

# Applications of ocean data assimilation into a coupled climate model to East Asian summer monsoon simulations

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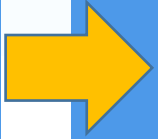
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**International Workshop on coupled data assimilation**

**Toulouse, 18th-21st October 2016**

# outline



**1**

**Motivation**

**2**

**Evaluation**

**3**

**Decadal Variation of EASM**

**4**

**Conclusions**



# Difficulty in simulating **decadal changes of EASM**

East Asian Summer Monsoon (EASM) is a complex system in which the **air-sea interaction** shouldn't be neglected (Wang et al. 2005). Its decadal variations are largely influenced by **SST variations** (e.g. PDO) (Yu et al. 2015)

## Two types of simulation for EASM

### CMIP-type

#### Advantages

- Fully coupled model
- **Air-sea interaction**
- Real external forcing: GHGs, aerosols...

#### Disadvantages

- cannot capture the real internal variability of climate system, **variations of SST**

### AMIP-type

#### Advantages

- **Forced by the real SST**

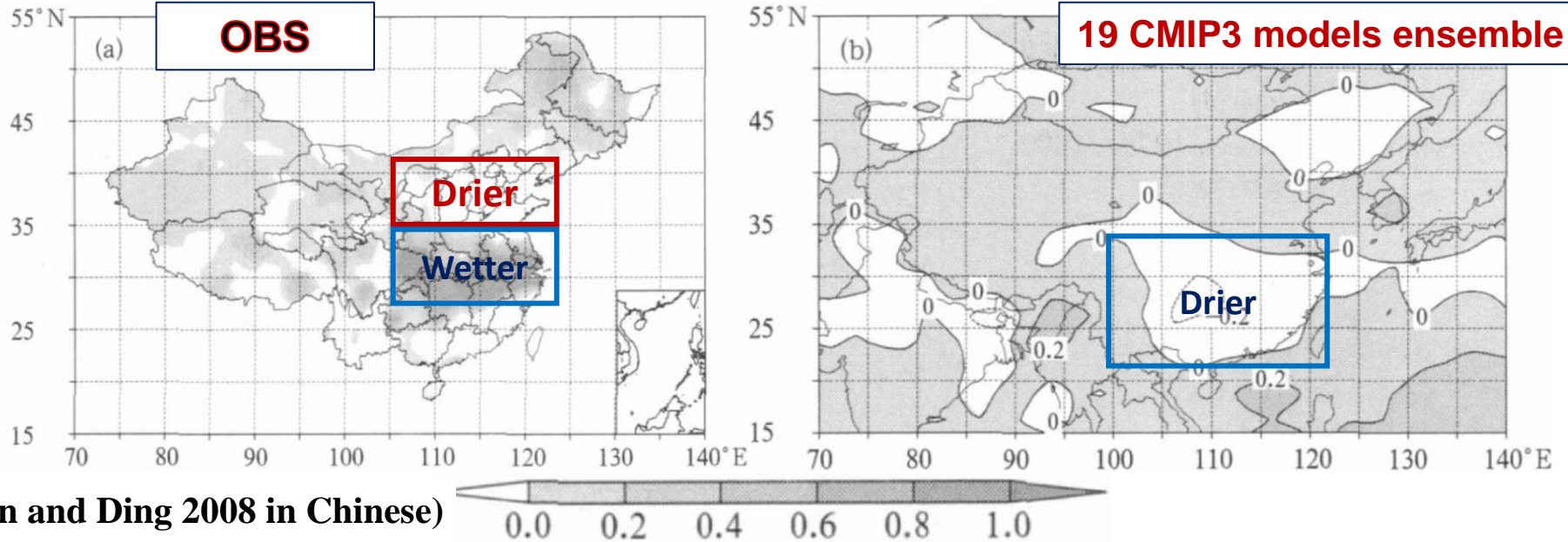
#### Disadvantages

- **Stand-alone atmospheric model**
- **break air-sea interaction**: lack the atmospheric feedback to the ocean



# Difficulty in simulating **decadal change of EASM**

Decadal change of Prec. 1979-1999 minus 1958-1978



(Sun and Ding 2008 in Chinese)

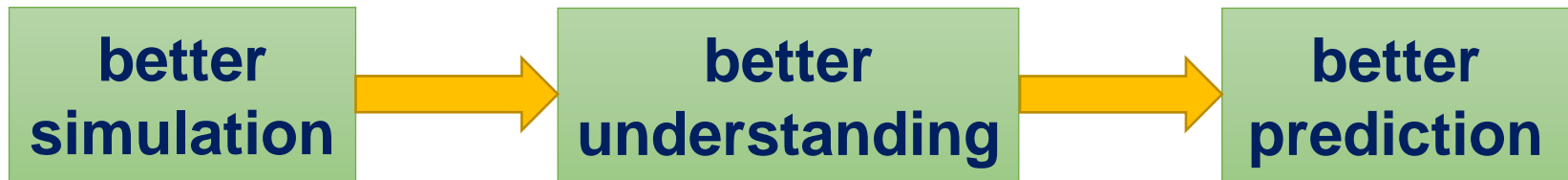
**OBS:** wetter-south-and-drier-north pattern over the eastern China.

**CMIP historical exp.** (using real external forcing): low skills (right Figure)

**Neither coupled climate model (CGCM) nor stand-alone atmospheric model (AGCM) can reveal the real decadal variation of EASM, even they've used real external forcing or observed SST and sea ice**

# Motivation

**Applying ocean data assimilation in a coupled climate model, to capture the oceanic variations without breaking air-sea interaction, and finally improve EASM simulation**



# outline

**1** Motivation

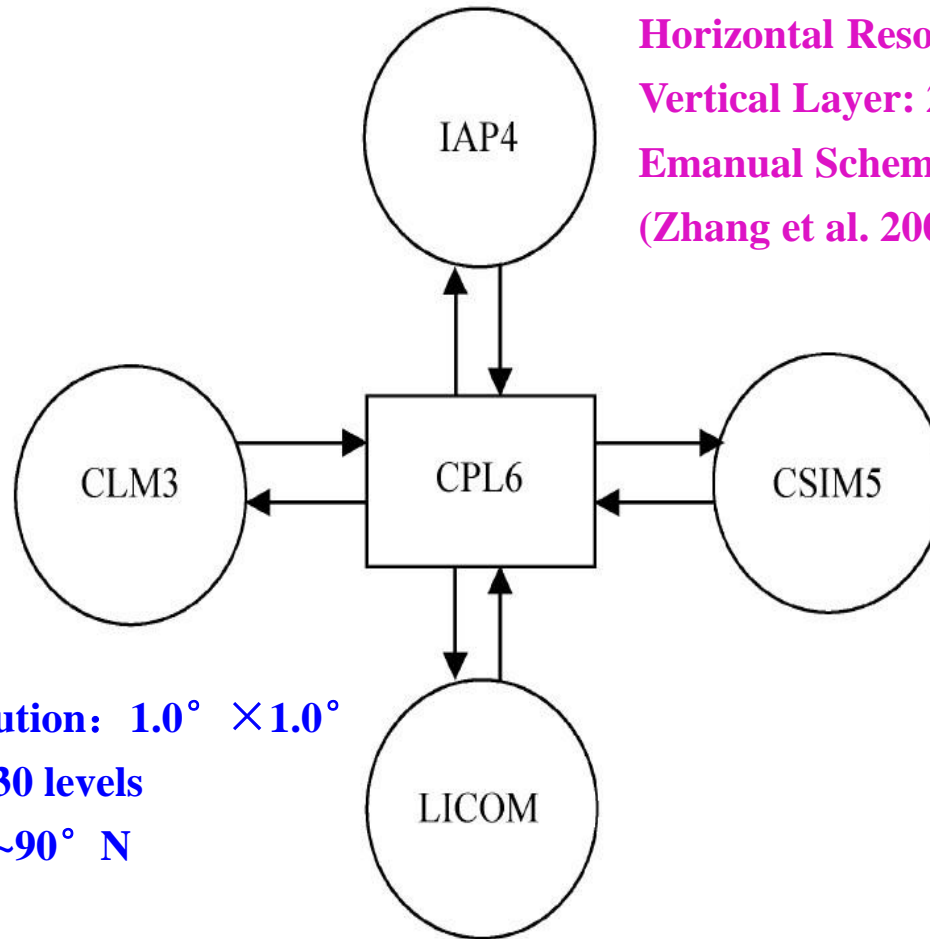
**2** Evaluation

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# Model Introduction: CAS-ESM-C



Horizontal Resolution:  $1.4^{\circ} \times 1.4^{\circ}$

Vertical Layer: 26 levels

Emanuel Scheme

(Zhang et al. 2009; 2011)

Horizontal Resolution:  $1.0^{\circ} \times 1.0^{\circ}$

Vertical Layer: 30 levels

Domain:  $79^{\circ} \text{ S} \sim 90^{\circ} \text{ N}$

(Liu et al. 2004)

fully coupled climate system model developed by Institute of Atmospheric Physics (IAP)



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# Two types of Experiment

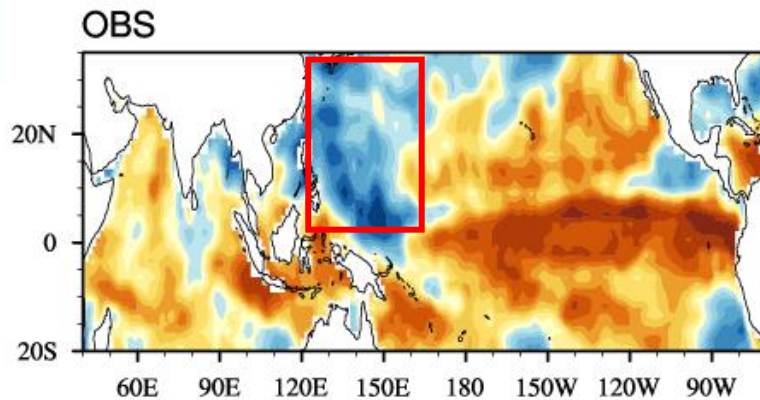
Name	Model	Experiment	Time Period
SST_Assim	CAS-ESM-C	assimilate SST	1981-2014
AMIP	IAP AGCM4	historical SST forcing	1979-2014

Although only SST field is assimilated, **the oceanic fields**, i.e. SSH, T, S, U and V current, **will adjust dynamically based on background error covariance**





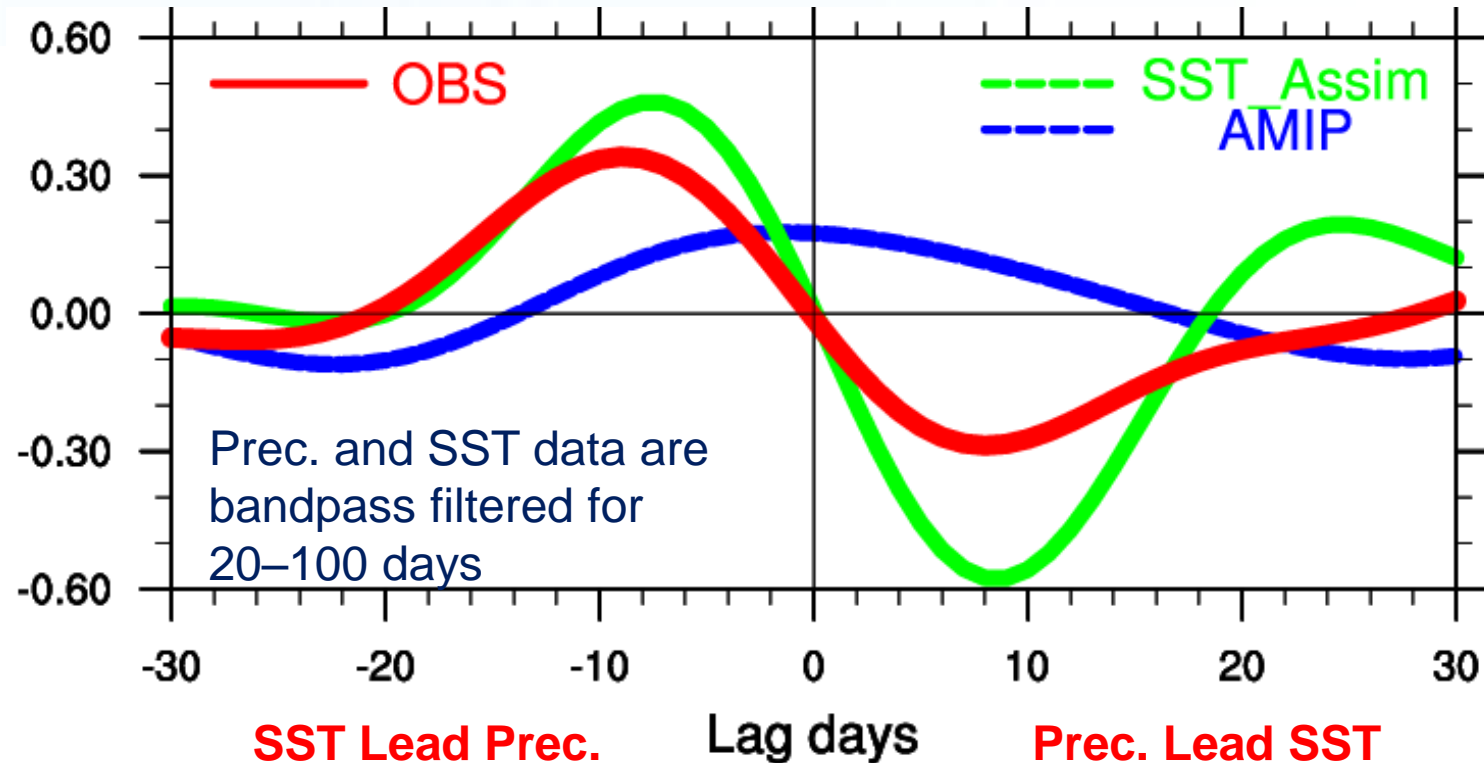
# Correlation between SST and Prec. in JJA



The local SST and Prec. anomalies are **positively correlated** in most tropical area. While **negatively correlated** in the western North Pacific (WNP) region.

- **Positive correlation** means the **ocean plays a major role** in determining atmospheric response
- **Negative correlation** means the **atmosphere affects SST** more than SST affects the atmosphere
- **In the WNP and East Asian monsoon regions**, The atmospheric feedback play a major role in determining local SST

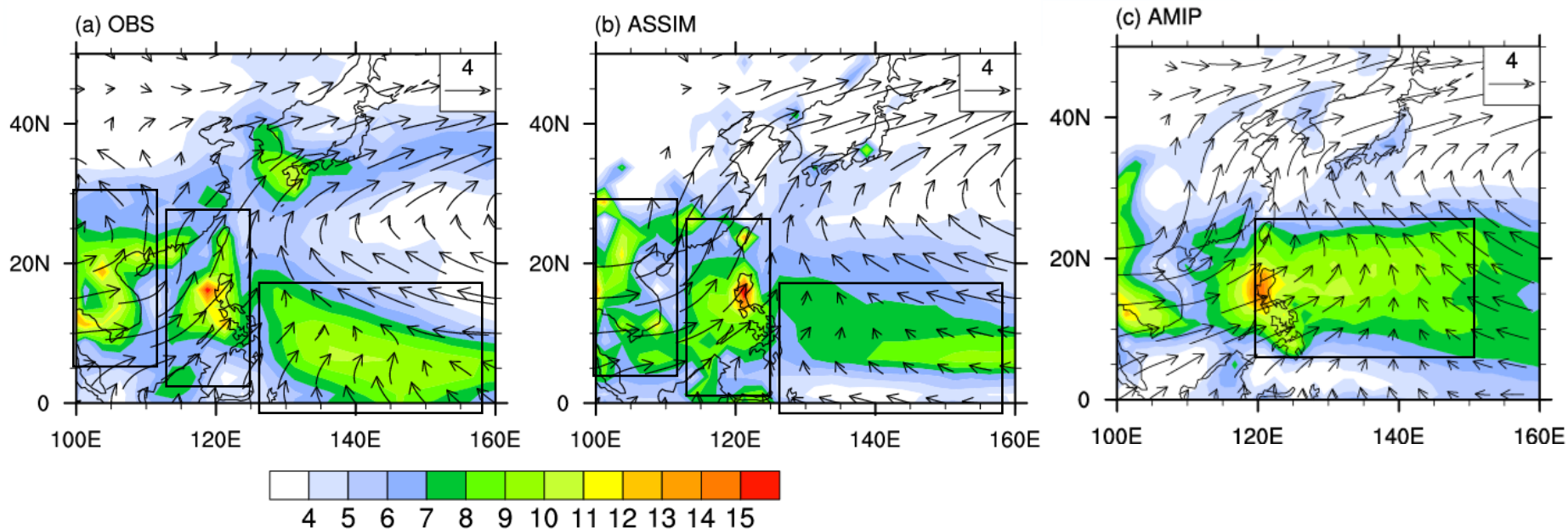
# Intra-seasonal Lead or Lag correlations between SST and Prec. In WNP region



- **obs. and SST\_Assim**: positive (negative) SST leads (lags) prec. by 10 days
- **AMIP**: positive SST is almost in phase with rainfall
- On intraseasonal scale, AMIP reveal wrong air-sea relationship



# The Climatology of JJA Prec. and UV850

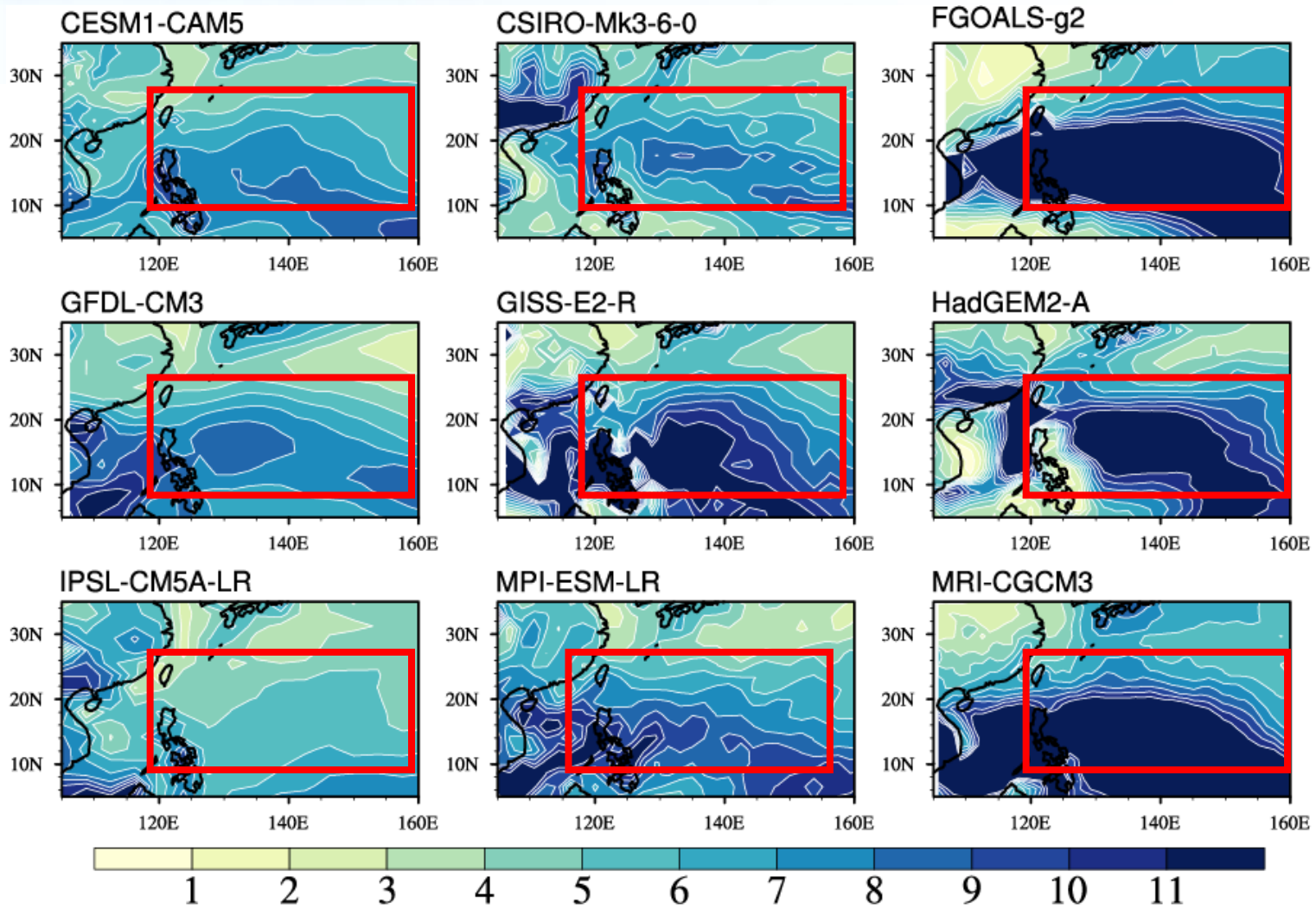


**SST\_Assim** can reasonably reproduce the three precipitation centers in low latitude.

**The AMIP** underestimate the precipitation along the monsoon rain-band and overestimate precipitation over the South China Sea.

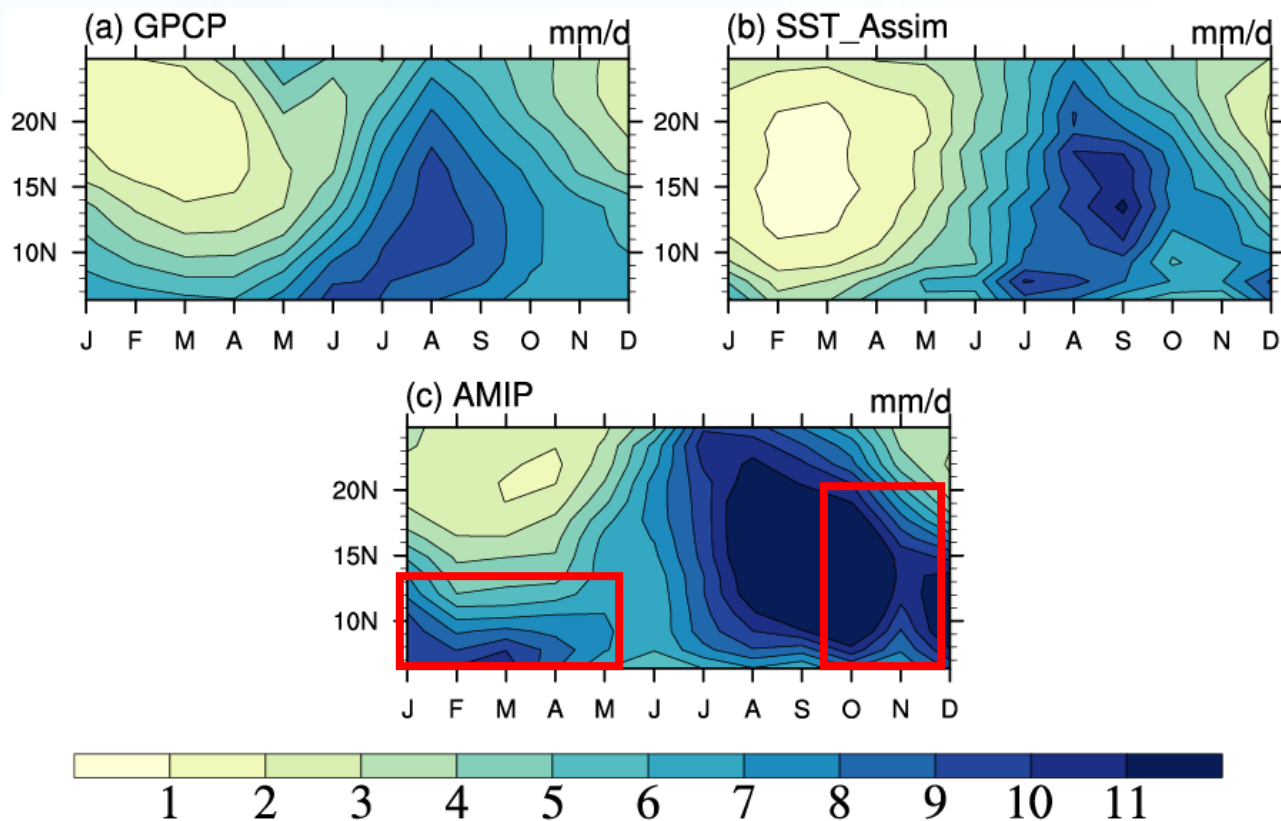


# Other AMIP results from CMIP5 models



Similar biases are also evident in other CMIP5 models

# Annual cycle of Prec. Over WNP

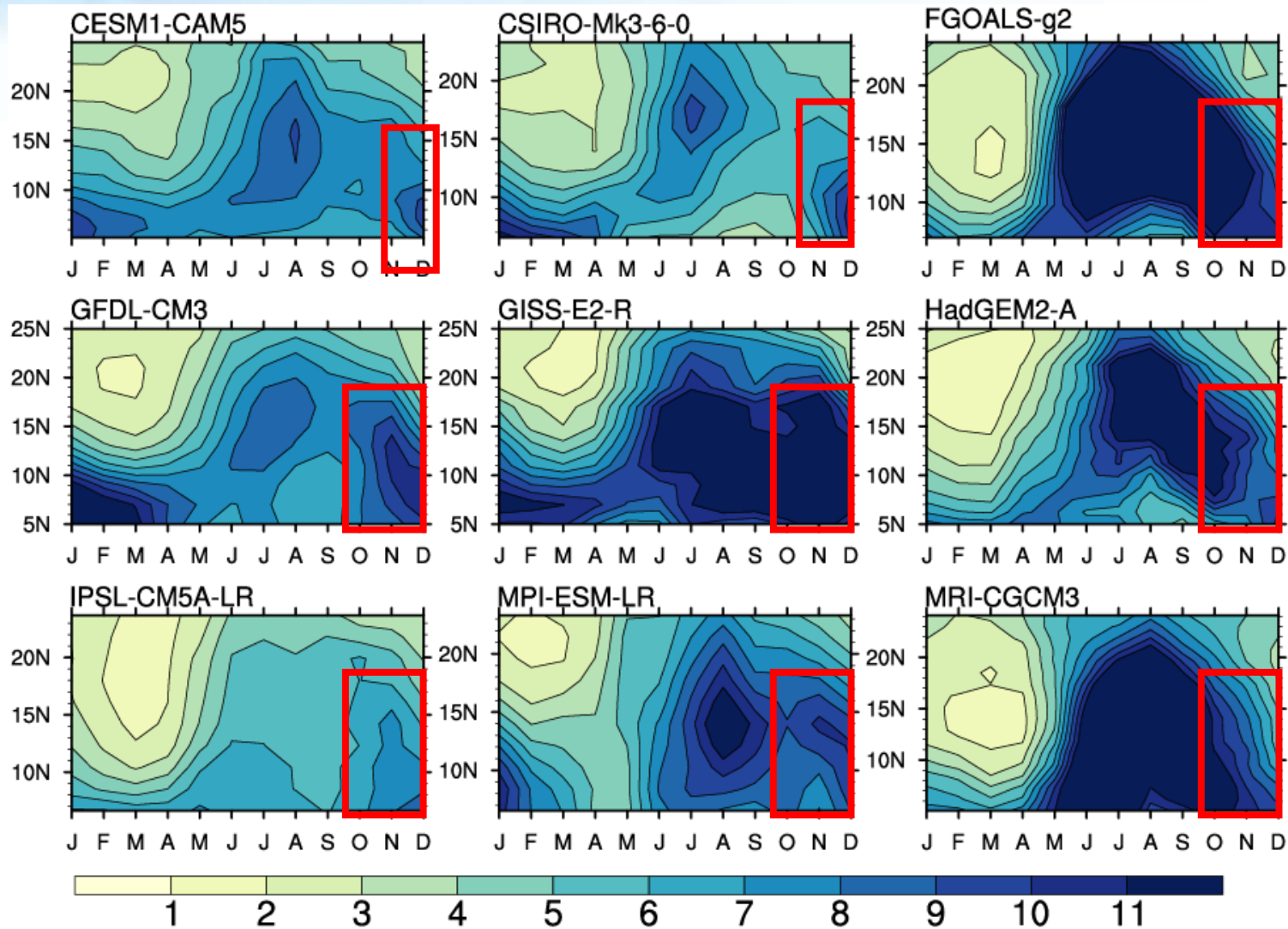


**SST\_Assim** reasonably reproduce the annual cycle of prec. over WNP region.  
**AMIP** overestimate the precipitation in boreal winter and spring.





# Other AMIP results from CMIP5 models



**Similar overestimation of boreal winter precipitation is evident in other CMIP5 models**

# outline

**1** Motivation

**2** Evaluation

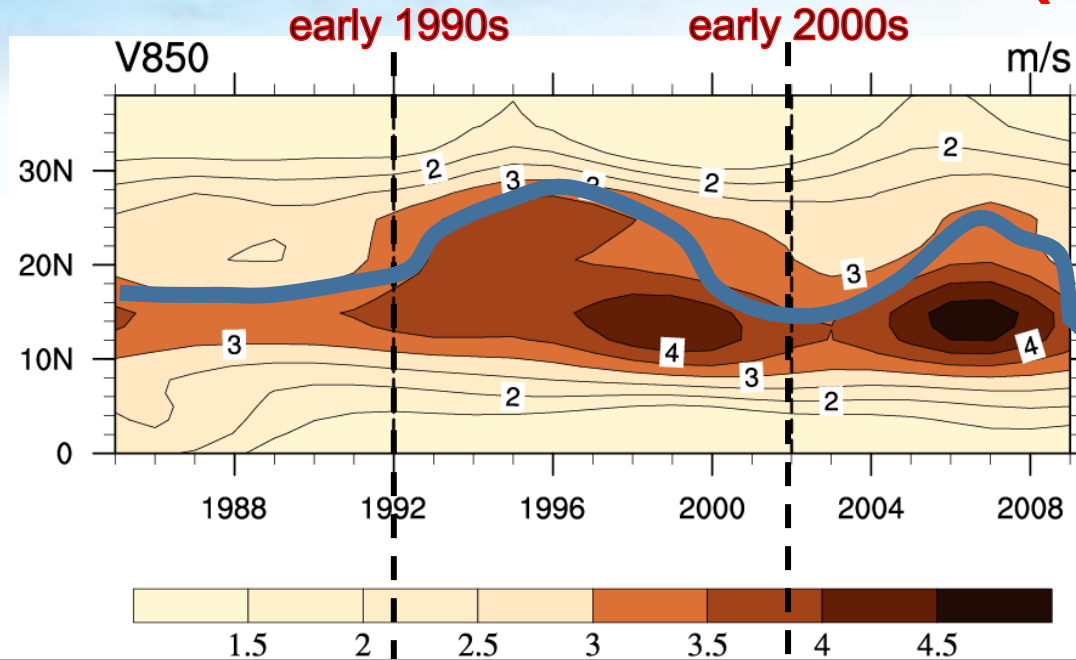
 **3** Decadal Variation of EASM

**4** Conclusions



# Decadal variations of EASM (OBS)

JJA south  
wind



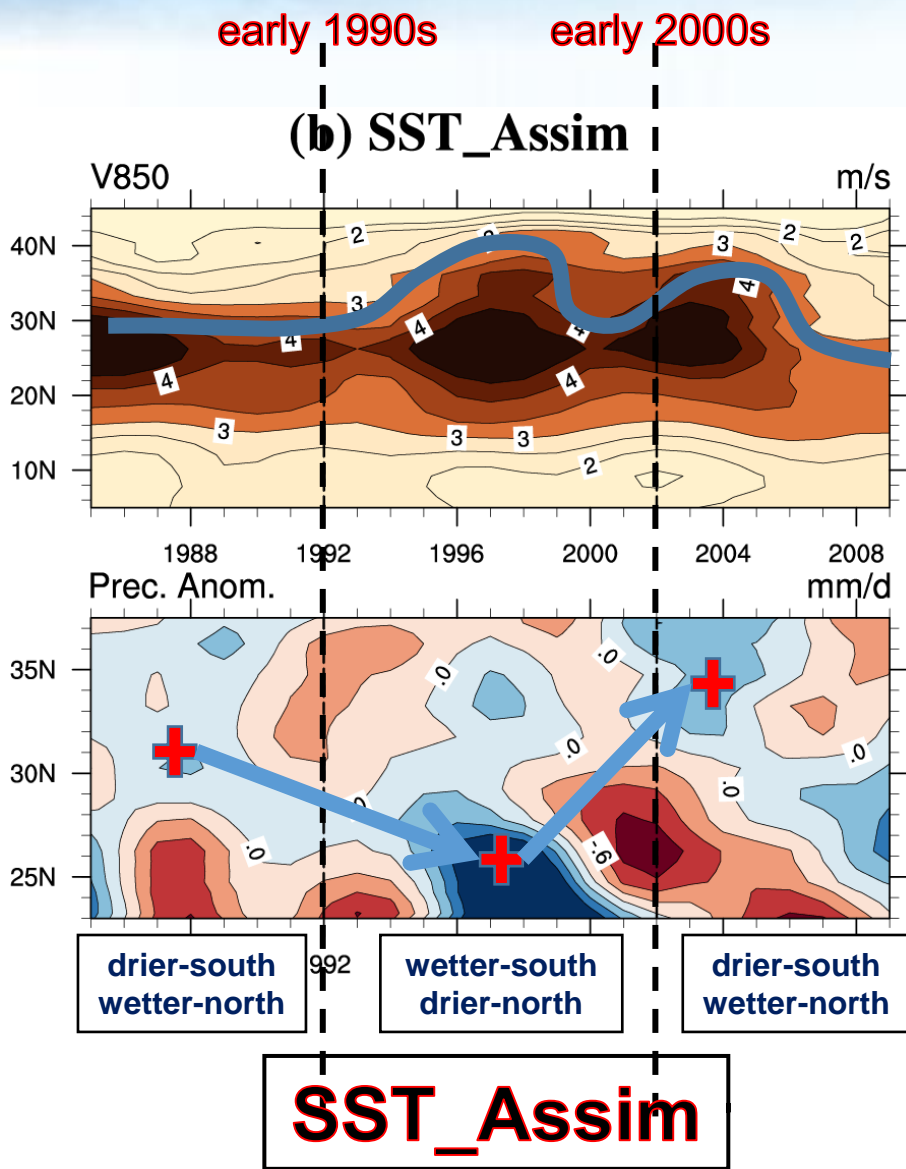
East China  
 $110^{\circ}E \sim 120^{\circ}E$

The 7-year low-pass  
filter is applied to  
suppress the  
interannual variability

- Evolution of JJA mean wind-850hPa; X Axis is time; Y Axis is latitude
- It reflects the evolution of EASM
- There are two marked decadal changes.
  - Since early-1990s: an increasing and northward shift of low-level south wind over East China → a decadal strengthening of EASM
  - another decadal variation take place in the early-2000s



# Decadal variation of EASM (SST\_Assim& AMIP)



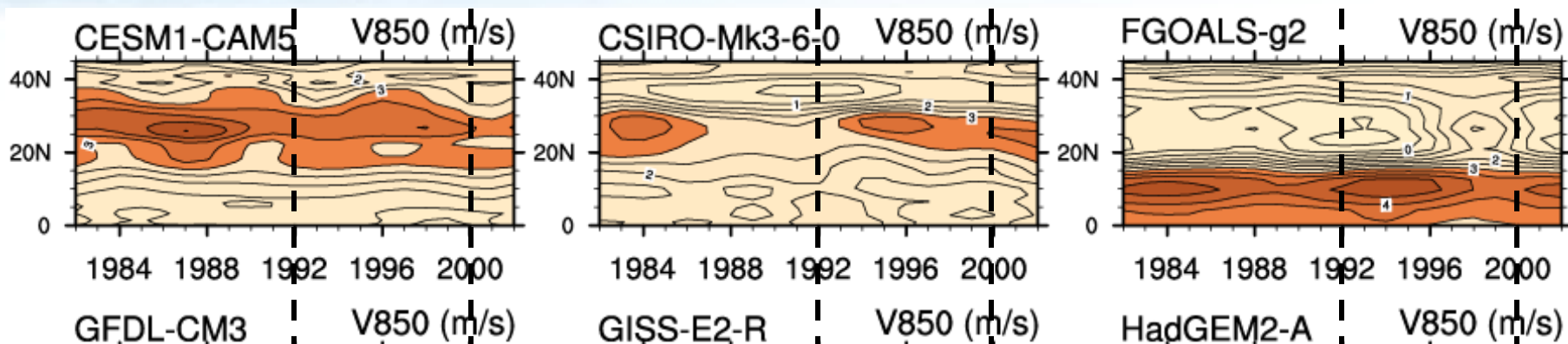
The results of SST\_Assim  
(**good simulation!**)

Main substantial features in the obs.  
are well captured

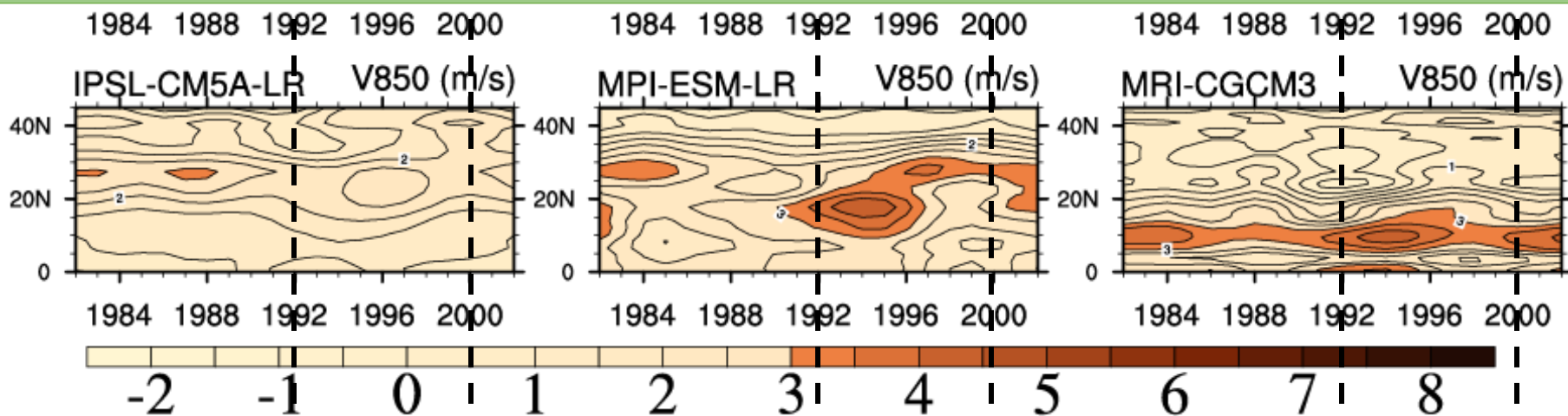
- the enhancing and northward shift of low-level southerly wind since the early 1990s
- the southward shift of the East Asian rain belt since the early 1990s
- The positive prec. anomalies over southeastern China in the 2<sup>nd</sup> decadal period is evident.



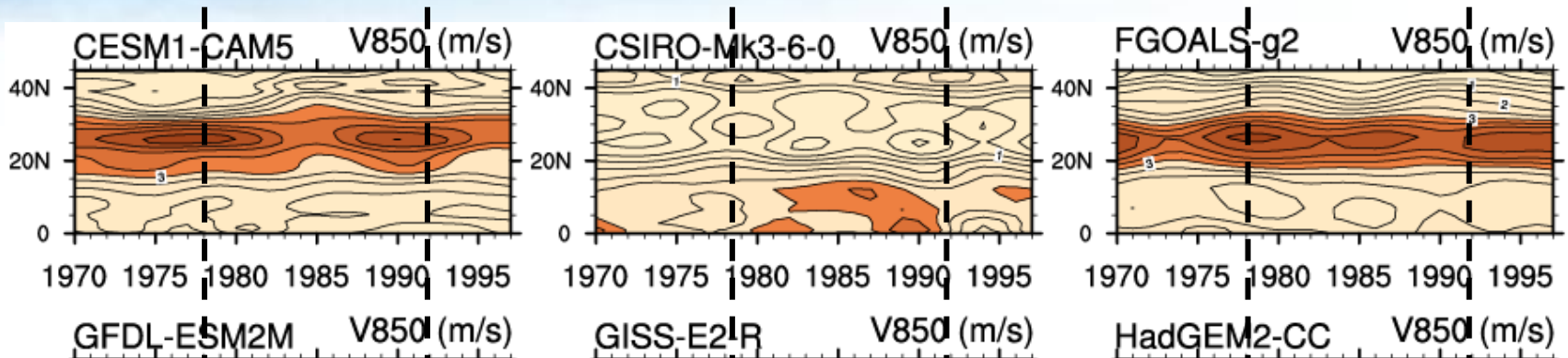
# Other AMIP results from CMIP5 model



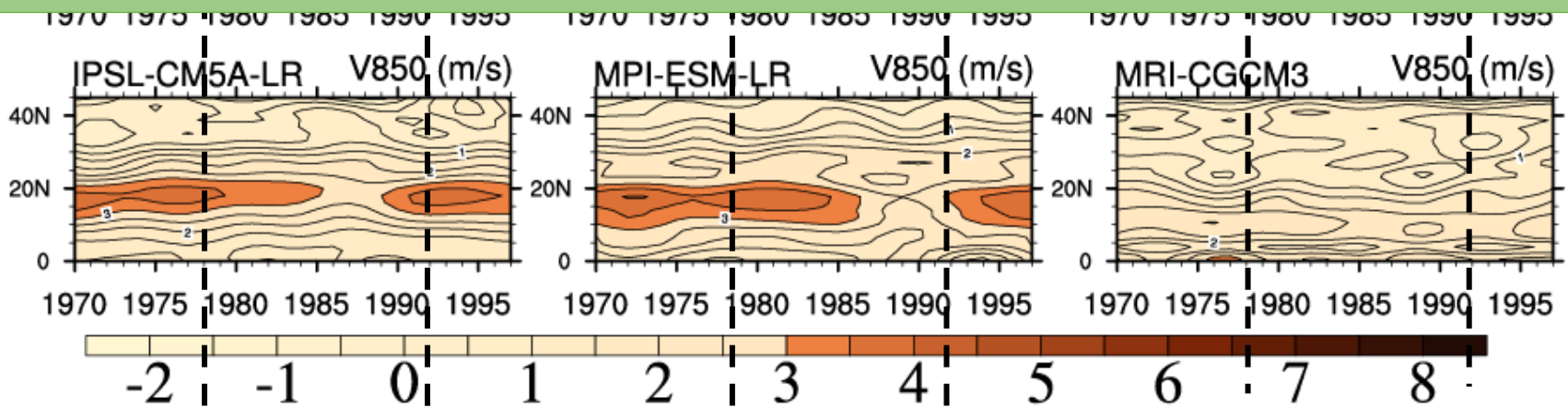
Other stand-alone atmospheric model also cannot capture the observed decadal variations of EASM



# Other Coupled model results from CMIP5



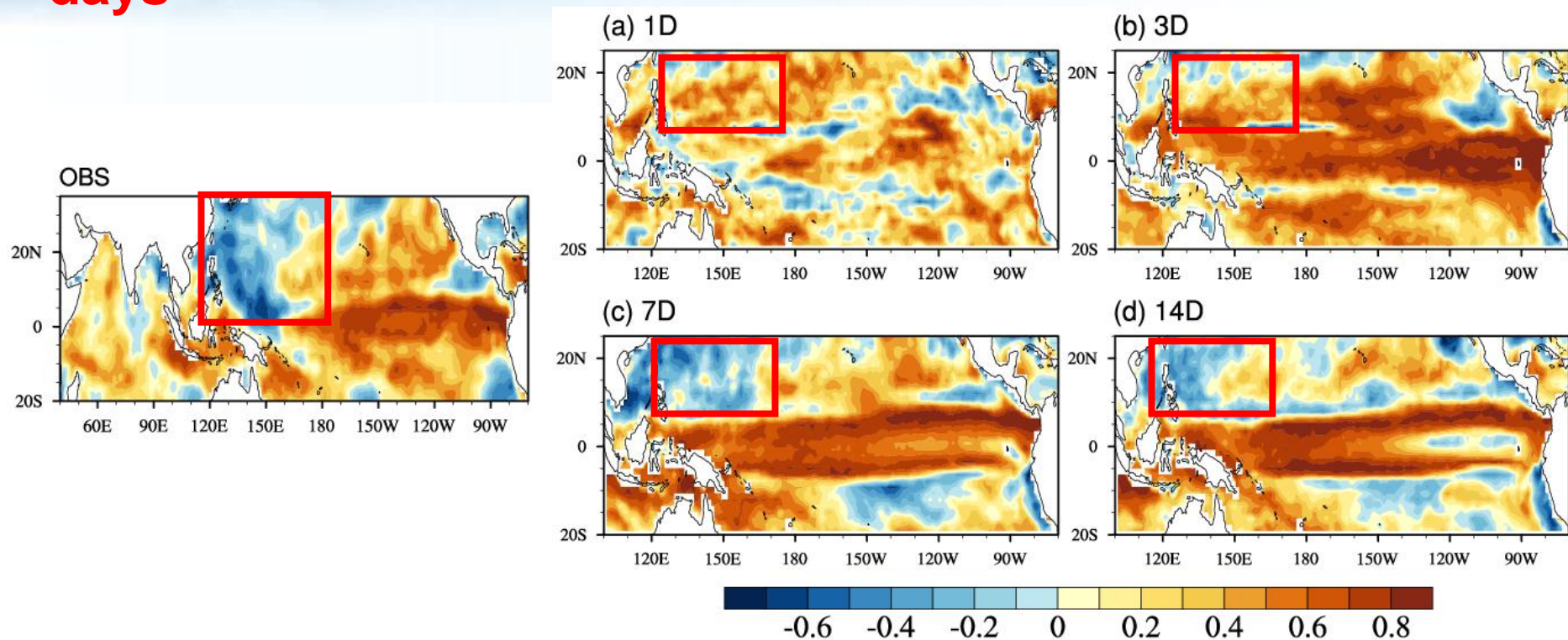
**Coupled climate model cannot capture the decadal variations of EASM with external forcing**



**All-forcing run** are forced by both natural (solar variability and volcanic aerosols) and anthropogenic forcings (GHG and anthropogenic aerosols)



# Worth noting: in our exp., The SST is assimilated **every 7 days**



- The 1-day and 3-day exp. cannot reproduce the observed negative SST-rainfall correlation.
- The **7-day** and longer intervals reproduce the observed negative correlation.



# outline

**1** Motivation

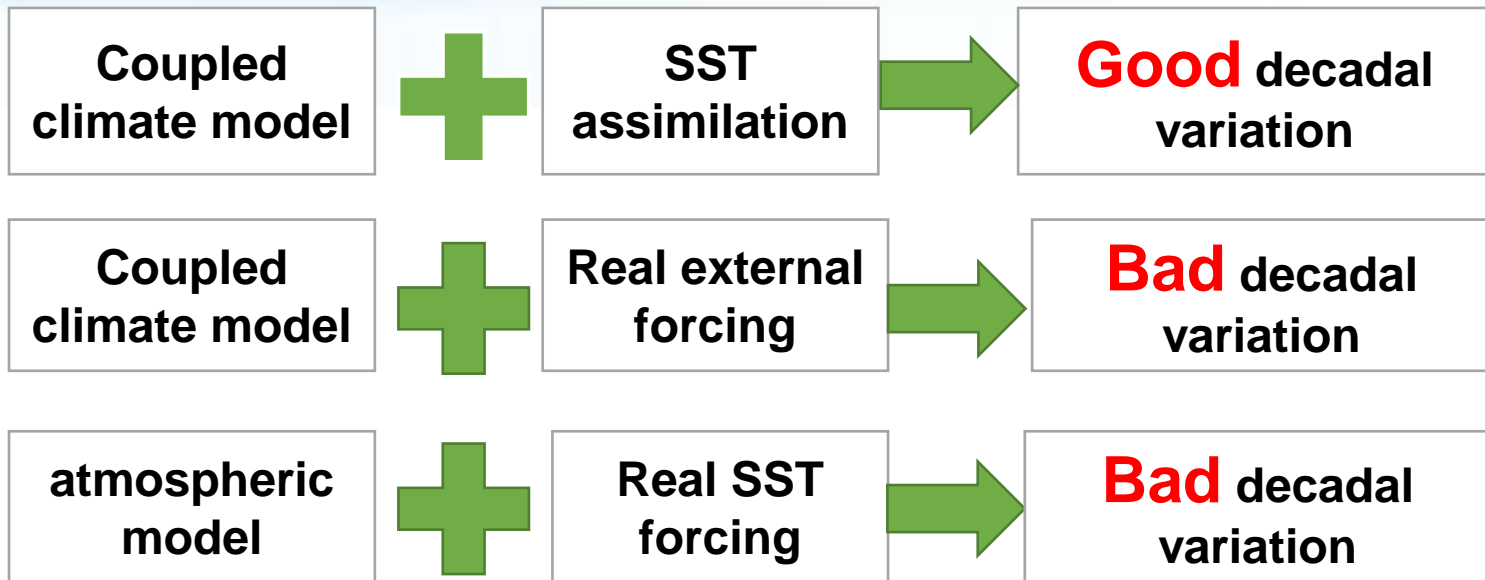
**2** Evaluation

**3** Decadal Variation of EASM

 **4** Conclusions



# Conclusions



- Failure of AMIP\_type is the lacking of air-sea interaction
  - Failure of CMIP\_type is that using only external forcing cannot capture the decadal variations of oceanic field.
  - Applying ocean data assimilation to a coupled climate model
    - input the real SST variations
    - Not break air-sea interaction
- ➔ **Right decadal variation**



***Thank you!***

Thanks for your attention



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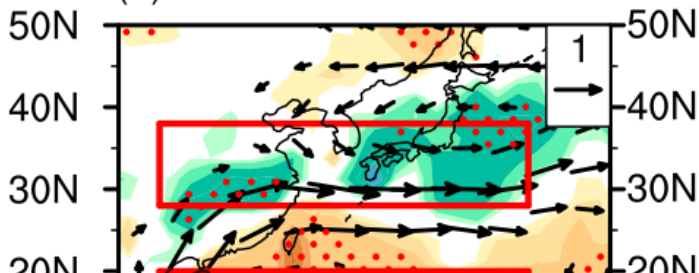
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# Difficulty in simulating **Interannual Variability**

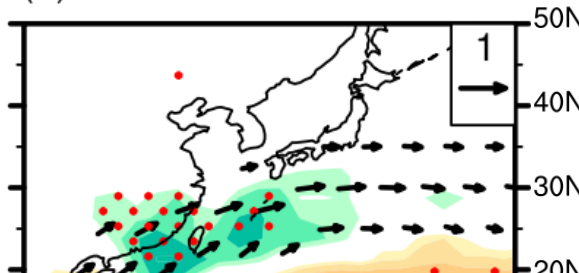
**OBS**

(a) GPCP/NCEP2



**AMIP runs**

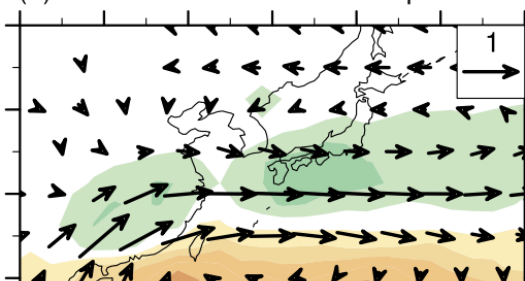
(a) MME



**Historical runs**

(b) MME

pr&uv850



**CGCM can better simulate the interannual variability of EASM rather than AGCM.**

**Because ENSO is an internal variability of climate system, CGCM is impossible to reproduce real ENSO variability with actual timing without inputting observed information.**

pattern. The dominant mode occurs in the decaying phase of ENSO (Wang et al. 2008)

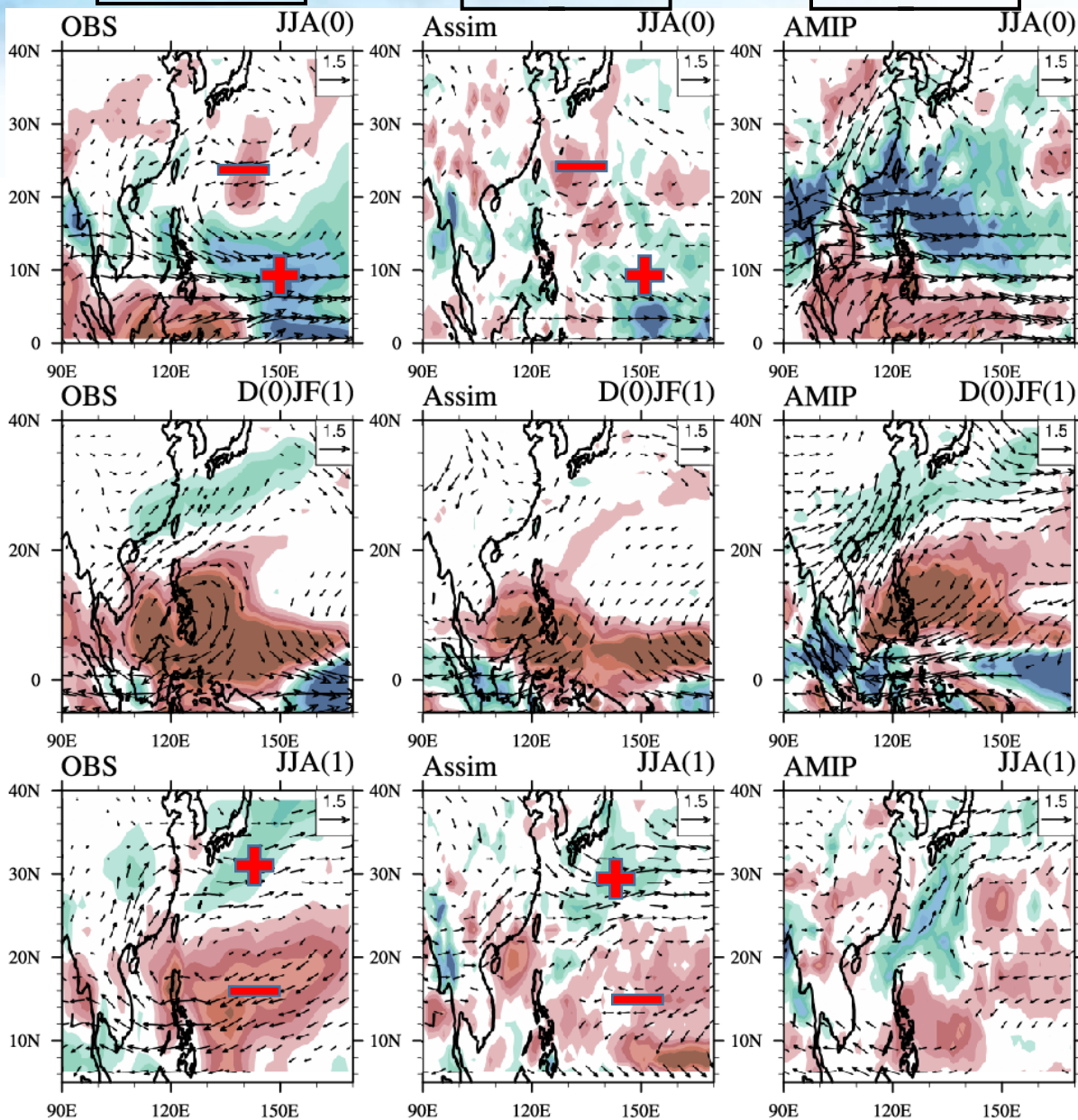
- In **AMIP runs**, the rainfall pattern is poorly simulated by AGCM.
- In **historical runs**, the interannual EASM pattern is better simulated by CGCM.

观测

同化

AMIP

观测的  
Nino3.4指数回归的  
850-hPa  
风和降水  
异常



发展年  
夏季

成熟期  
(DJF)

衰减年  
夏季

理研究所

Academy of Sciences

# outline

**1 Motivation**

**2 Evaluation**

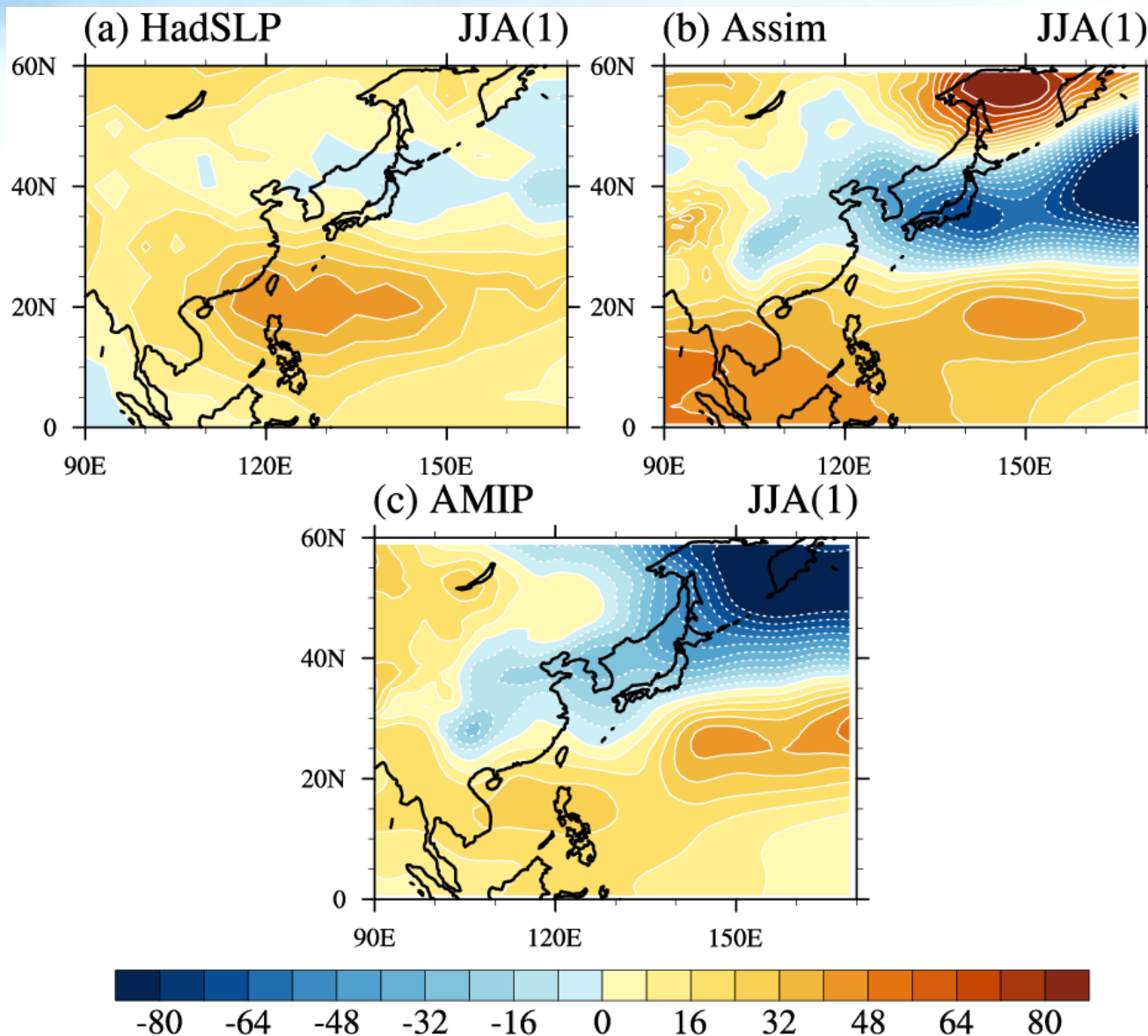
 **3 Decadal Variability**

**4 Interannual Variability**

**5 Conclusion**



# 观测的Nino3.4指数回归的海平面气压异常



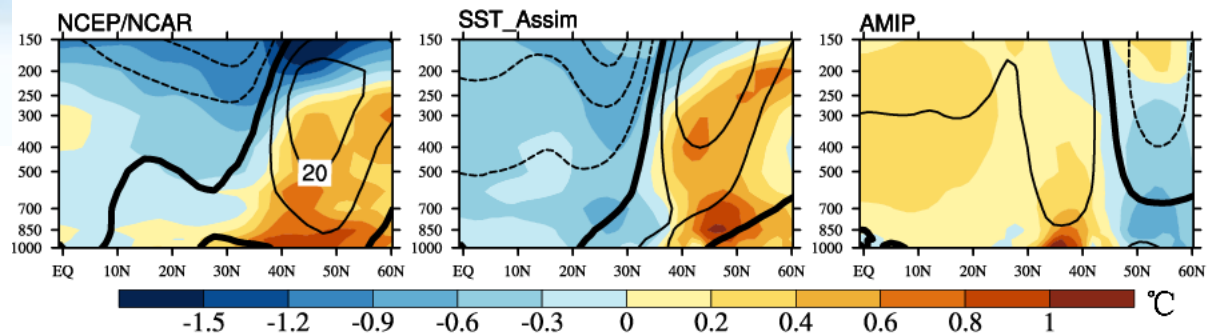
- **A shorter time interval less than 7 days** may interrupt the atmospheric feedback process and destroy the persistence of atmospheric disturbance
- **A time interval longer than 7 days** will constrain the ocean fields with fewer observations.
- Therefore, we believe that **the 7 days' time interval is suitable in our simulation.**



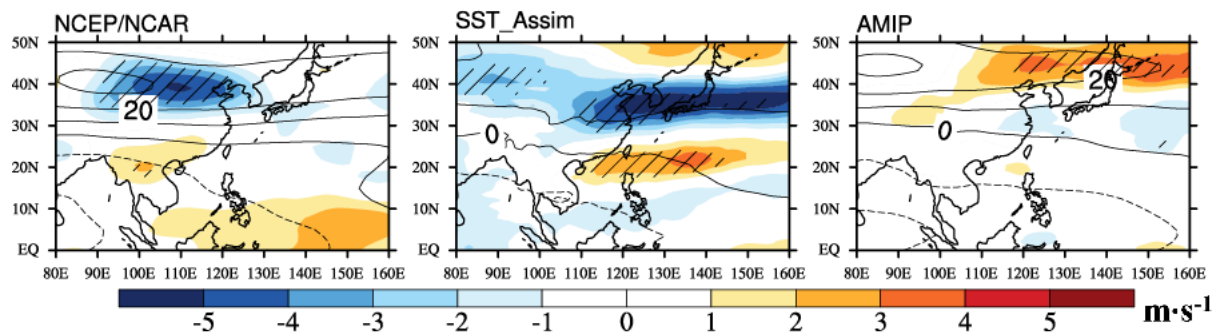


# Decadal Change of EASM Rainband (SST\_Assim& AMIP)

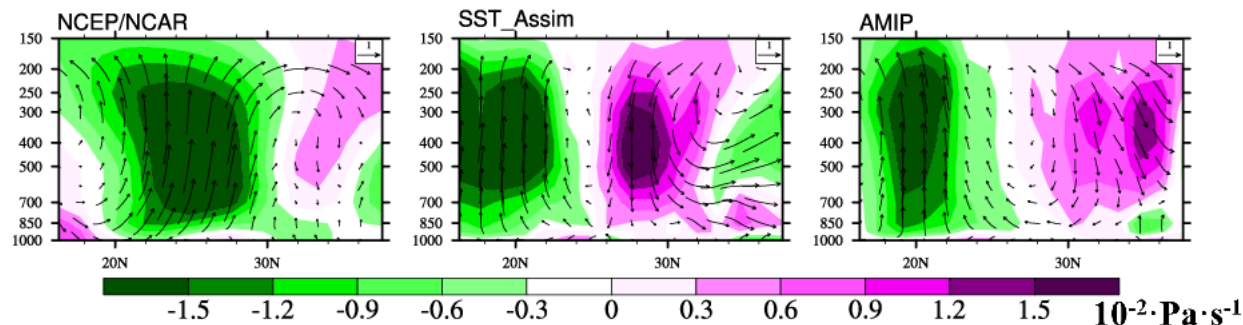
(a) H (contour) and T (shaded)



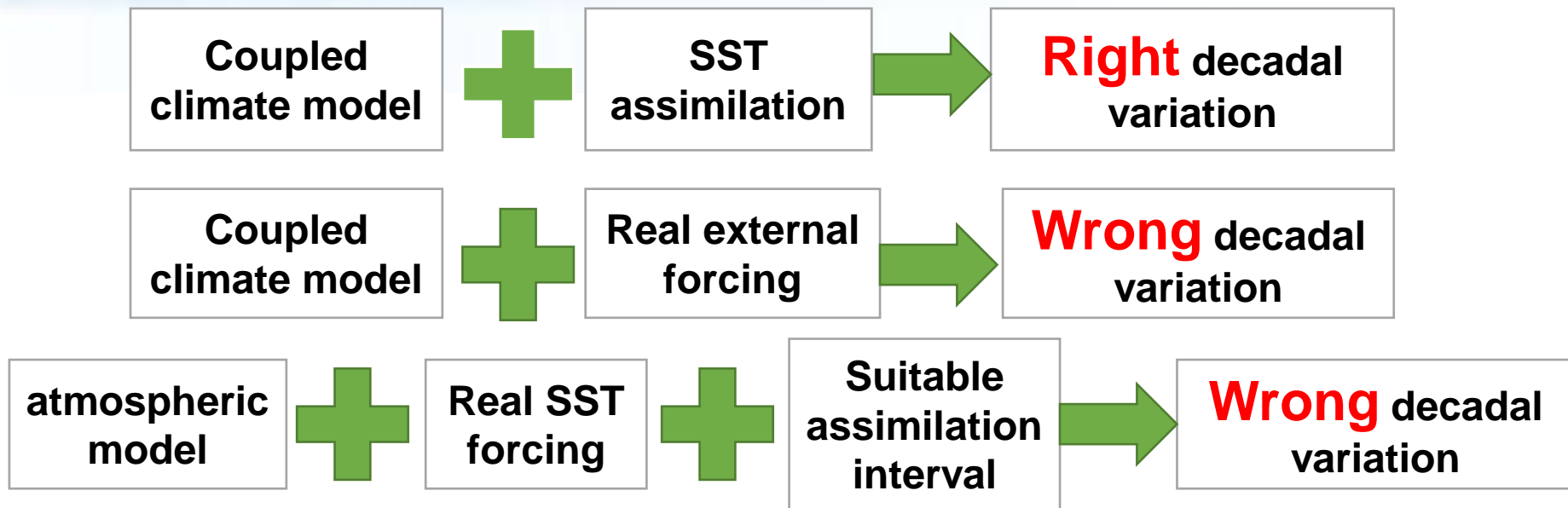
(b) U200 anomalies (shaded) & climate (contour)



(c) Meridional wind (vector) & OMEGA (shaded)



# Conclusions

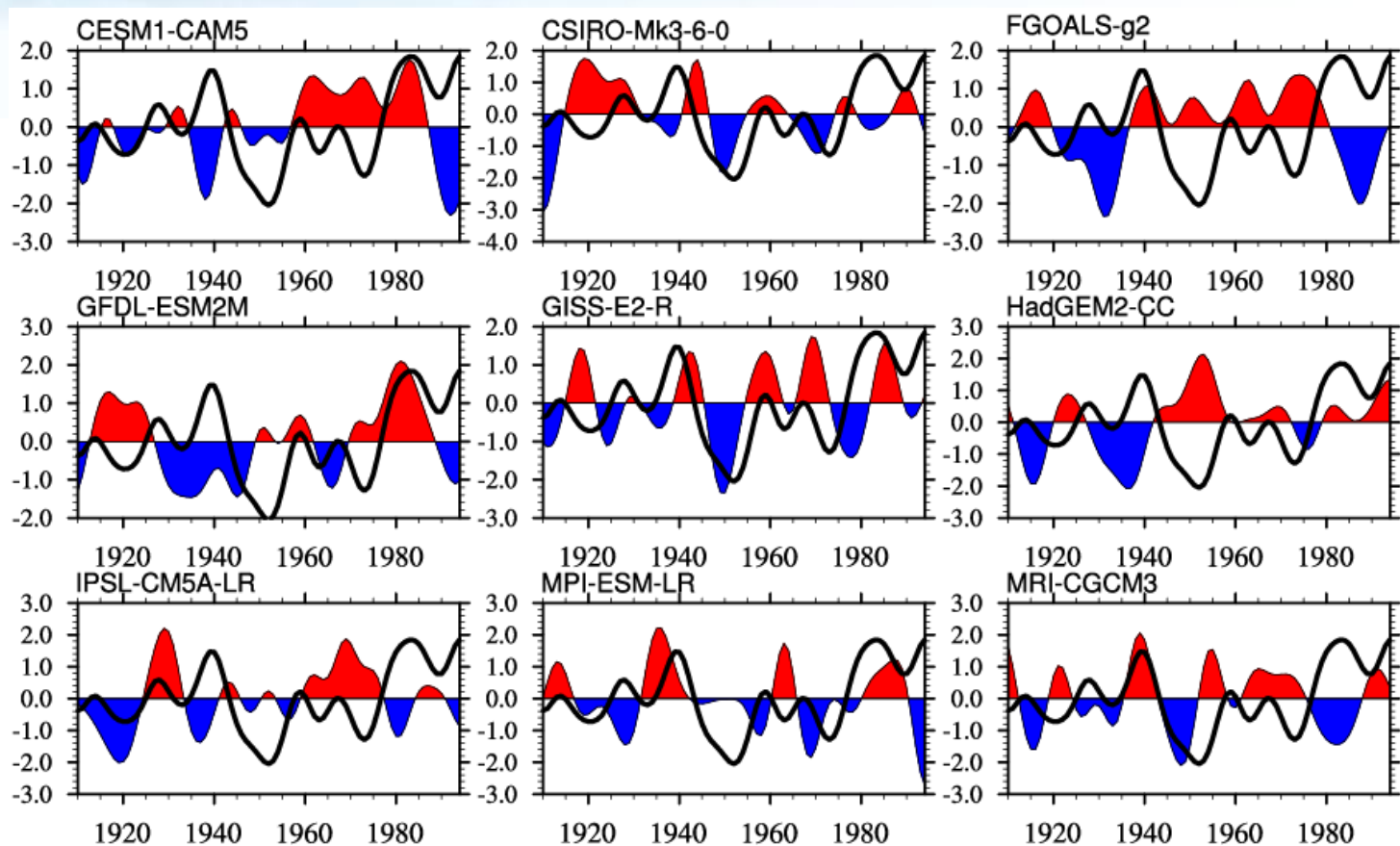


- Failure of AMIP run is the lacking of air-sea interaction
  - Failure of all forcing run is that using external forcing cannot simulate the internal variability of climate system
  - Applying ocean data assimilation to a coupled climate model
    - input internal variability signal
    - Not break air-sea interaction
- ➔ **Right** decadal variation





# PDO index of CMIP5 all forcing run (1900-2005)



- The black curves indicate the observed PDO index.
- The simulated PDO indices of CMIP5 models are at odds with observation

