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# Warming-induced hydrothermal anomaly over the Earth's three Poles amplifies concurrent extremes in 2022

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[https://faculty.nuist.edu.cn/zhangjie/zh\\_CN/index.htm](https://faculty.nuist.edu.cn/zhangjie/zh_CN/index.htm)

2024-7-17 Xining

# CONTENT



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- 2. Three Poles effect on concurrent extremes**
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# 1、 Background— extremes

## WCRP 7 scientific challenges

## New feature of extremes



Larger magnitude



Increased frequency



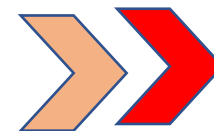
New locations



Different timing



New combinations (compound)



combinations

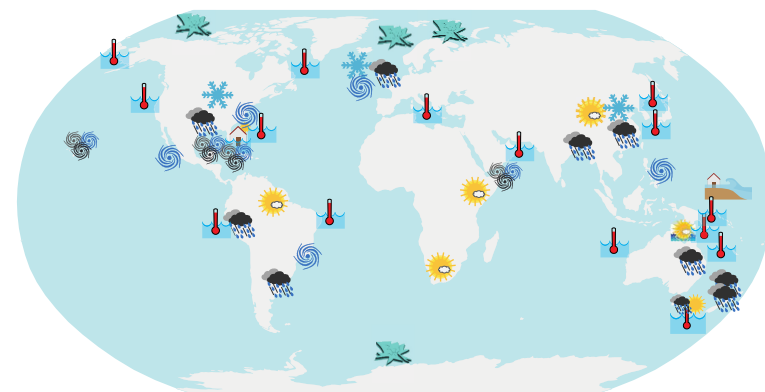
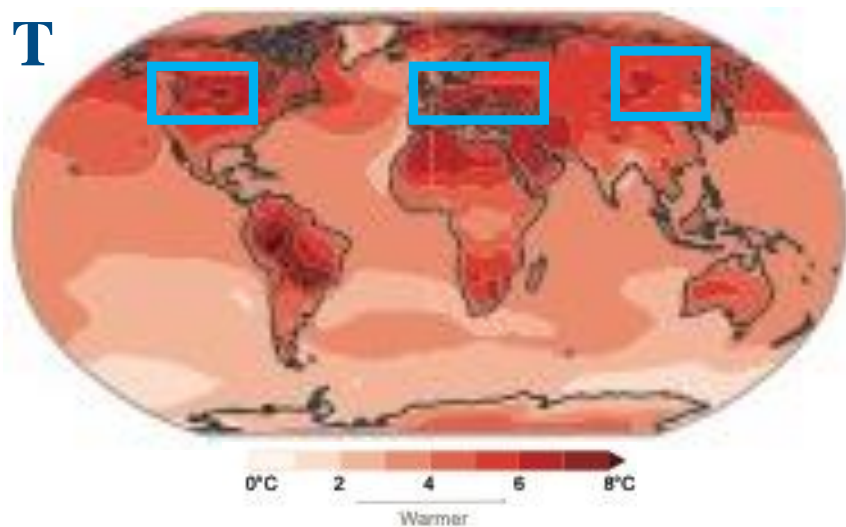
Cluster & concurrent

continuity

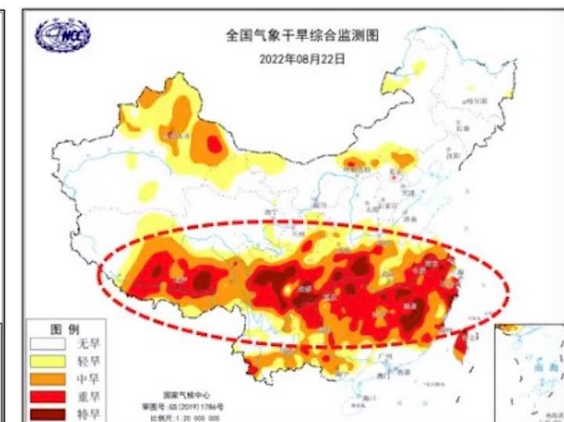
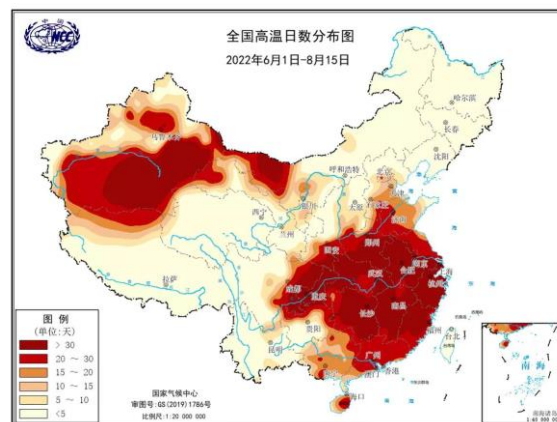
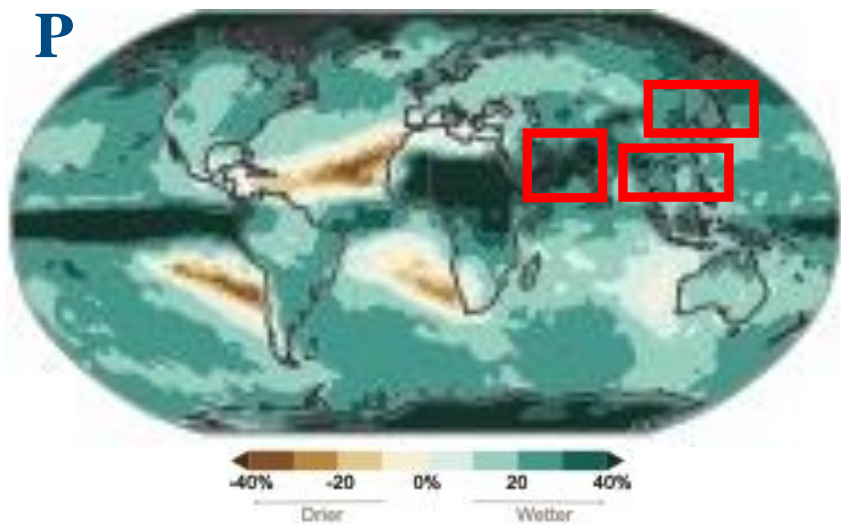
extremity

# 1、Background— extreme heat wave and rainstorms

T



P



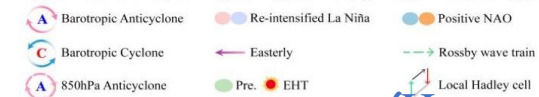
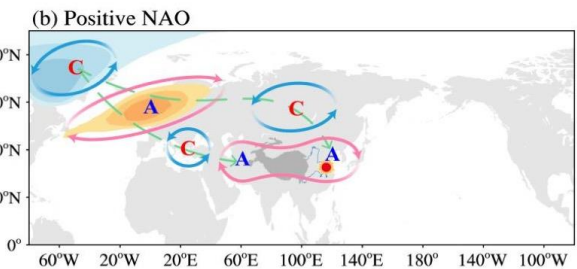
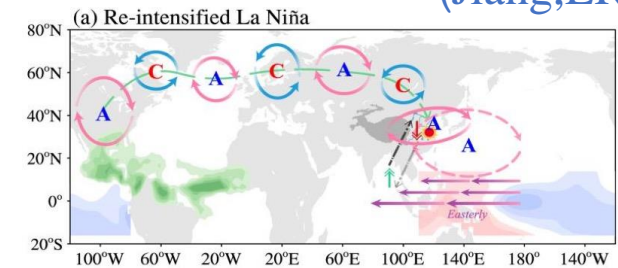
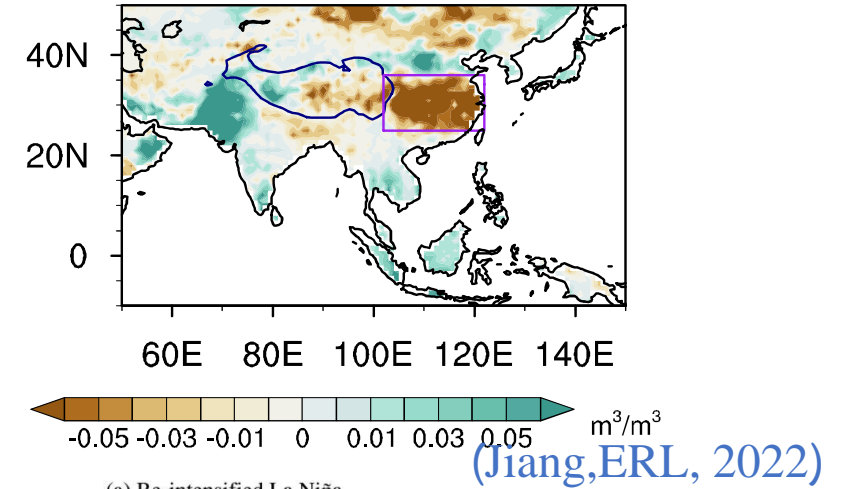
2022.6.1-7.15 heatwave days 2022.8.22 drought

(IPCC AR6)



# 1、Background— extreme heatwave and rainstorms

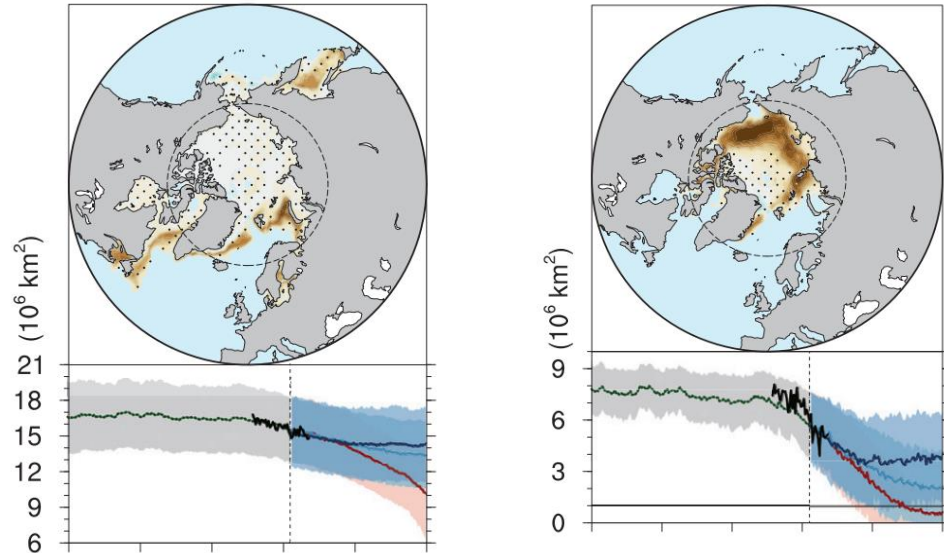
- Human activity (Hua et al. 2023 GRL; Li et al., BAMS, 2023)
- SST, LaNina, NAO (Jiang et al., ERL, 2022; Huang et al., JC, 2023)
- Soil moisture feedback (Jiang et al., ERL, 2022)
- Eurasian snowcover (Zhang et al., npj, 2020)
- Forest degradation (Liu et al., JGR, 2023)
- Arctic ice loss (Zhang et al., npj, 2020)



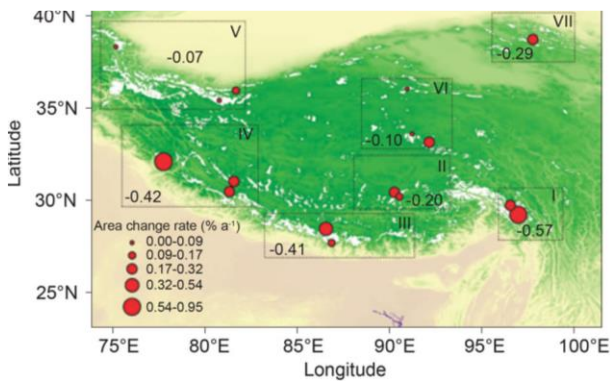
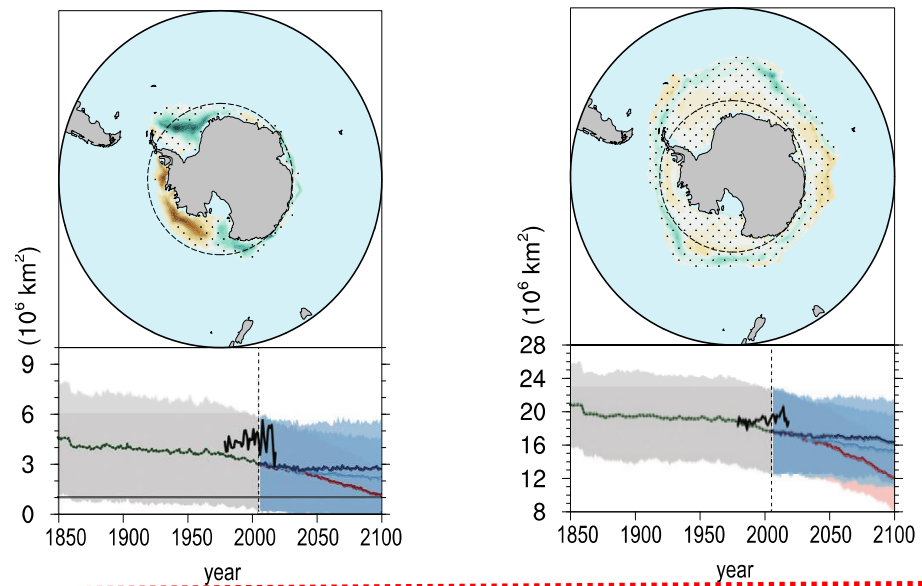
(Huang, JC, 2023)

# 1、Background— Three Poles ice and glacier reduced

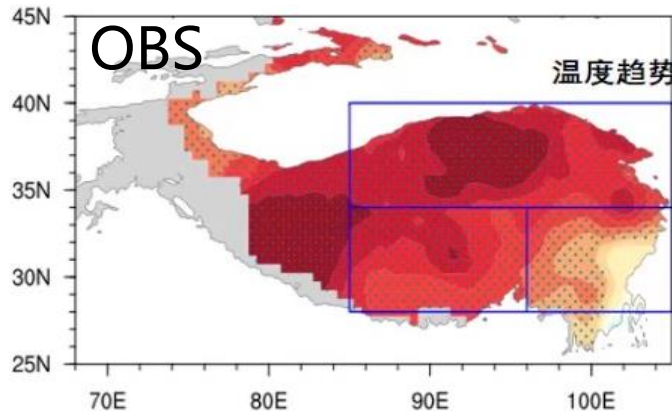
March and Sep. **Arctic** ice loss



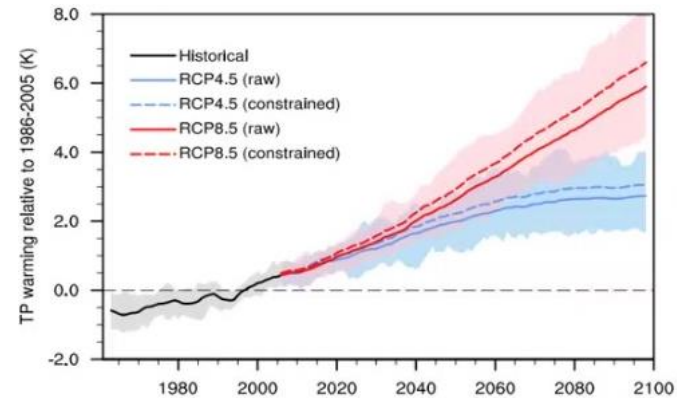
March and Sep. **Antarctic** ice loss



Glacier reduced Yao et al., Geo.,2015



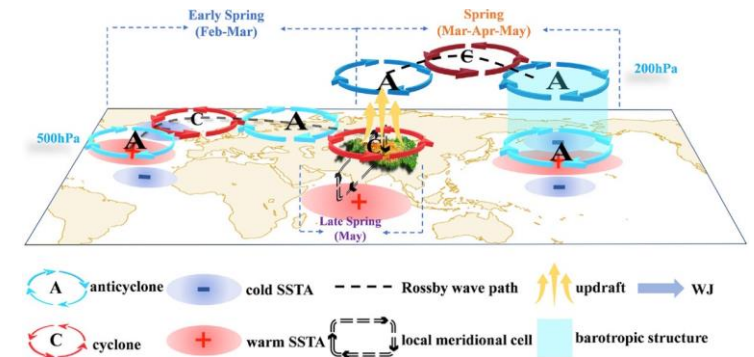
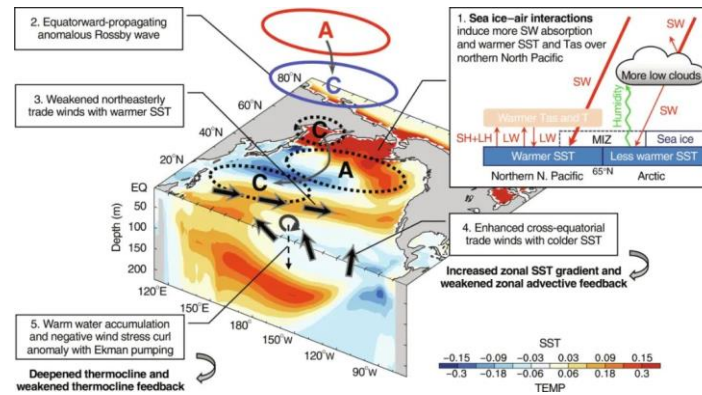
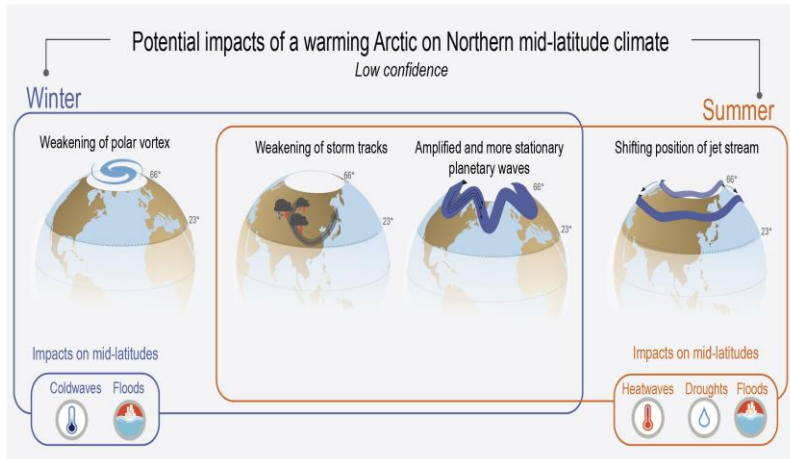
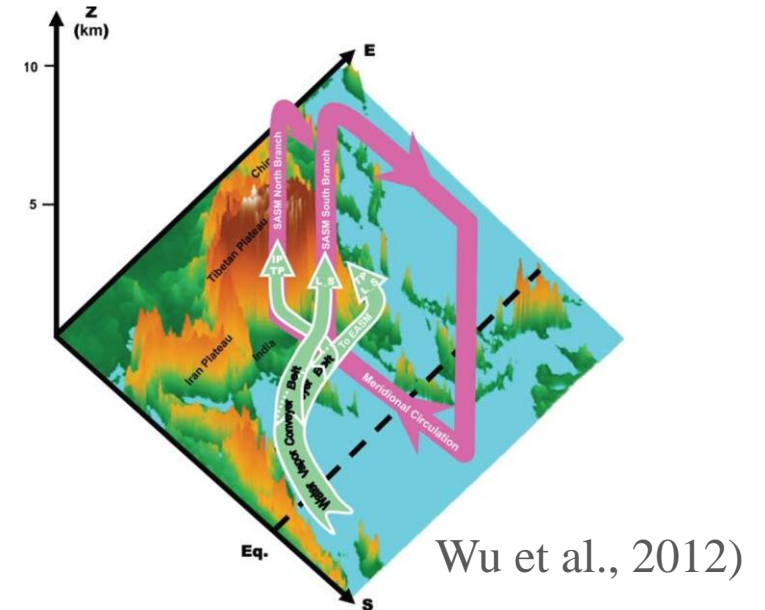
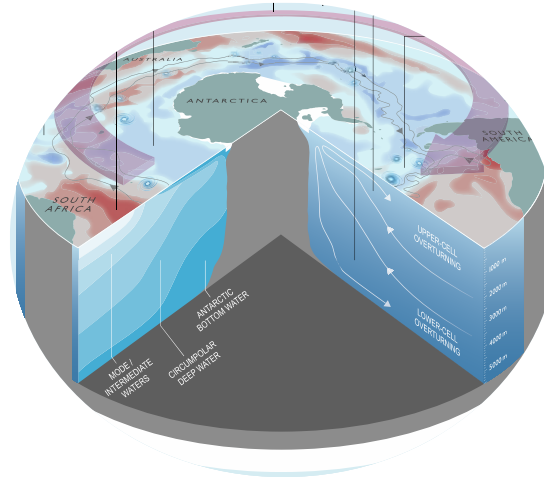
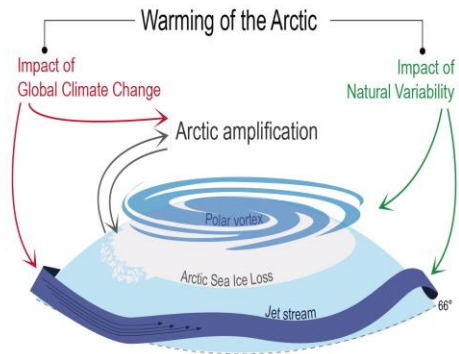
T increased IPCC AR6



Zhou & Zhang,2021

Tibet Plateau (TP)

# 1. Background— Three Poles ice and glacier reduced



Polar vortex

Jet

Planetary waves

Ocean currents, ocean eddies, surface/deep water, overturned currents, planetary waves, monsoons

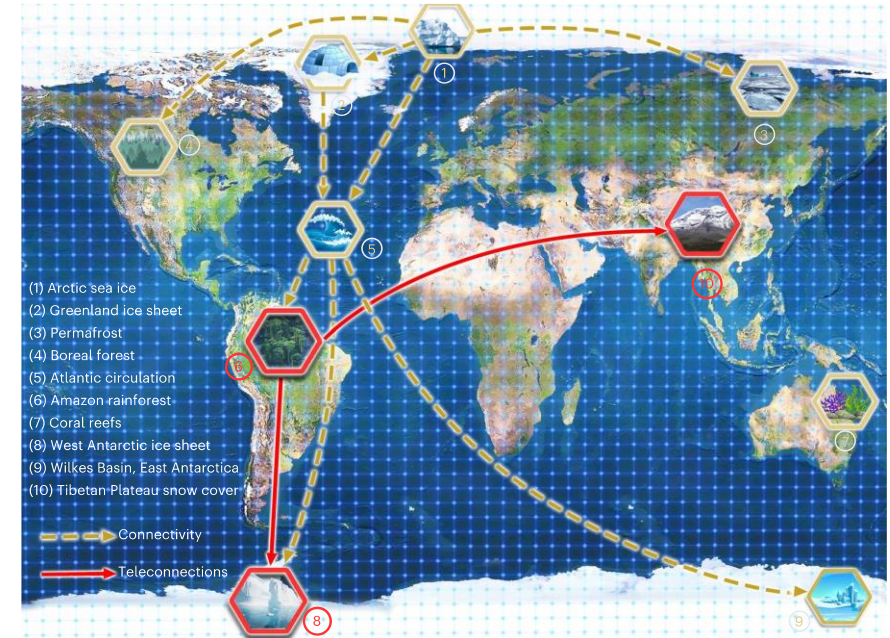
(Wu et al., 2022)

(IPCC AR6)

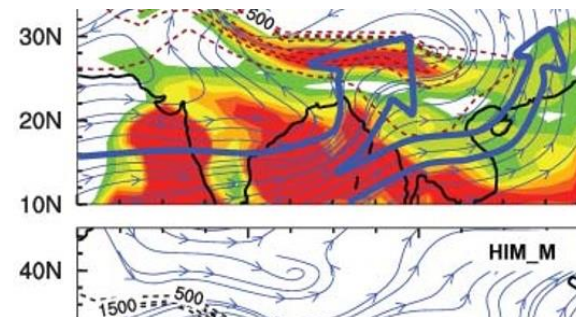
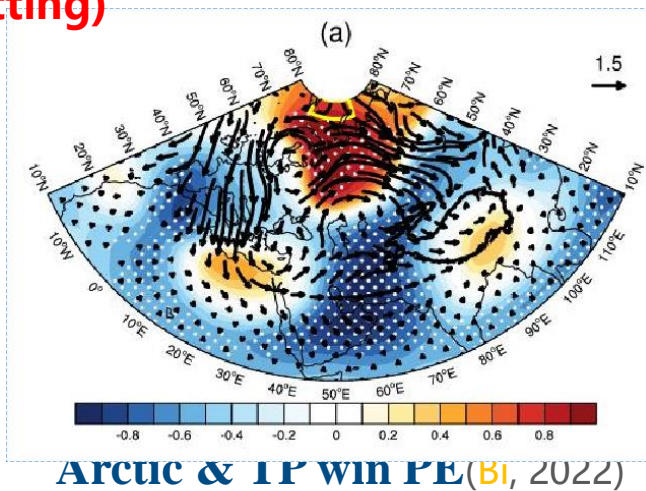


# 1、Background— Three Poles linkage

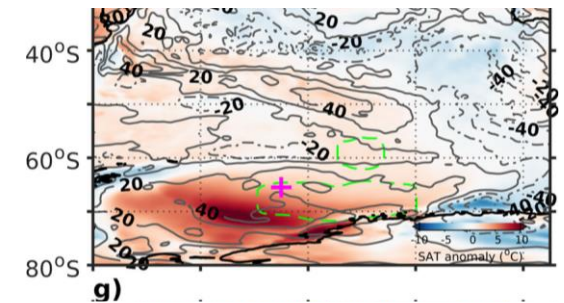
- Linkage response to warming (Li et al., 2021)
- Interaction (Duan et al., 2022npj; Tang et al., 2022 JGR; Hu et al., 2023 JGR; Xie et al. 2023 ERL)
- The coupling/synergy/intermediate effect (Duan et al., 2023 submitting)



Three Poles linkage (Liu et al, 2023)



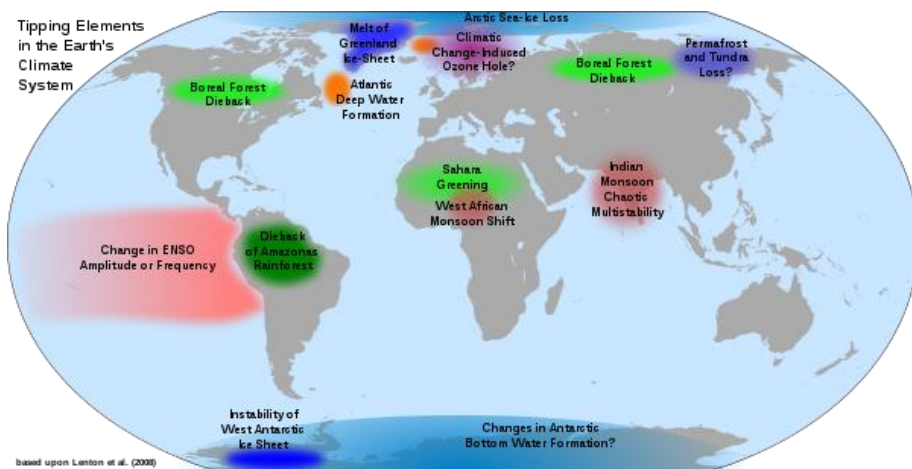
ASM Wu et al., 2012)



MH Jena et al., 2022

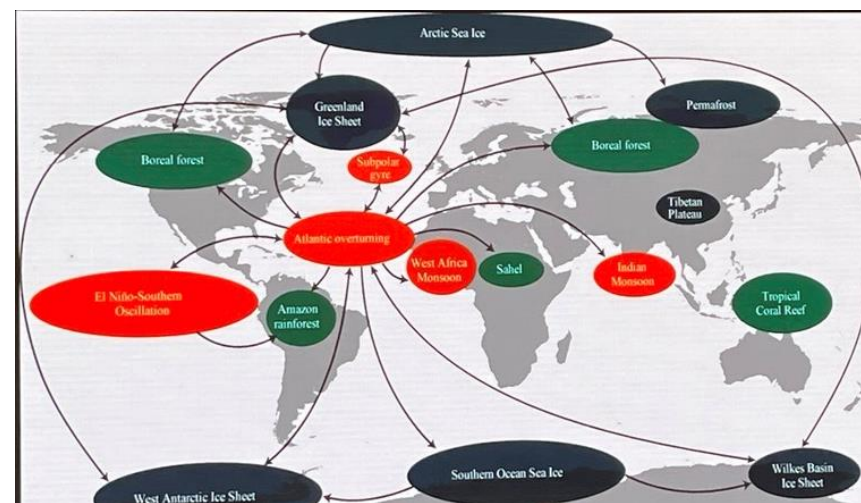
# 1、Background— Three Poles linkage

## Arctic ice loss—Climate system



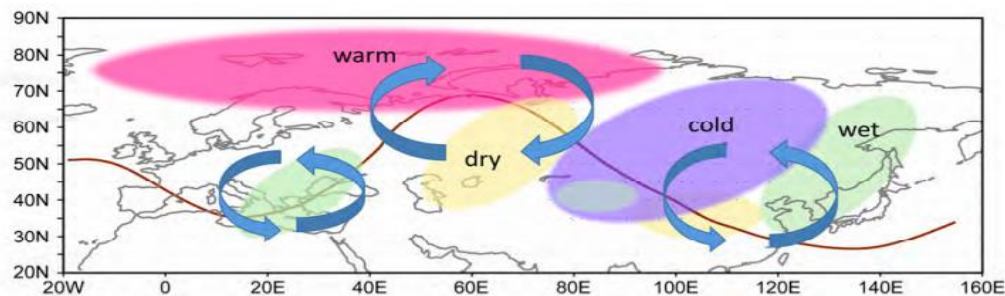
Lenton et al.,PNAS,2008

## Arctic —Climate system linkage



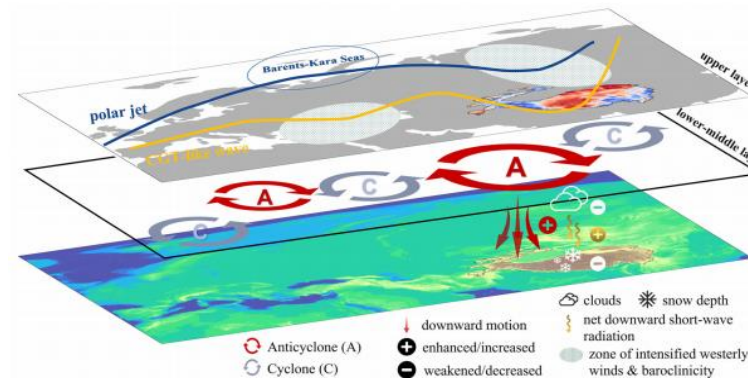
Chen et al.,2023

## Arctic ice loss—Eurasian weather



武炳义,大气科学,2018

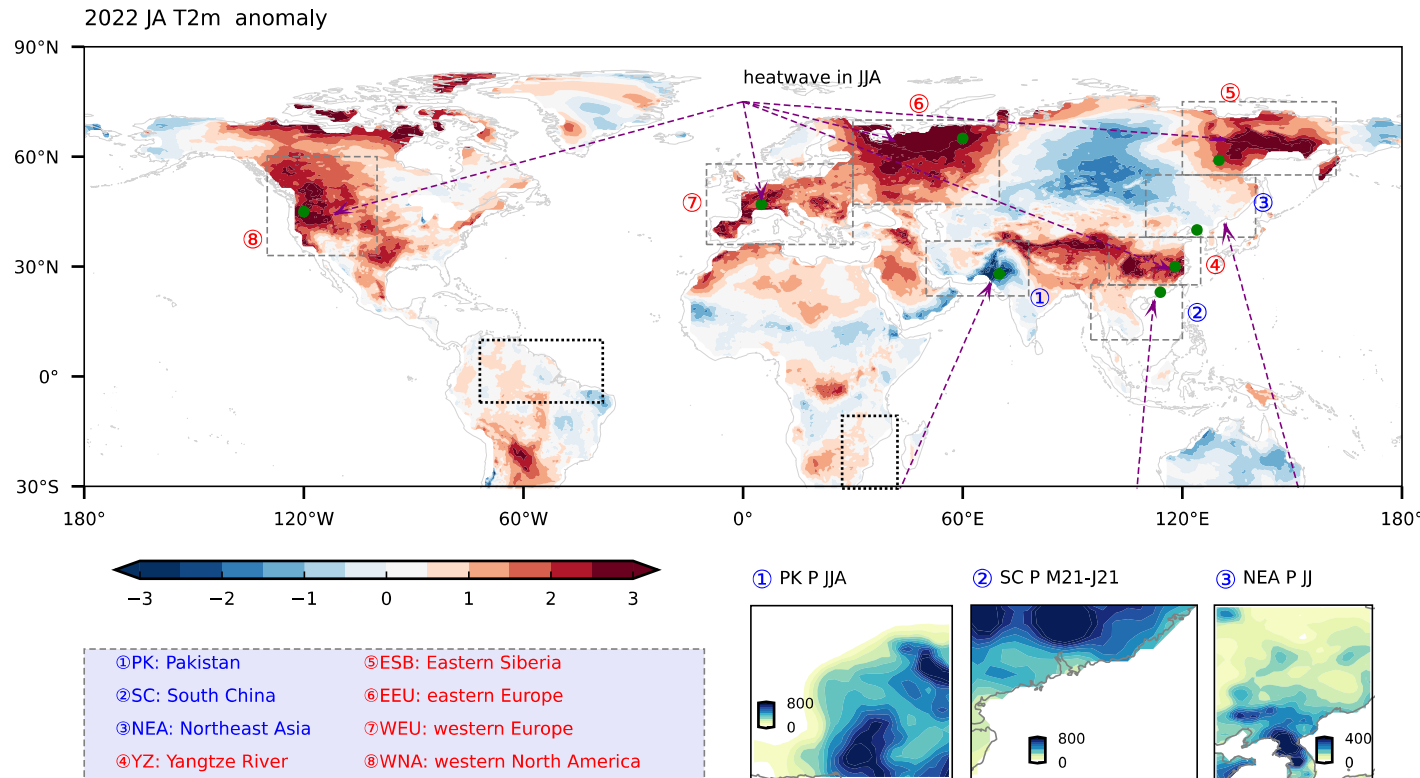
## Arctic ice loss—TP thermal



Hu et al.,JGR,2023



# 2、 NH T and P extremes in 2022 and spatial concurrent



## Top 10 International Weather and Climate Events in 2022 :

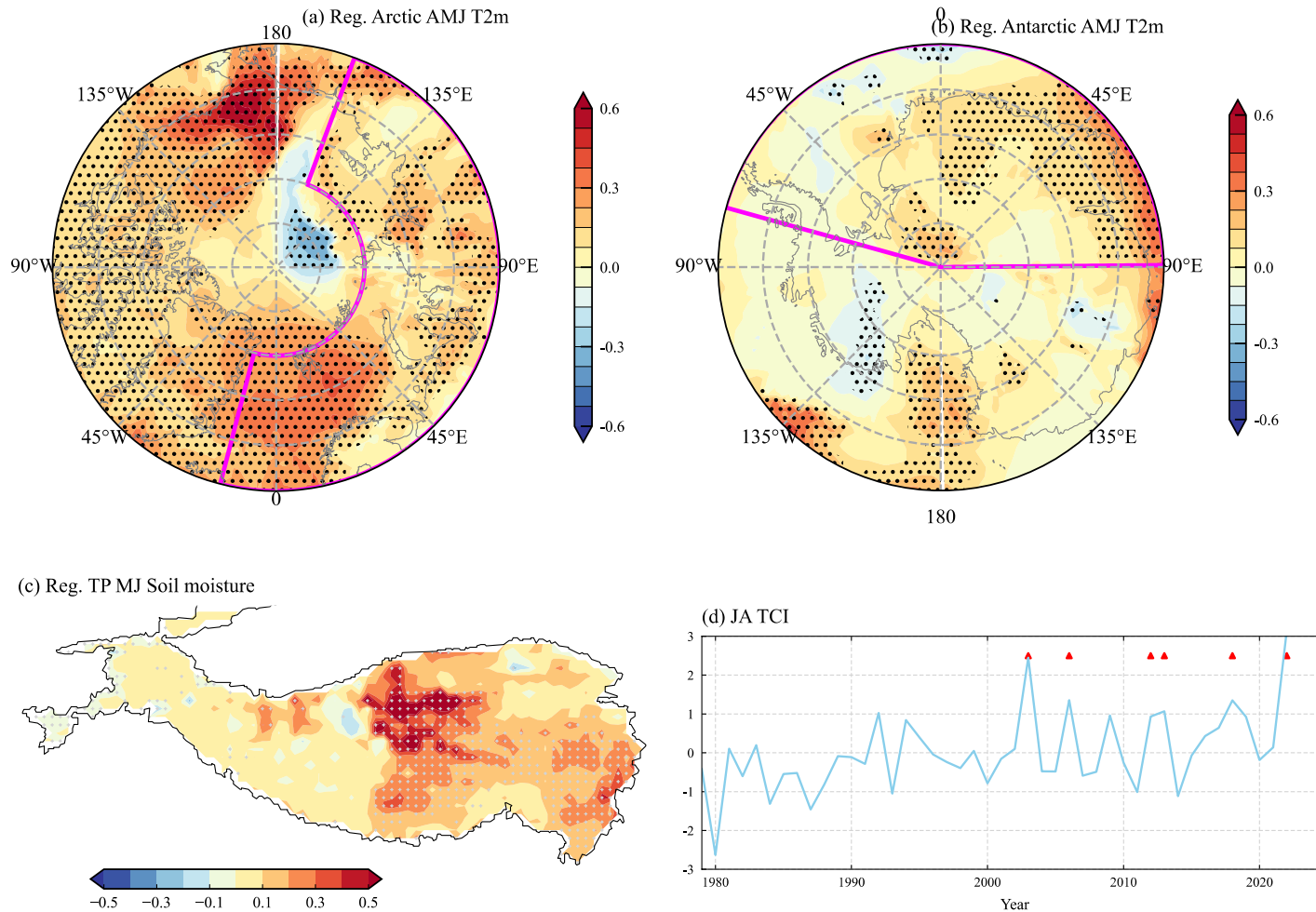
- 1、 Extreme high temperature and drought over Eurasian and North American land.
- 2、 Pakistan flood in **JJA**
- 3、 Korean rainstorm in **August 7th to 11th**
- 4、 The second strongest Loong Boat water since 1961 , **May 21th to June 21th**
- 5、 Brazil flood in **May 29<sup>th</sup> –June 1st**,
- 6、 East South Africa experiences the strongest precipitation in nearly 60 years , April 11—12th

**JJA T anomaly and record-broken P in 2022**

$$TCI = S ( T_{NA} + T_{EU} + T_{YZ} ) - ( T_{PK} + T_{SC} + T_{NEA} )$$

**TCI : Temperature concurrent index**

# 2、 NH T and P extremes in 2022 linked with three Poles



East Hemisphere in Arctic

Antarctic Circle South Atlantic

South Indian Ocean, Queen

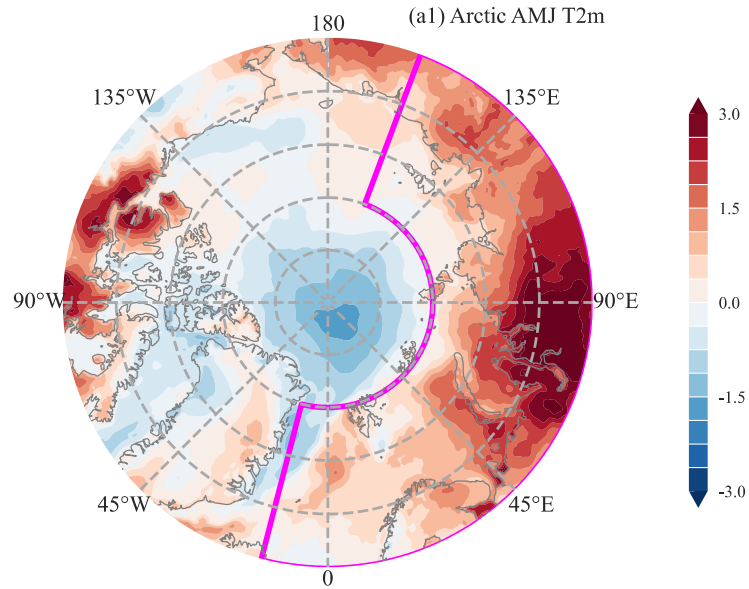
Maud Land, MacRobertson

Land

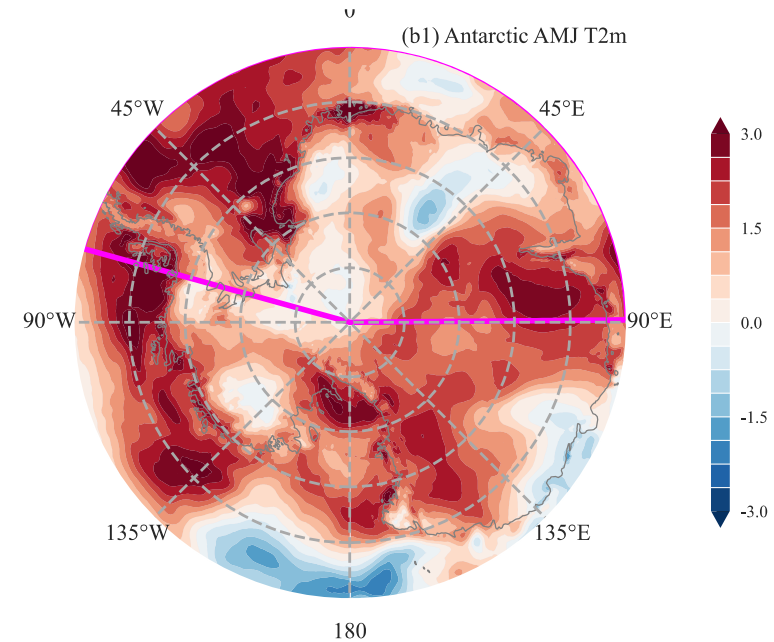
**TCI regressed AMJ t2m over Arctic and Antarctic and SM in TP**

# 2、 Warm and moist anomaly in three Poles in 2022 and causal relationship

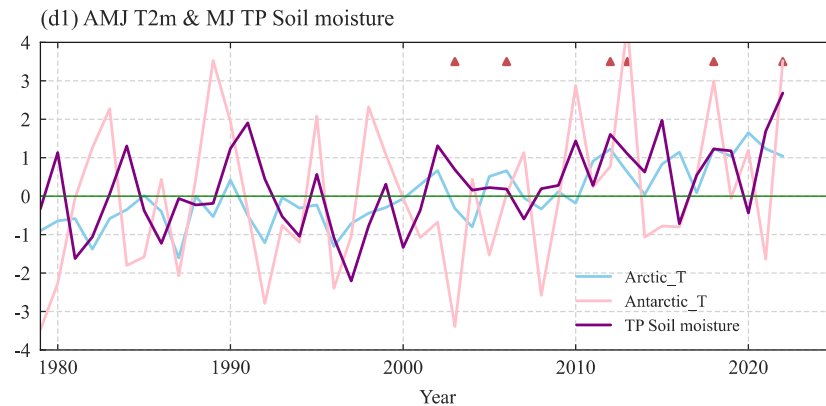
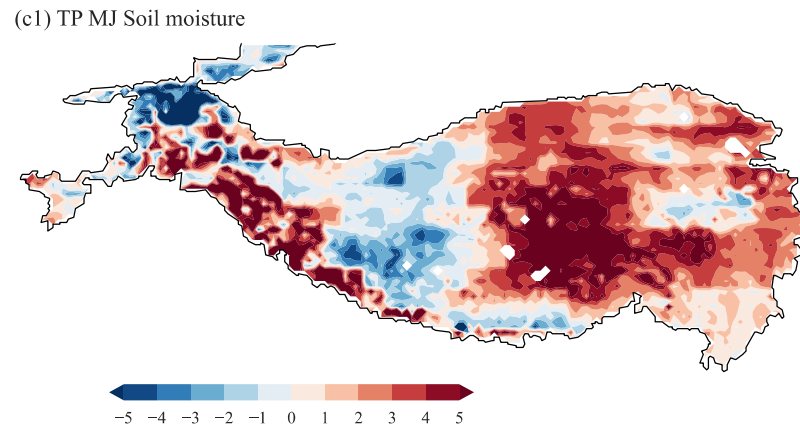
AMJ T2m  
Arctic



AMJ T2m  
Antarctic

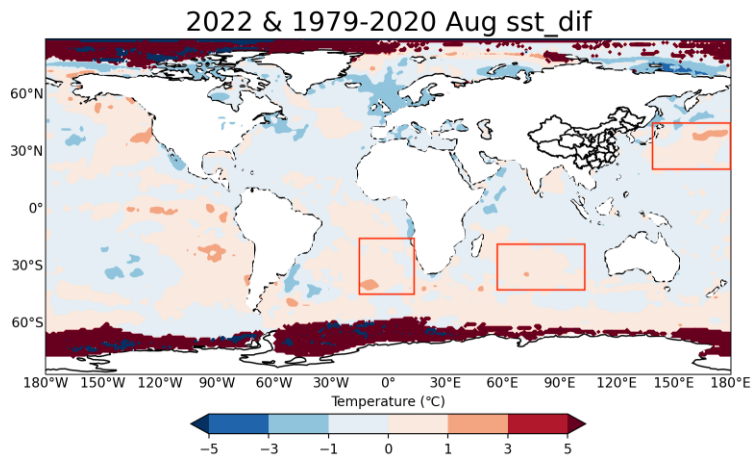


AMJ SM  
TP

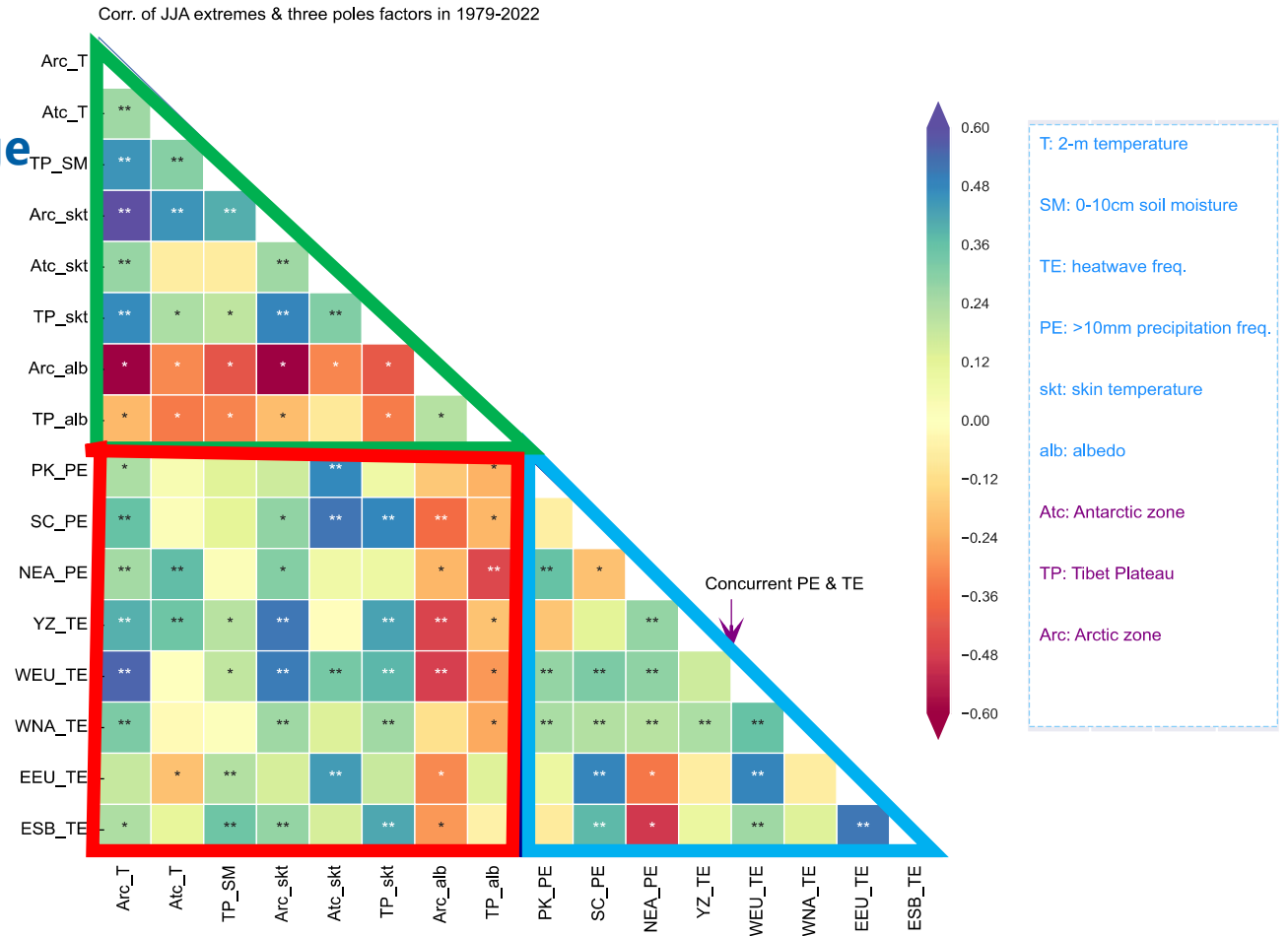


# 2、 Causal relationship between three Poles T and SM with global extremes

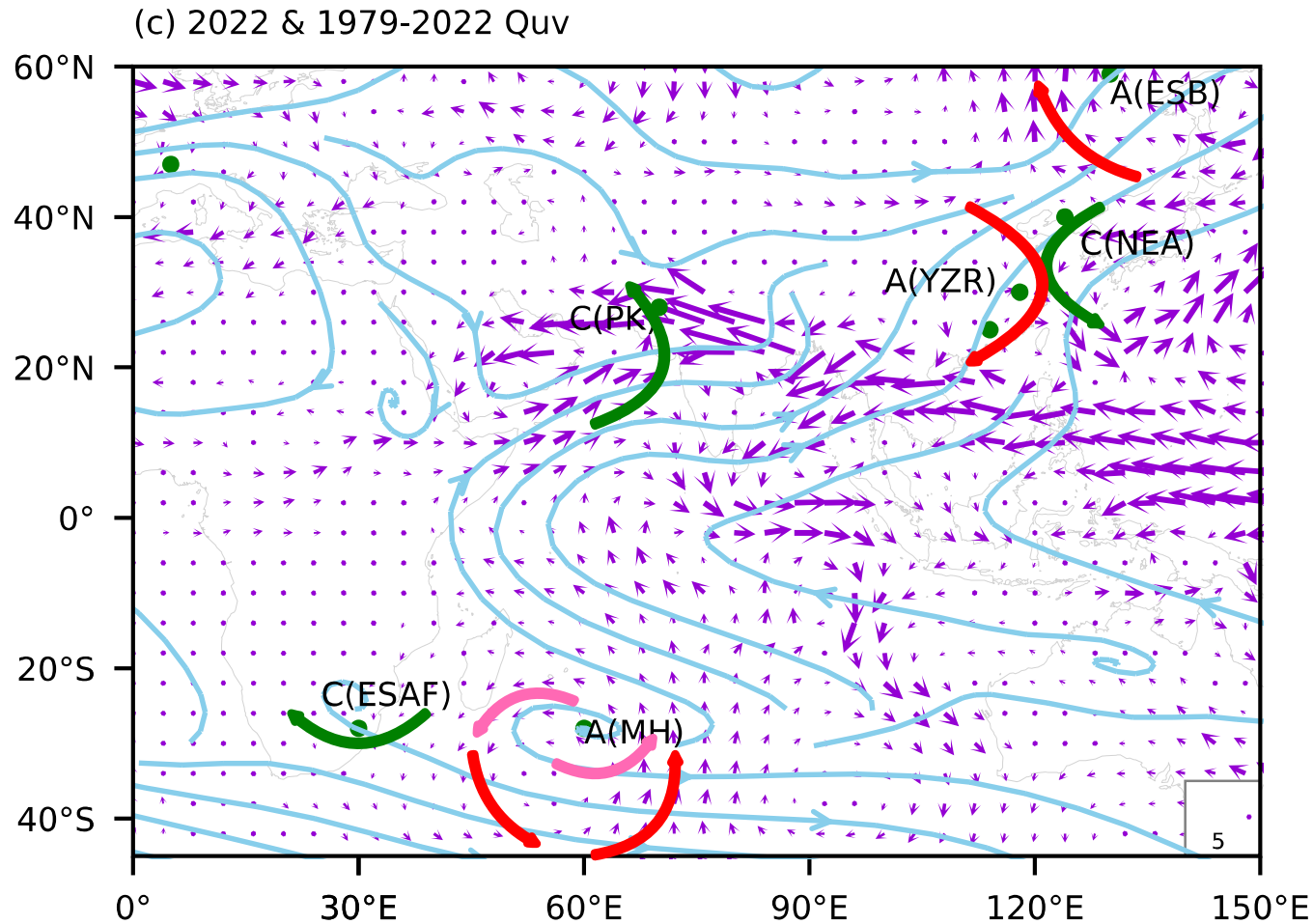
## Three Poles linkage



## Causal relationship



## 2、Circulation anomaly in JJA in 2022



### North Hemisphere

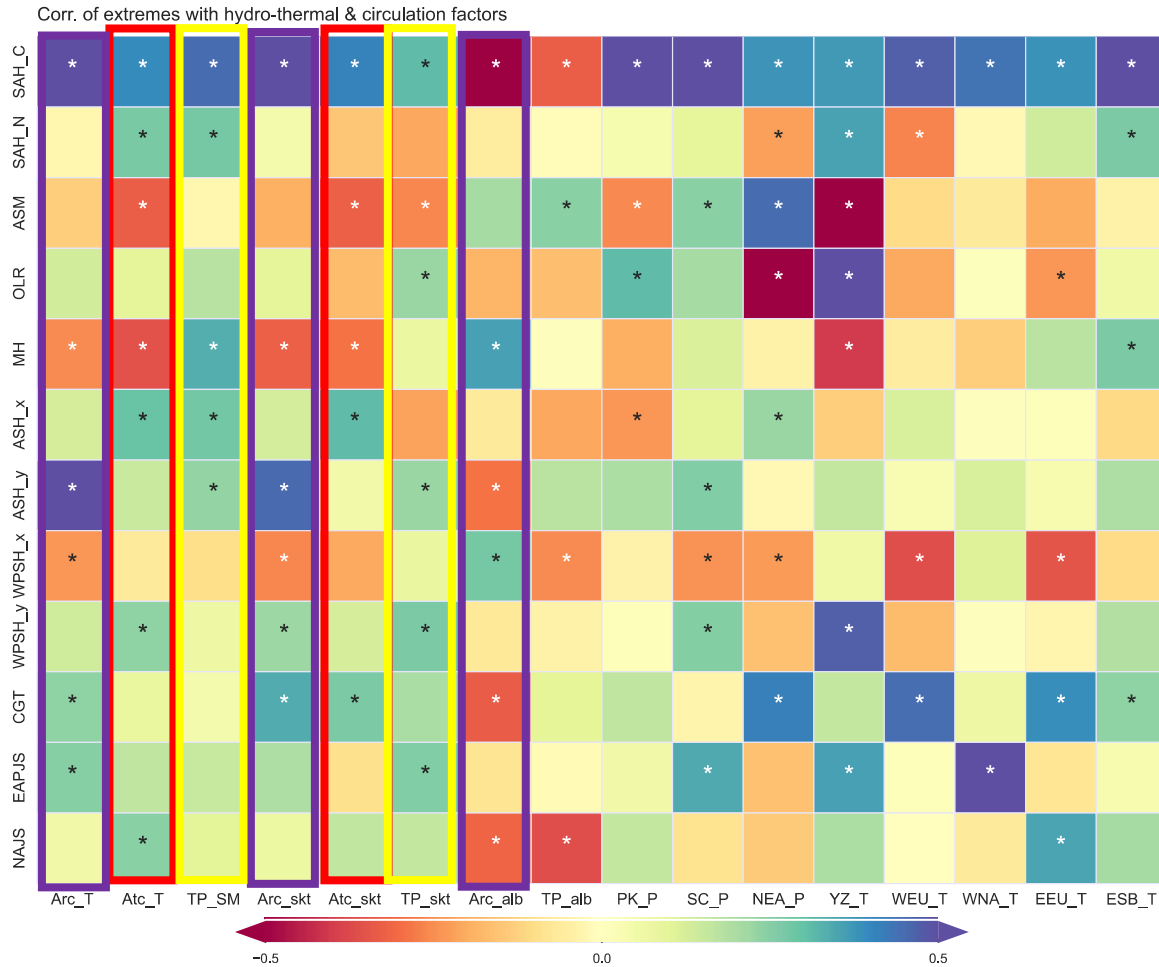
- Northward JS & SH  $\nabla T \downarrow$
- meridional circulation  $\nabla T \downarrow$
- NAFSH & WPSH, TP\_SHF  $\downarrow$
- Northward SAH, TP\_LHF  $\uparrow$

### South Hemisphere

- Southward wave & SH,  $\nabla T \downarrow$
- meridional circulation  $\nabla T \downarrow$
- southward ASM TP\_SHF  $\downarrow$ ,  $\nabla P \downarrow$



## 2、 Three Poles warming effect on circulations



**Antarctic glacier** ↓  $-\nabla T$  ↓

—southward MH ↓  $\nabla P$  ↓ ASM ↓ SAH ↑

Northward WPSH ↑ North-east NAFSH ↑

CGT ↑

**Arctic ice** ↓  $-\nabla T$  ↓

—southward MH ↓ SAH ↑ Northward

WPSH ↑ North-east NAFSH ↑ CGT ↑

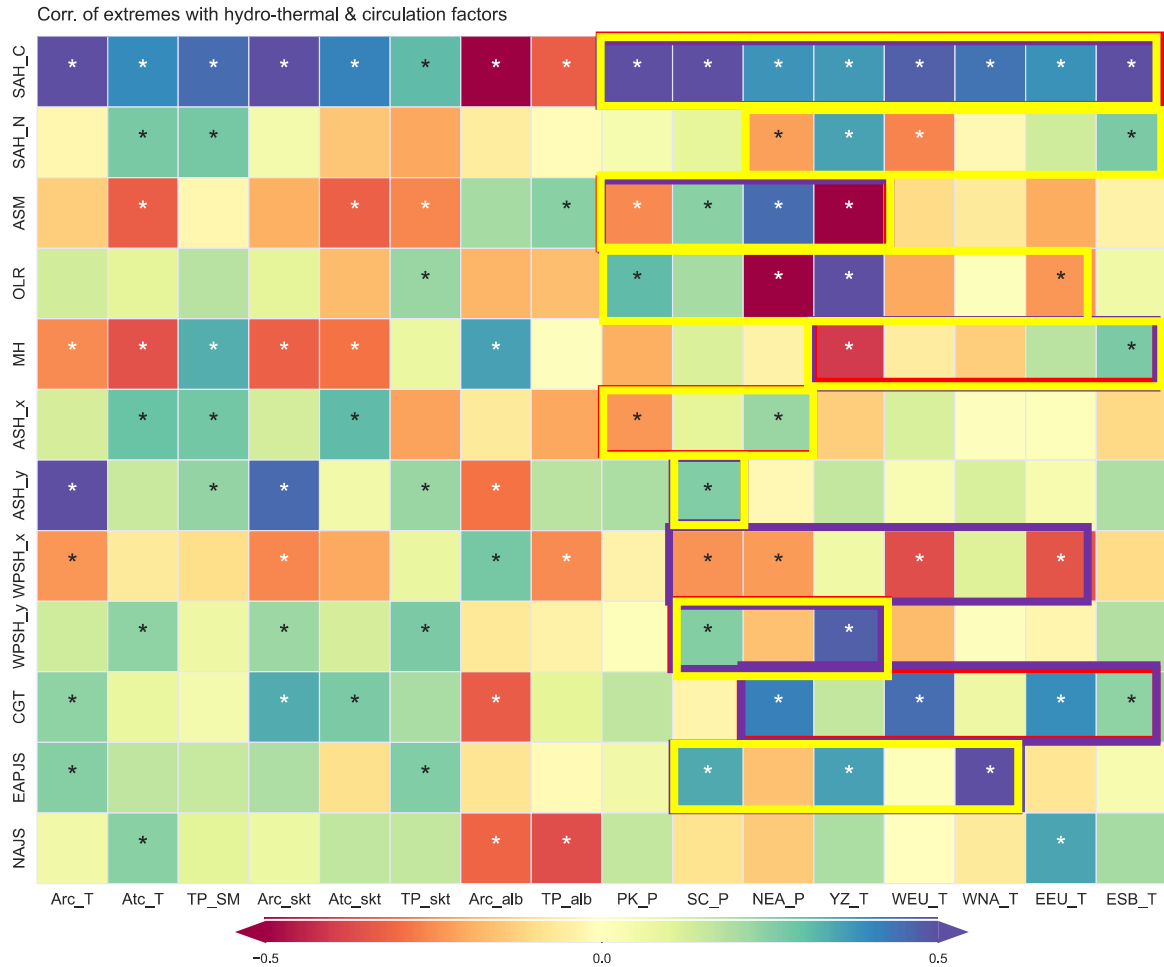
**TP SM** ↑ TP\_SHF ↓ TP\_LHF ↑

—southward MH ↑ ASM ↓ SAH ↑

Northward WPSH ↑ North-east NAFSH ↑

CGT ↑

## 2、Circulations effect on extremes



**Southward ASM** ↓

—rainstorm in SC NEA ↑ heatwave & drought in Yangtze River ↑

**Northward NAF SH** ↑ —rainstorm in SC

↑

**Southward MH** ↓ —heatwave & drought in Yangtze River ↑

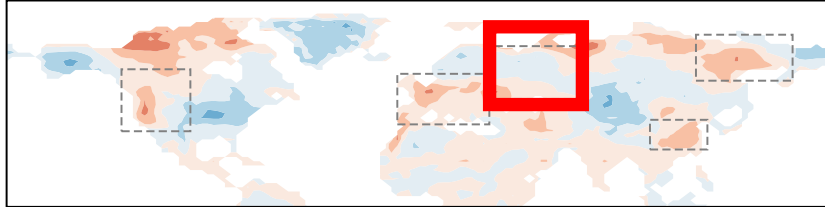
SAH ↑ CGT ↑ EA JET ↑ Northwest WPSH ↑

# 2、CESM simulation on three Poles ice loss

Arctic

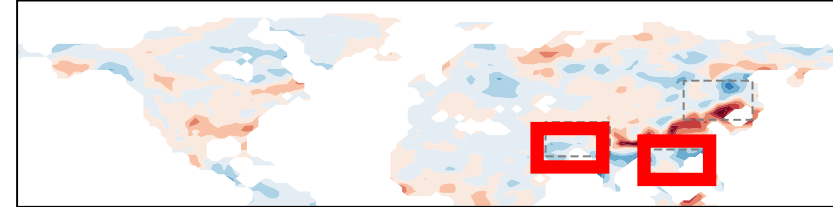
(a1) t2m by Arctic forcing

**T**



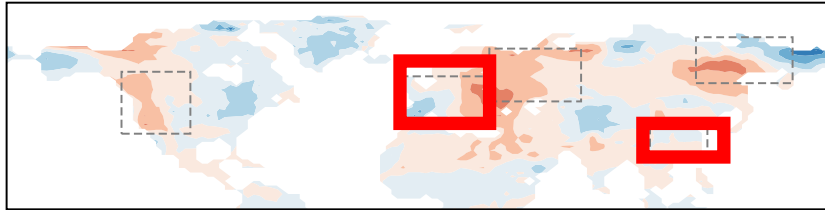
(a2) P by Arctic forcing

**P**

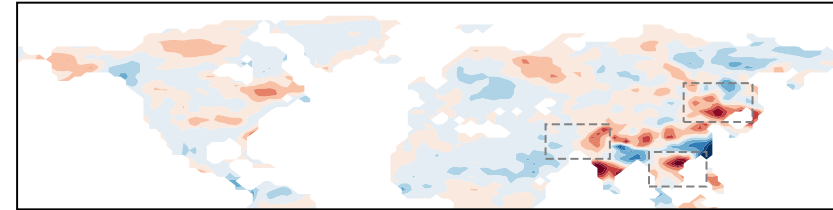


Antarctic

(b1) t2m by Antarctic forcing

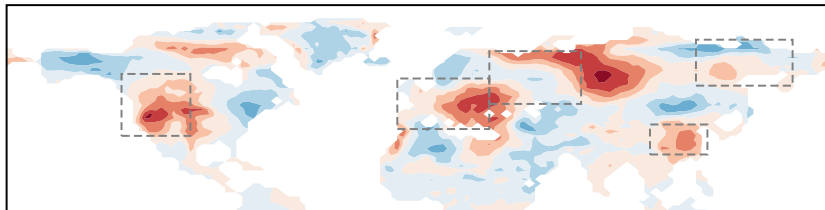


(b2) P by Antarctic forcing

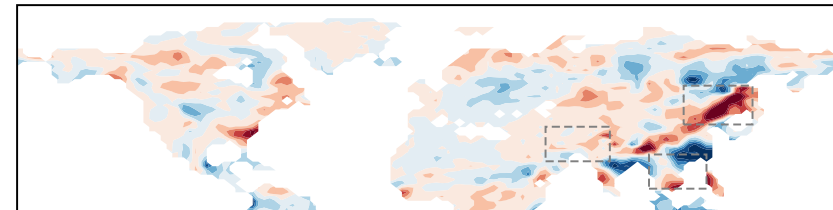


Tibet Plateau

(c1) t2m by Tibet Plateau forcing

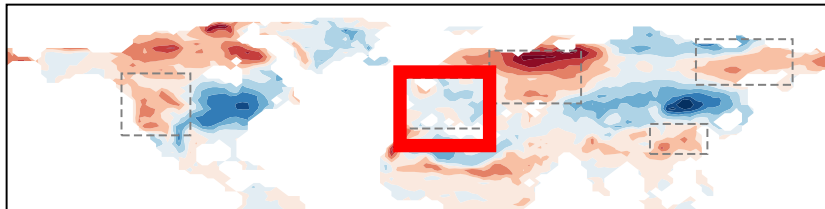


(c2) P by Tibet Plateau forcing

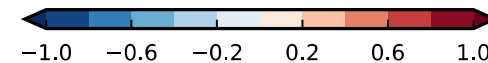
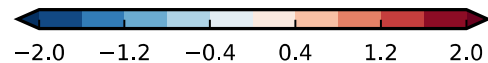
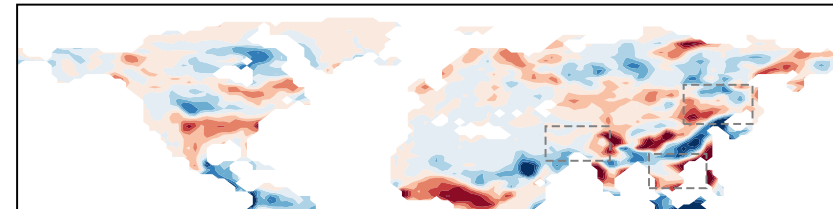


Three Poles coupling

(d1) t2m by three poles forcing

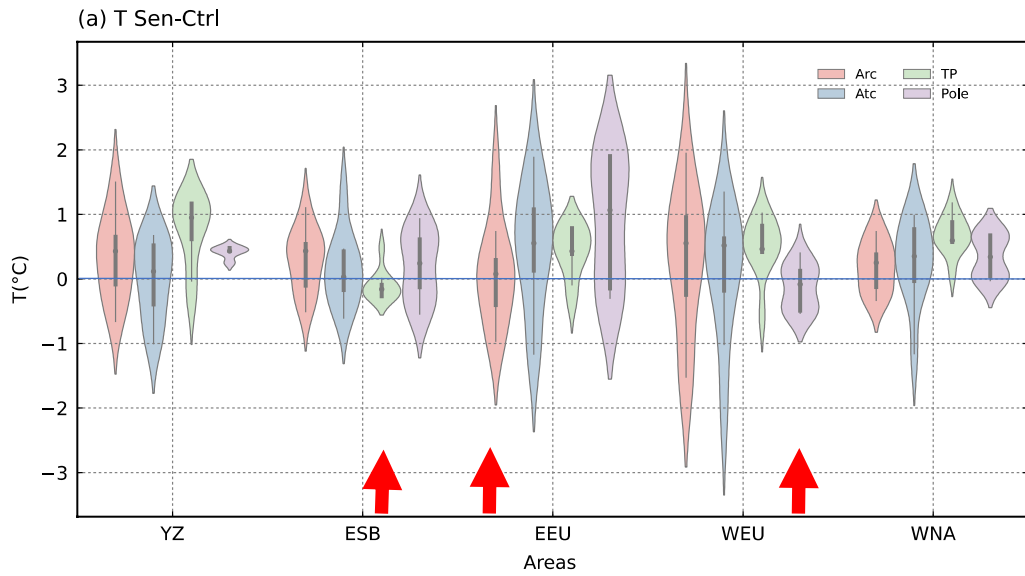


(d2) P by three poles forcing

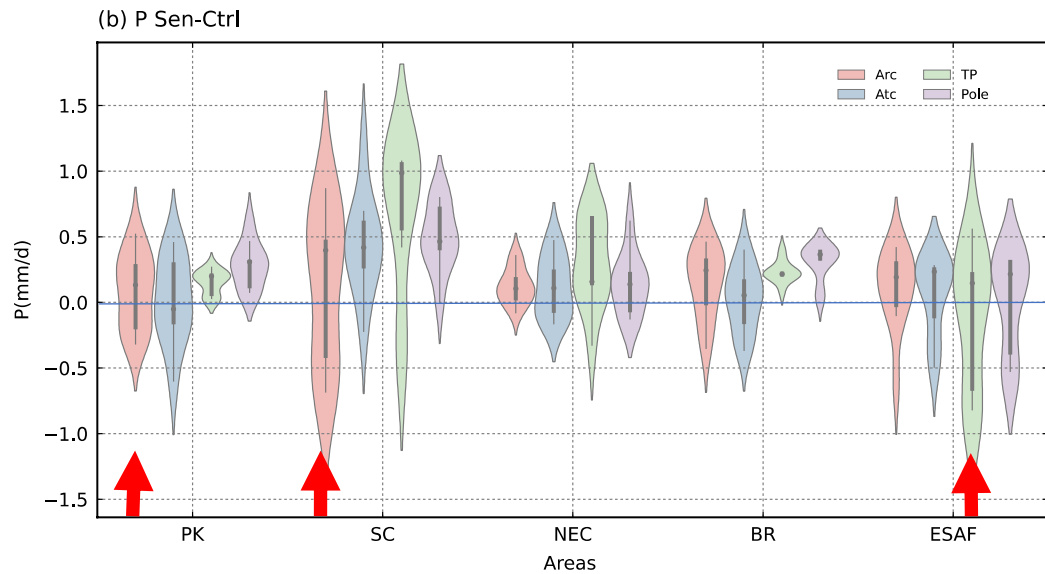


# 2、CESM simulation on three Poles ice loss

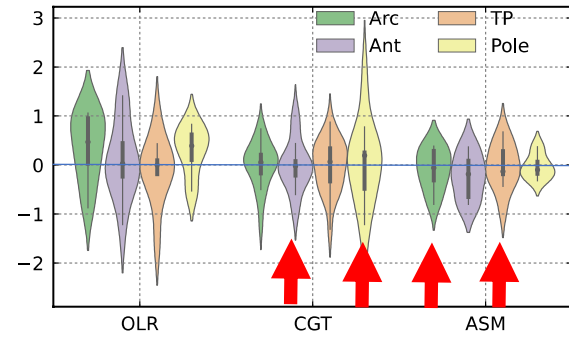
T



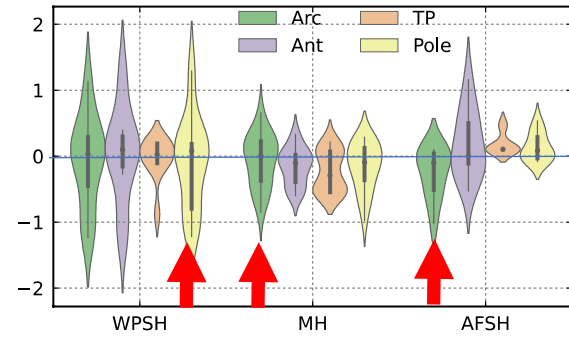
P



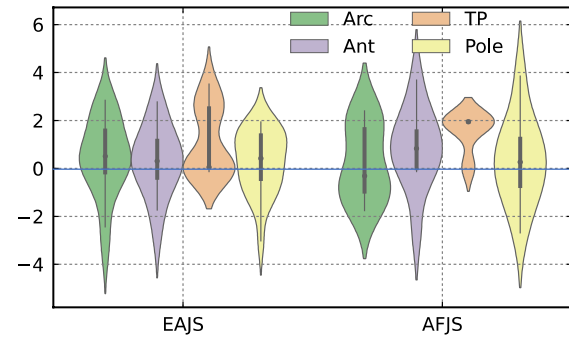
(c) Standardized factors



(d) Subtropical High



(e) JS

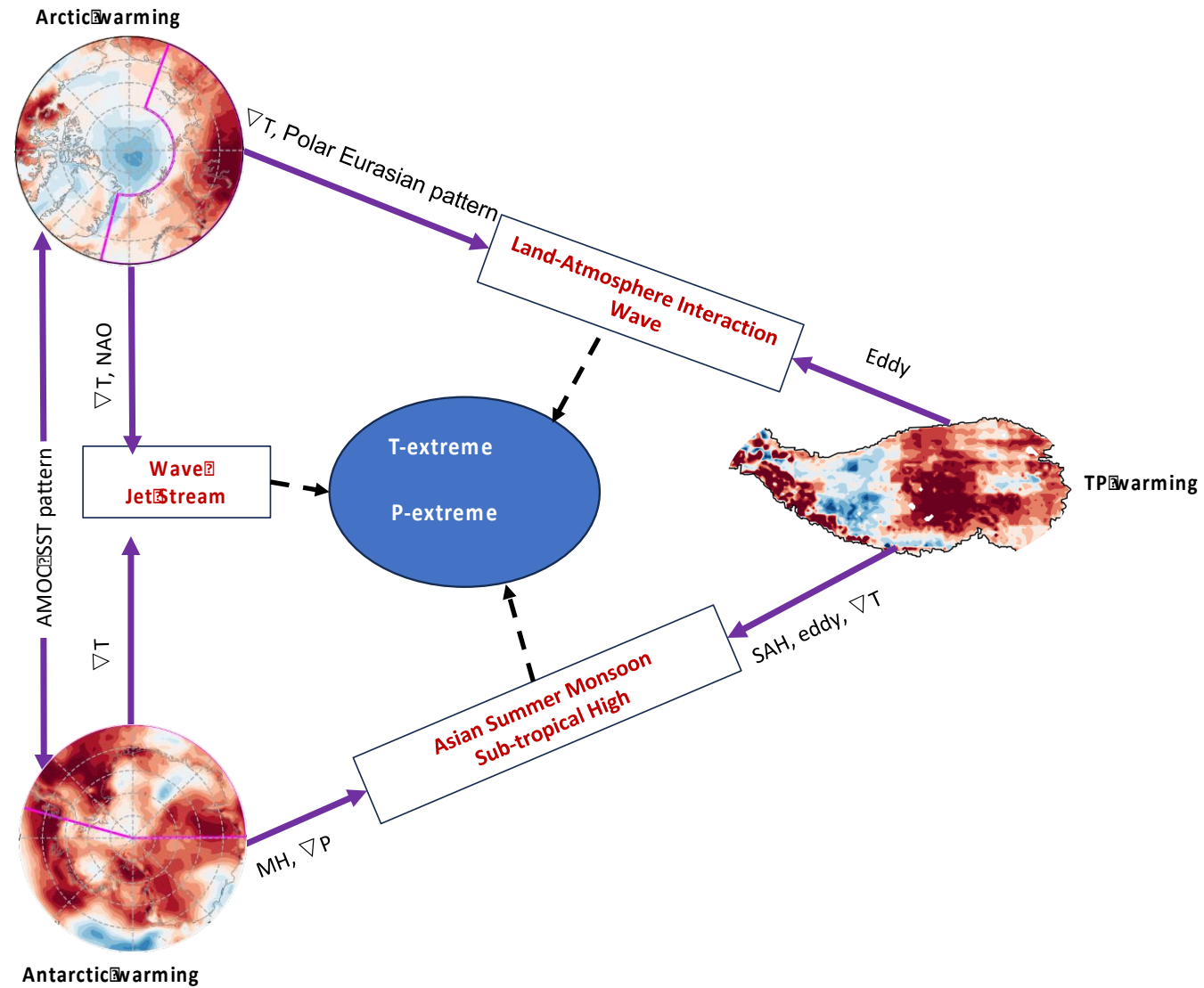


Circulations 1

SH

JS

## 2、 Mechanisms of three Poles effect on global concurrent extremes





# 3、 Summary

---

- 5 record breaking extreme events in 2022 may have clustered characteristics
- There is a correlation between frequent extreme events in 2022 and abnormal warmth and humidity in the three poles
- In 2022, the impact of the three extreme anomalies on the polar jet stream, wave train, and three subtropical high pressures will strengthen the CGT and weaken the Asian monsoon to the south - different paths will lead to the same outcome
- Three Poles impact on concurrent extreme events is statistically significant, and 2022 is only a manifestation of signal amplification

## 4、 Reverences

Zhang J.\* ,H. Chen, X. Fang, Z. Yin, and R. Hu. Warming-induced hydrothermal anomaly over the Earth's three Poles amplifies concurrent extremes in 2022. *npj Climate and Atmospheric Science*,2024.7:8. <https://doi.org/10.1038/s41612-023-00553-6>.

Fang X., J. Zhang. Antarctic warming induced South Atlantic warming effect on the heatwaves in East Asia in 2022 . *Clim. Dynamic.*, major revision.

Zhang J.\* ,H. Chen, A. Dai,et al. The Tibetan Plateau warming in spring intensify Pakistan summer flood in 2022-2023.



**Thank you for your attentions!**

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