Leading Modes of East Asian Winter Monsoon Variability and Their Predictability

東亞冬季風年際變化之主要模態及其可預測度

Chi-Yung Francis Tam[1,2], Soo-Jin Sohn[3] and N. H. Saji[3]

1 Department of Physics and Material Science, City University of Hong Kong
2 Guy Carpenter Asia-Pacific Climate Impact Center, City University of Hong Kong
3 APEC Climate Center (APCC), Busan, Republic of Korea

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East Asian winter monsoon variability

- The East Asian winter monsoon (EAWM) is characterized by strong Siberian high and active cold surges, which strongly affect the local weather in the region (Chan 2005).
- The EAWM variation projects on a variety of time scales. Fluctuations from the synoptic to intraseasonal (Murakami, 1979; Pan and Zhou, 1985), inter-annual to interdecadal have been examined in (Zhang et al., 1997; Chen et al., 2000; Zhu et al., 2005).
- On the inter-annual timescale, EAWM is also associated with the AO (Thompson and Wallace 2000; Gong et al. 2001; Wu and Wang 2002) and other climate modes such as the Eurasian pattern (or EU pattern; Wallace and Gutzler 1981; Gong et al. 2001). The El Nino and Southern Oscillation (ENSO) also has an impact on EAWM (Zhang et al., 1997a; Chen et al., 2000; Lau and Wang, 2005; Takaya and Nakamura 2007).

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- Overall, many efforts have been made to understand the observed variability of EAWM (Lau and Li 1984; Zhang et al. 1997; Gong et al. 1997; Wu and Wang 2002; Jhun and Lee 2004; Takaya and Nakamura 2005). However, there are still relatively few diagnostic studies on the performance of GCMs on EAWM simulations, compared to that on the summer monsoon.

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The goal of this study is to examine the EAWM inter-annual variability and predictability in multi-model ensemble (MME) seasonal prediction, focusing on the leading EAWM modes.

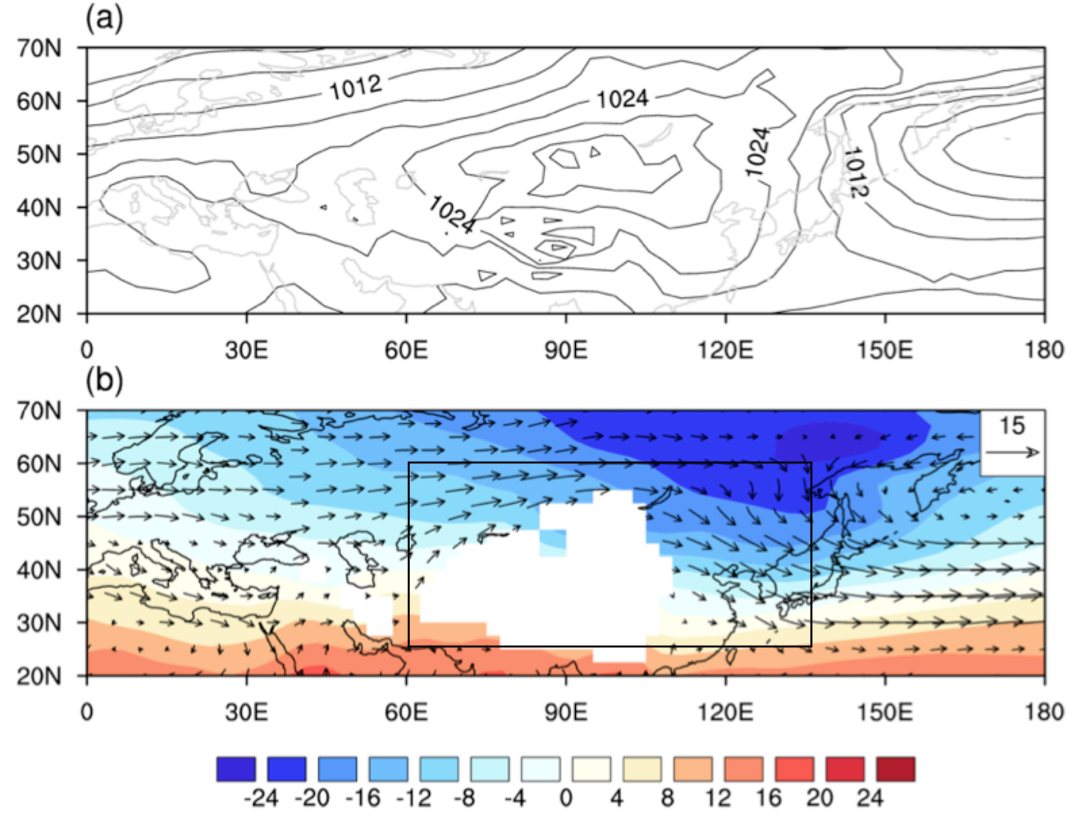
APEC Climate Center (APCC) MME experiments

Acronym	Participating Institute (Member Economy)	No. of ensemble members	Experimental Type	SST Specification
GCPS	Seoul National University (Korea)	12	SMIP/ HFP	Persisted / Predicted
GDAPS	Korea Meteorological Administration (Korea)	20	SMIP / HFP	Persisted / Predicted
HMC	Hydrometeorological Centre of Russia (Russia)	20	SMIP / HFP	Persisted
JMA	Japan Meteorological Agency (Japan)	5	SMIP / HFP	Persisted / Predicted
NCEP CFS	National Centers for Environmental Prediction (USA)	15	CMIP	Predicted

➡ Multi-model ensemble (MME) mean = (unweighted) average of ensemble mean from each model

- Experimental Period : DJF season from 1983/4 to 2003/4
- Variables : SLP, T850, UV850, Z500
- Observational data: NCEP-NCAR reanalysis products

East Asian winter monsoon (EAWM) climatology



observations

(DJF mean SLP, 850hPa temperature and wind)

- model and observed EAWM climatology are in good agreement
- preform multi-variant EOF analysis based on monthly T850 & v850 within 60-125E, 25-60N

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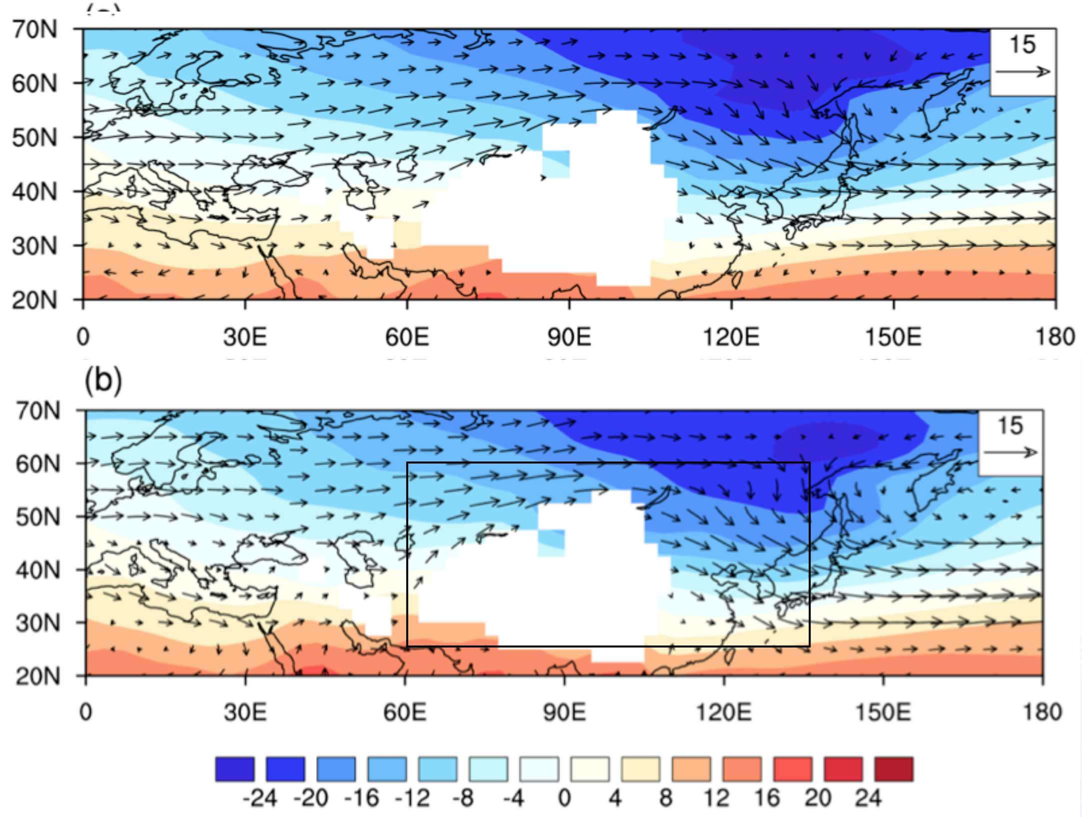

MME mean

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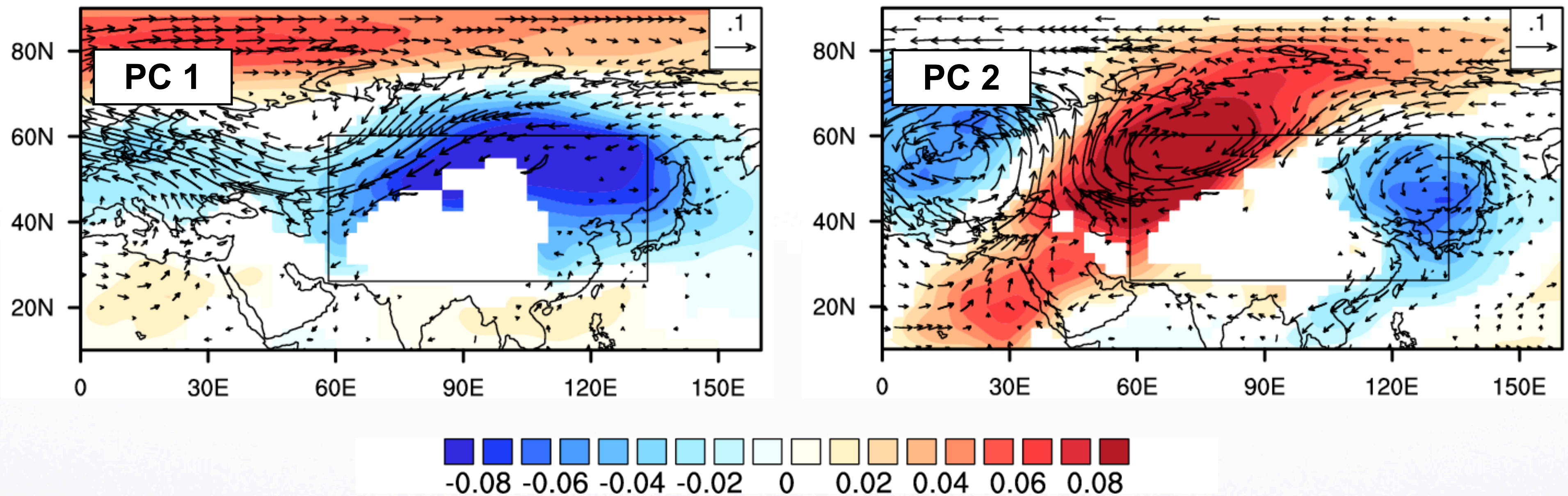
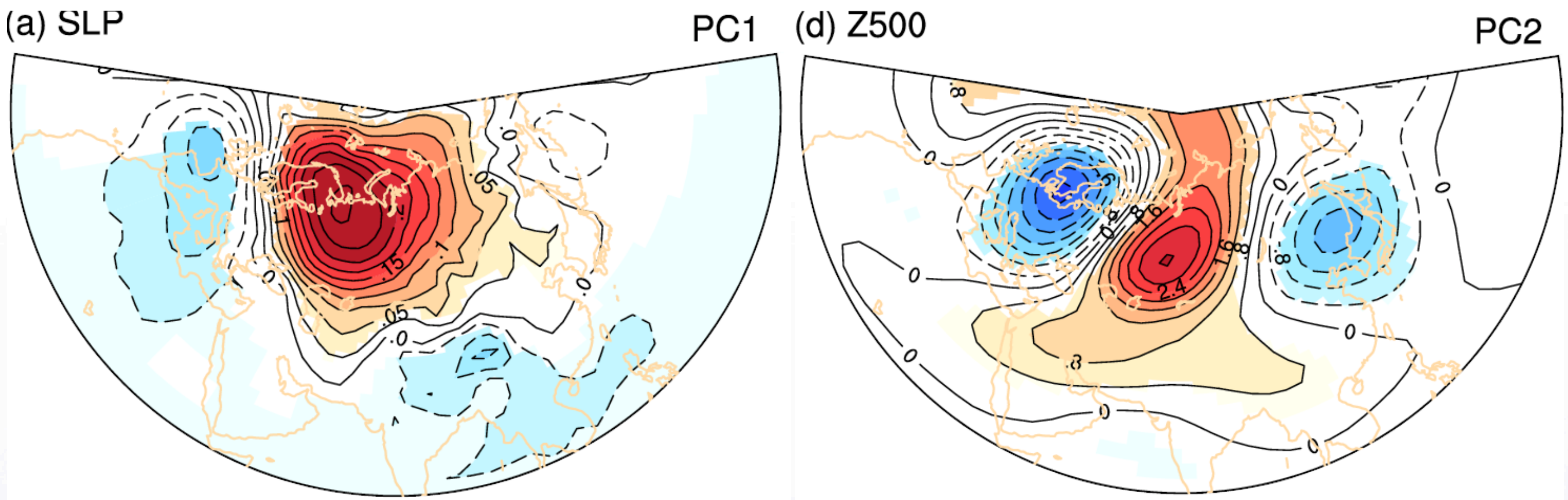
Leading modes of EAWM variability- observations



(Regression of 850hPa temperature and wind onto PC 1 & 2)

- The first EAWM mode is characterized by cold anomalies from the northwestern flank of Siberian high to northeastern part of Asia.
- The second mode has a distinctive tripole pattern across Eurasia; anomalous cold condition and northwesterlies are found over eastern to northeastern China, Korea and Japan.

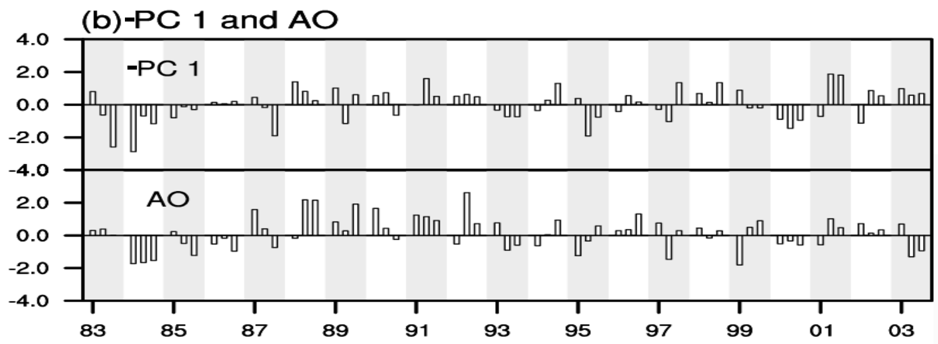
Leading modes of EAWM variability- observations

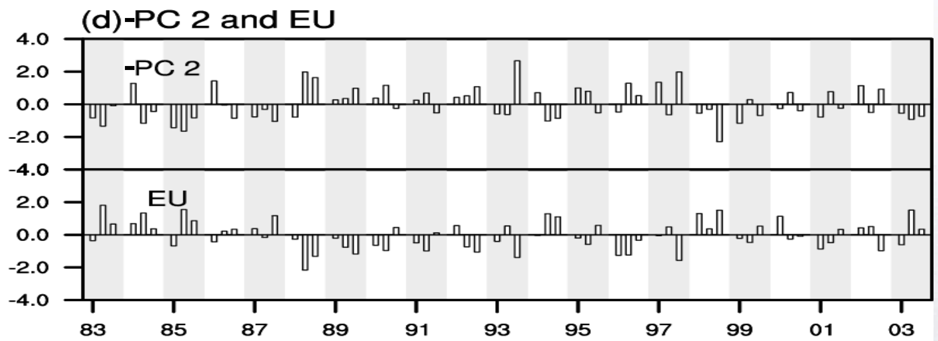


- SLP anomalies associated with mode 1 is reminiscent of the AO
- 500hPa height anomalies for mode 2 is very similar to the EU pattern

Temporal variability of the EAWM modes- observations

- **PC time series and other climate indices**





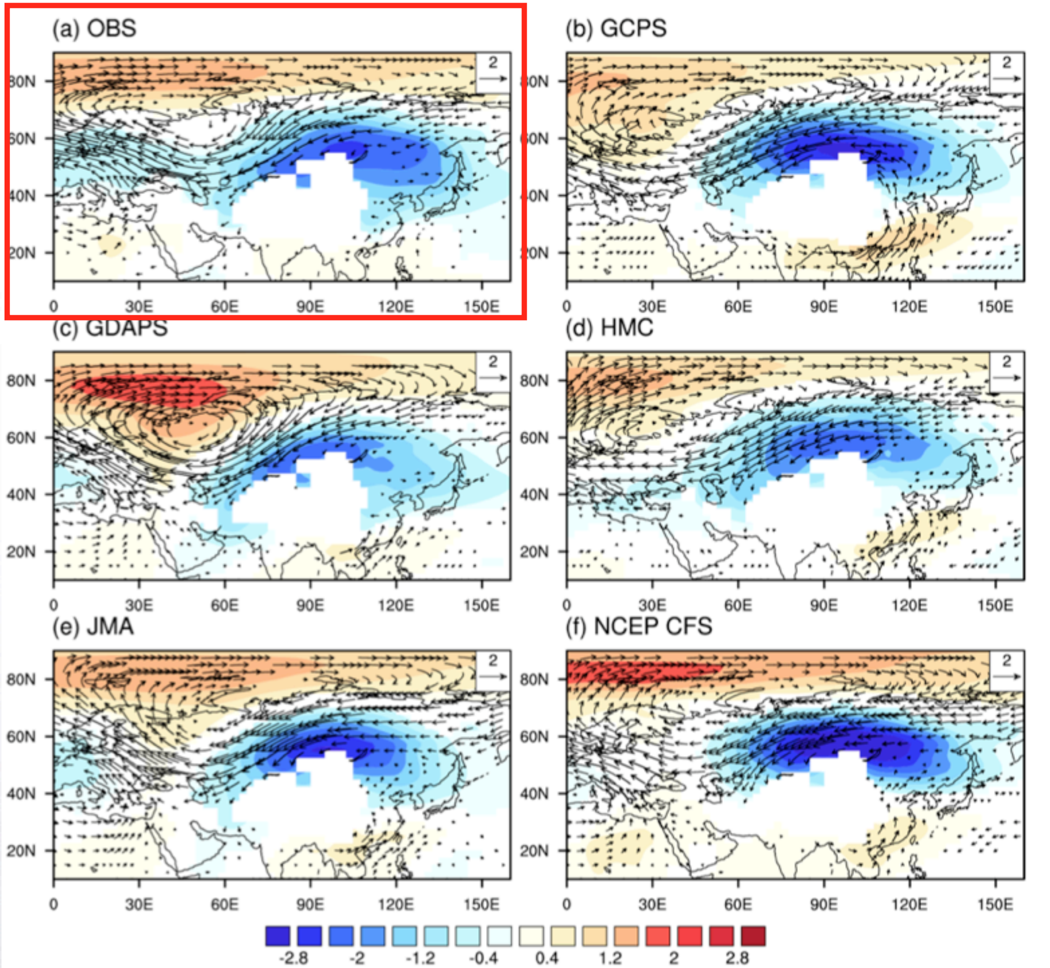
CORR	AO	EU	Nino 3	SH**
PC 1	-0.45*	0.11	-0.08	0.55*
PC 2	-0.38*	0.90*	-0.17	0.35*

* Significant at 99% level

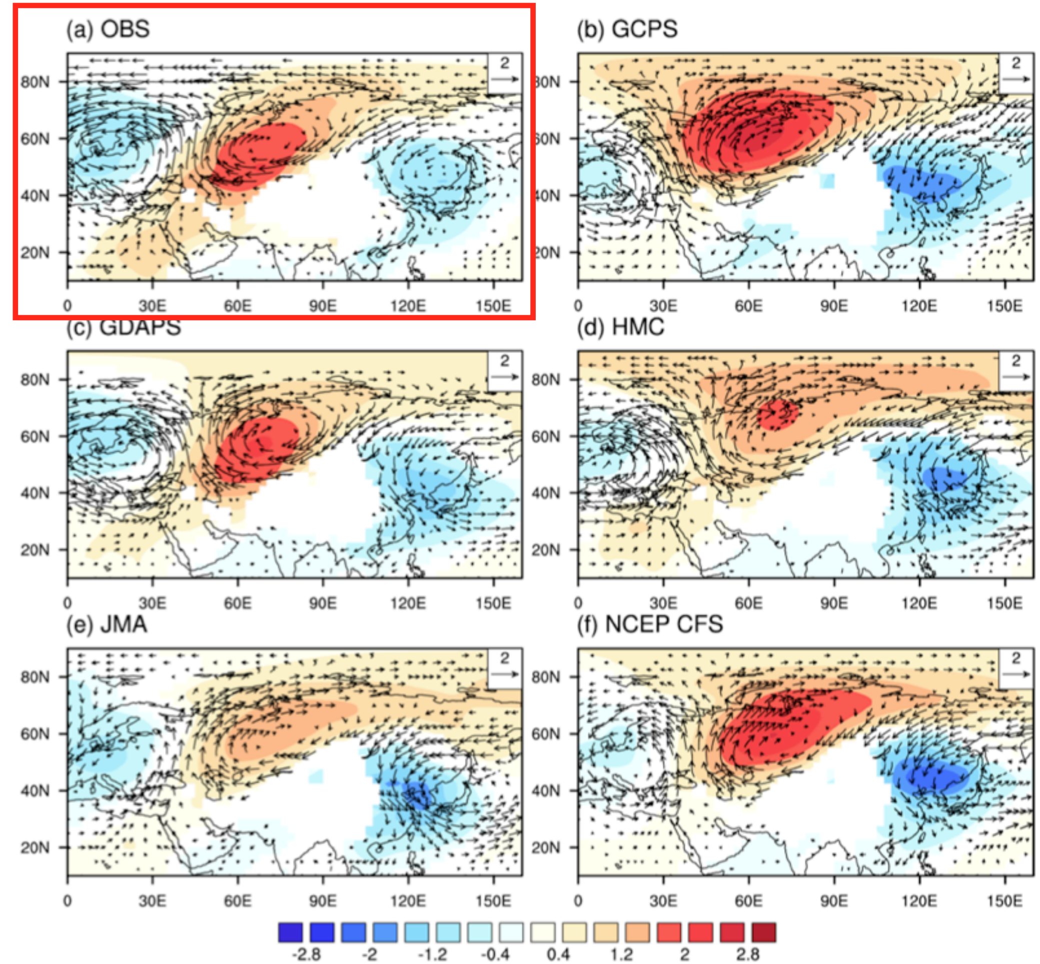
- The first EAWM mode is linked to variations of the AO; the second mode is strongly associated with EU pattern.
- Both EAWM modes lead to the strengthening of the Siberian high.

Leading modes of EAWM- obs and model simulations

obs

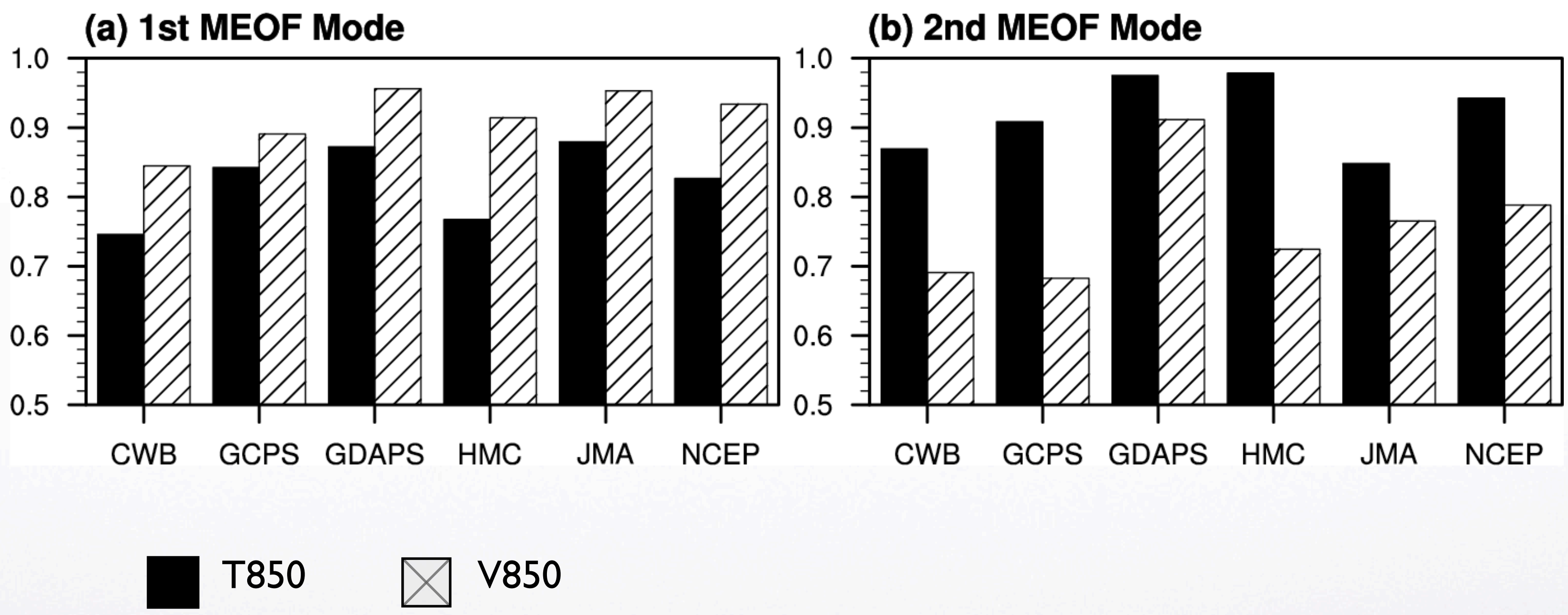


obs



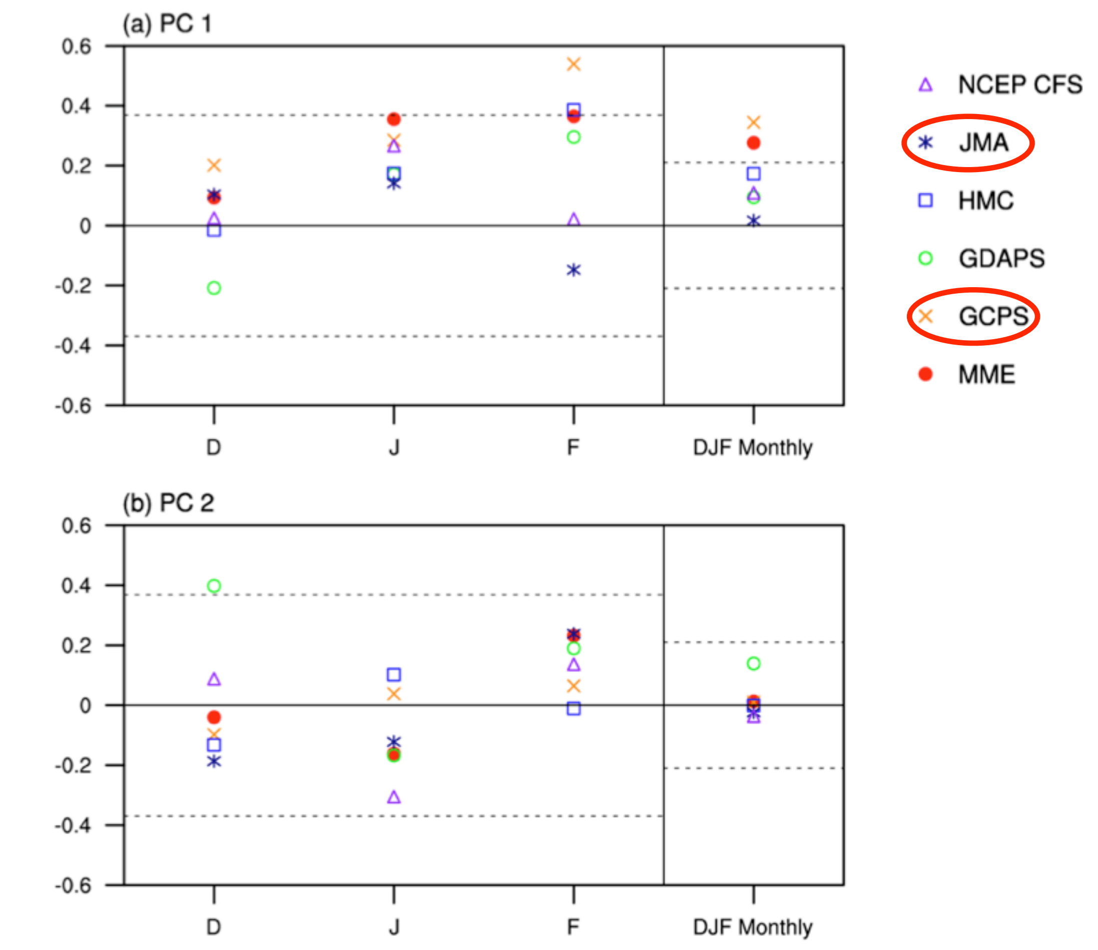
- the leading EAWM modes are captured well in model environments

Pattern correlation between model and obs EOFs



- high pattern correlation between the observed eigenvectors and simulated eigenvectors.

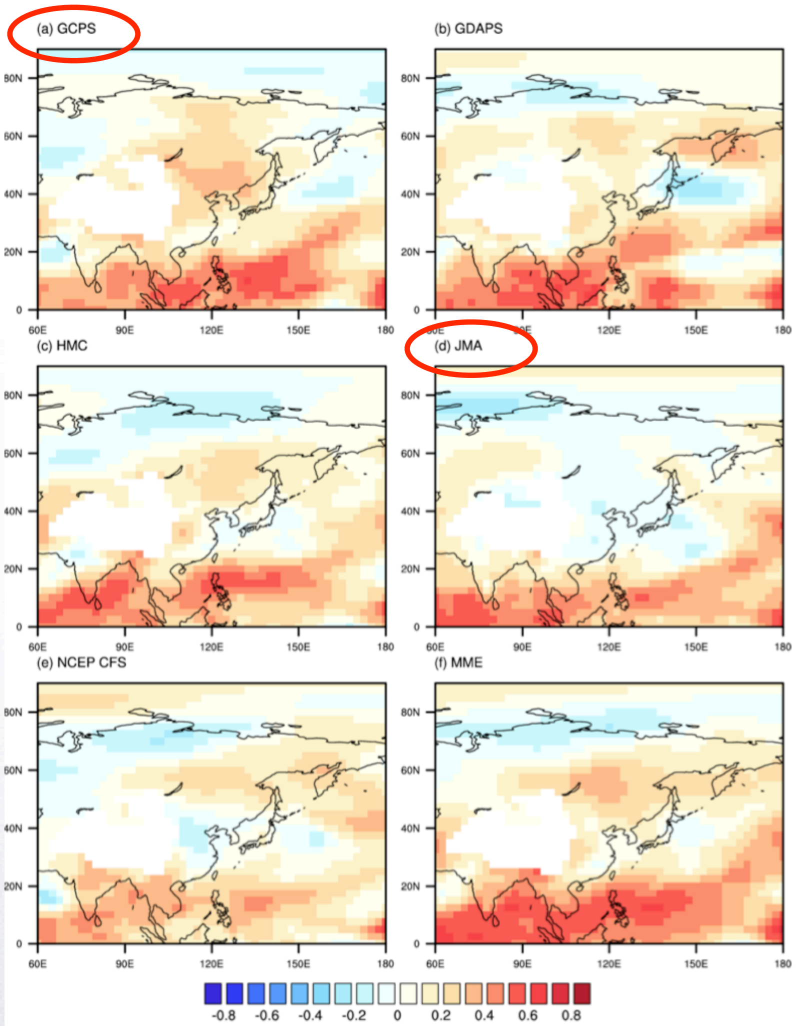
EAWM predictability in models and MME



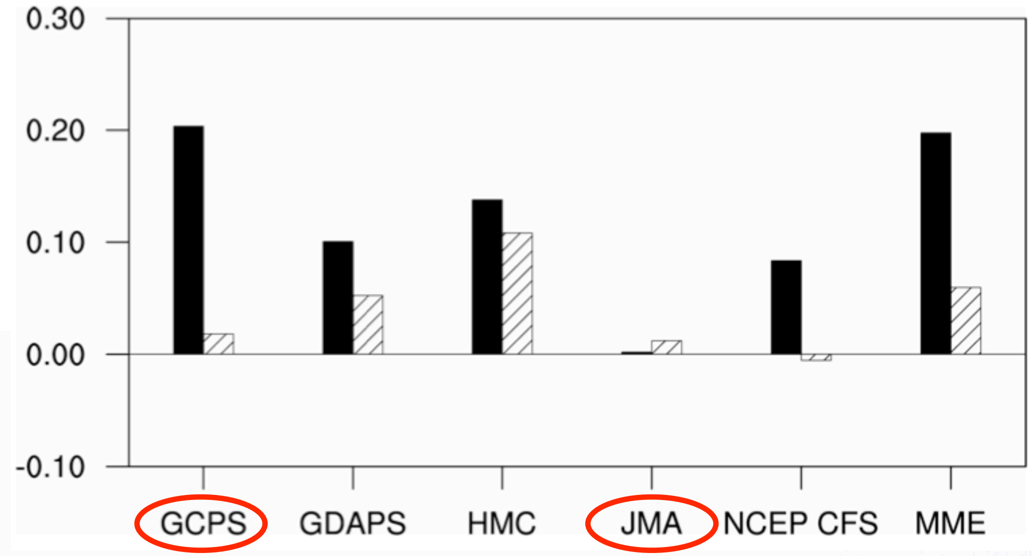
- significant correlation between obs and prediction from GCPS and MME for the 1st mode
- almost no skill for 2nd mode

(Temporal correlation between Models/MME projection time series and observed PCs)

EAWM predictability in models and MME



(correlation between model and observed T850)

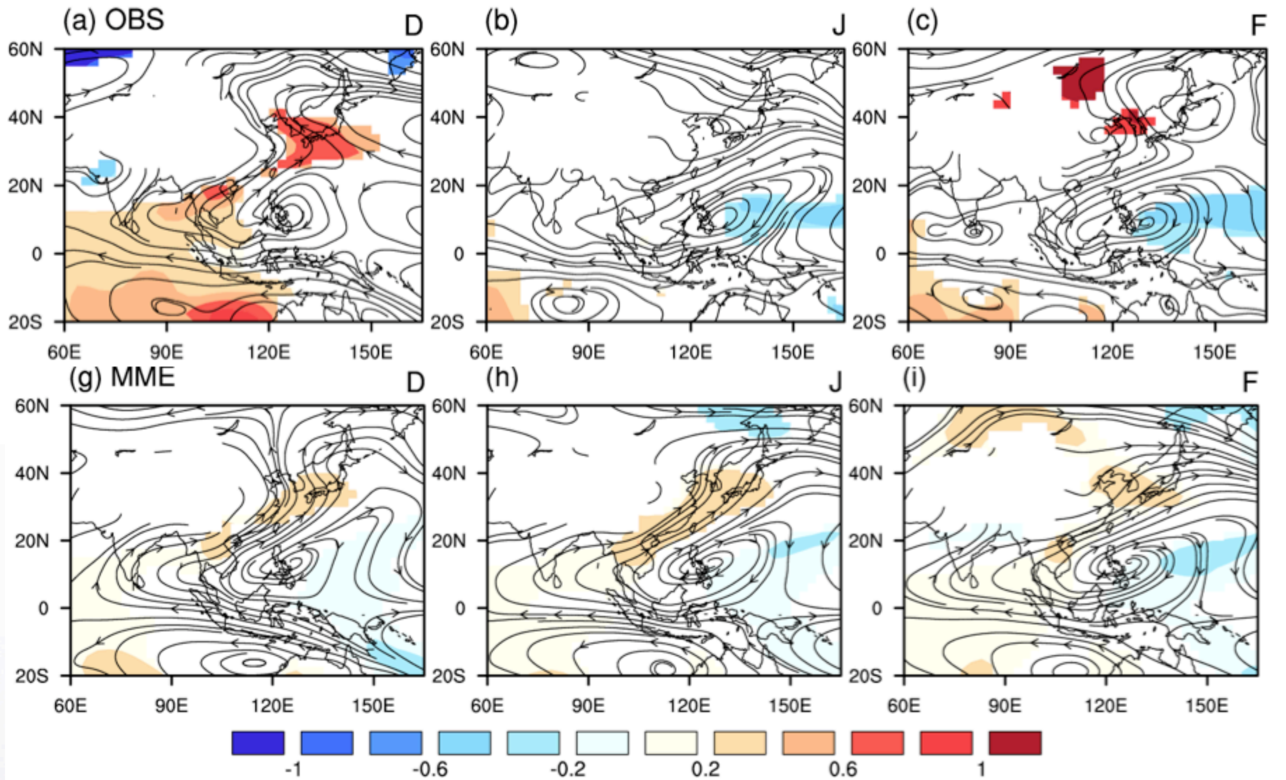


(T850 correlation over 75-135E,40-60N)

- original data
- 1st EAWM mode removed

- skill of GCPS is greatly reduced, while JMA is not affected
- 1st mode is important for predictability over continental NE Asia

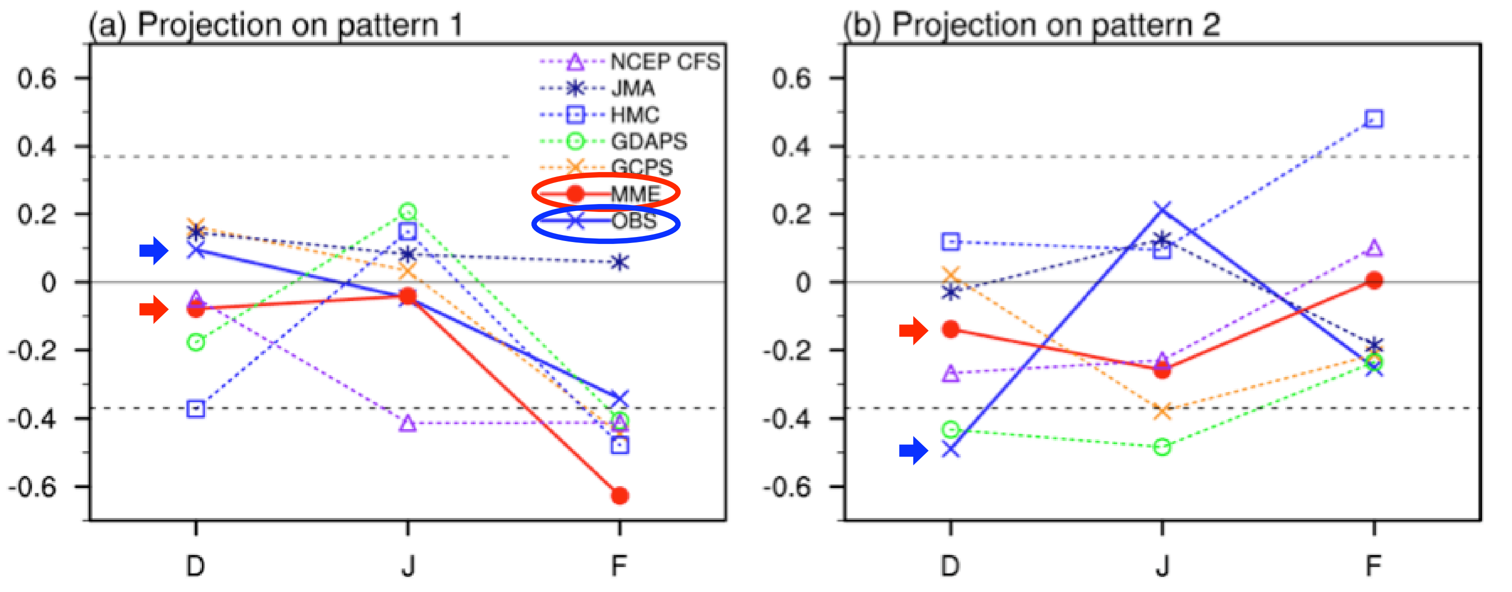
Impact of ENSO on EAWM



(Regression of 850hPa temp & wind onto Nino3 index)

- warming near Lake Baikal in February is well captured in models
- warm signal near Eastern part of China, Korea and southern Japan in models tends to persist throughout the DJF period, in contrast to observations

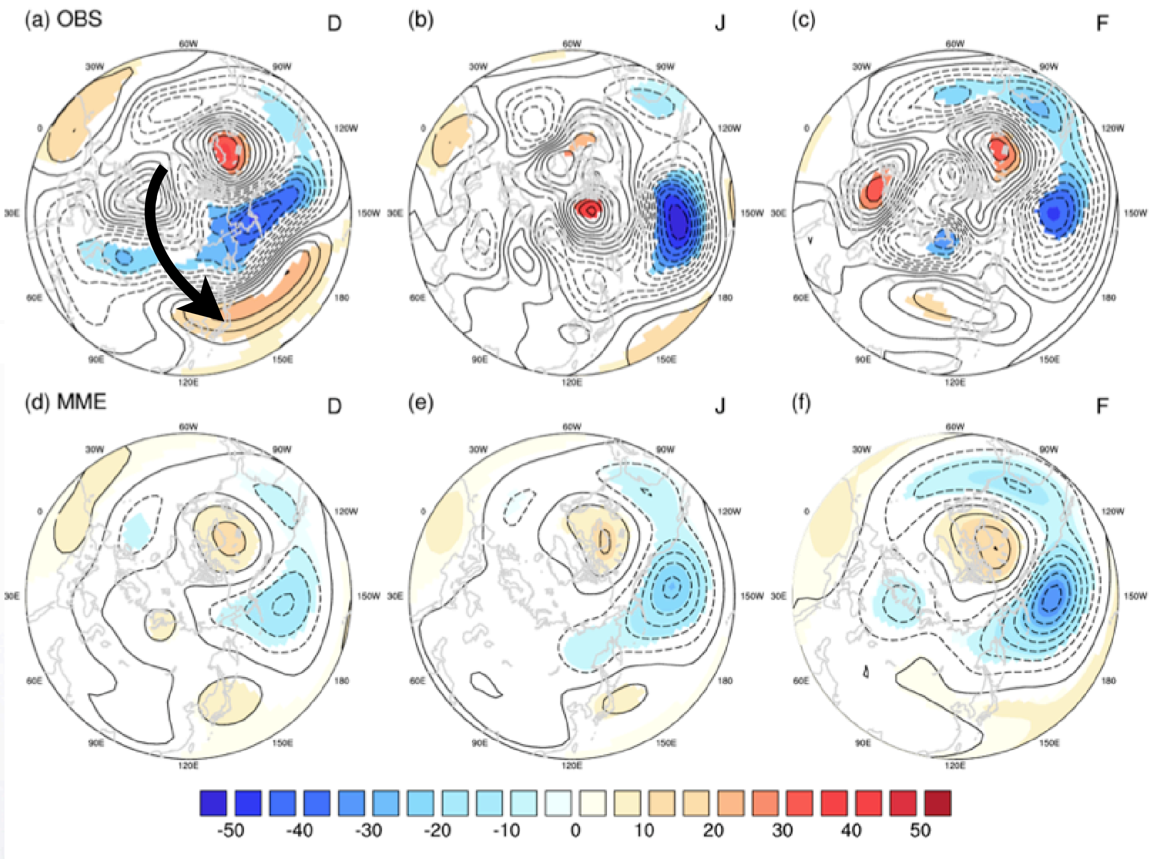
Impact of ENSO on EAWM



(correlation between 1st/2nd mode projection and Nino3 index)

- increasingly -ve projection onto 1st mode from observations is well reproduced in MME
- the strong (-ve) projection onto 2nd mode in December, and weak signals in the following months, are not captured in most models

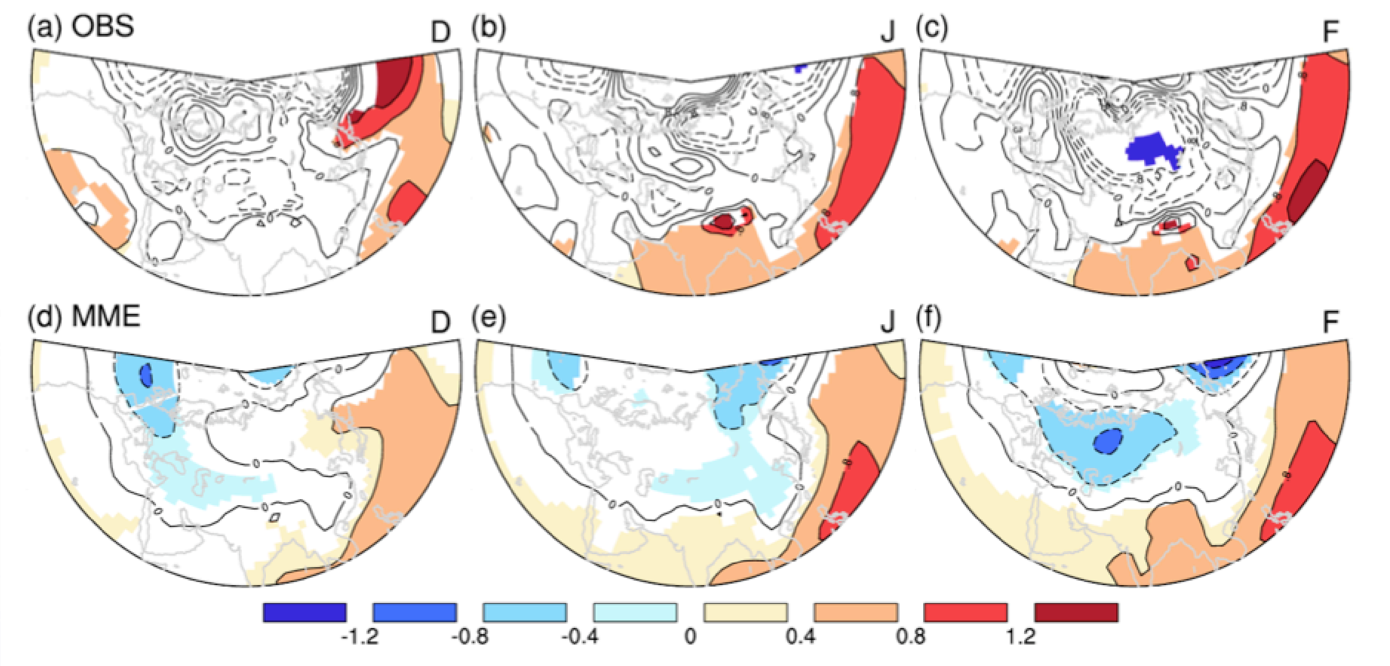
Impact of ENSO on EAWM



(Regression of 500hPa Z onto Nino3 index)

- in obs, strong riding over western N Pac/Japan in December due to Eurasian wavetrain
- the wavetrain is not captured in models

Impact of ENSO on EAWM



(Regression of SLP onto Nino3 index)

- low pressure develops during mid to late winter over northern central Asia, which weakens the Siberian high
- similar pattern is found in MME hindcast prediction

Summary

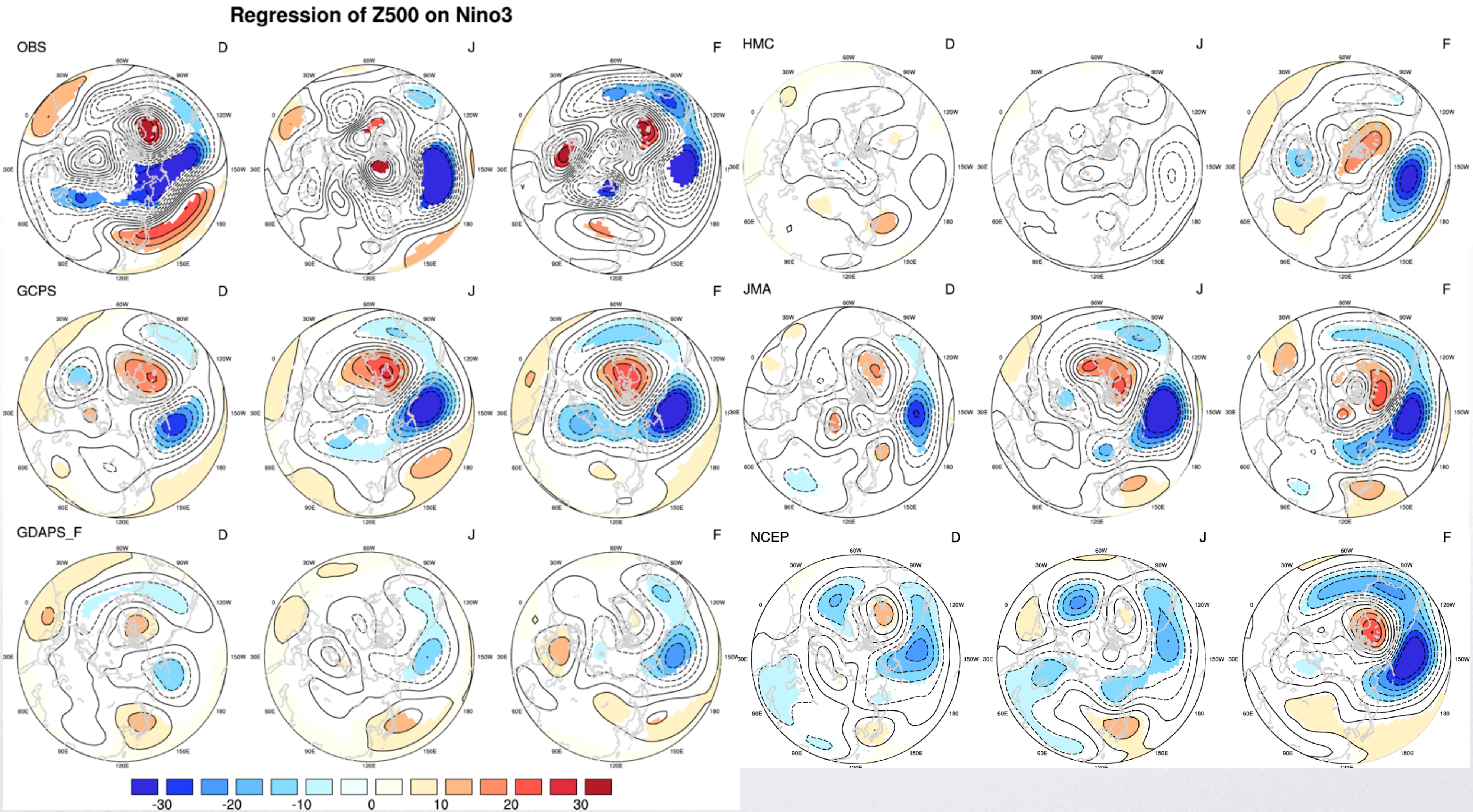
1. Observations show that the first EAWM mode is characterized by planetary-scale features, with prominent cooling over the northeastern part of Asia. For the second EAWM mode, cold anomaly is present over coastal East Asia including the eastern part of China, Korea peninsular and Japan.

2. While the spatial patterns of two leading EAWM modes are well reproduced in model simulations, their temporal variations are relatively more difficult to capture. There is evidence that there is some predictability for the leading EAWM mode. This mode is especially important for the winter monsoon predictability in the mid-to-high latitude East Asia (from Lake Baikal to the East Asian coast). On the other hand, there is almost no skill in predicting the fluctuations of the second mode.

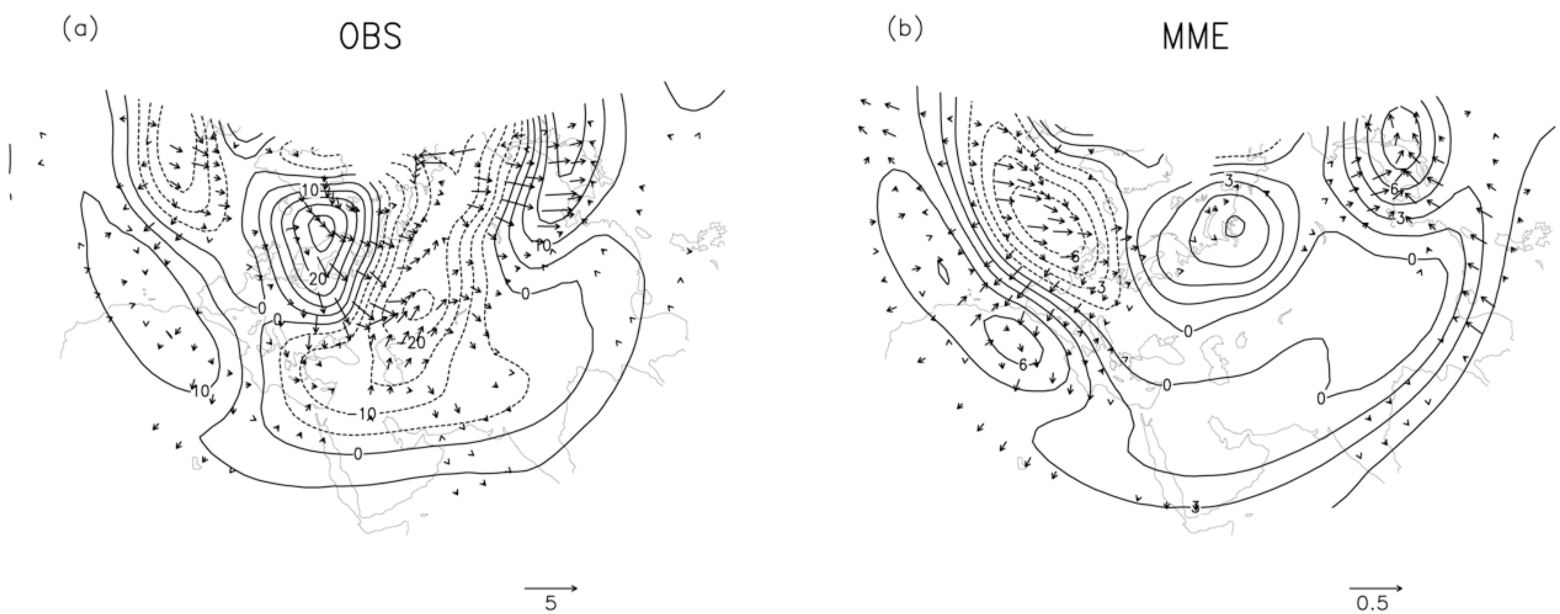
3. During ENSO, most models have difficulty in capturing the timing and strength of the second EAWM mode variations. This is because the Eurasian wavetrain, which is responsible for exciting this mode during early winter, is either too weak or absent in model simulations. On the other hand, variations of the first EAWM mode are robustly predicted. Hindcast results from most models are able to capture the development of an associated continental-scale SLP anomaly centered at the northern central part of Asia in late northern winter during ENSO episodes.

Thank You !

Z500 regression onto Nino3



Wave activity analysis based on Z500 regression for December



(wave activity based on Takaya and Nakamura 2001)

SLP regression onto Nino3