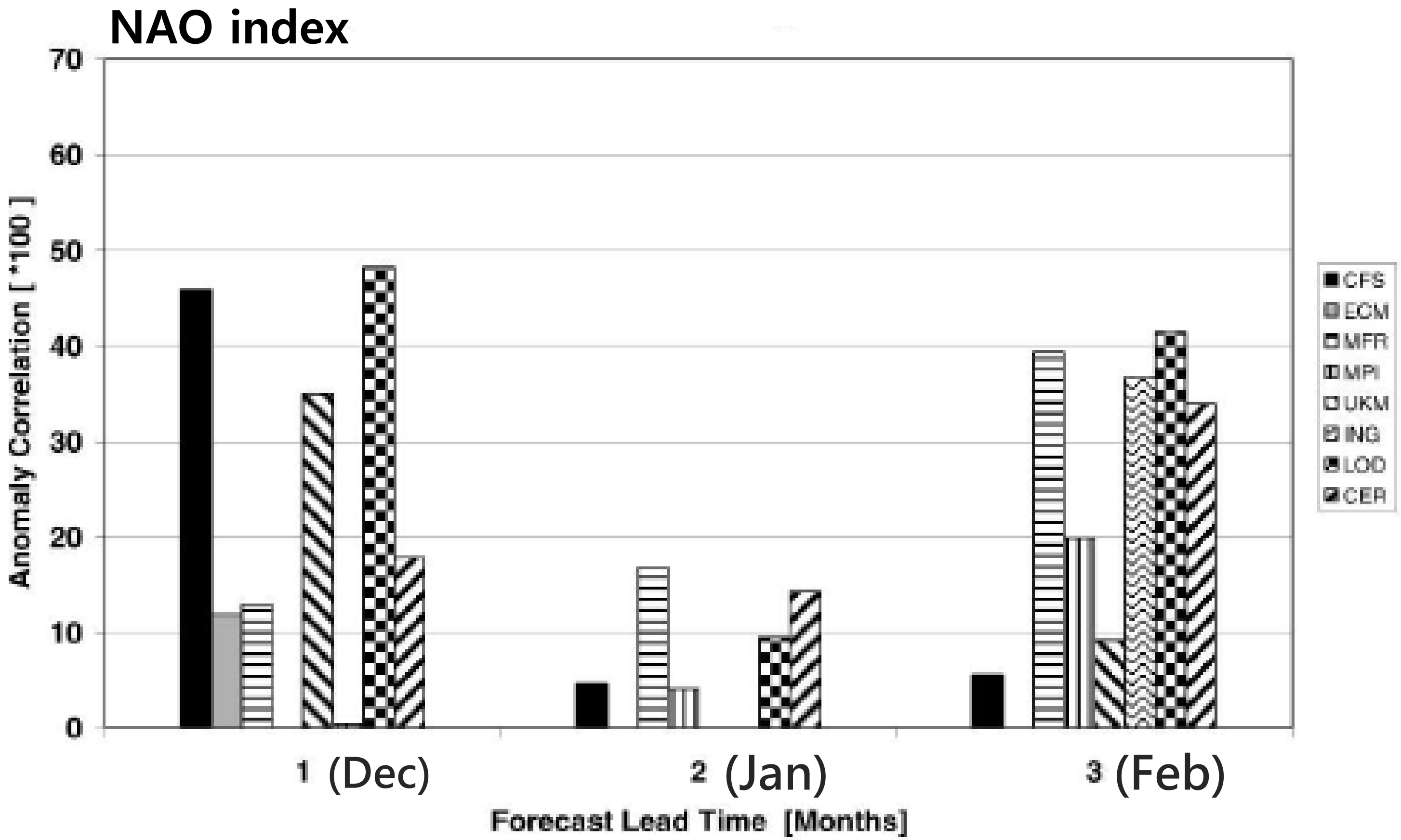

Prediction skill change with lead time
Correlation skill
?
1
2
3
4
NOV
DEC
JAN
FEB
MAR
Lead month

Monthly-mean correlation skill of PNA index for 1-3 lead months (starting from November)



CFS and the seven models in the DEMETER project
Johansson (2007)

Monthly-mean correlation skill of NAO index for 1-3 lead months (starting from November)



* CFS and the seven models in the DEMETER project

Johansson (2007)

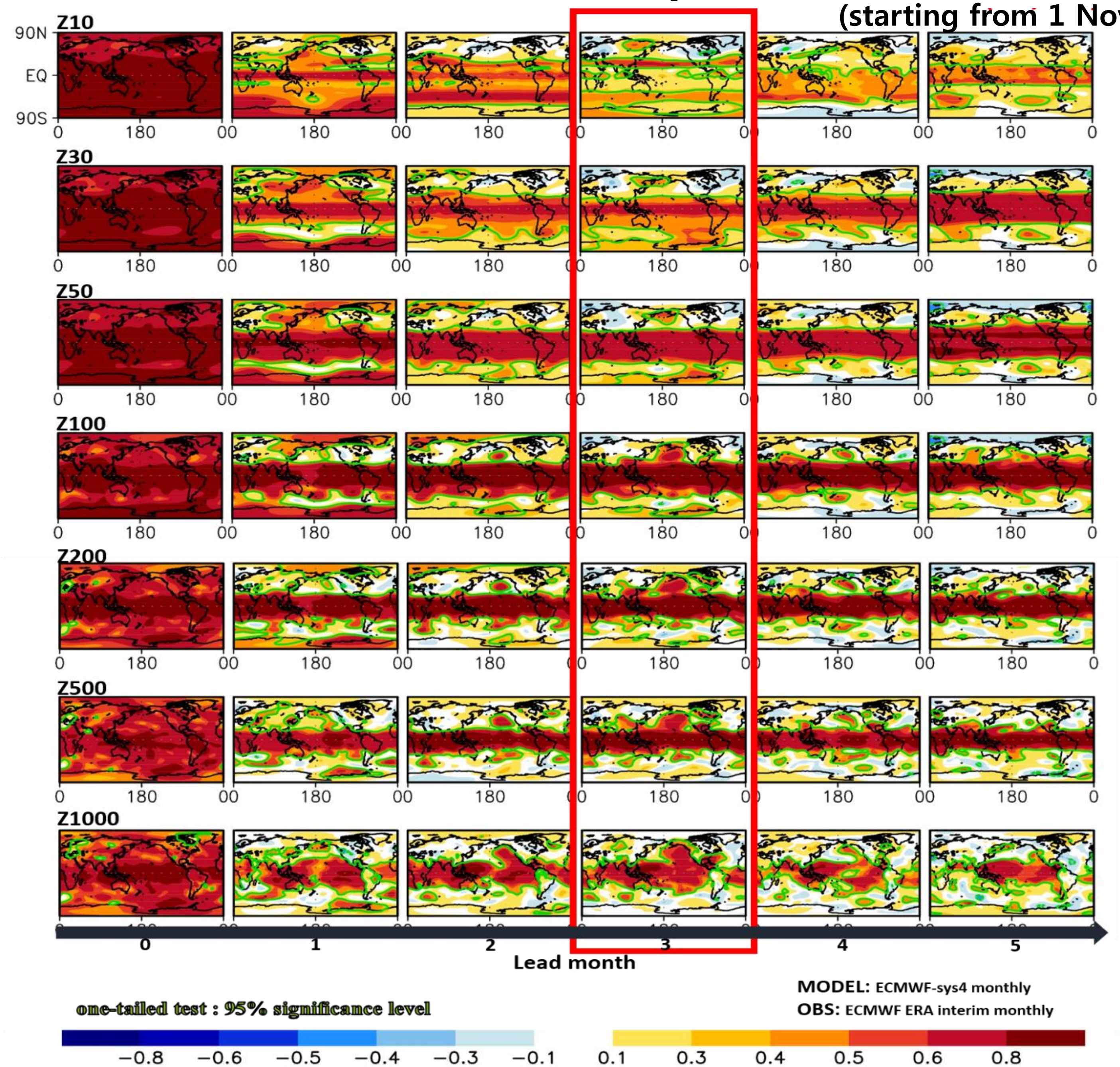
DATA

- ECMWF sys4 hindcast for 32 years for 1981 – 2002
- 20 ensemble predictions
- Winter prediction initialized on 1 Nov.

Obs: ECMWF ERA-interim monthly data

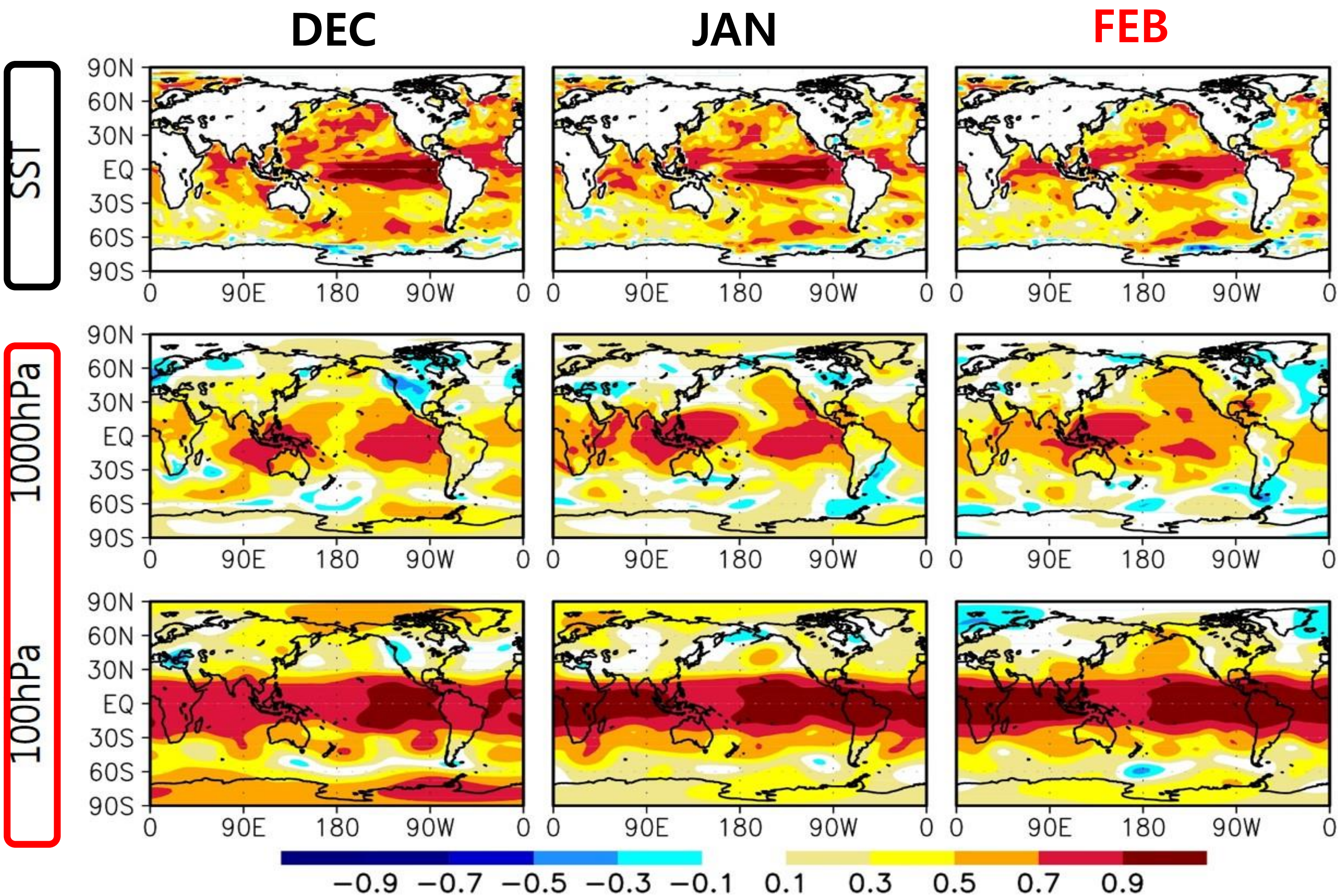
Prediction skill of GPH for 32 years at each level

(starting from 1 November)



Monthly-mean correlation skills for 1, 2, and 3 lead months

(starting from 1 November.)



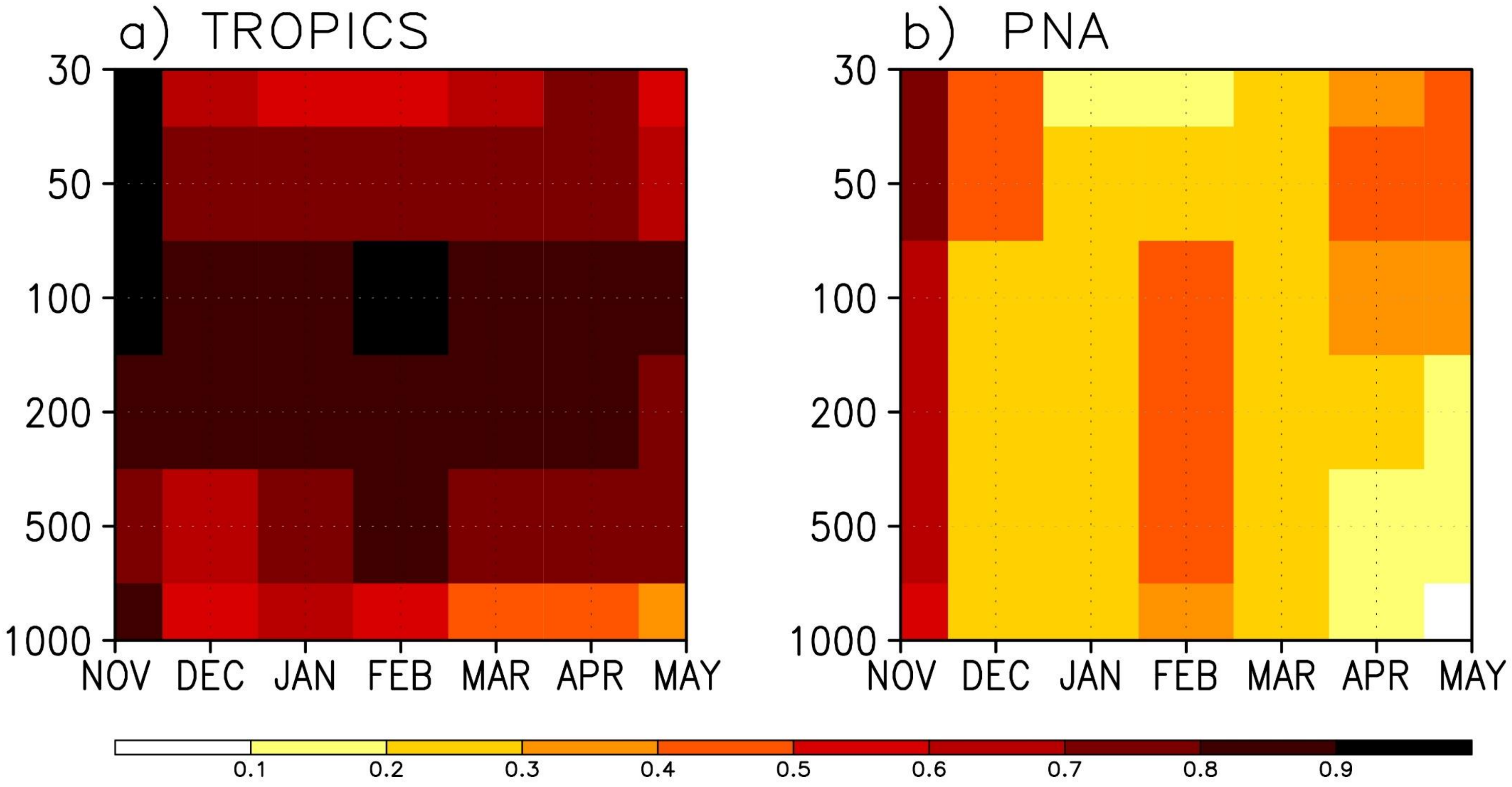
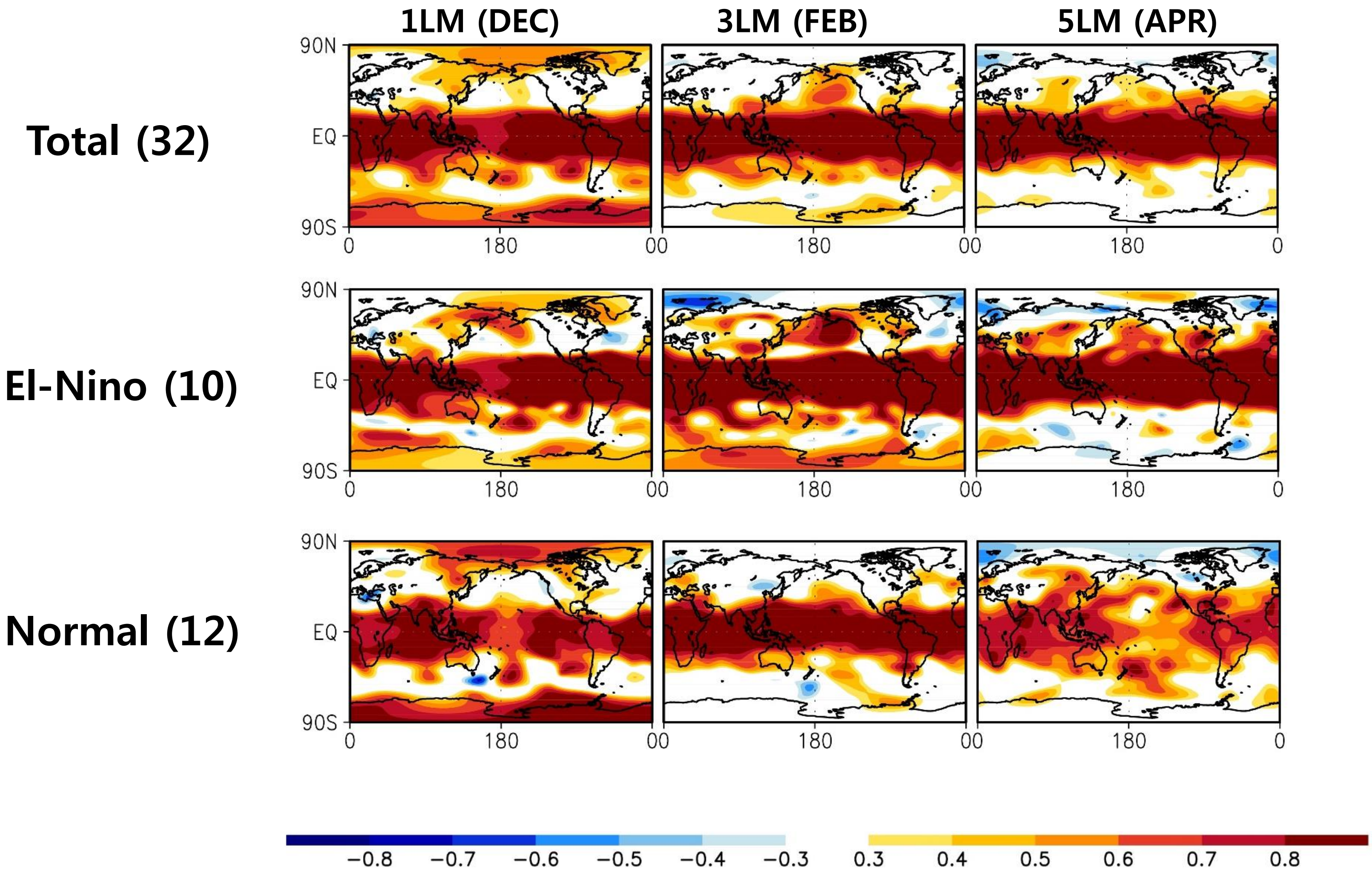


Fig. 2. Regional averages of correlation skills for geopotential heights from 1000 hPa to 30 hPa with lead times from 0 to 6 months. 0 and 6 months correspond to November and May, respectively. a) is for the average over the tropics between 20N and 20S, and b) for the Pacific-North American region of 20N-70N and 150E-60W.

Covariance map of normalized monthly-mean 100hPa GPH anomaly

(Starting from 1 Nov.)



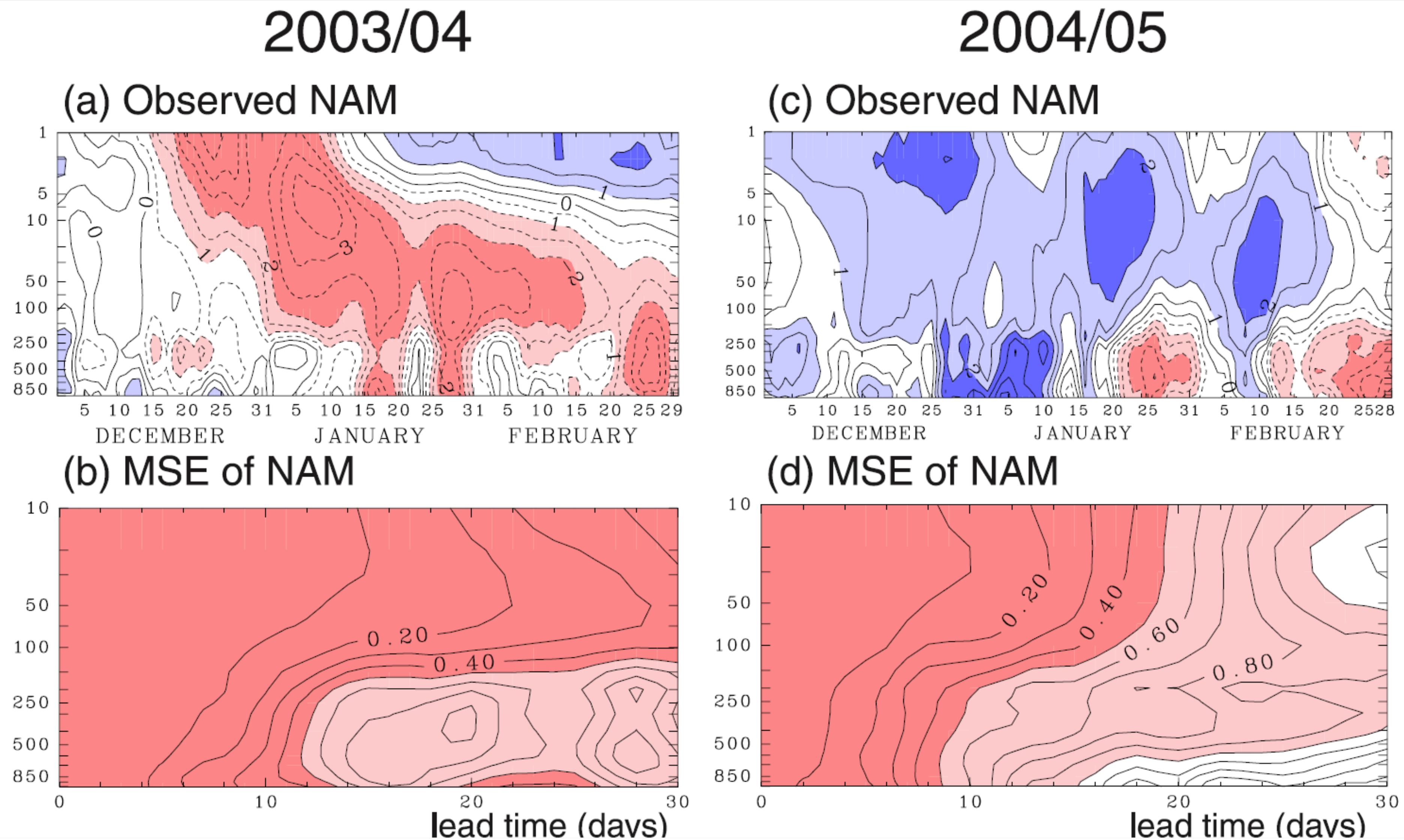
Well known phenomena

1. Stratosphere influences the troposphere: Stratospheric ENSO signal can be added in the signal in the troposphere (teleconnection signal).

2. Weaker polar vortex (polar warming) in the stratosphere provides a good condition for the downward propagation to the troposphere.

Stratospheric (climatological) condition?

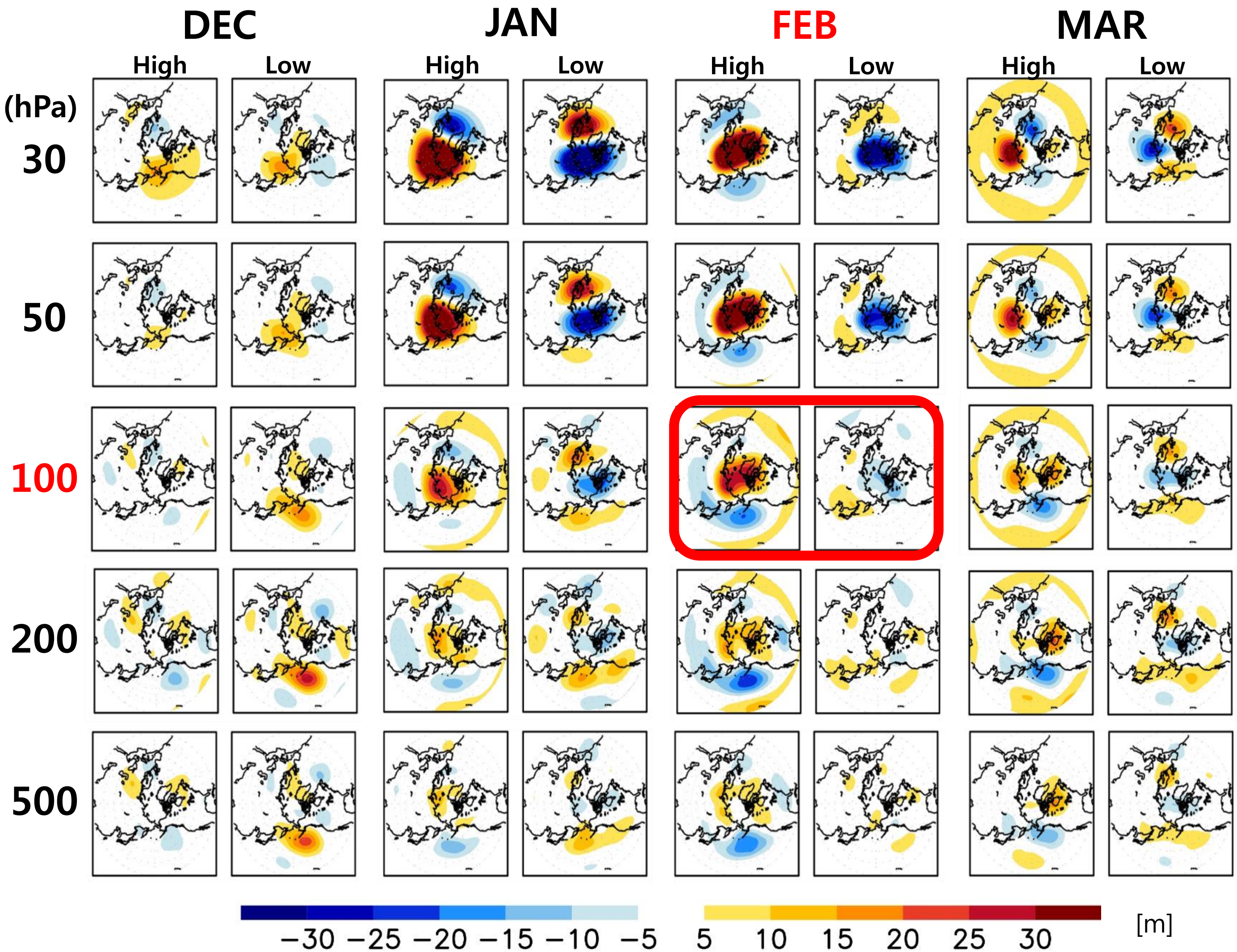
Stratospheric downward influence on prediction skill



The mean square error (MSE) of the forecasts with negatively large 30-hPa NAM anomalies at the initial time is significantly smaller than that of the forecasts with positively large NAM anomalies for the lead time from 5 to 13 days.

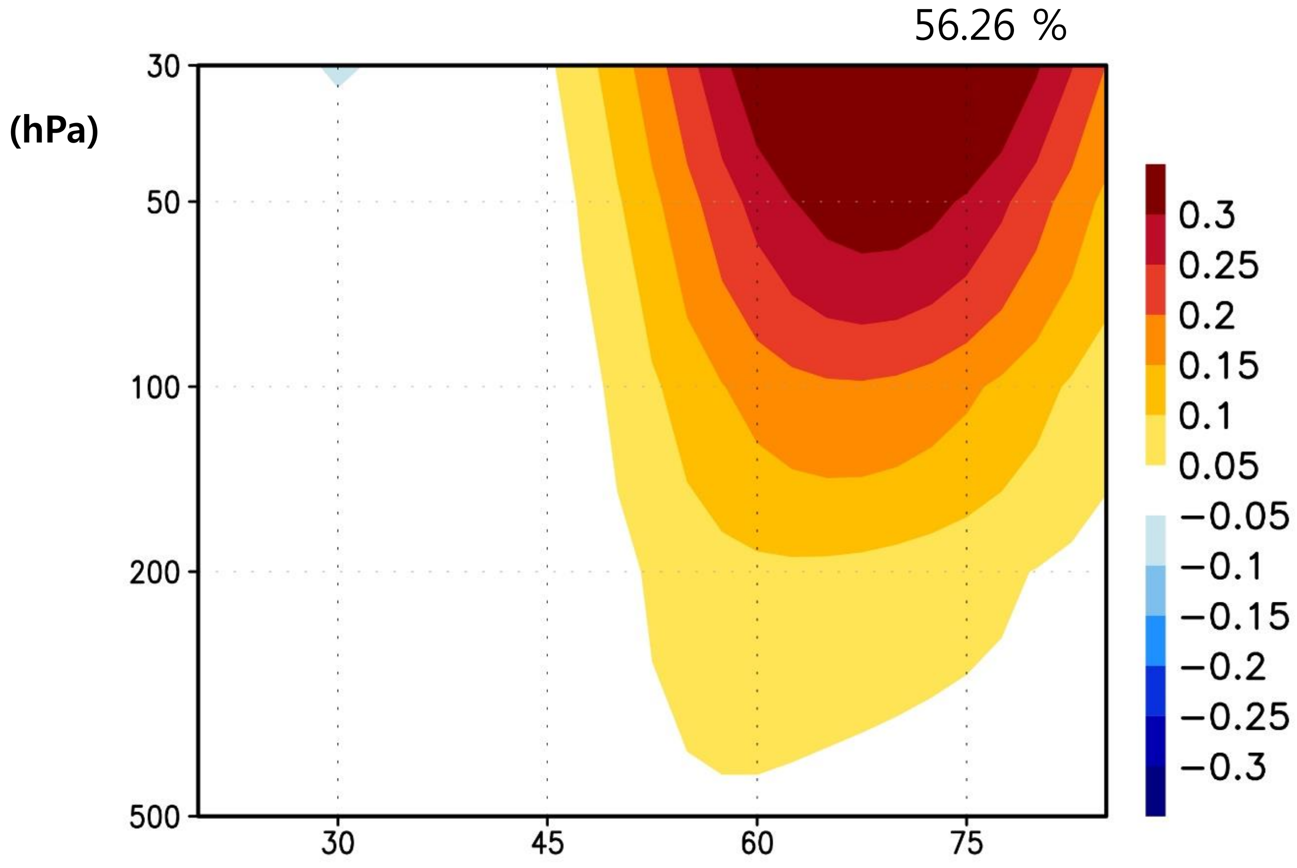
Mukougawa et al. (2009)

Composite of GPH anomaly of high, low pattern correlation[150E-90W, 20N-70N] events at 100hpa, Feb.



The high(low) correlation event is defined as the pattern correlation at 100hPa, lead3 is upper(lower) 1/3 among total 480 cases(15 ensembles * 32 years)

1st EV of zonal mean zonal wind for NOV-MAR, 32 years

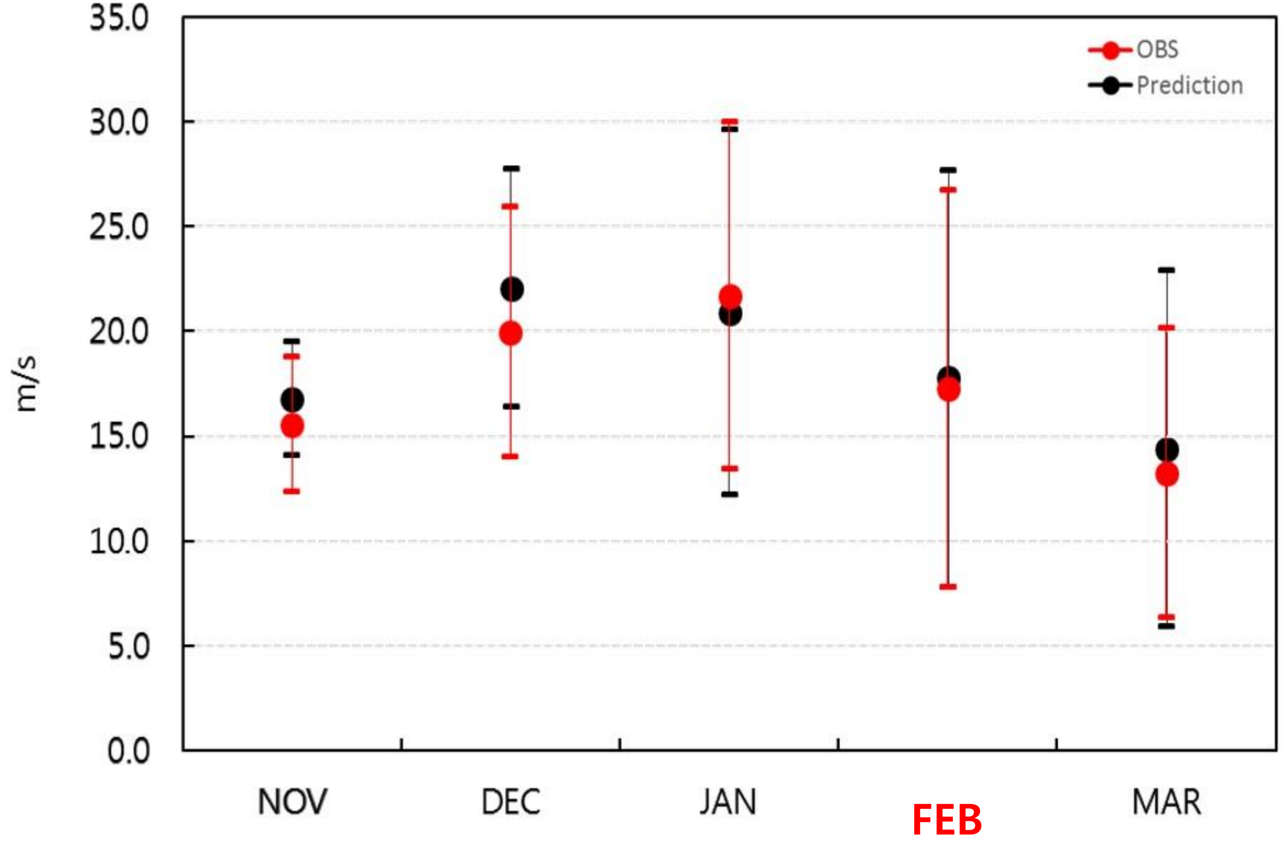


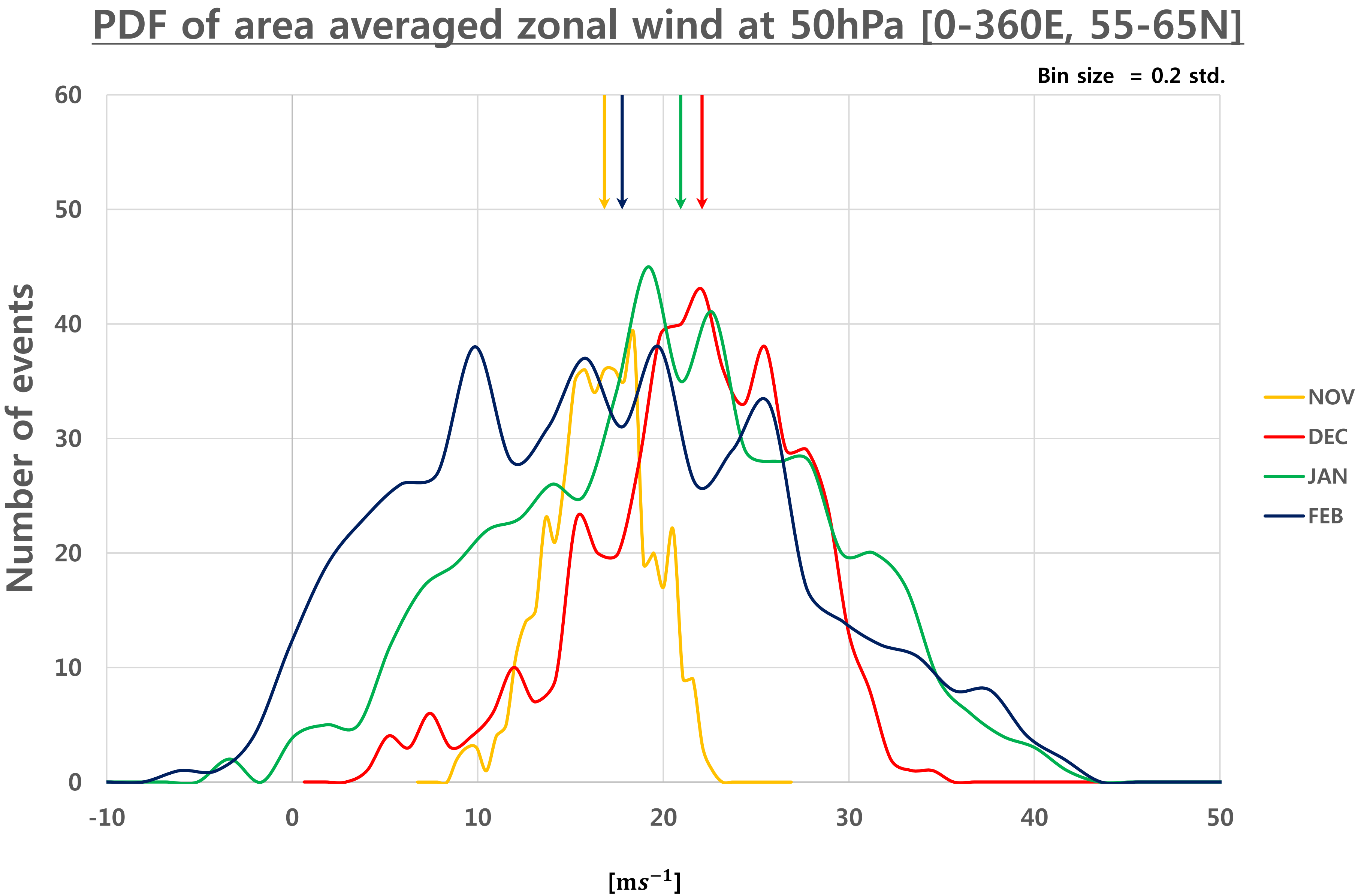
-0.77 Temporal corr. (Z200 1st PCT)

0.36 Temporal corr. (Surface temp. 1st PCT)

Climatological mean & Spread of monthly-mean zonal wind

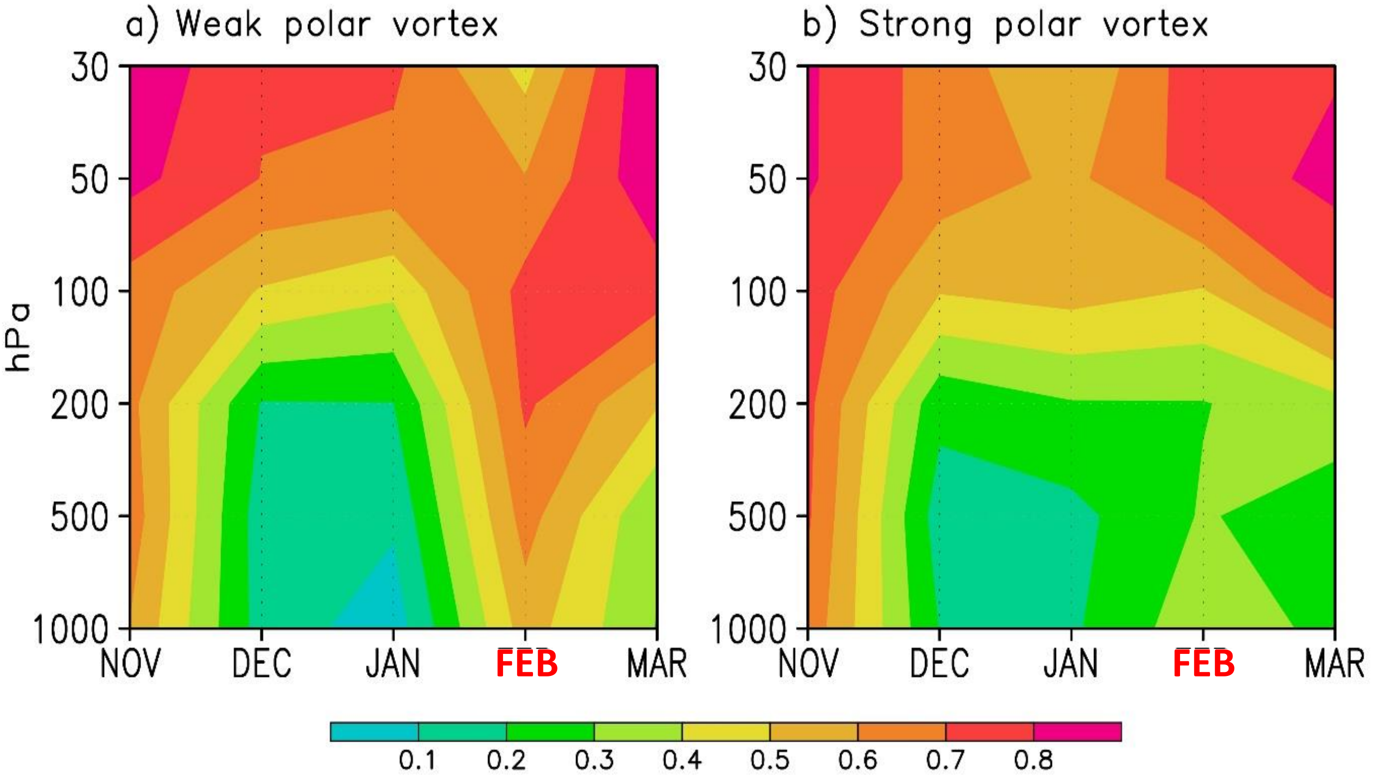
(1.0 std. of the area averaged U (0-360E, 55N-65N) at 50hPa)




PDF of area averaged zonal wind at 50hPa [0-360E, 55-65N]
Bin size = 0.2 std.
Number of events
60
50
40
30
20
10
0
-10
0
10
20
30
40
50
[ms⁻¹]
NOV
DEC
JAN
FEB

Averaged pattern correlation of GPH anomaly

(90E-270E, 20N-90N)



High prediction skill in Feb. associated with the stratospheric signal downward to the troposphere all the way to the surface.

* 'Weak[strong] polar vortex state' : area averaged U-wind (55-65N) < 10m/s [> 30m/s]

El Nino vs La Nina

- The stratospheric warming and weakening of Polar vortex are more frequent during El Nino, and vice versa during La Nina

Is PNA more predictable during El Nino?

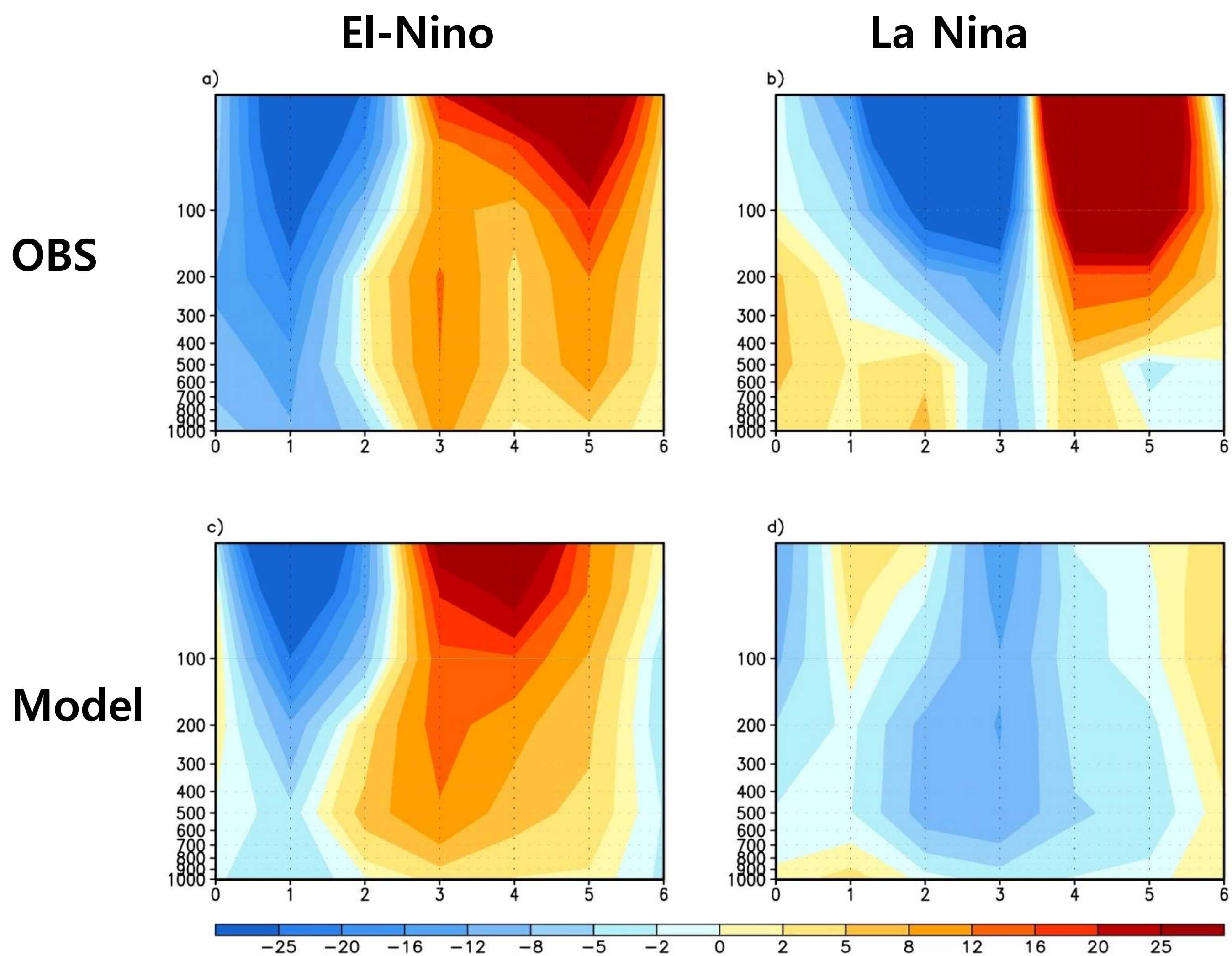


Fig. 5. Vertical cross-section of the composite of polar regional average (60-90N and 0-360E) of geopotential height anomaly for a) El-Nino years and observation, and b) La-Nina years and observation. and c) and d) are the prediction counterparts of a) and b), respectively.

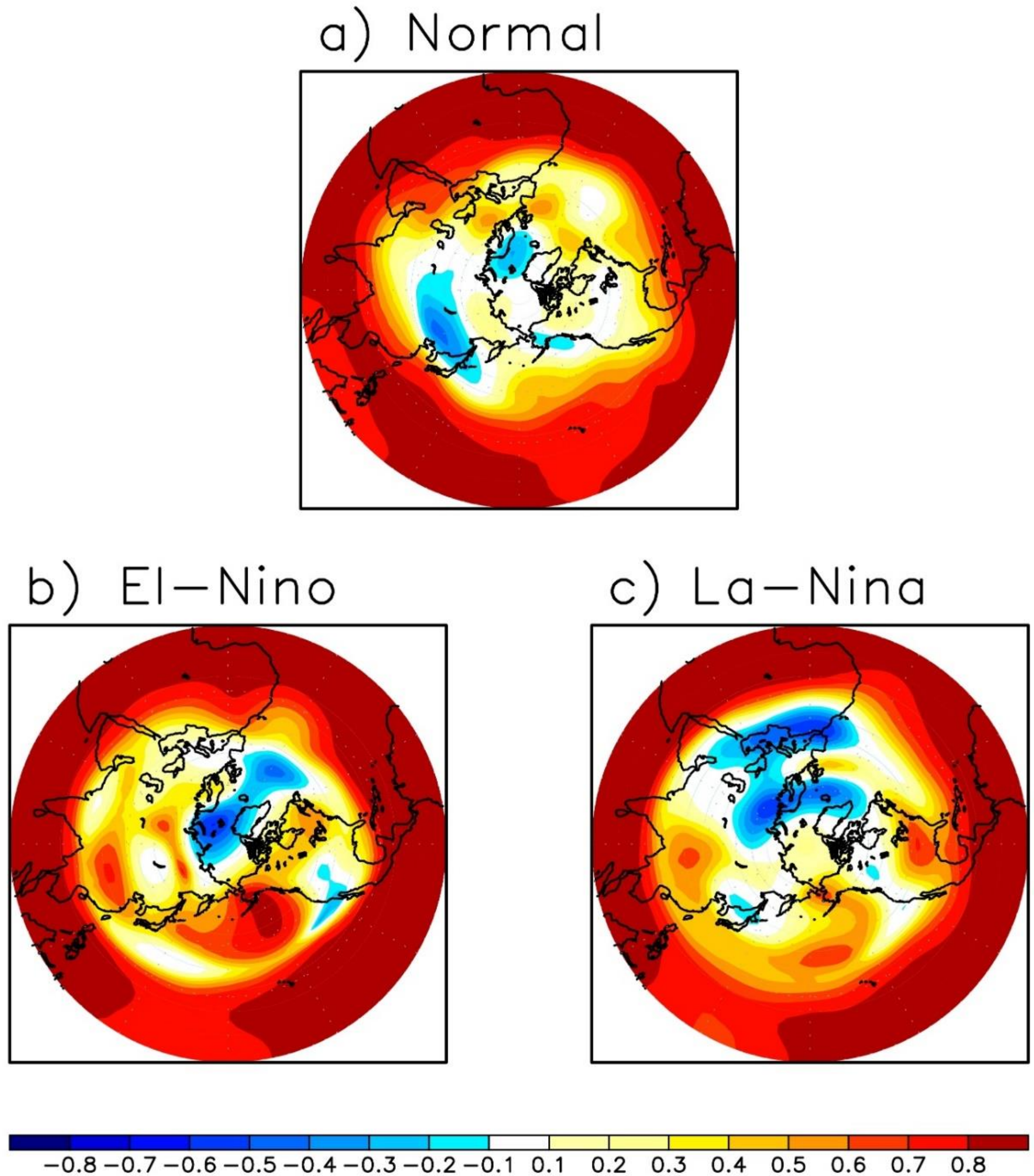


Fig. 5 Covariance map of normalized observation and prediction monthly-mean anomalies of 100 hPa geopotential height for 10 El-Nino years with lead times 3months (b), for corresponding 12 normal years (a), and for corresponding 10 La-Nina years (c). Normalization is done by dividing anomalies of each case (e.g. El-Nino) by the root-mean-square of the corresponding anomalies.

Summary

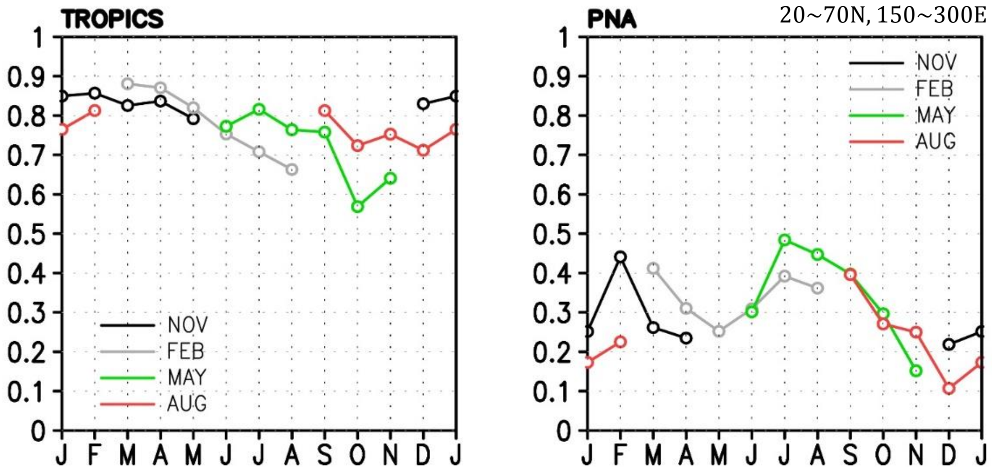
- For the prediction starting from 1 November, the monthly prediction skill is enhanced in late winter

- Stratospheric influence to troposphere is more favorable in February with weaker polar vortex.

GPHT 200hPa

Area averaged of Temporal correlation skill

(with latitude weighting)



Lead time 1 to 6 (excluding t=0)

Thank you!

Kang et al. (2017) submitted to
"Nature partner journal (npj)"
Climate and Atmospheric Sciences

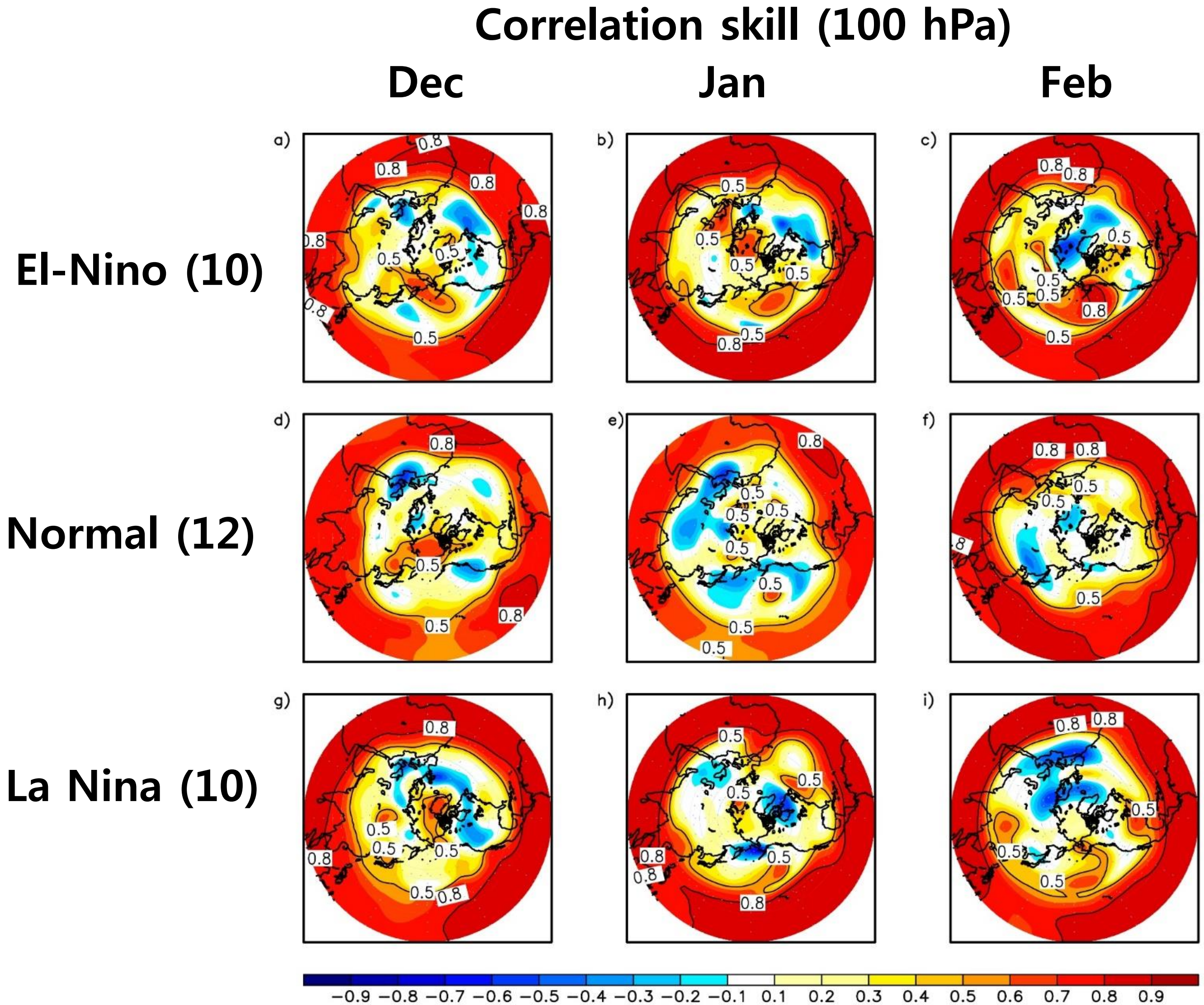
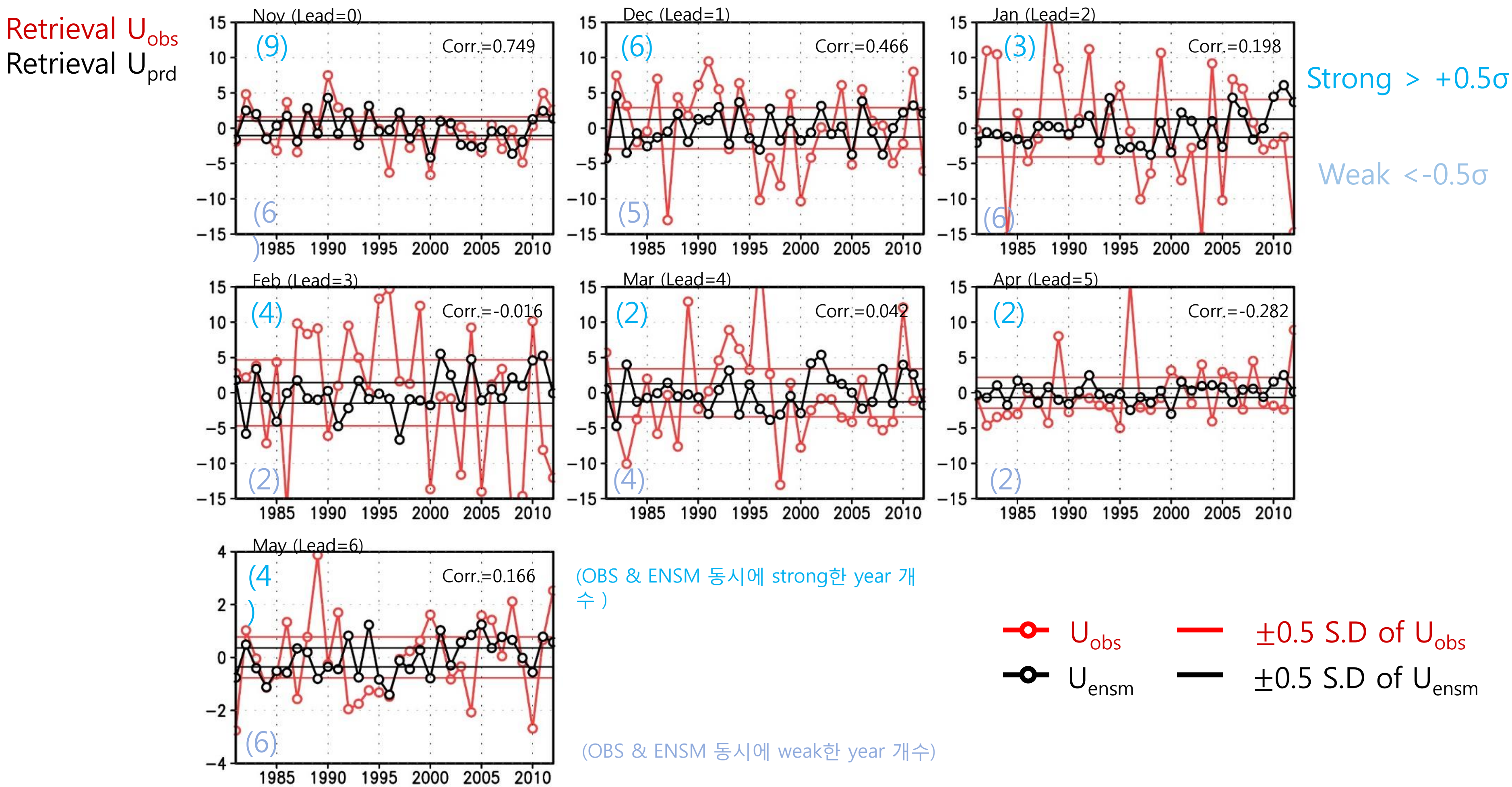


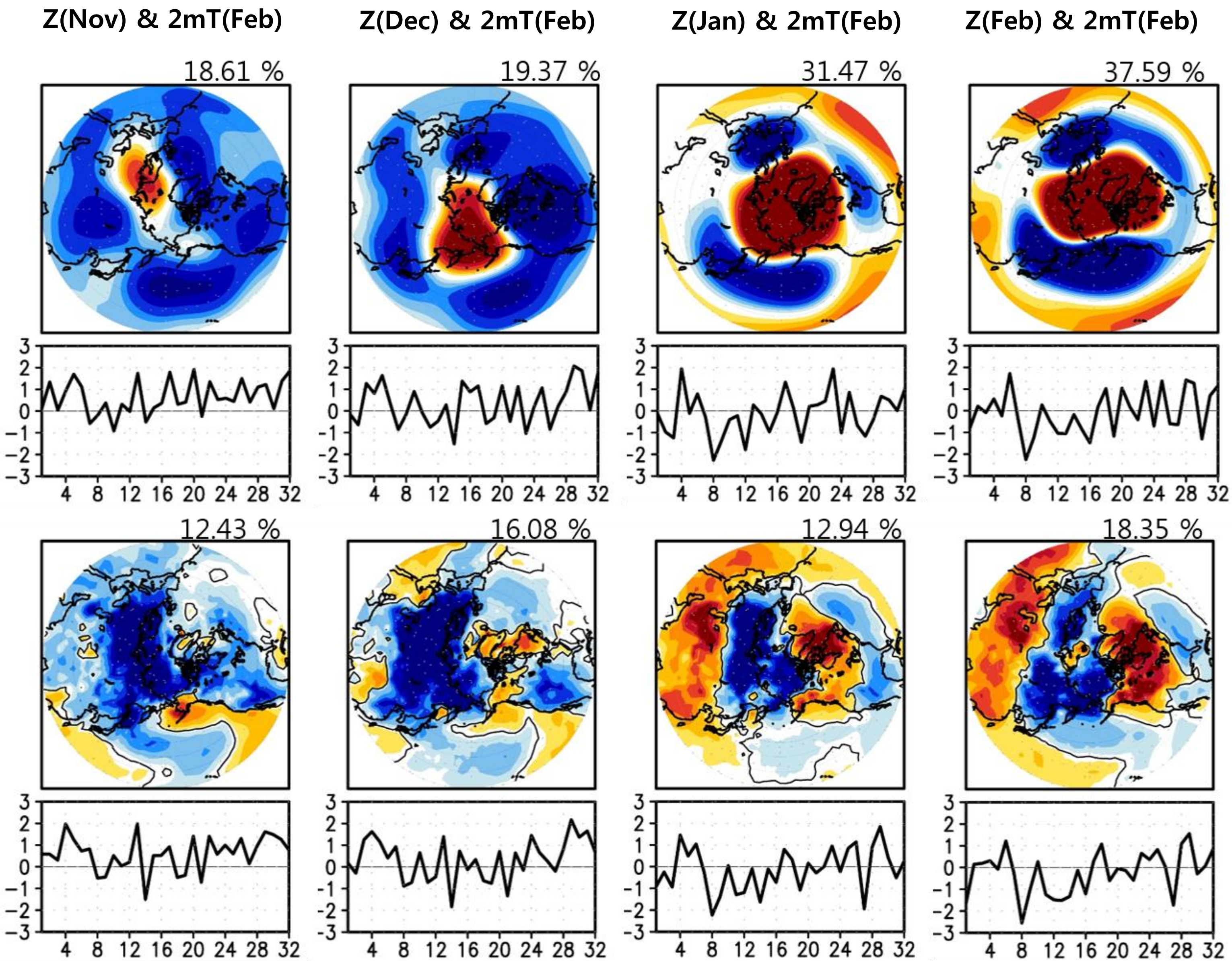
Fig. 3. Covariance map of normalized observation and prediction monthly-mean anomalies of 100 hPa geopotential height for 10 El-Nino years with lead times of 1-3 months (a, b, and c), for corresponding 12 normal years (d, e, and f), and for corresponding 10 La-Nina years (g, h, and i). Normalization is done by dividing anomalies of each case (e.g. El-Nino) by the root-mean-square of the corresponding anomalies.

U at 50hPa (averaged over 55N to 65N, 0E to 360E)

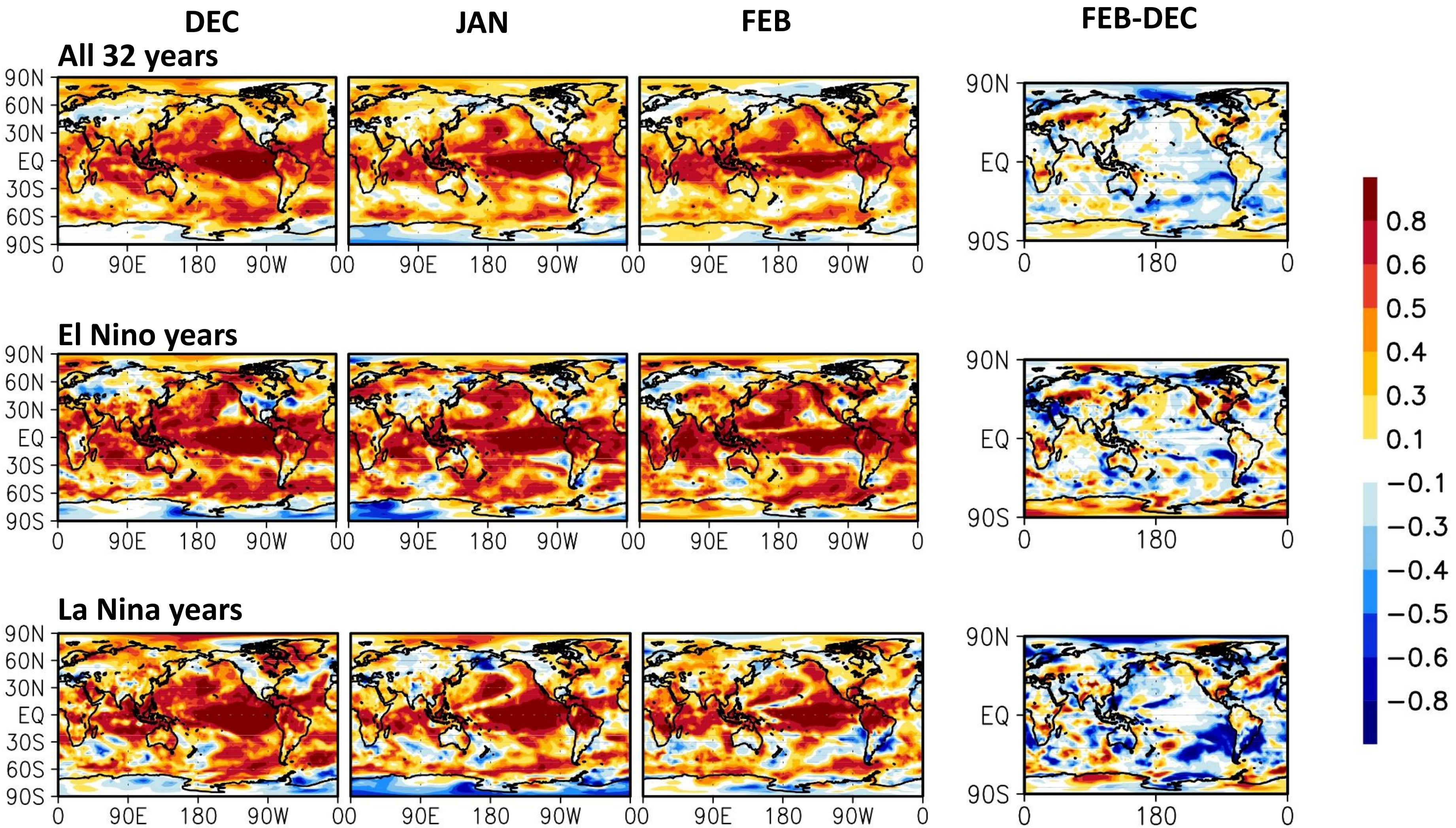


1st SVD of 100hPa GPH and 2mT for 32 years

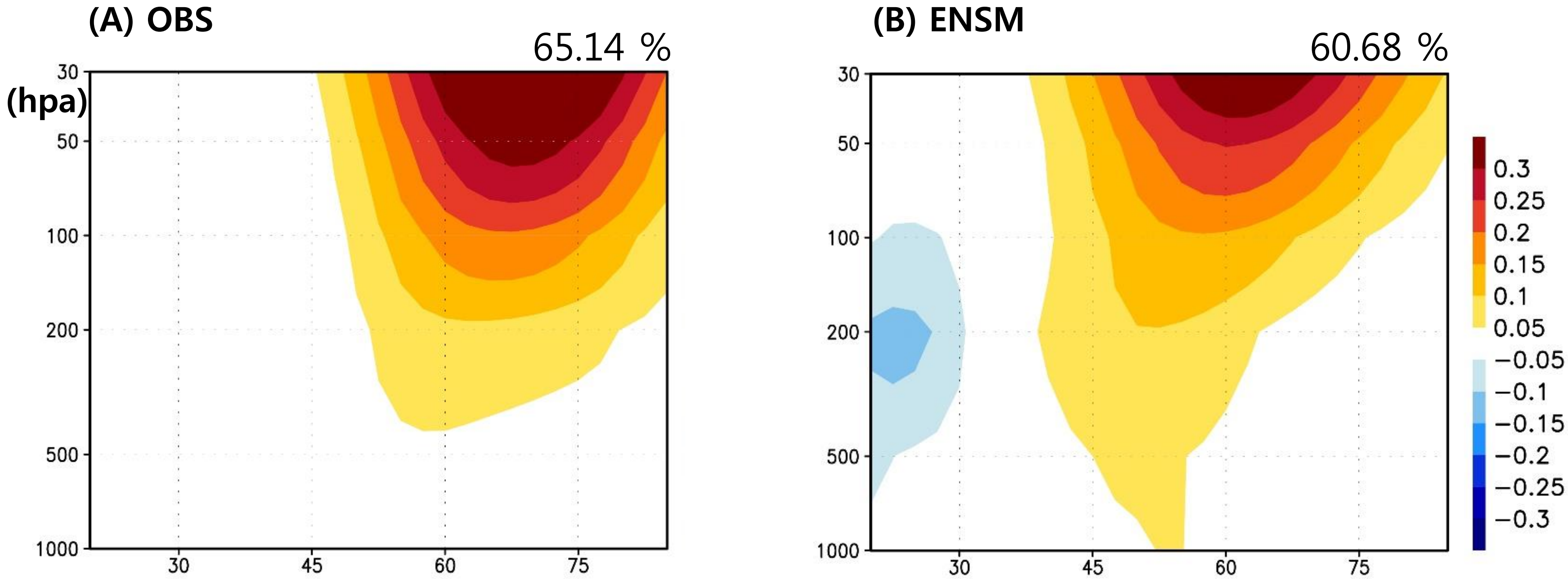
All variables are detrended



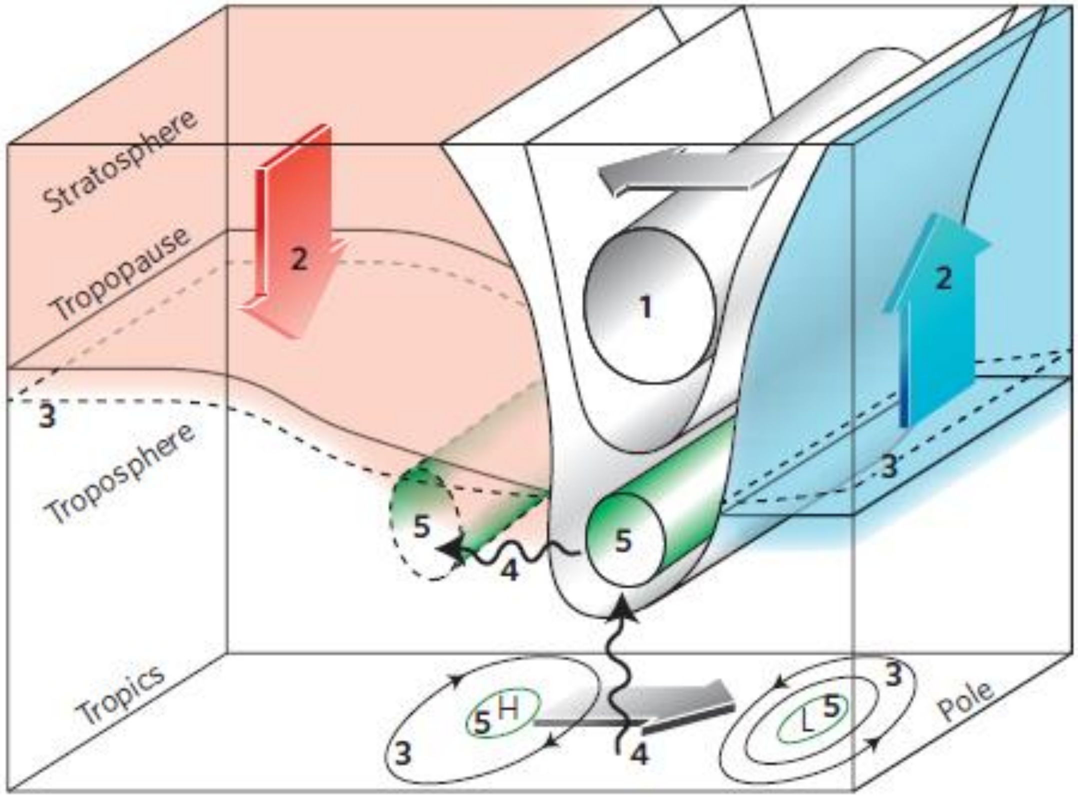
Prediction skill of 2m temperature



1st EV of zonal mean zonal wind for DEC~MAR, 32 years



A Possible Mechanism of Stratospheric downward influence



(1) Wave-driving ⟶ Changes in the speed of the stratospheric jet

(2) Return flow within the planetary boundary layer for the anomalous circulation

(3) Increase of the tropopause height & Decrease of mean SLP in polar latitudes and vice versa in mid-latitudes

(4) Tropospheric eddy feedbacks

(5) Poleward shift of the tropospheric jet

Kidston et al. (2015)