Subseasonal strength reversal of the East Asian winter monsoon

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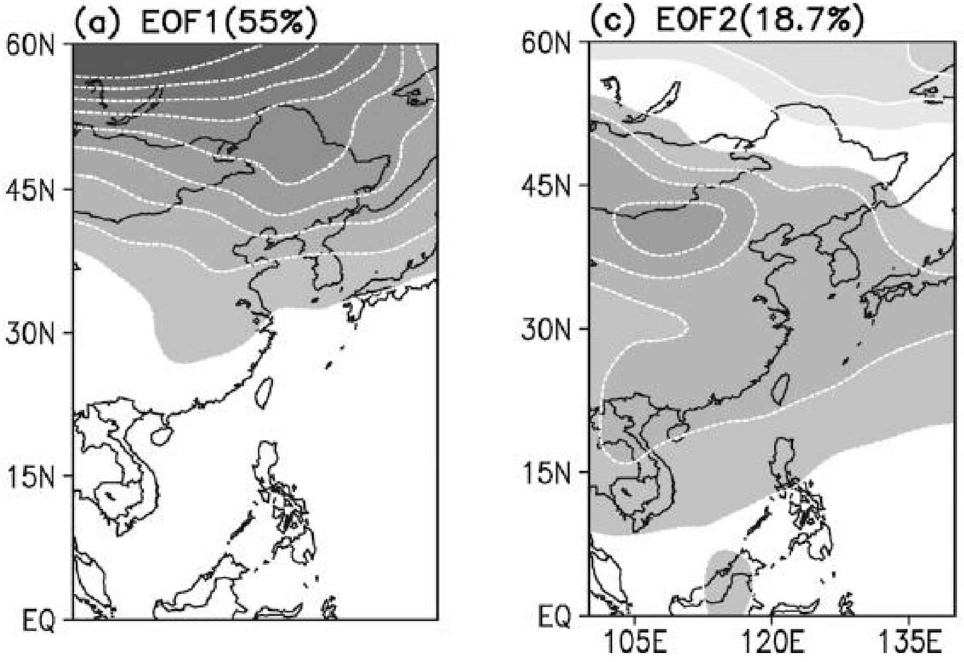
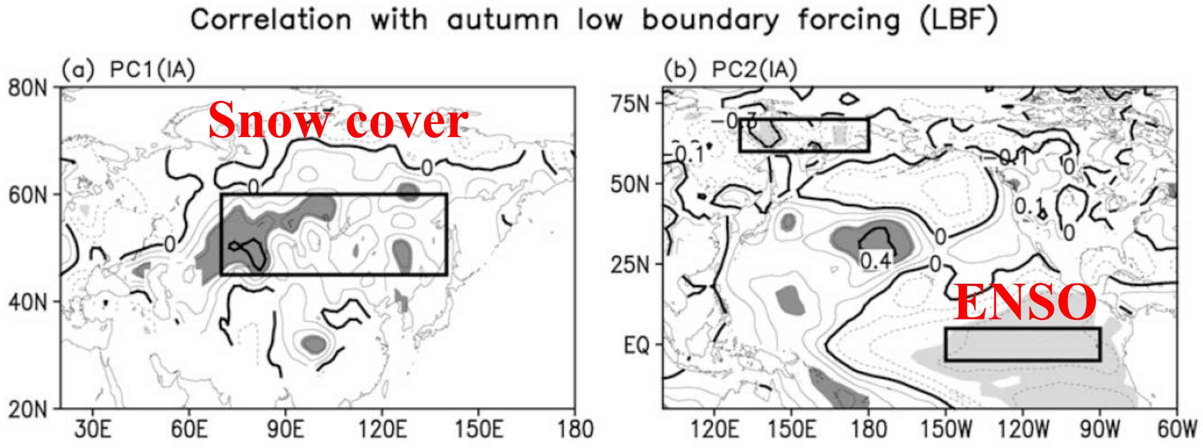
1 Motivation

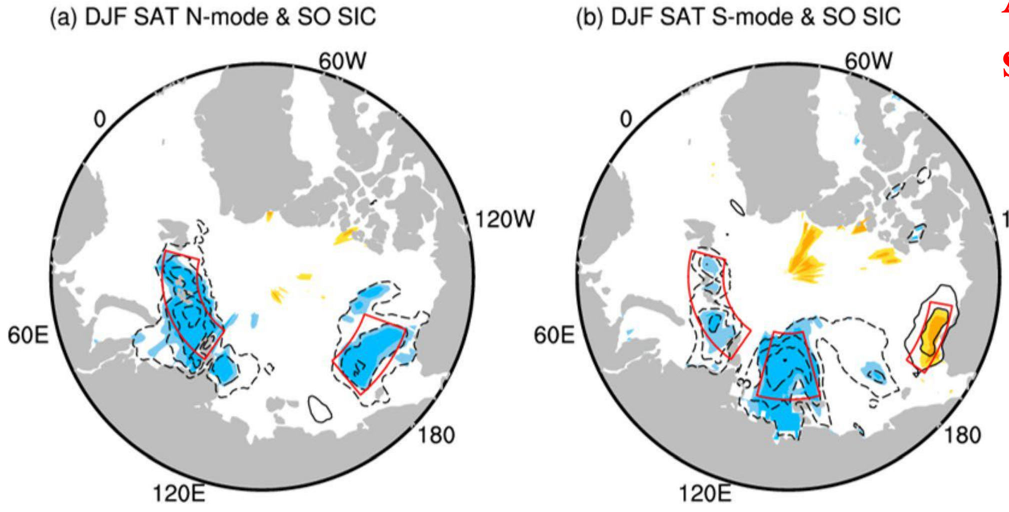
- Importance of the East Asian winter monsoon (EAWM)
- **Seasonal prediction of the EAWM and SAT variations**

Northern Mode **Southern Mode**





(Wang et al., 2010)



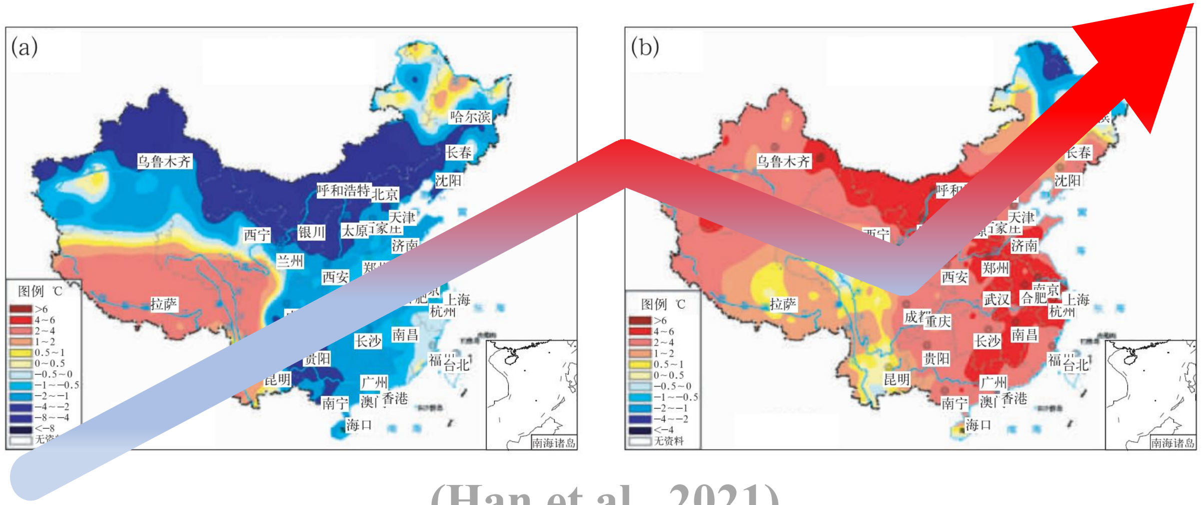
Arctic sea ice

(Zhang et al., 2020)

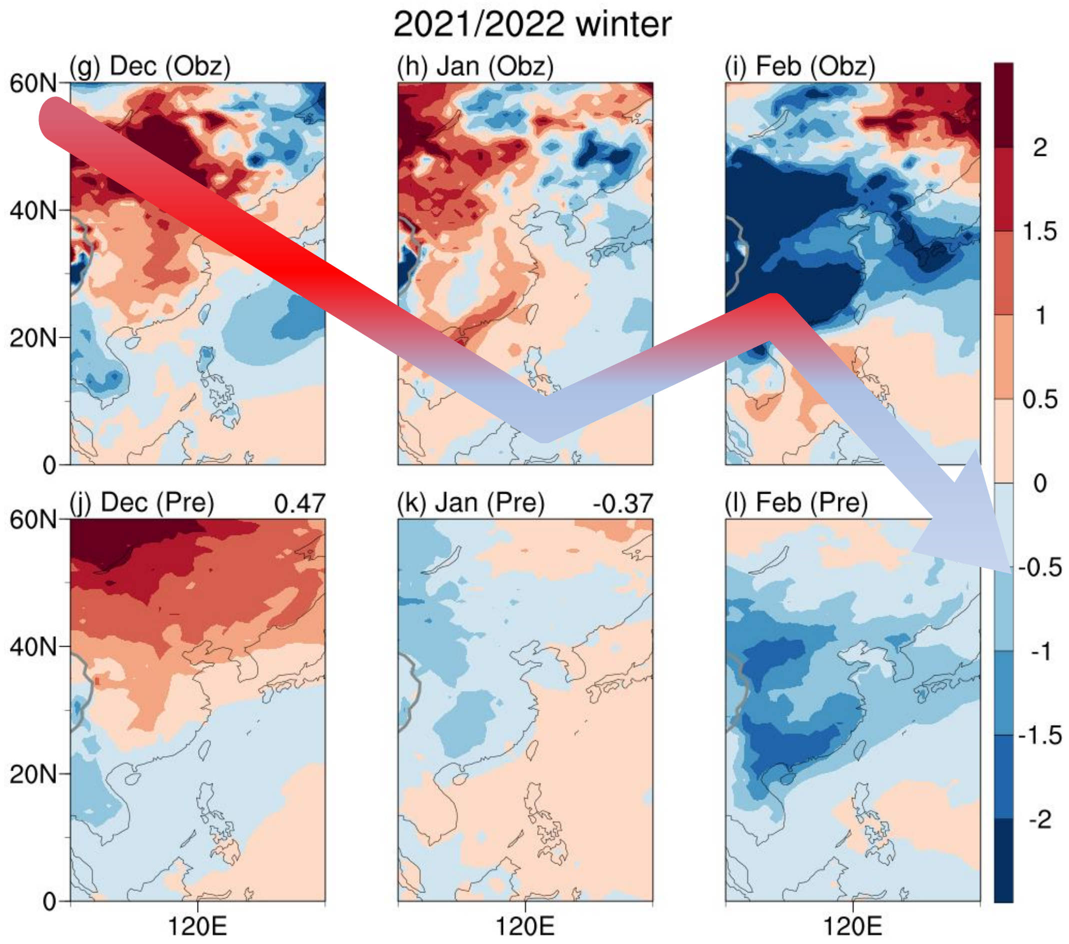
1 Motivation

- A reversal of SAT anomaly (**Icy weather to abnormal warm and vice versa**) occurs more frequently in East Asia during the past winters.

2020/12/1-2021/1/10 **2021/1/13-2021/2/28**



(Han et al., 2021)

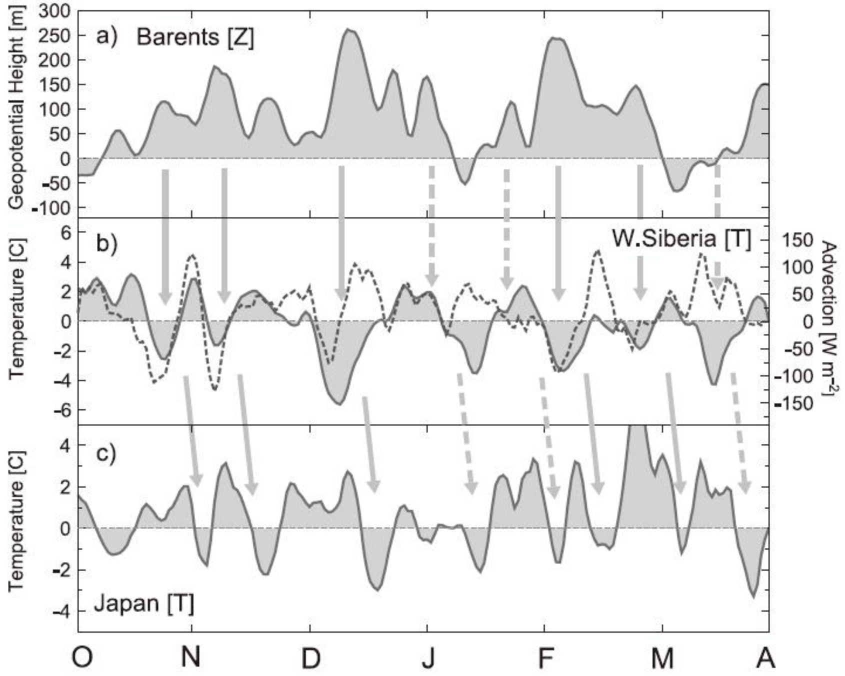


(Zhong and Wu, 2022)

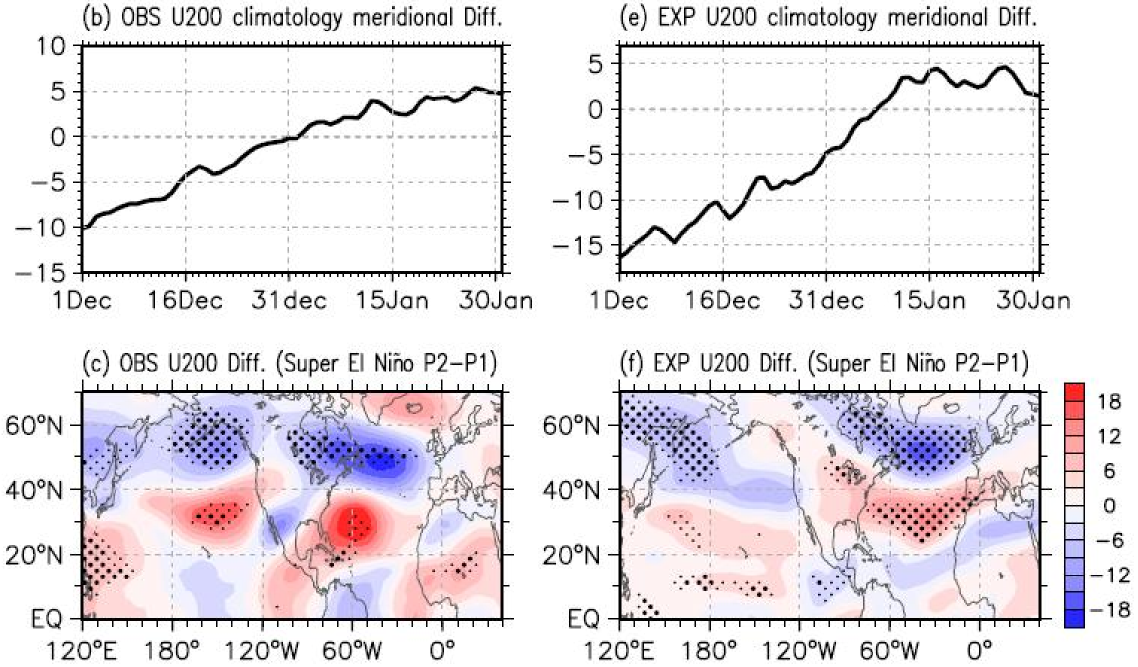
1 Motivation

➢ Some **case studies** suggested that **the subseasonal SAT reversal phenomenon** might be related to changes in the atmospheric condition over the Barents-Kara Sea, super El Niño, the modulation of the Pacific Decadal Oscillation on El Niño and Arctic sea ice. **2014/2015**

2009/2010



(Hori et al., 2011)



2015/2016

(Geng et al., 2017)

1 Scientific questions

- The **leading modes** of subseasonal variations of the EAWM?
- Roles of atmospheric variability and surface boundary conditions?
- How to **predict** subseasonal variations of the EAWM?

2 Data and method

[Data]

Atmospheric circulation | ERA5 reanalysis data **(1979/1980-2021/2022)**

Sea surface temperature | ERSST version 5

Sea ice concentration | HadISST_ice

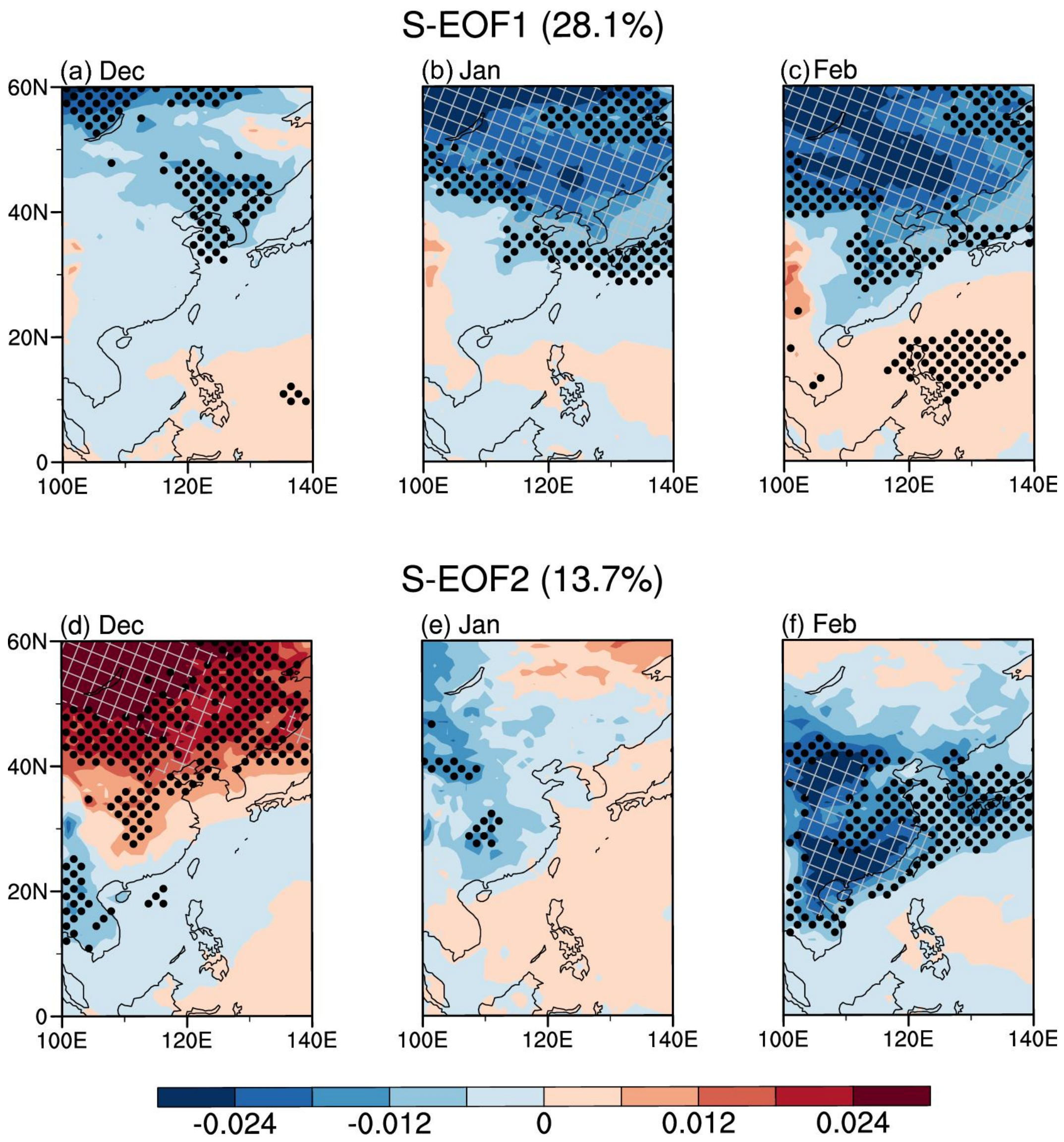
[Method]

Season-reliant Empirical Orthogonal Function (S-EOF) analysis (Wang and An, 2005): to illustrate the **interannual variations** of wintertime SAT with emphasis on the monthly evolving pattern. Gridded SAT anomalies are **detrended**.

[Model]

Linear baroclinic model (LBM): Dry version; applied to solve steady linear equations with a given basic state and a thermal forcing; resolution: T42L20; basic state: **1979–2020** climatology based on ERA5 reanalysis.

3 Results

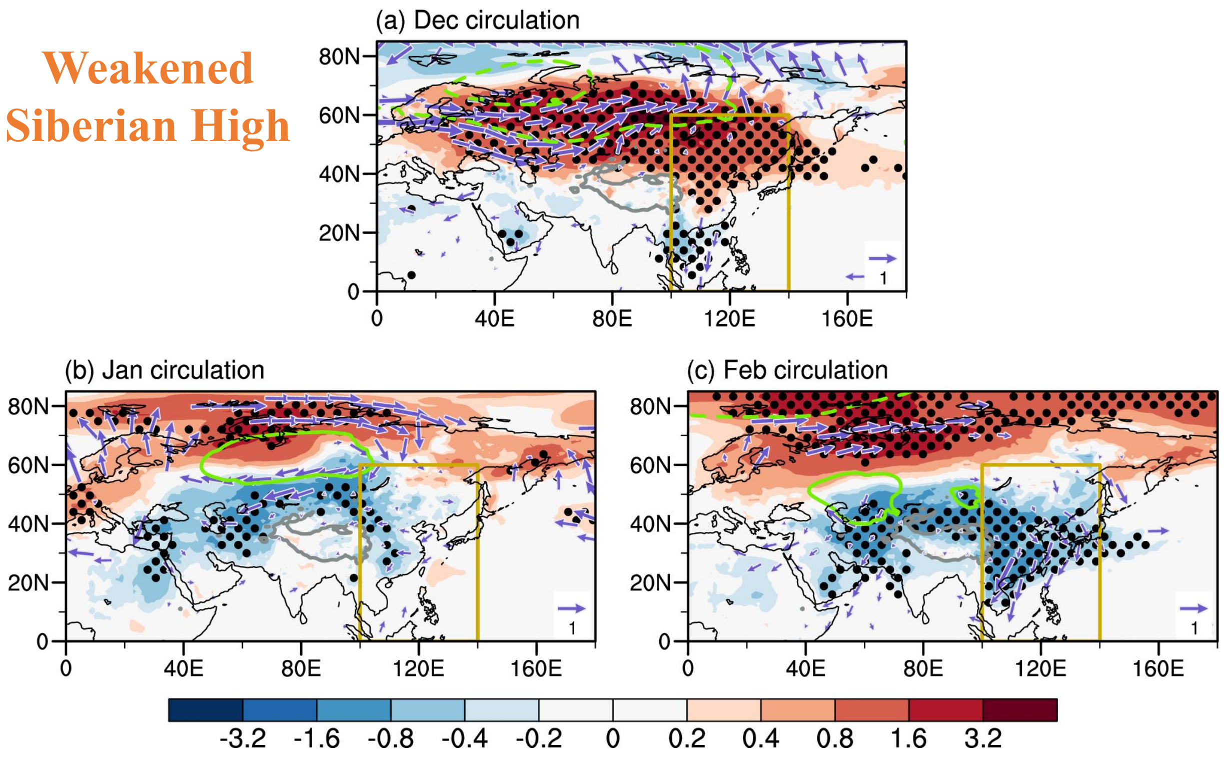


- **SAT anomalies** have been used as the key variable **to measure the strength of the EAWM** (Wu et al. 2009; Wang et al. 2010; Sun et al. 2016).
- S-EOF1 is characterized by **a persistent stronger/weaker EAWM** throughout the whole winter.
- S-EOF2 is featured by **a reversal of the EAWM** between early winter (December) and late winter (January–February).

3 Results

- S-EOF2 can capture **subseasonal changes in the EAWM subsystems** and is thus labelled as the **SR-EAWM**.

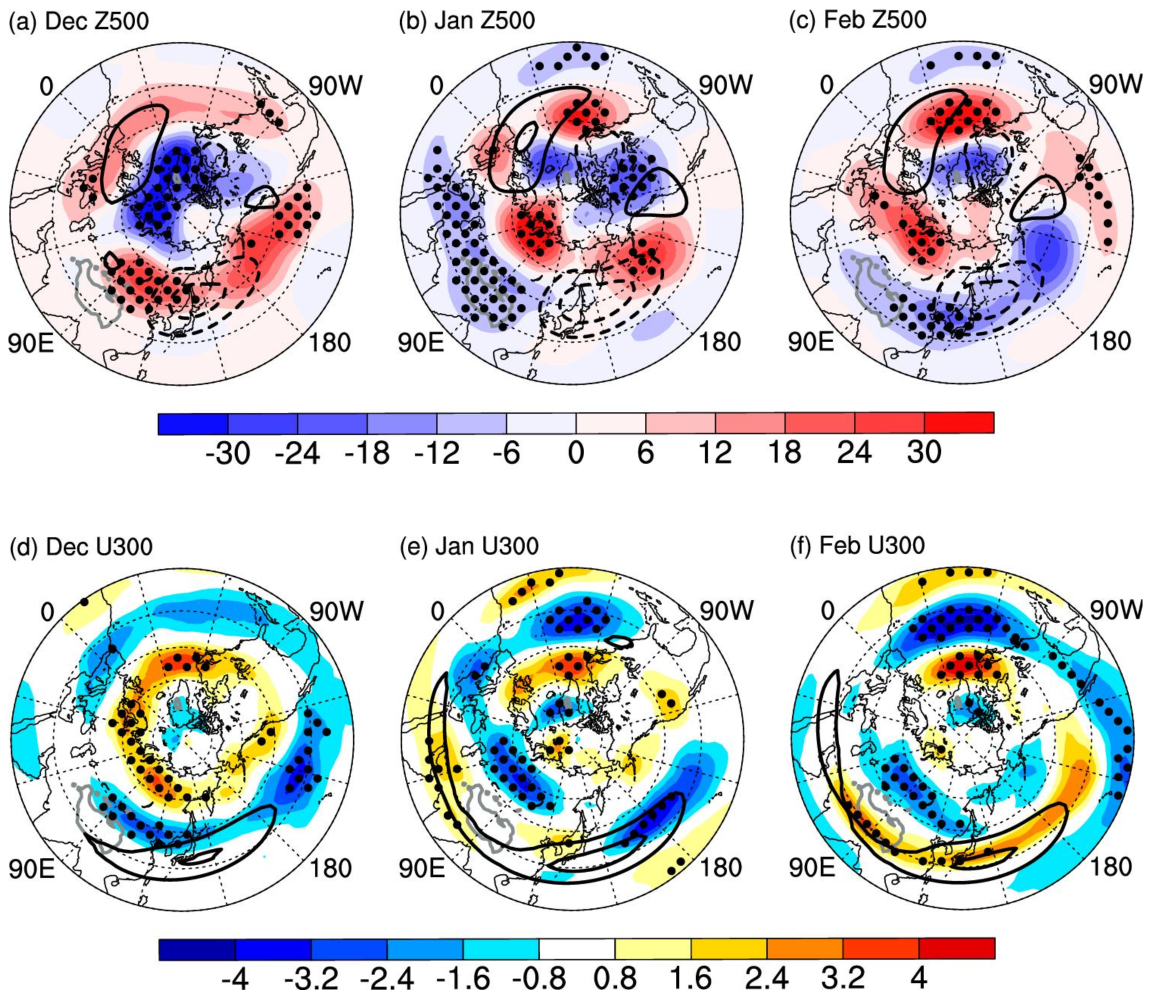
Regression of PC2 and SAT SLP&UV925



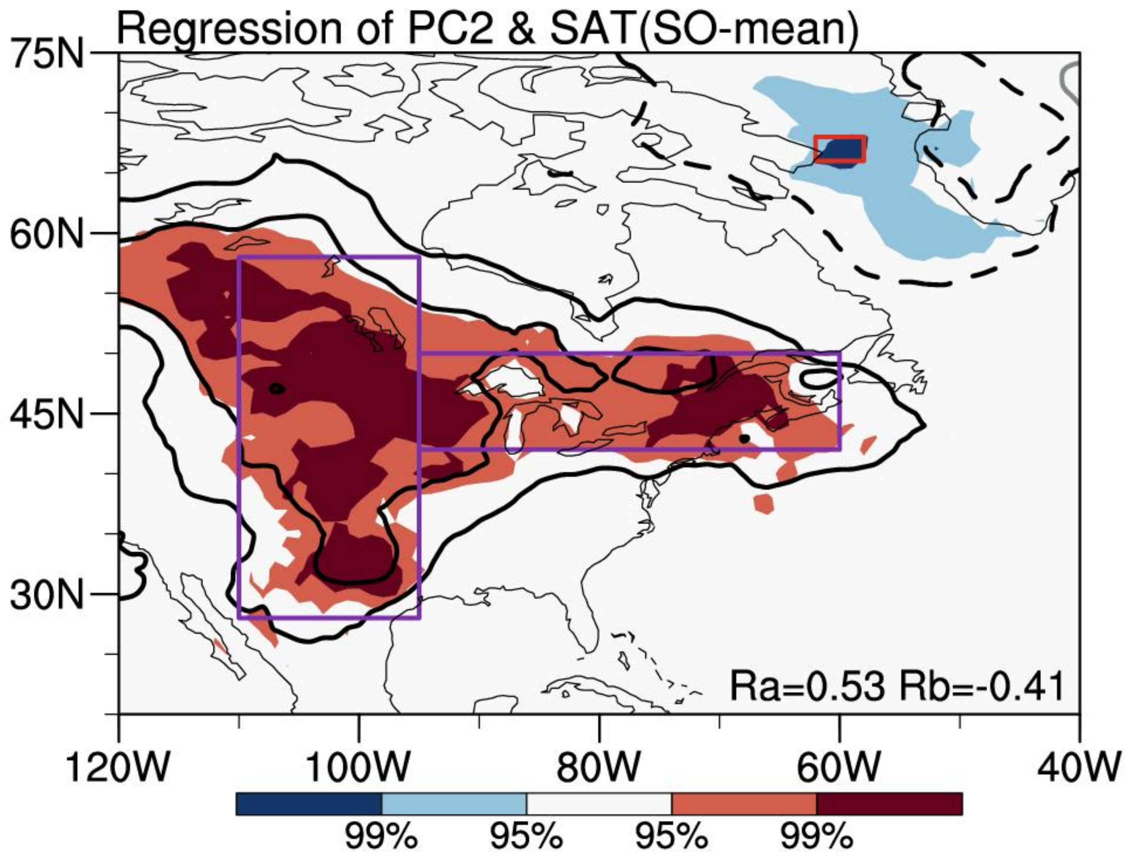
Strengthened Siberian High

Weakened East Asian major trough

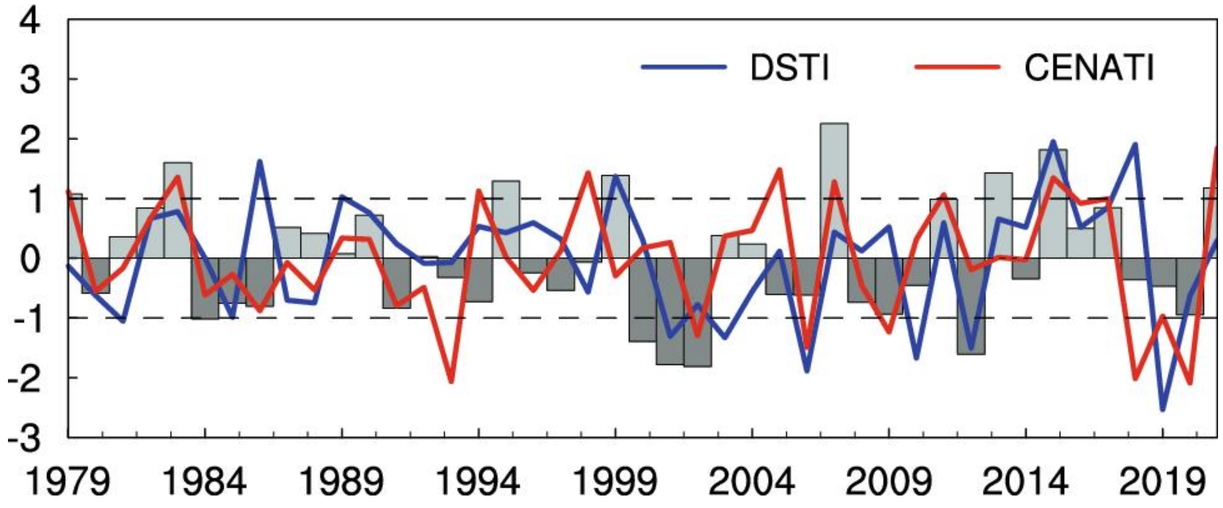
Deepened East Asian major trough



3 Results

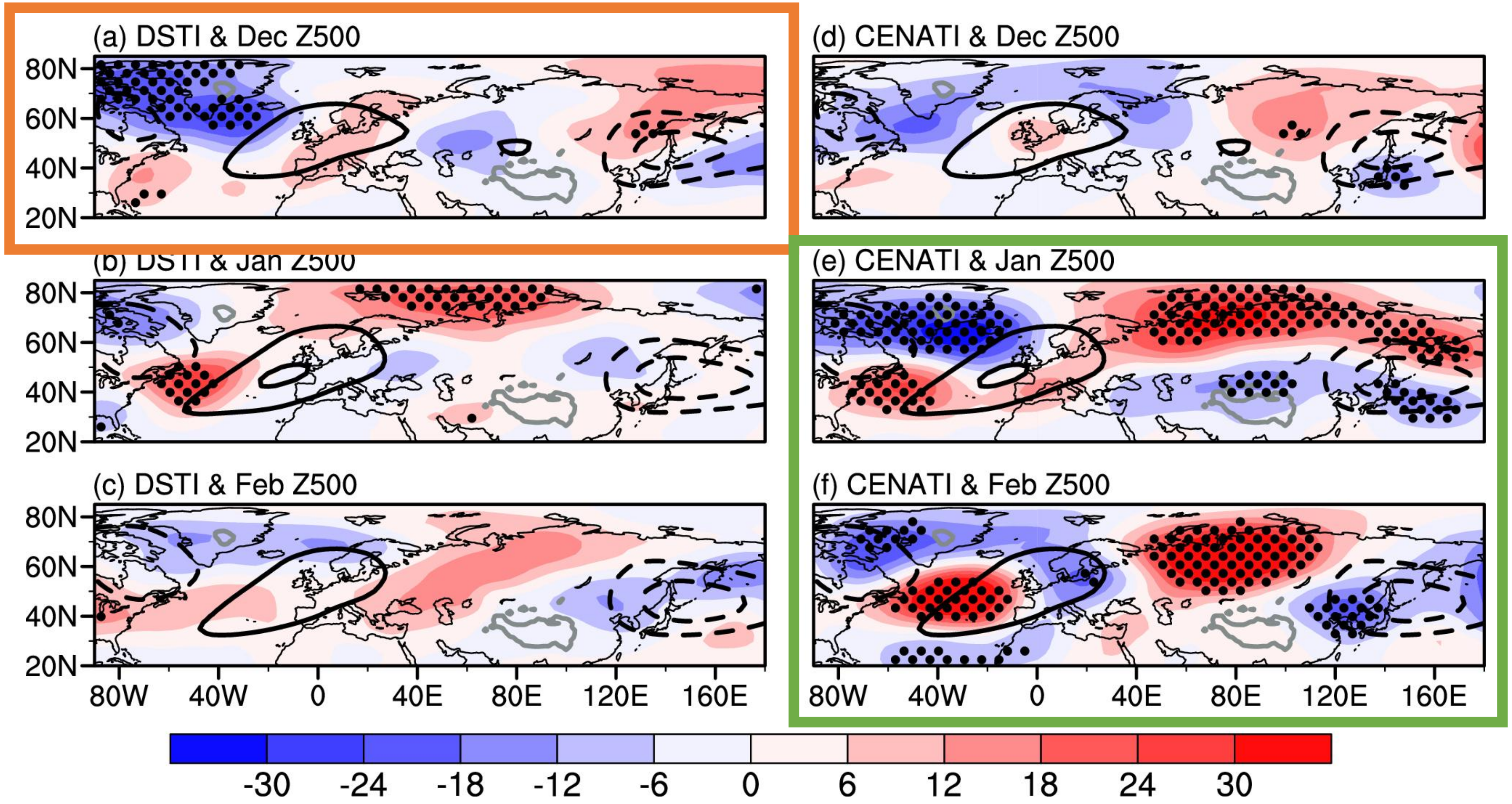


- The SR-EAWM is preceded by **surface air temperature anomalies over Davis Strait (DST)** and **those over central-eastern North America (CENAT)** in September–October.



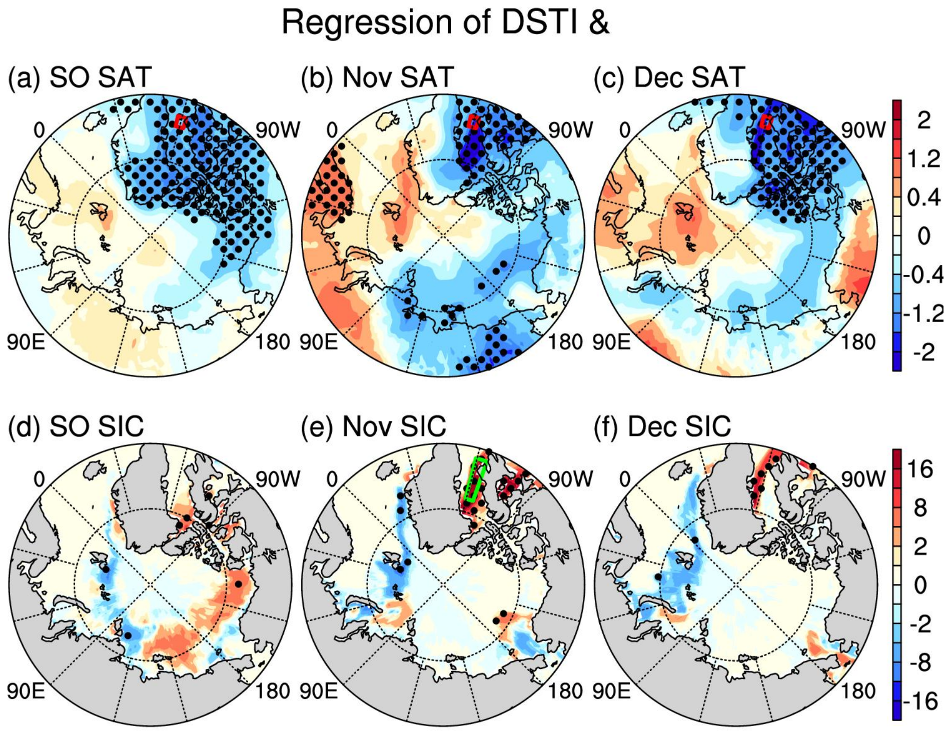
3 Results

- The **DST** mainly modulates the strength of the EAWM in **early winter**, while the **CENAT** exerts an impact on the SR-EAWM in **late winter**.



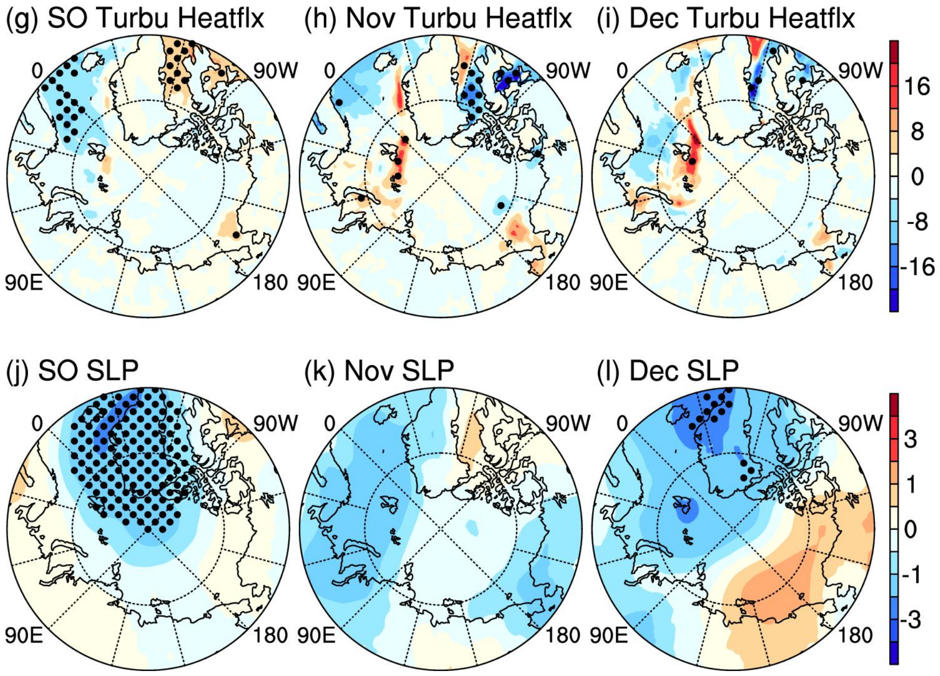
3 Results

➢ The DST mainly influences the SR-EAWM in early winter through a **“sea ice bridge”** of the November Baffin Bay sea ice concentration anomaly (BBSIC). The BBSIC could intensify the DST in December by **altering surface heat flux**.

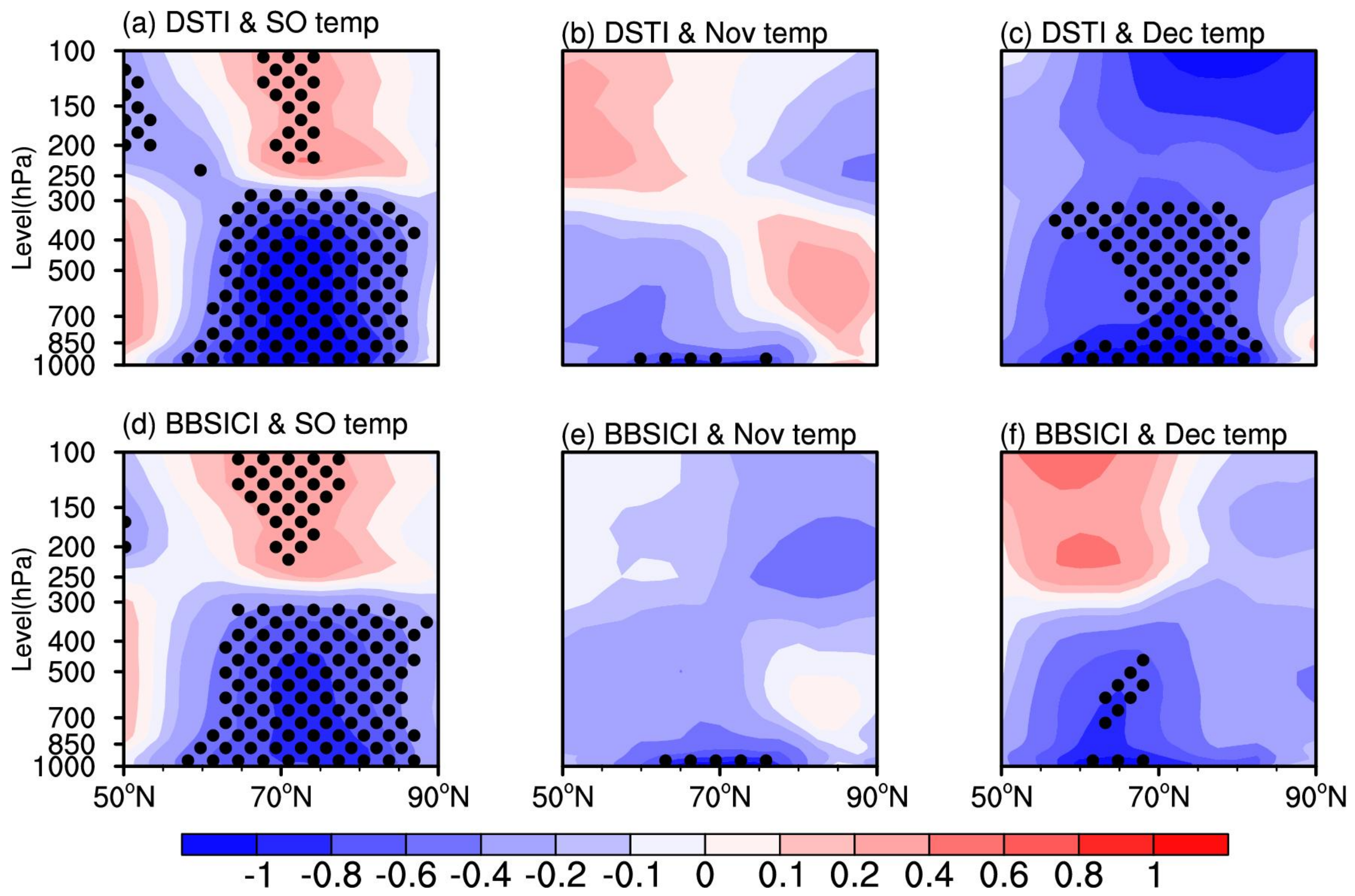


Upward heat flux: Atmos->SIC

Downward heat flux: SIC->Atmos



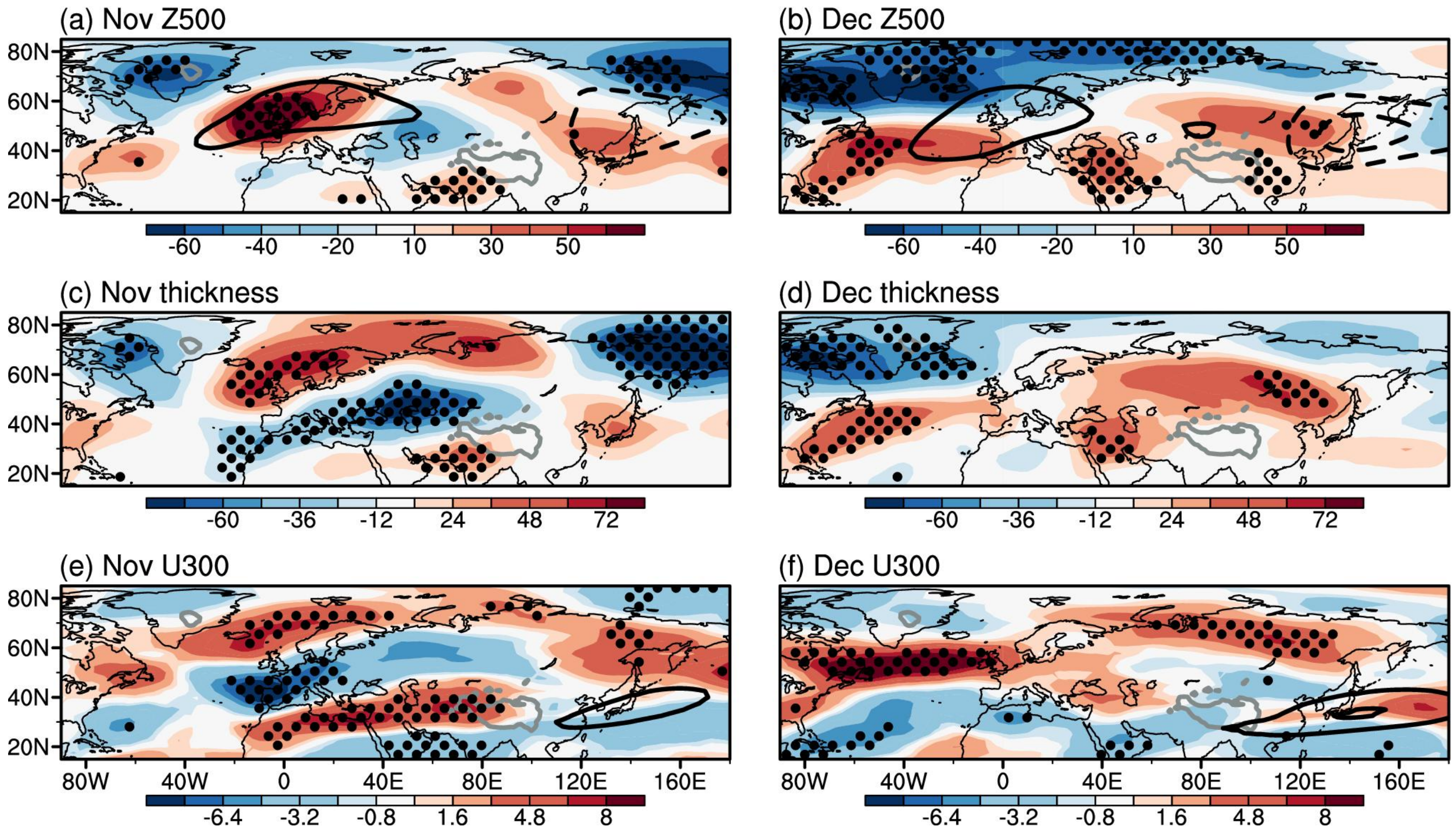
3 Results



- The formation of the BBSIC in late autumn greatly affects the **surface energy balance** and restricts the heat transfer between the warmer ocean and the colder atmosphere, thus **the surface cooling intensifies and develops to the middle troposphere in early winter**.

3 Results

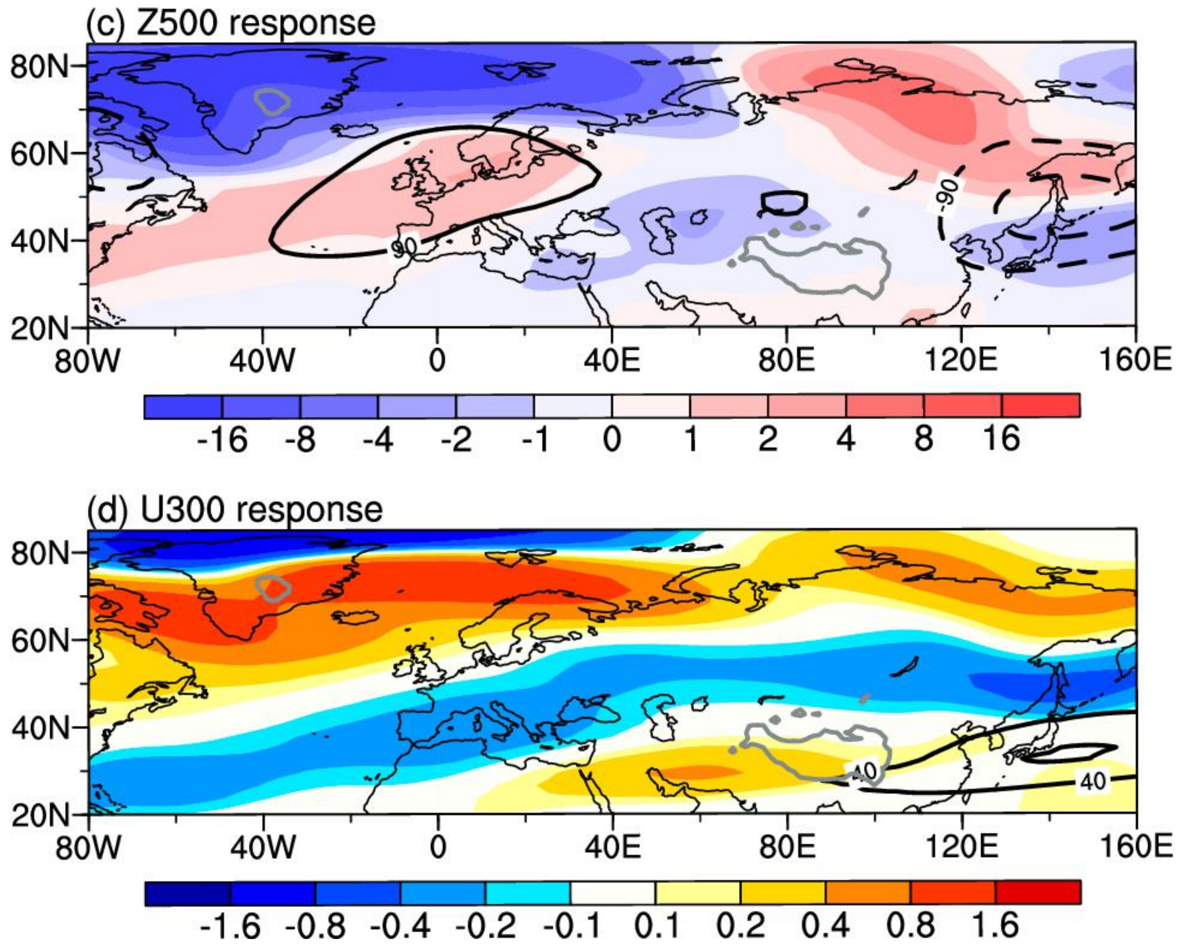
➢ Air-sea ice interaction leads to **a NAO-like circulation pattern**, thus modulating the strength of the EAT in early winter.

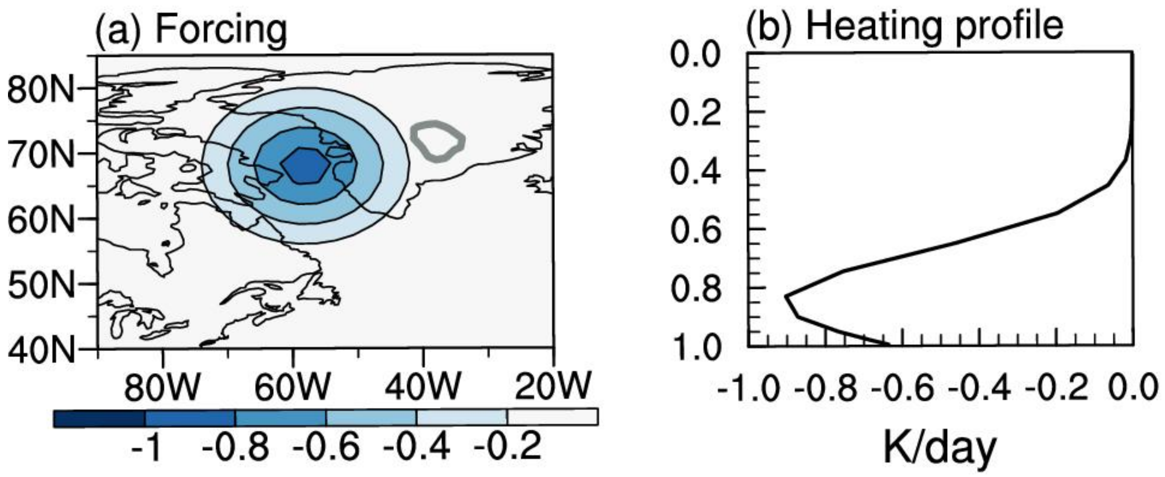


Composite differences of (a–b) Z500 anomalies (units: gpm), (c-d) 1000–300-hPa thickness anomalies (units: gpm), (e–f) U300 anomalies (units: m/s) in November and December between heavy and light BBSIC winters.

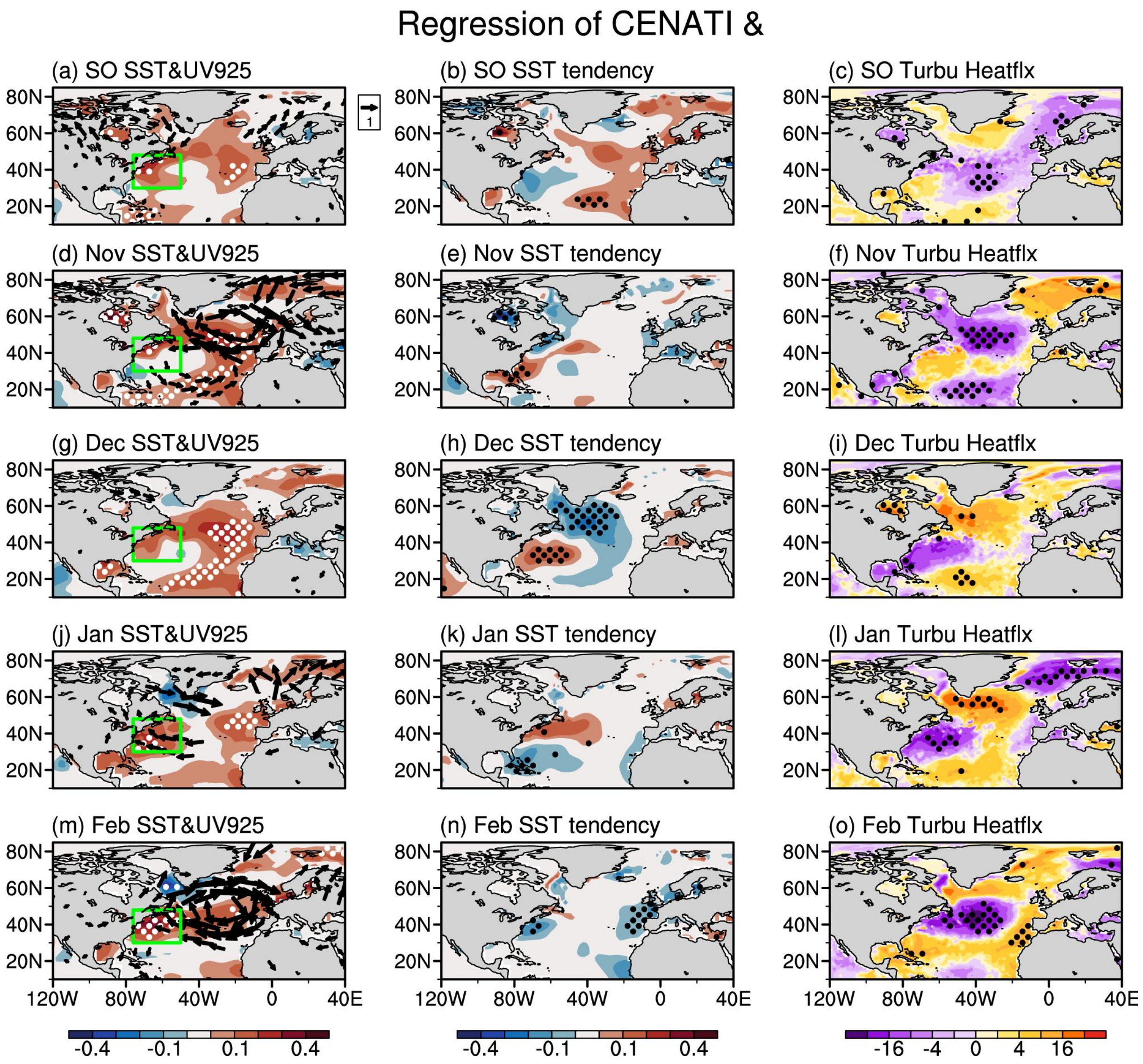
3 Results

- The **LBM experiment** suggests that a cooling over Davis Strait can generate a NAO-like circulation anomaly and modulate the SR-EAWM in early winter.

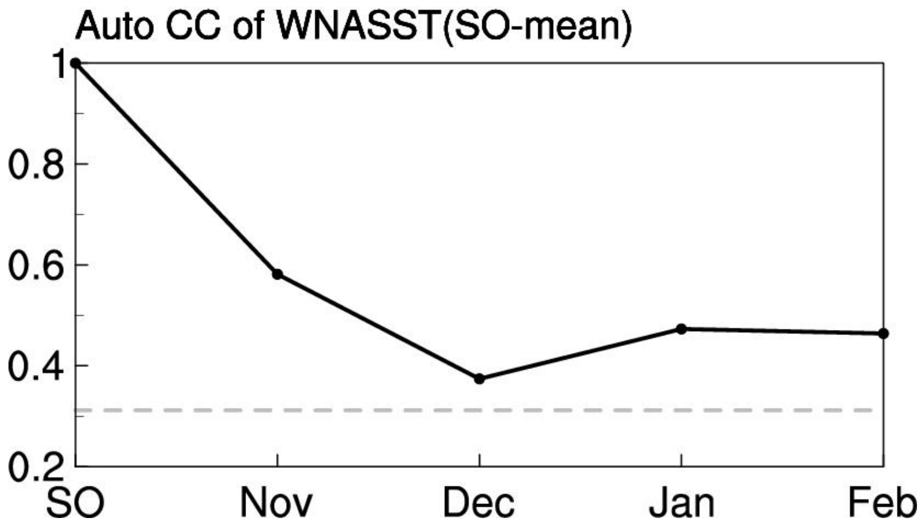




3 Results

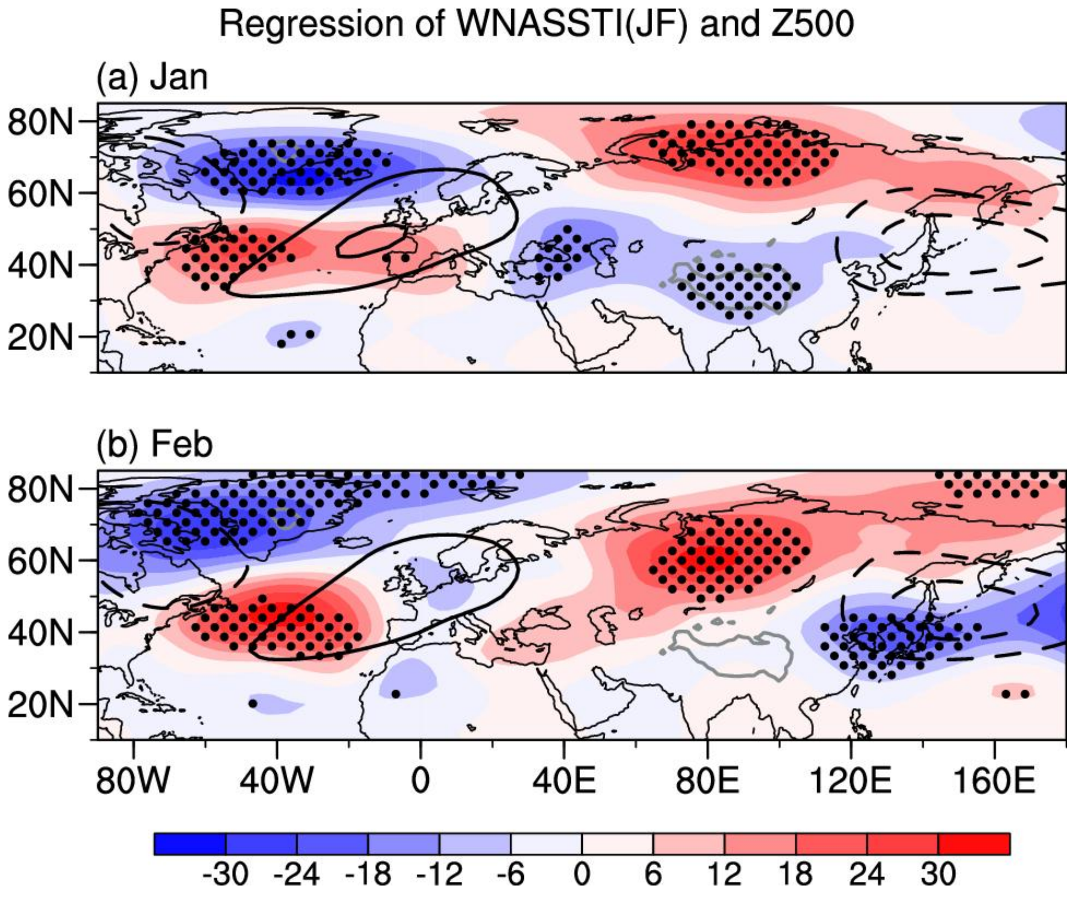


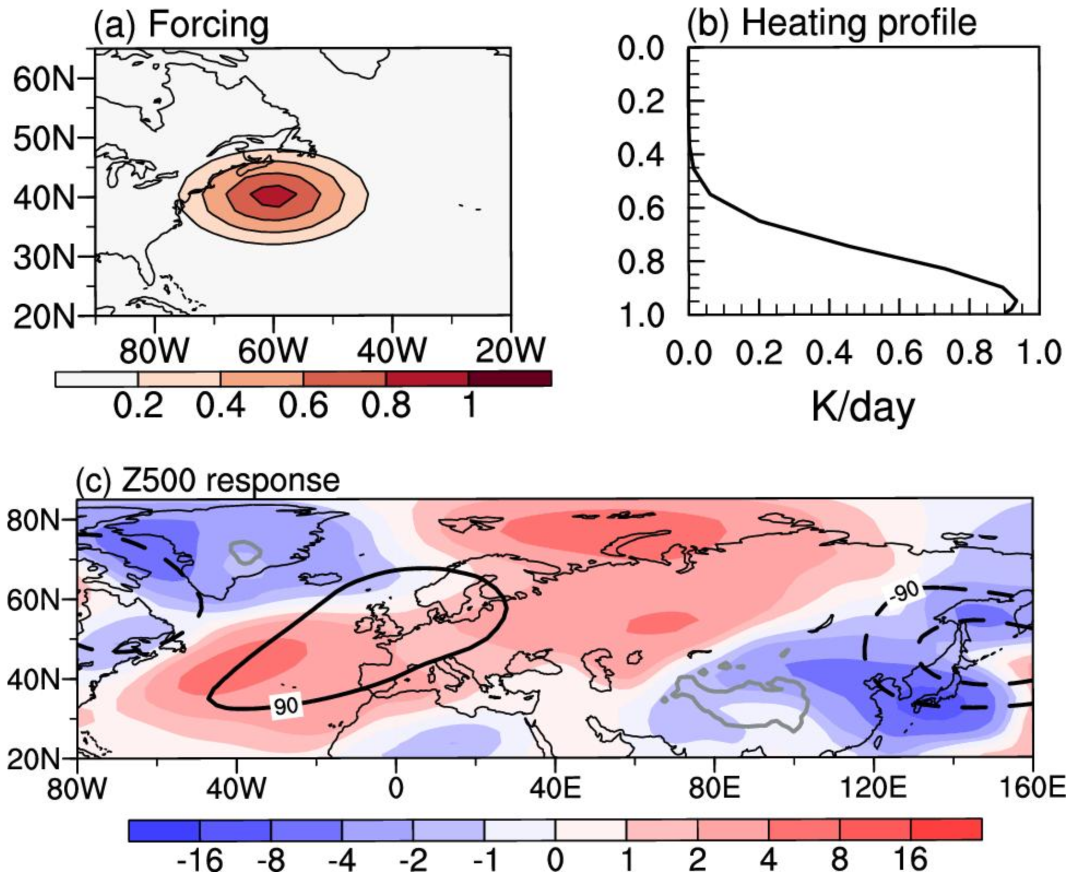
- The CENAT affects the SR-EAWM in late winter by inducing an **"ocean bridge"** of the western North Atlantic sea surface temperature anomaly (WNASST). The WNASST can **persist into late winter**.



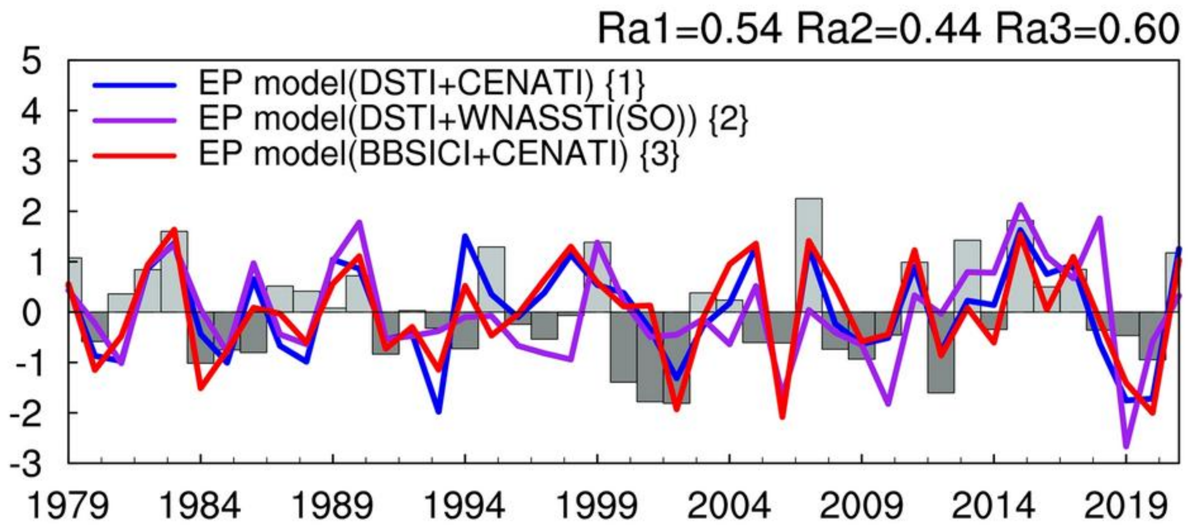
3 Results

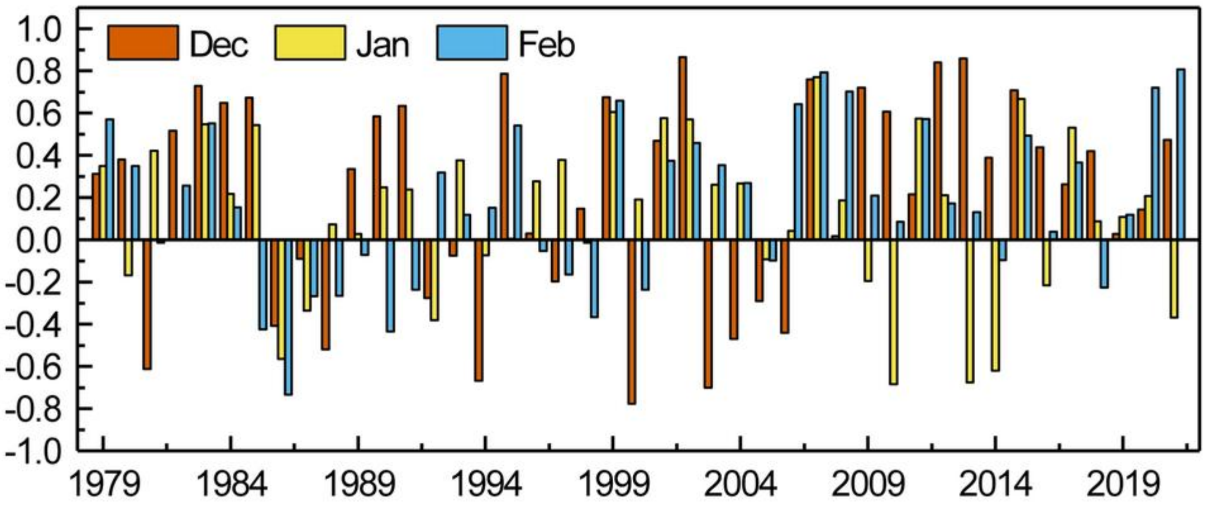
- The WNASST significantly affects the SR-EAWM by regulating Eurasian circulation anomalies and the downstream **EAT**, which can be further verified by the **LBM**.





3 Results

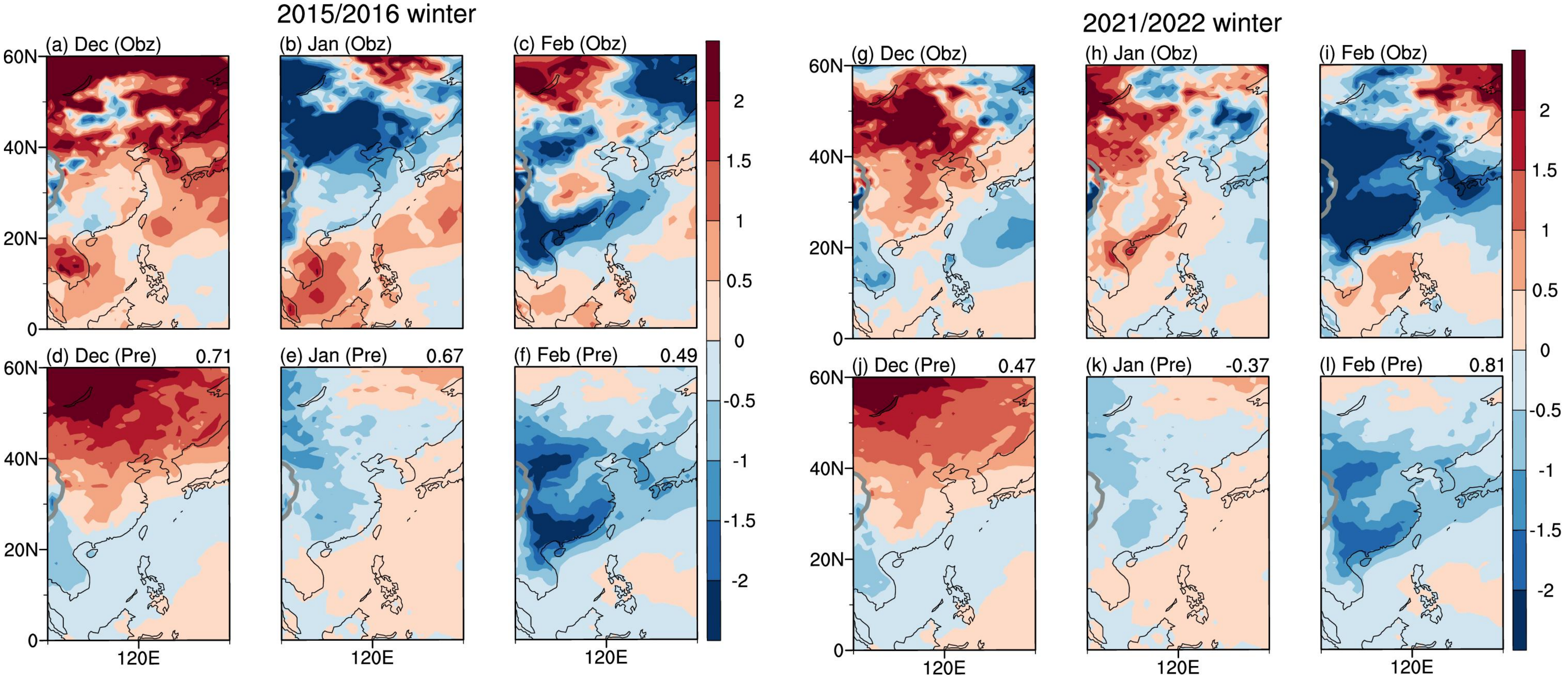




- Two **physical-empirical models** are established using the DST/BBSIC and the CENAT indices, respectively. Both exhibit promising prediction skills.
- The results highlight that **the DST, BBSIC, and CENAT** are crucial **predictability sources for the SR-EAWM**.

3 Results

- The physical-empirical models show good performances in predicting the subseasonal reversals of the EAWM in the winter of **2015/2016 and 2021/2022**.



4 Take-home messages

- The **leading modes** of subseasonal variations of the EAWM?
  - **S-EOF1 A consistent in-phase EAWM**
  - **S-EOF2 A reversal of the EAWM between Dec and JF**
- Roles of atmospheric variability and surface boundary conditions?
  - **Interactions between the preceding atmospheric variability and surface boundary conditions**
- How to **predict** subseasonal variations of the EAWM?
  - **Physical-empirical models based on the DST/BBSIC and the CENAT indices**

Thank You

For Your Attention

EGU QR code

Reference: Zhong Wogu, Wu Zhiwei* (2022). Subseasonal strength reversal of the East Asian winter monsoon. ***Climate Dynamics***, DOI: 10.1007/s00382-022-06610-9.