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Effects of Large Volcanic Eruptions on Global Summer Climate and East Asian Monsoon Changes

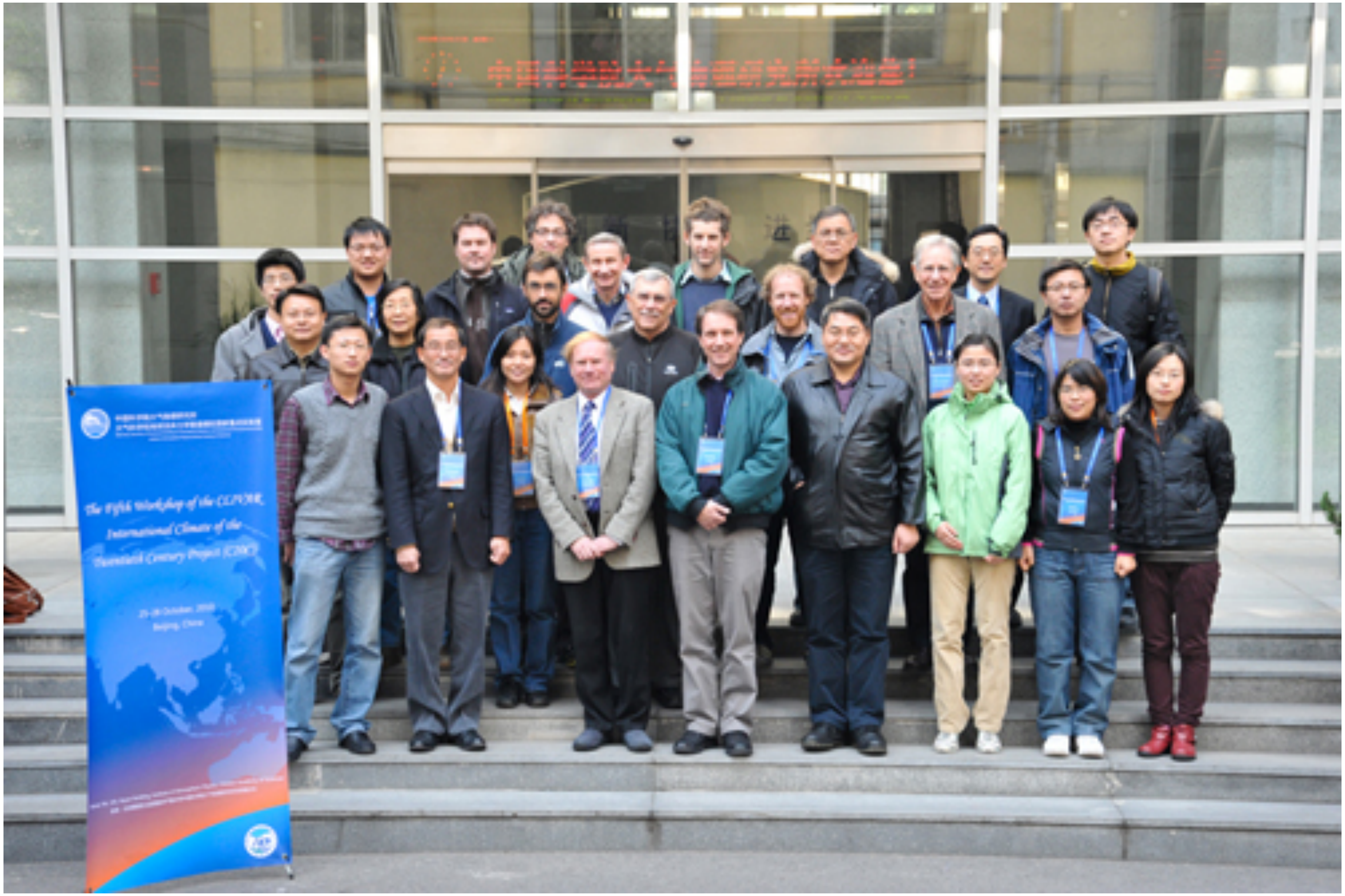
CLIVAR C20C Project 6th Workshop, Melbourne, Australia

5-8 November, 2013

Outline

- Background
- MPI model Responses for the observed cases
- MPI model Responses for the 21 cases of large volcanic eruptions
- IAP/LASG model simulation
- Summary

The 5th C20C workshop , Oct. 25-28, 2010, IAP, Beijing

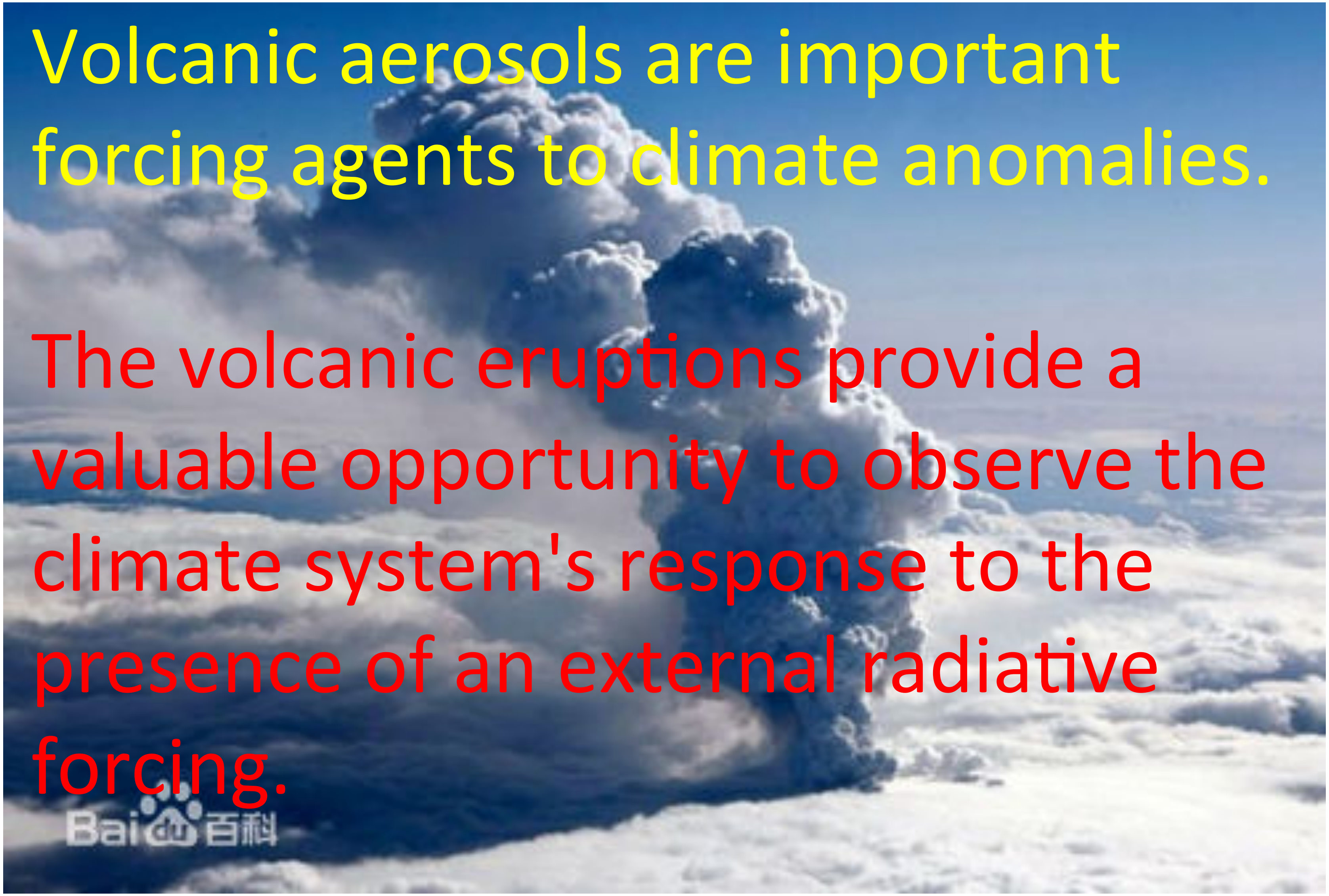


The 5th C20C Beijing workshop was delayed to Oct. 2010 due to the eruption of Icelandic Volcano in May 2010

Motivation

Volcanic aerosols are important forcing agents to climate anomalies.

The volcanic eruptions provide a valuable opportunity to observe the climate system's response to the presence of an external radiative forcing.

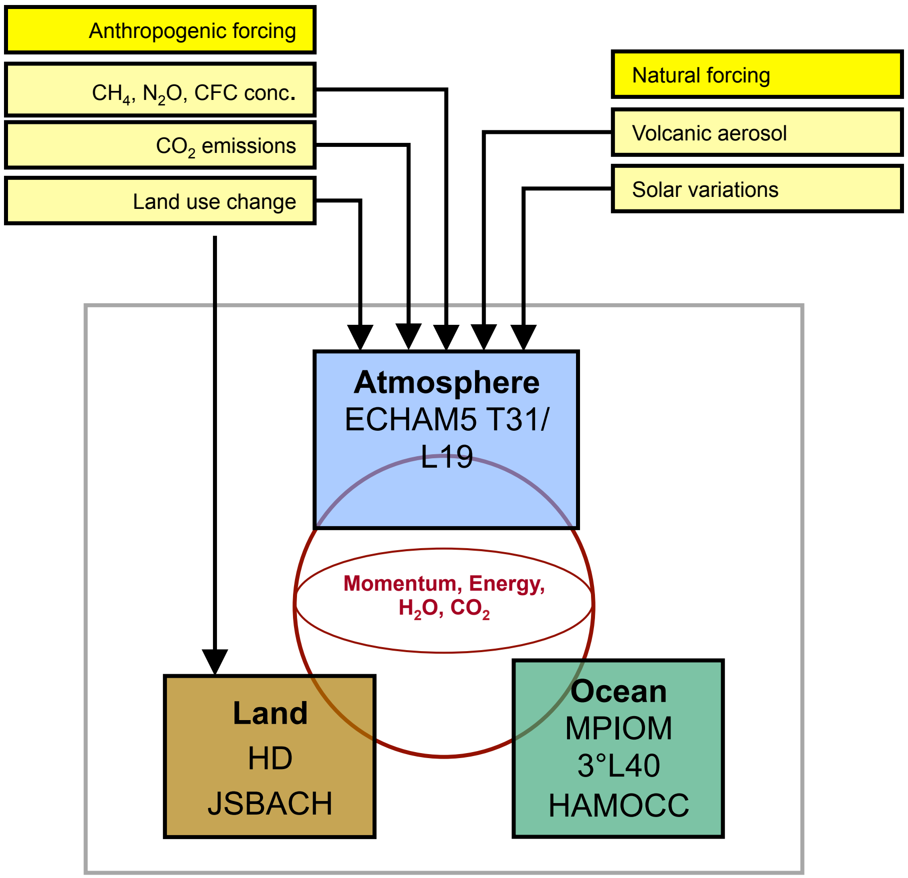


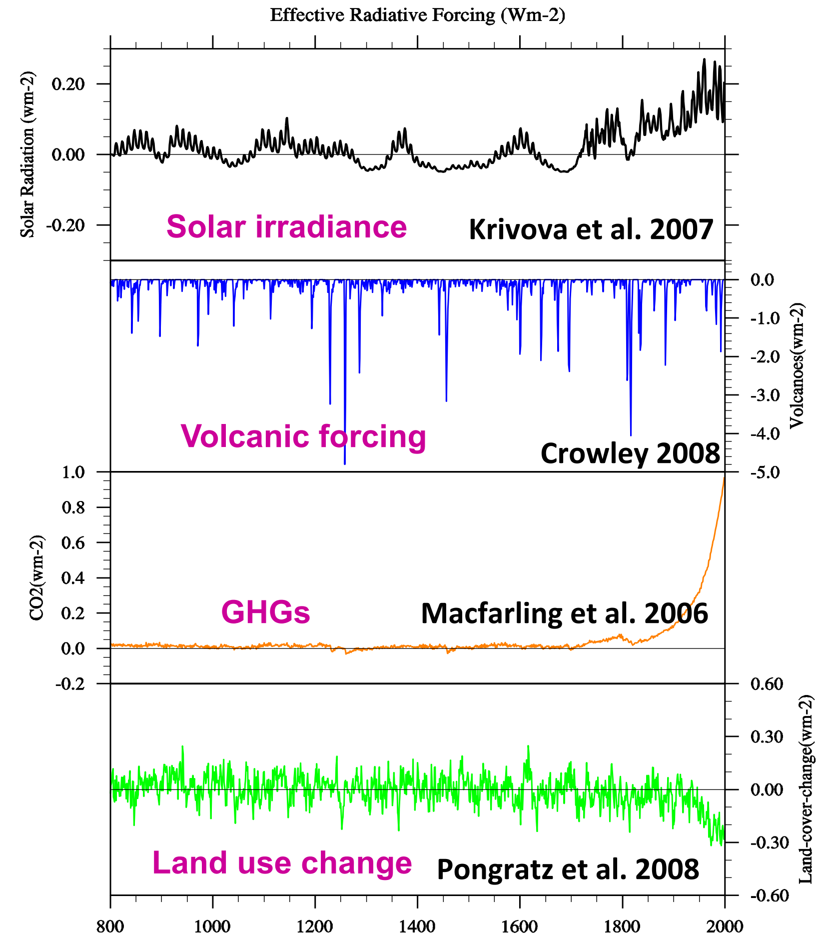
Motivation

To examine the volcanic effort from a millennial perspective.

The simulations were driven by monthly and latitudinally varying volcanic aerosol dataset for a better understanding of the effects of volcanic aerosol on global and regional climate.

Millennial climate simulation of MPI-ESM





The ensemble of 5 realizations; period AD 800-2005

Man W., **T. Zhou** , J. H. Jungclaus, 2012: Simulation of the East Asian Summer Monsoon during the Last Millennium with the MPI Earth System Model, **Journal of Climate**, 25(22), 7852-7866

List of the selected 21 volcanic eruptions in 800-2005 (eruption year is defined by a decrease in net top solar irradiation of at least $-2.0\ W\ m^{-2}$)

No	Year	Name	VEI
1	842	Unknown	
2	854	Unknown	
3	897	Unknown	
4	971	Unknown	
5	1193	Unknown	
6	1228	Unknown	
7	1258	Unknown	
8	1286	Unknown	
9	1442	Unknown	
10	1456	Kuwae Vanuatu	
11	1600	Huaynaputina	
12	1641	Parker	6
13	1673	Capelo	6
14	1694	Serua	6
15	1809	St Helen	
16	1815	Tambora	7
17	1832	Babuyan Claro	4
18	1835	Cosigulna	
19	1884	Krakatau	6
20	1903	Grimsvotn	4
21	1992	Pinatubo	6

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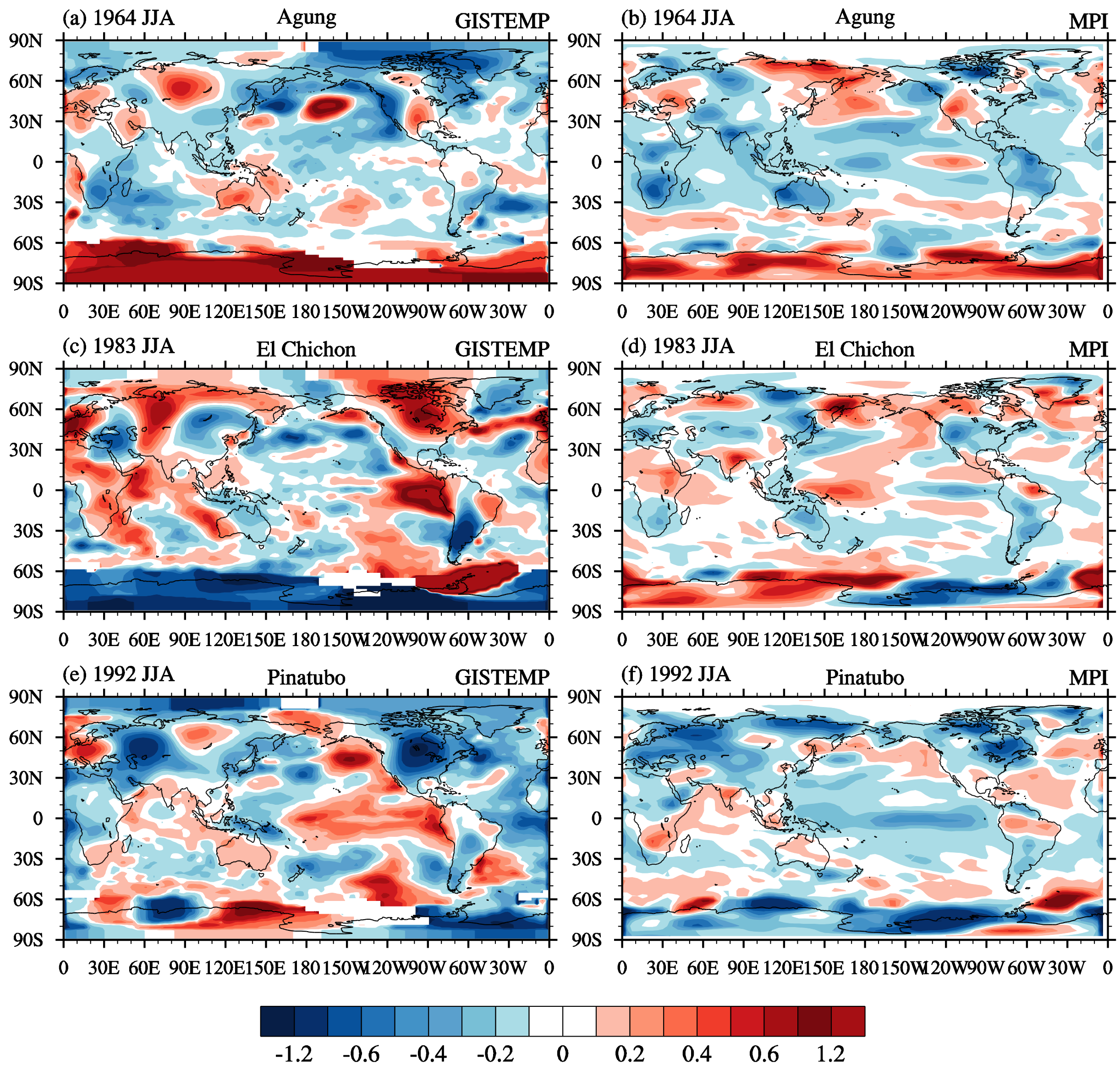
Spatial patterns of global temperature anomalies in the first summer after the volcanic eruptions

Obs. | **MPI-ESM**

Agung,1963

El Chichon,1982

Pinatubo,1991

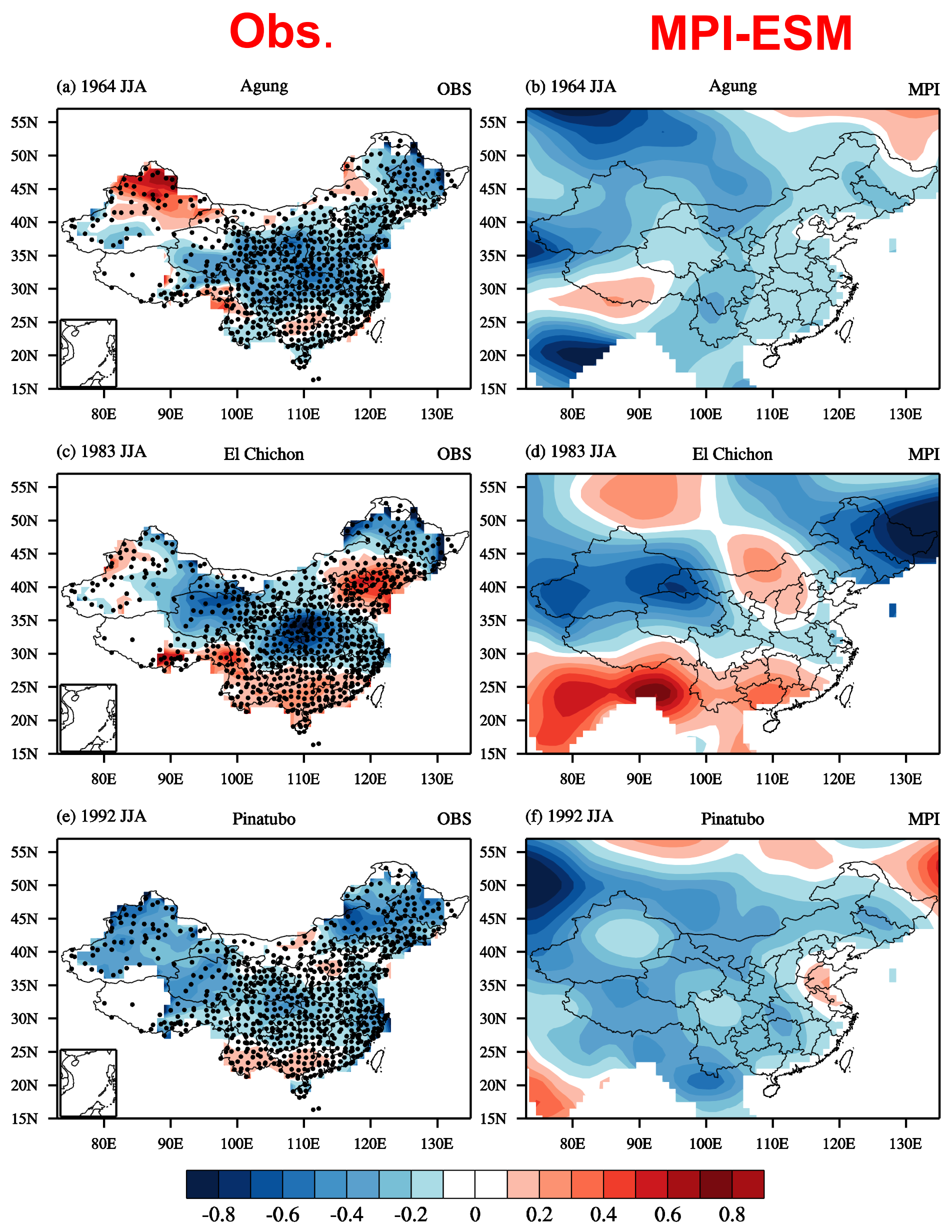


Temperature anomalies over China in the first summer after the volcanic eruptions

Agung,1963

El Chichon,1982

Pinatubo,1991

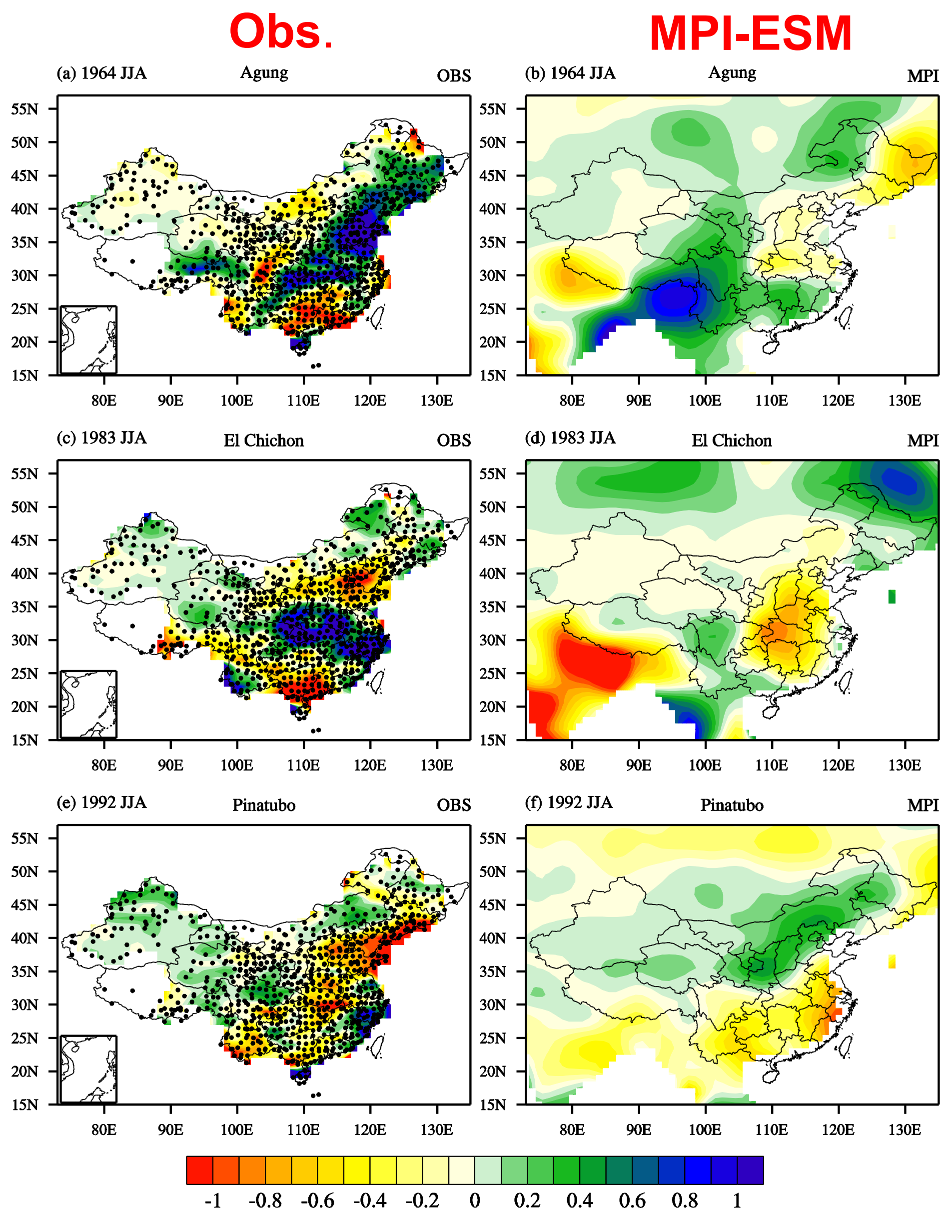


Precipitation anomalies over China in the first summer after the volcanic eruptions

Agung,1963

El Chichon,1982

Pinatubo,1991



Simulation of precp is a difficult task

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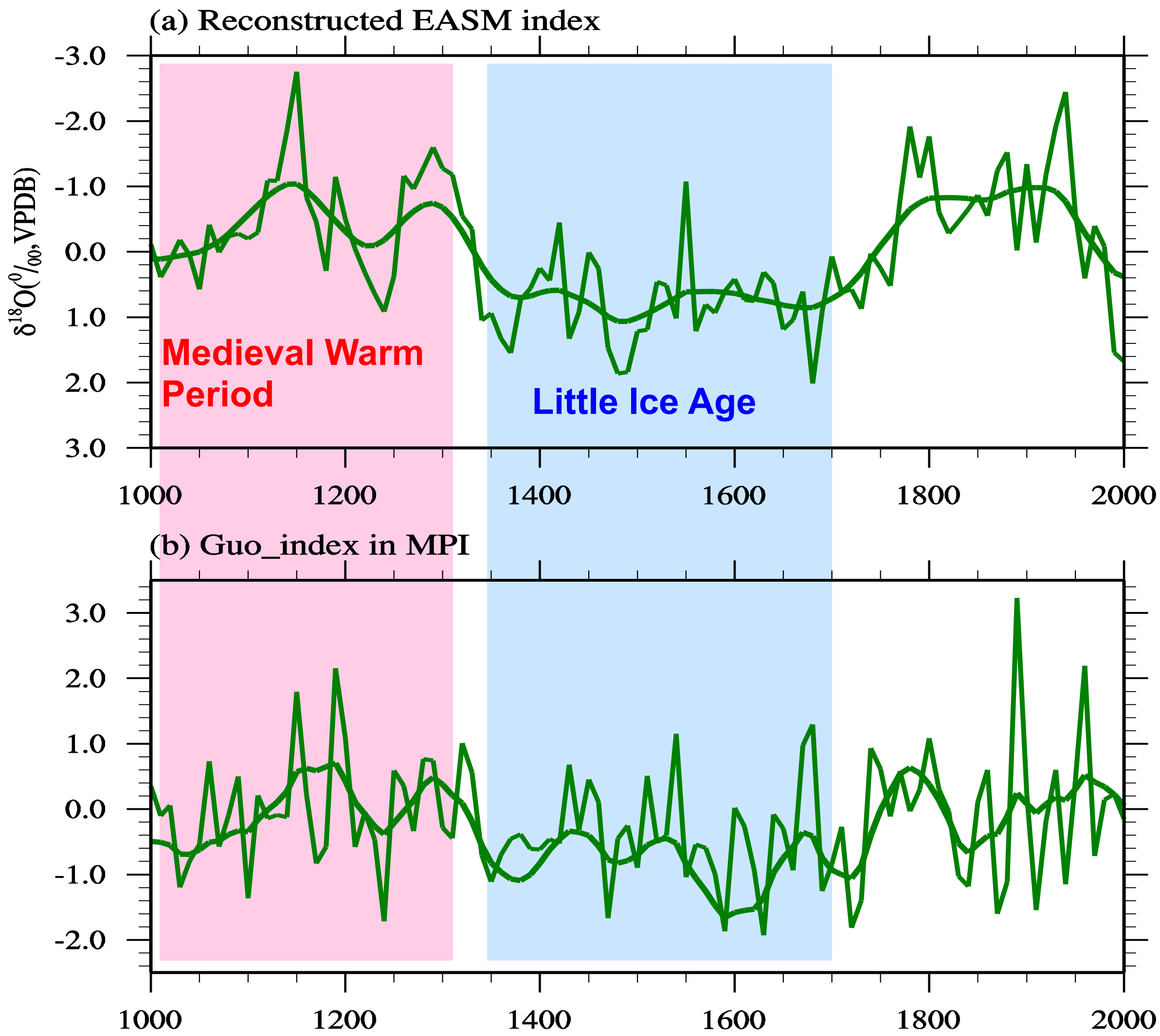
Comparison of reconstructed and simulated EASM index



Reconstructed

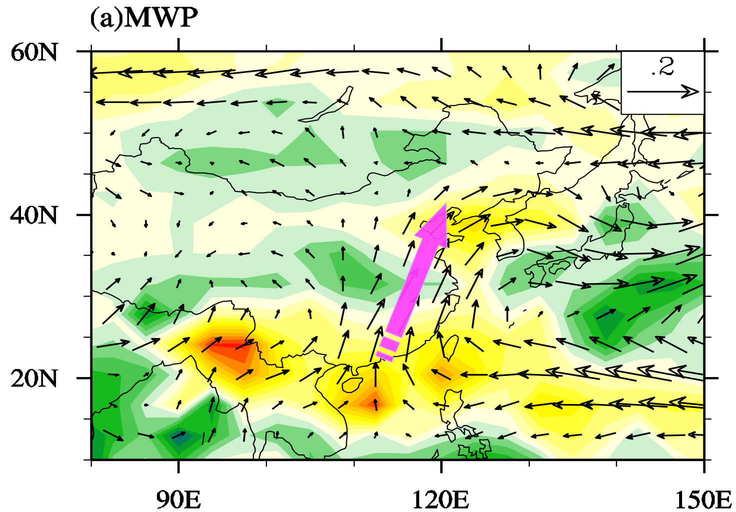
Simulated

Man W., **T. Zhou** , J. H. Jungclaus, 2012: Simulation of the East Asian Summer Monsoon during the Last Millennium with the MPI Earth System Model, **Journal of Climate**, 25(22), 7852-7866

EASM circulation and precipitation during the MWP and LIA

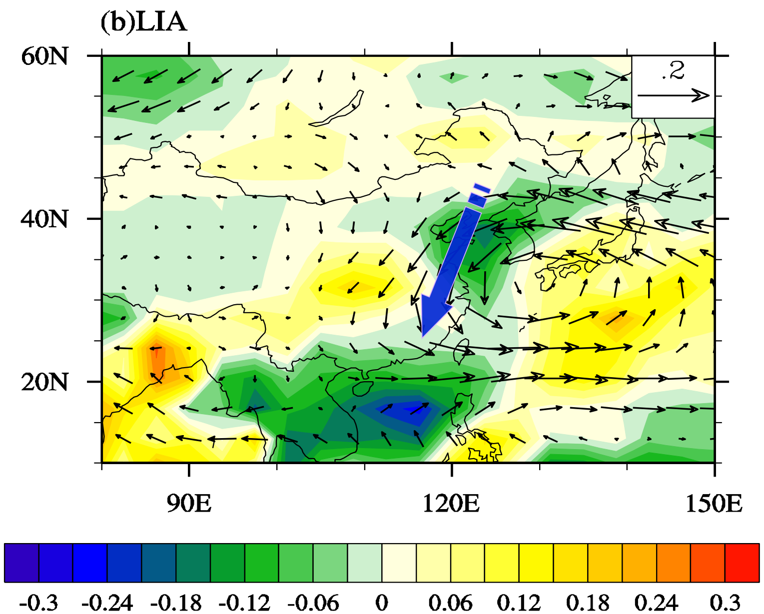
MWP, AD 1000-1100/LIA, AD 1600-1700

MWP
AD 1100-1200



Stronger EASM

LIA
AD 1600-1700



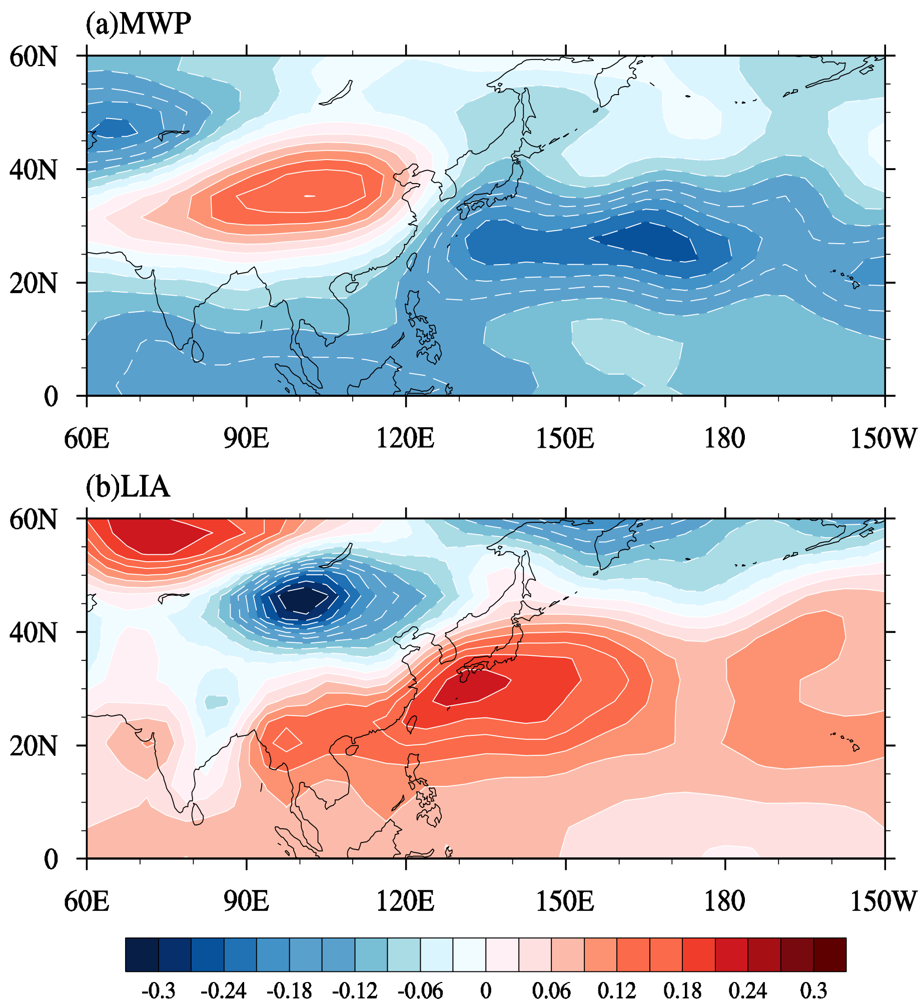
Weaker EASM

Man W., **T. Zhou** , J. H. Jungclaus, 2012: Simulation of the East Asian Summer Monsoon during the Last Millennium with the MPI Earth System Model, **Journal of Climate**, 25(22), 7852-7866

The land-sea thermal contrast change

Summer tropospheric mean temperature anomalies

MWP
AD 1100-1200



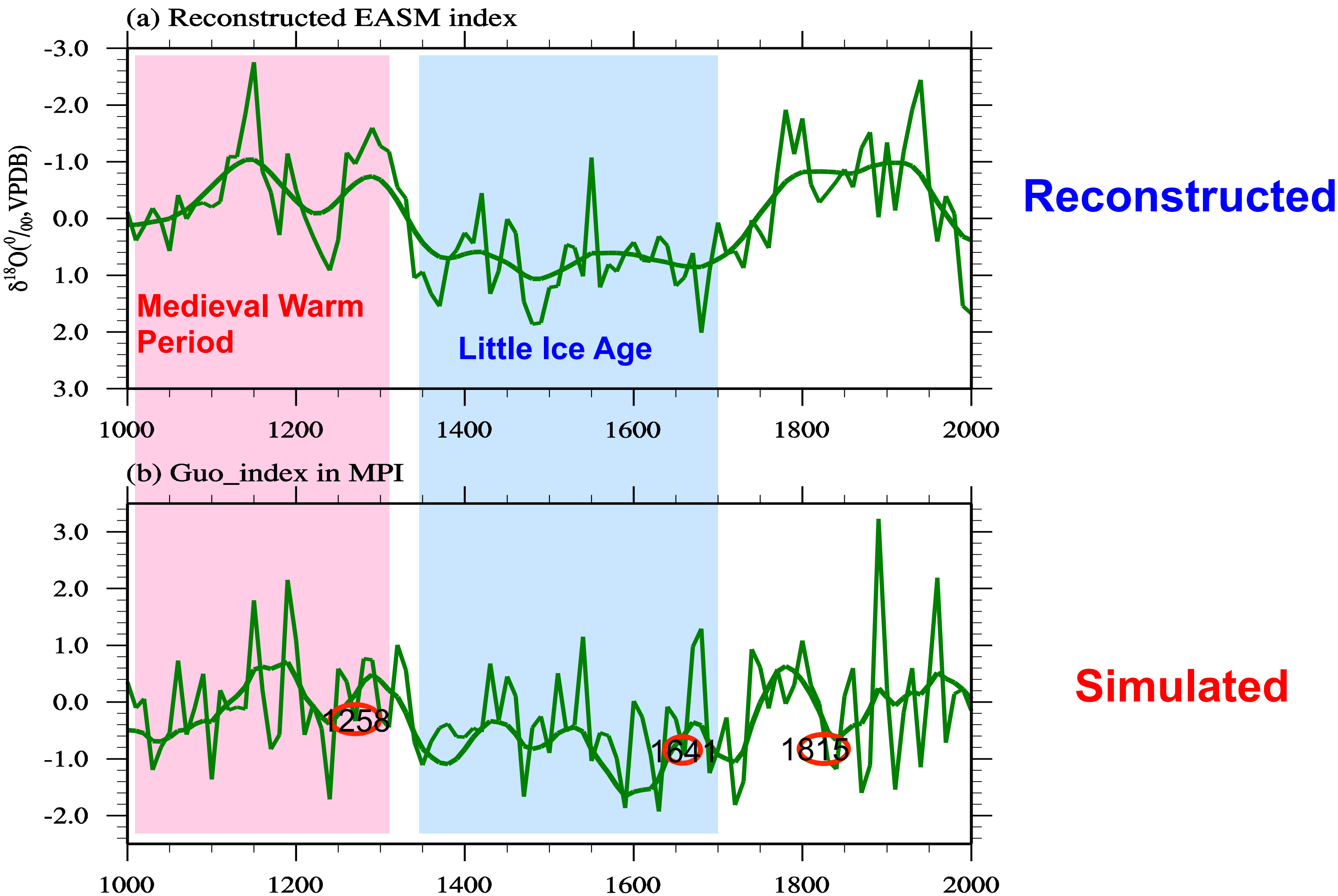
"warmer-land-colder-ocean"

LIA
AD 1600-1700

"colder-land-warmer-ocean"

Man W., **T. Zhou** , J. H. Jungclaus, 2012: Simulation of the East Asian Summer Monsoon during the Last Millennium with the MPI Earth System Model, **Journal of Climate**, 25(22), 7852-7866

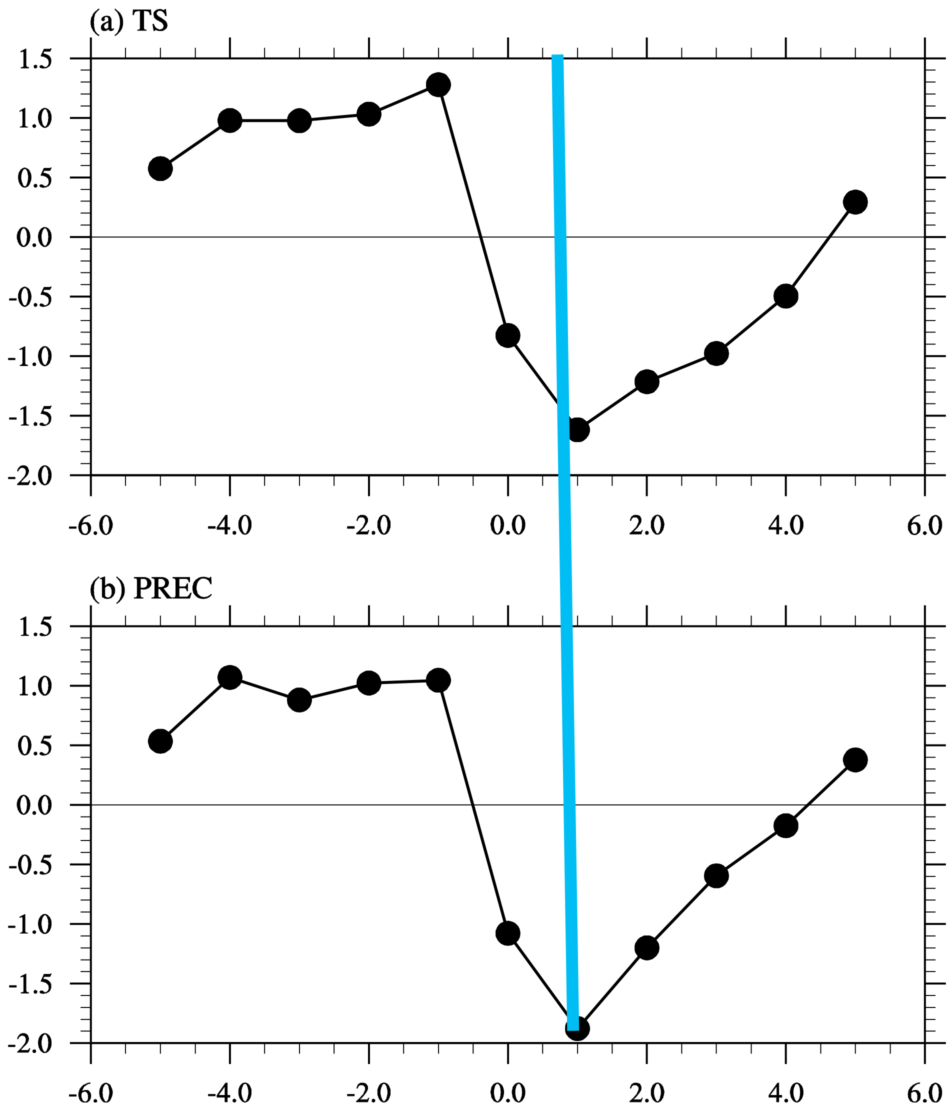
Reconstructed and simulated EASM index in MPI-ESM



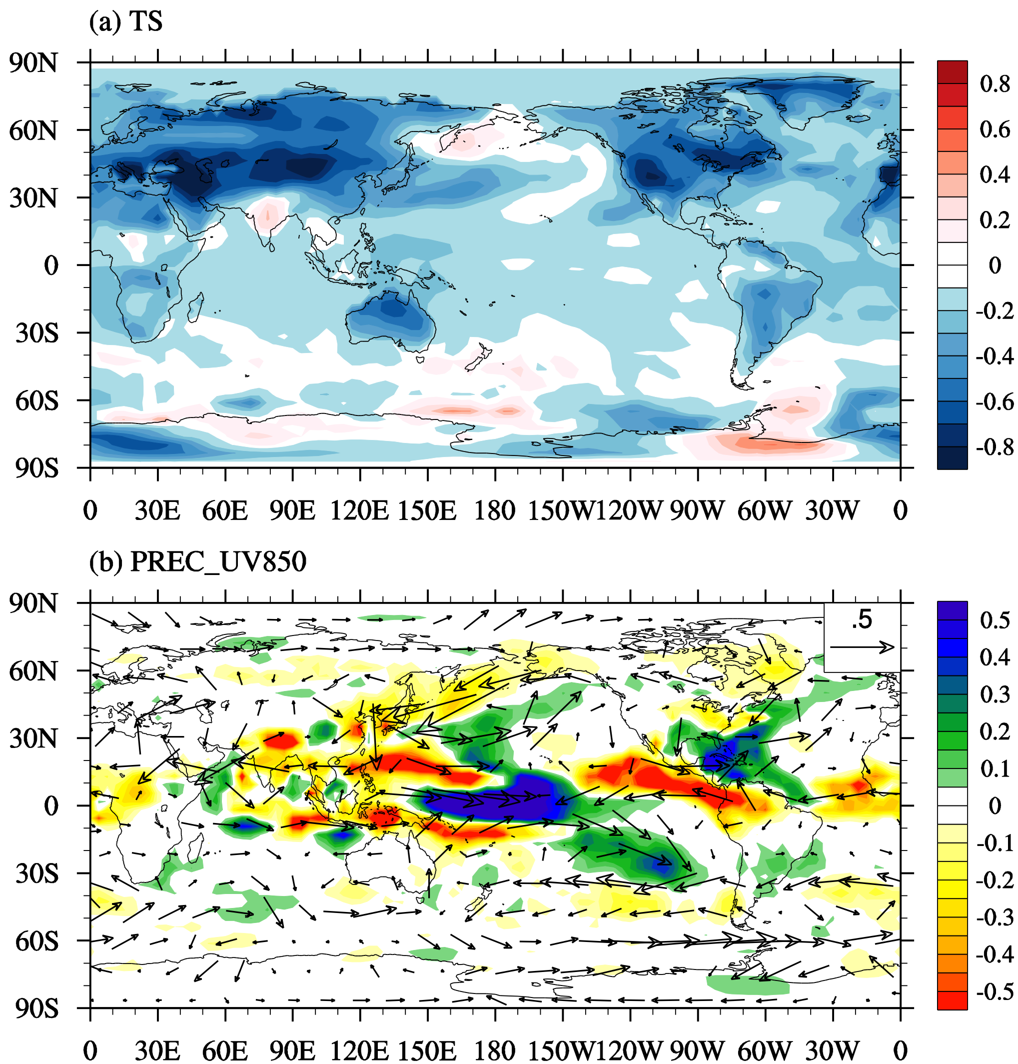
Man W., **T. Zhou** , J. H. Jungclaus, 2012: Simulation of the East Asian Summer Monsoon during the Last Millennium with the MPI Earth System Model, **Journal of Climate**, 25(22), 7852-7866

Temporal pattern of global mean (a) temperature and (b) precipitation anomalies for the 21 cases of large volcanic eruptions

Global response



Spatial patterns of global temperature and precipitation anomalies in the first summer after the volcanic eruptions



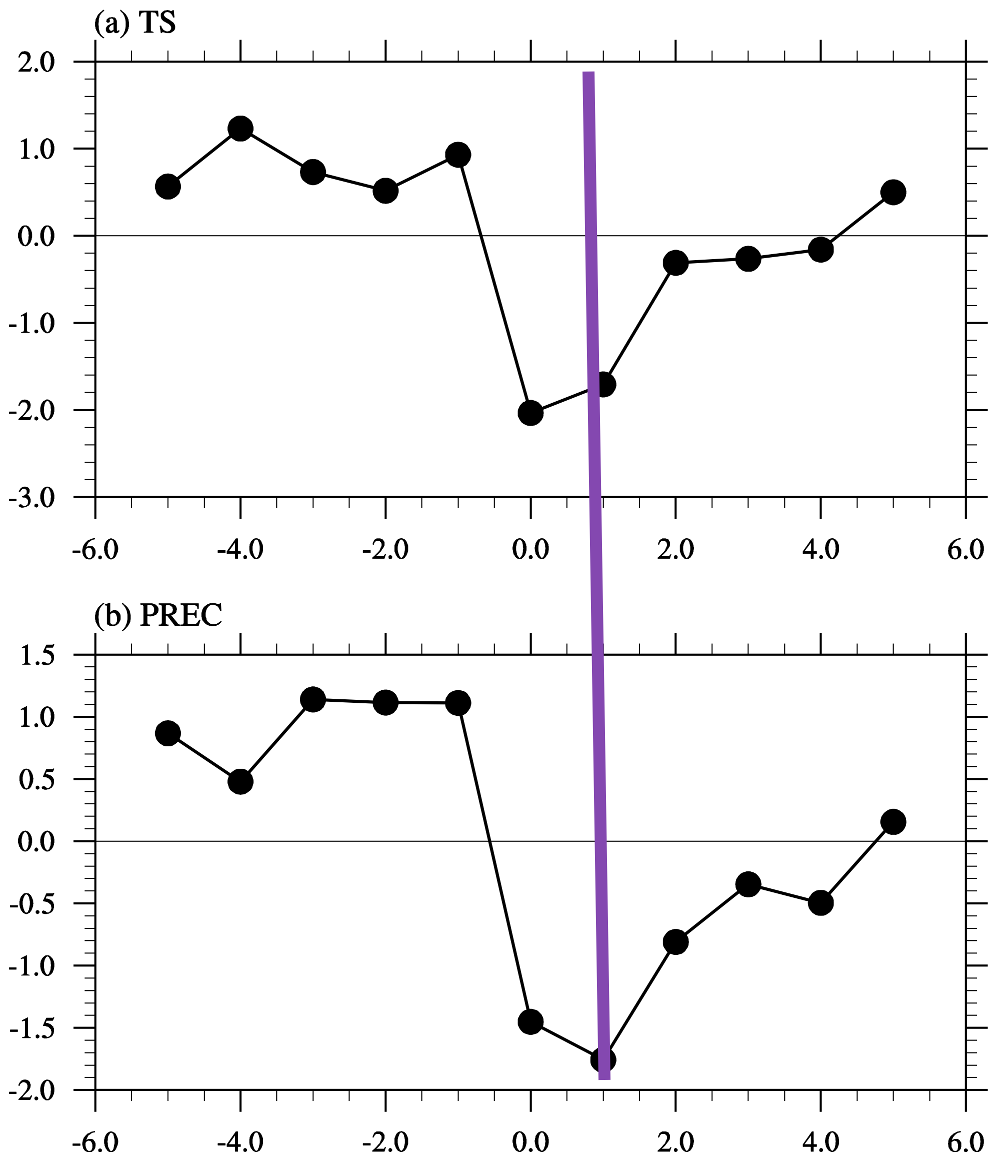
Cooling in NH is stronger than that in SH.

Cooling over the land is stronger than that over the ocean.

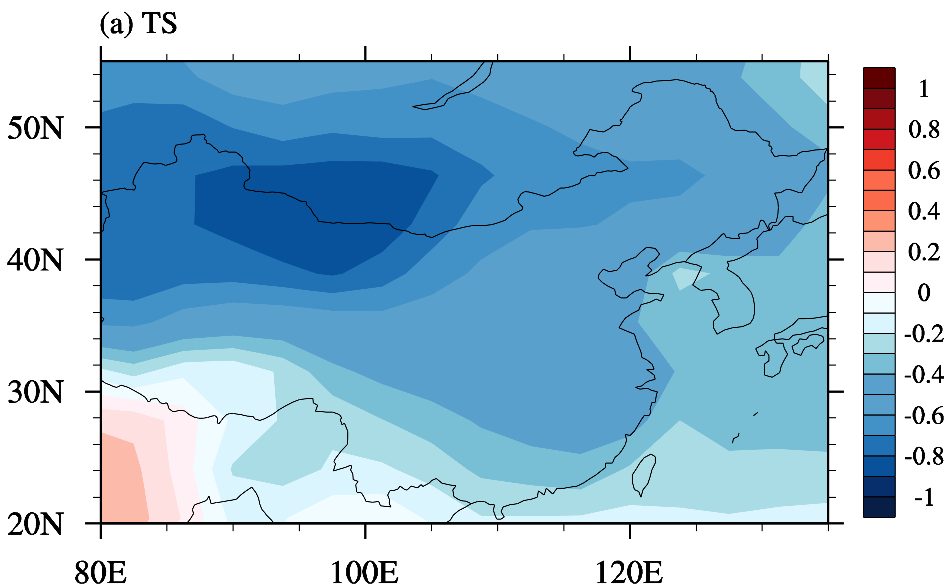
There is a general decrease of precipitation in the tropics and subtropics, except for the Equatorial central Pacific Ocean.

Temporal pattern of temperature and precipitation anomalies over East Asia for the 21 cases of large volcanic eruptions

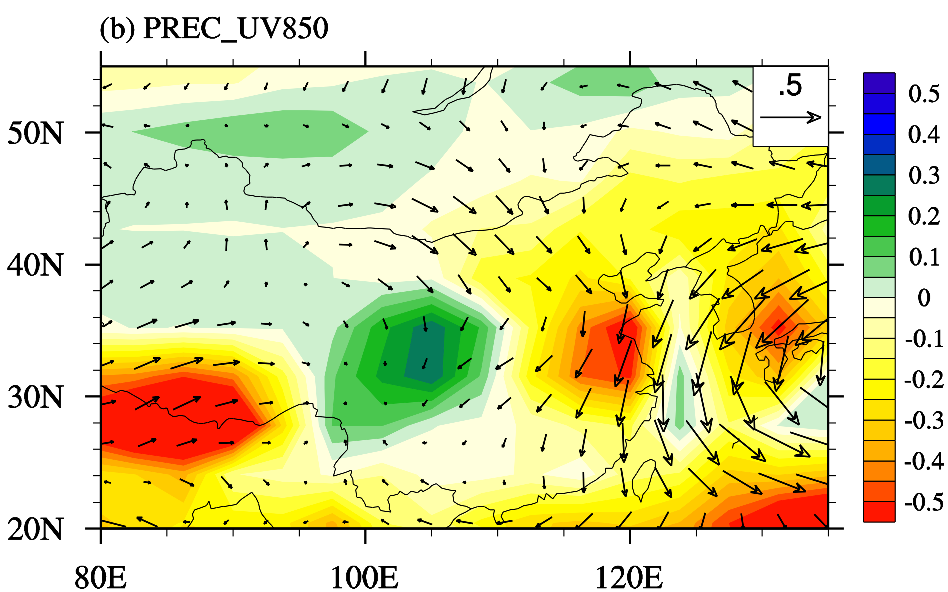
EA Response



Spatial patterns of temperature and precipitation anomalies over East Asia in the first summer after the volcanic eruptions

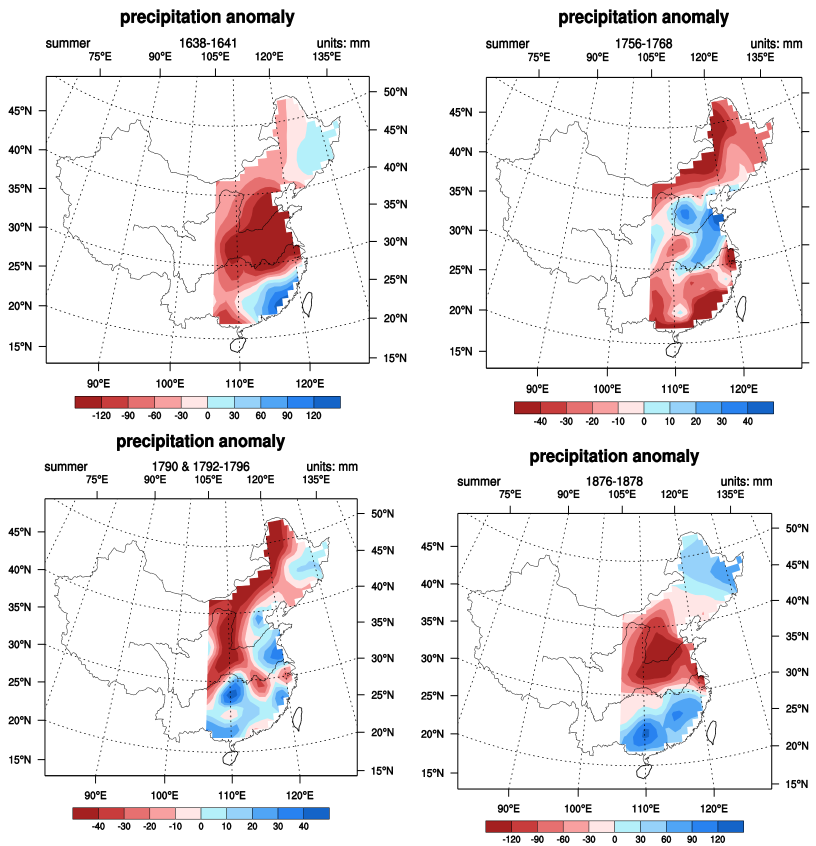


A cooling with amplitude up to -0.4 °C is seen over EA.



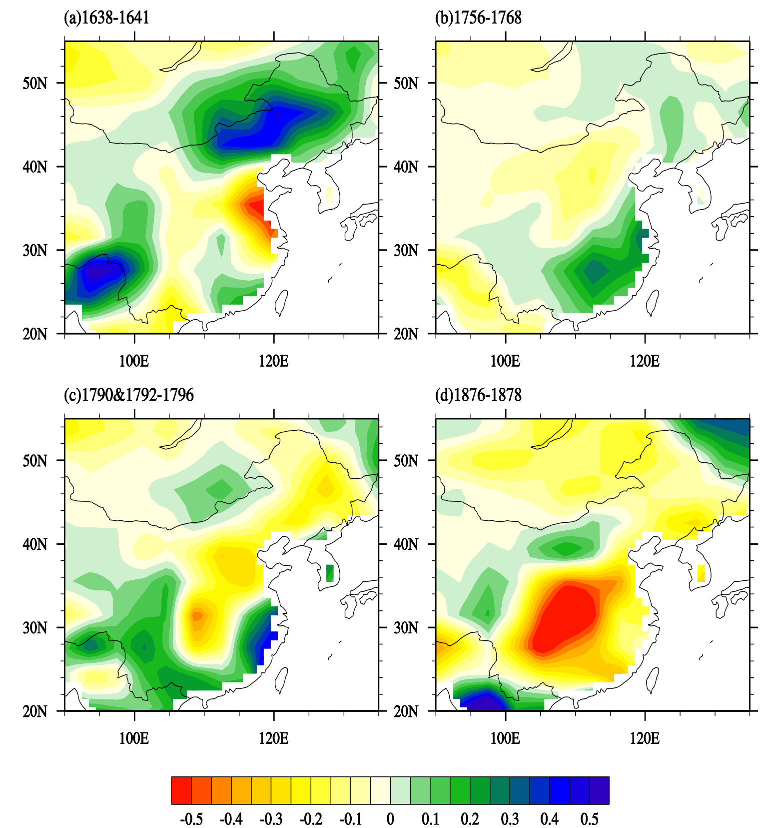
- ◆East Asian continent is dominated by northerly wind anomalies;
- ◆E. China sees coherent reduction of summer precipitation.
- ◆ indicate a weakened summer monsoon

Model-data comparisons



Proxy data from historical documents

Personal communication with Prof. S. W. Wang



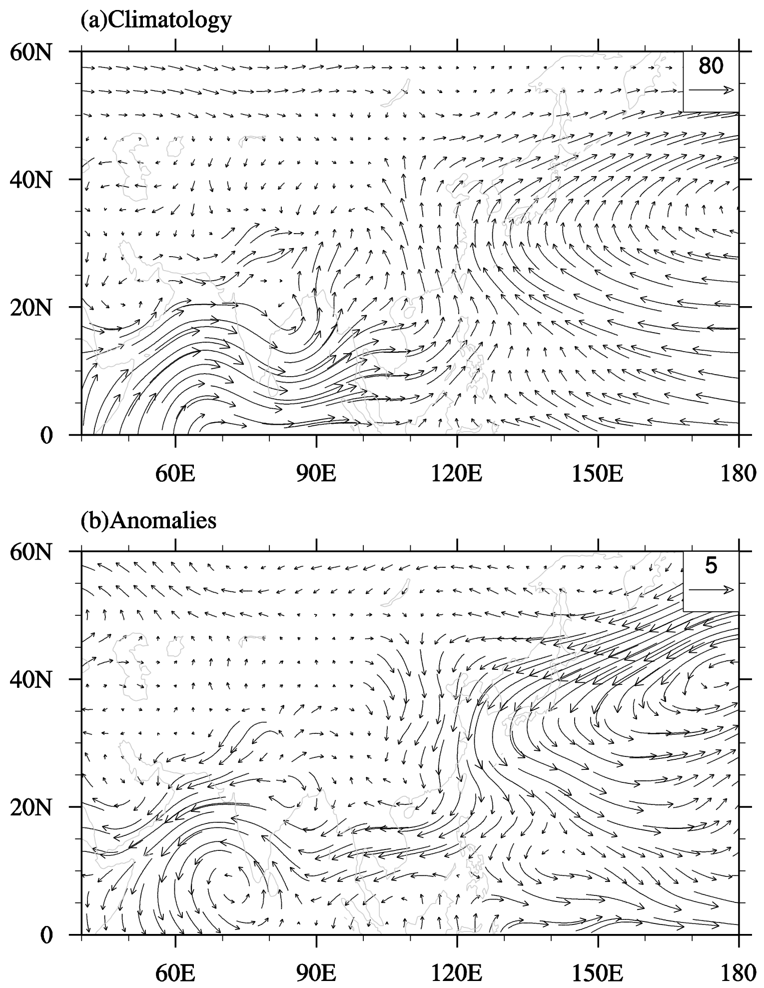
MPI-ESM

The four drought events correspond well with the explosive low-latitude volcanic eruptions in Shen et al. (2008), which include: (a)1640,1641, (b)1756, 1760, 1761, 1764, 1768, (c)1791, 1793, (d)1877.

850hPa water vapor transport (in unit of kg×m^{-1}s^{-1})

Climatology

Composite

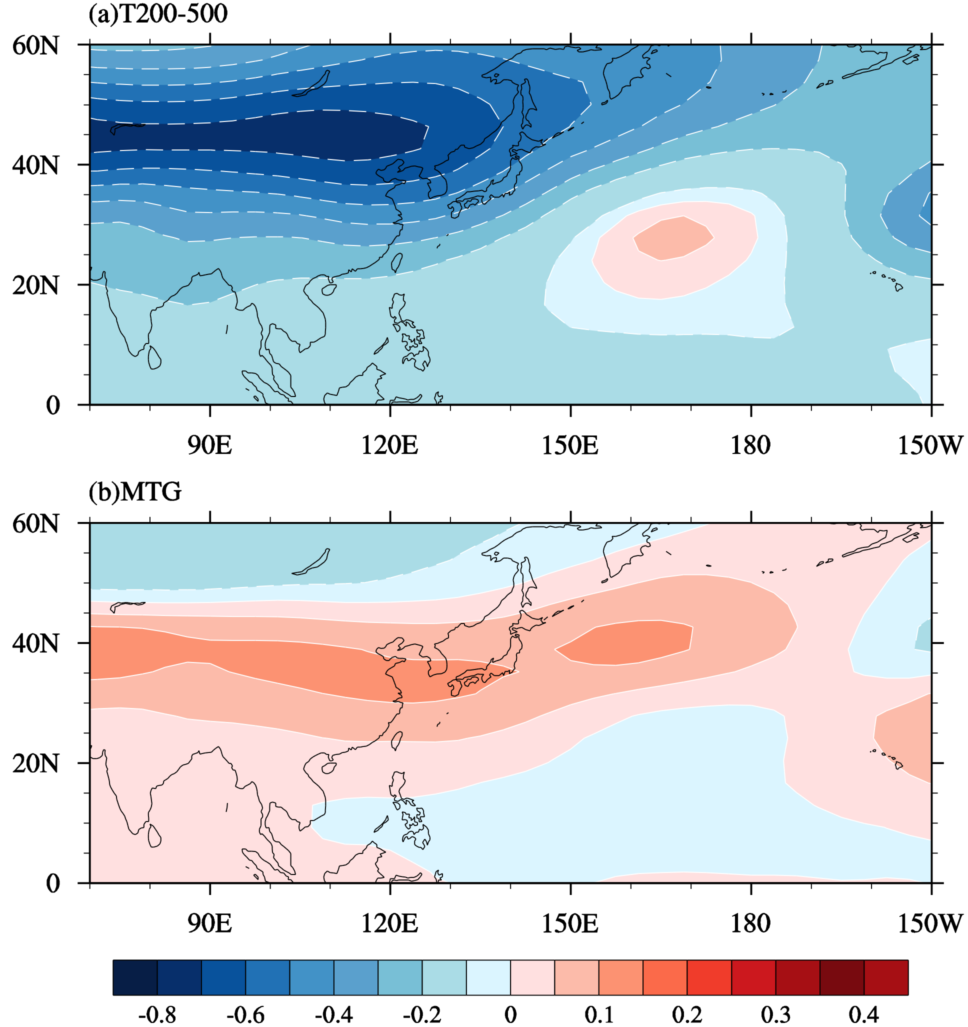


the northward transport of tropical water vapor to North China has reduced.

The land-sea thermal contrast changes (200-500 hPa average)

T200-500

Meridional Temperature Gradient



"colder-land-warmer-ocean"->reduced land-sea thermal contrast changes ->weakened EASM circulation

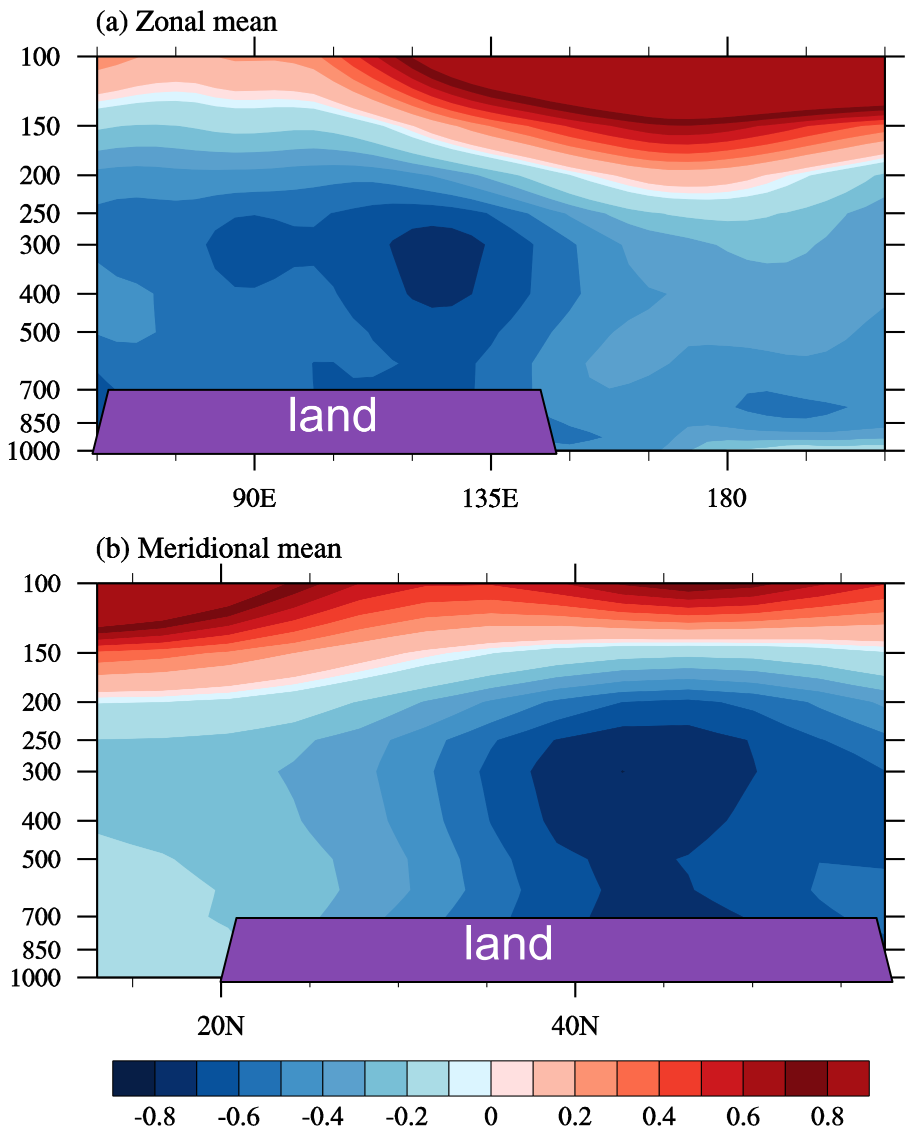
Longitude-height cross section averaged over 30°-45°N and latitude-height cross section averaged over 105°-122°E

Zonal mean

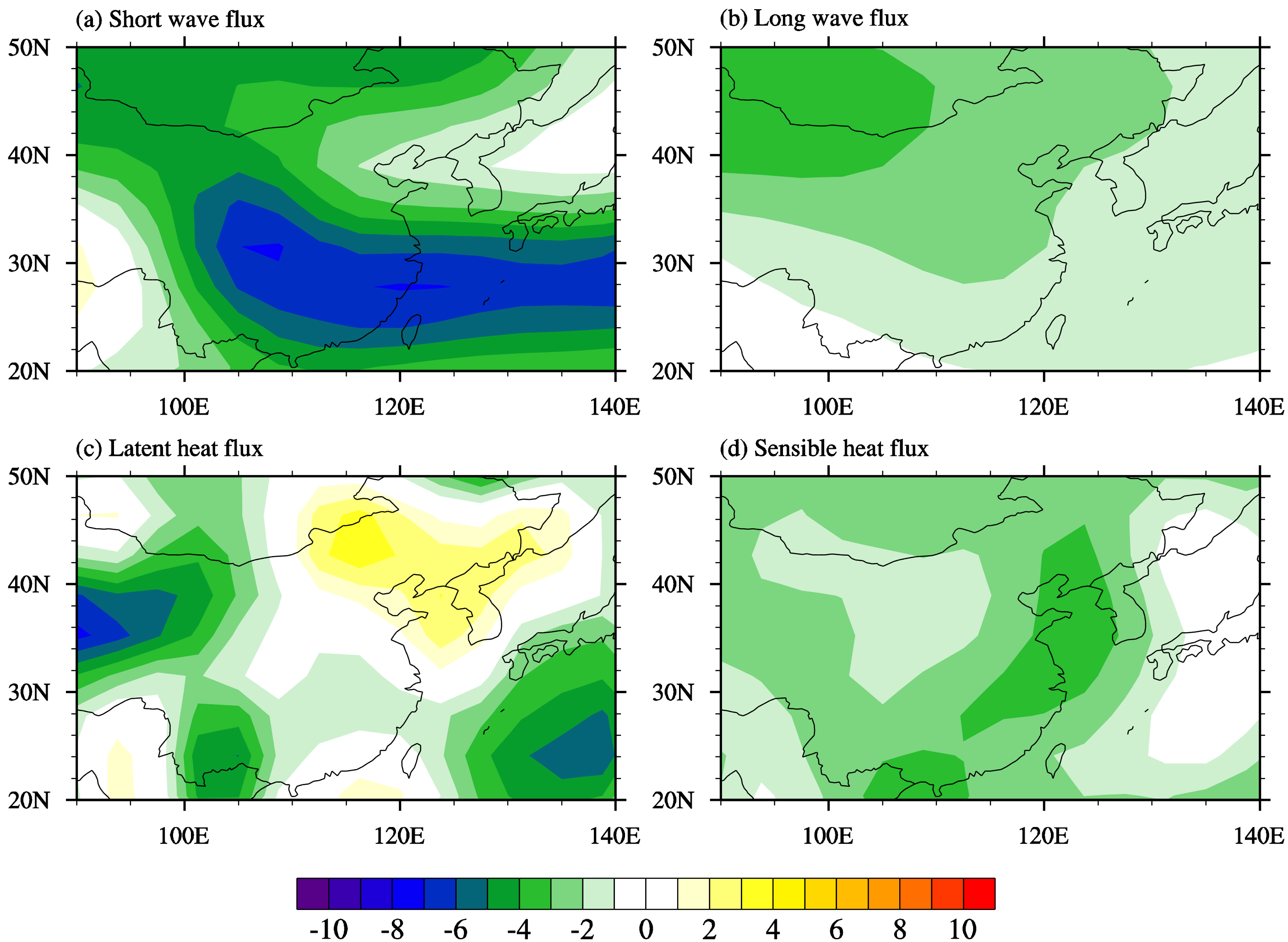
“colder-land warmer-ocean”

Meridional mean

“colder-land warmer-ocean”



Spatial patterns of the surface heat flux



The decrease of latent heat flux over ocean indicates a decline of the evaporation in the tropical regions and reduction of precipitation over EA.

The reduction in sensible heat flux over land implies a reduced land-sea thermal contrast.

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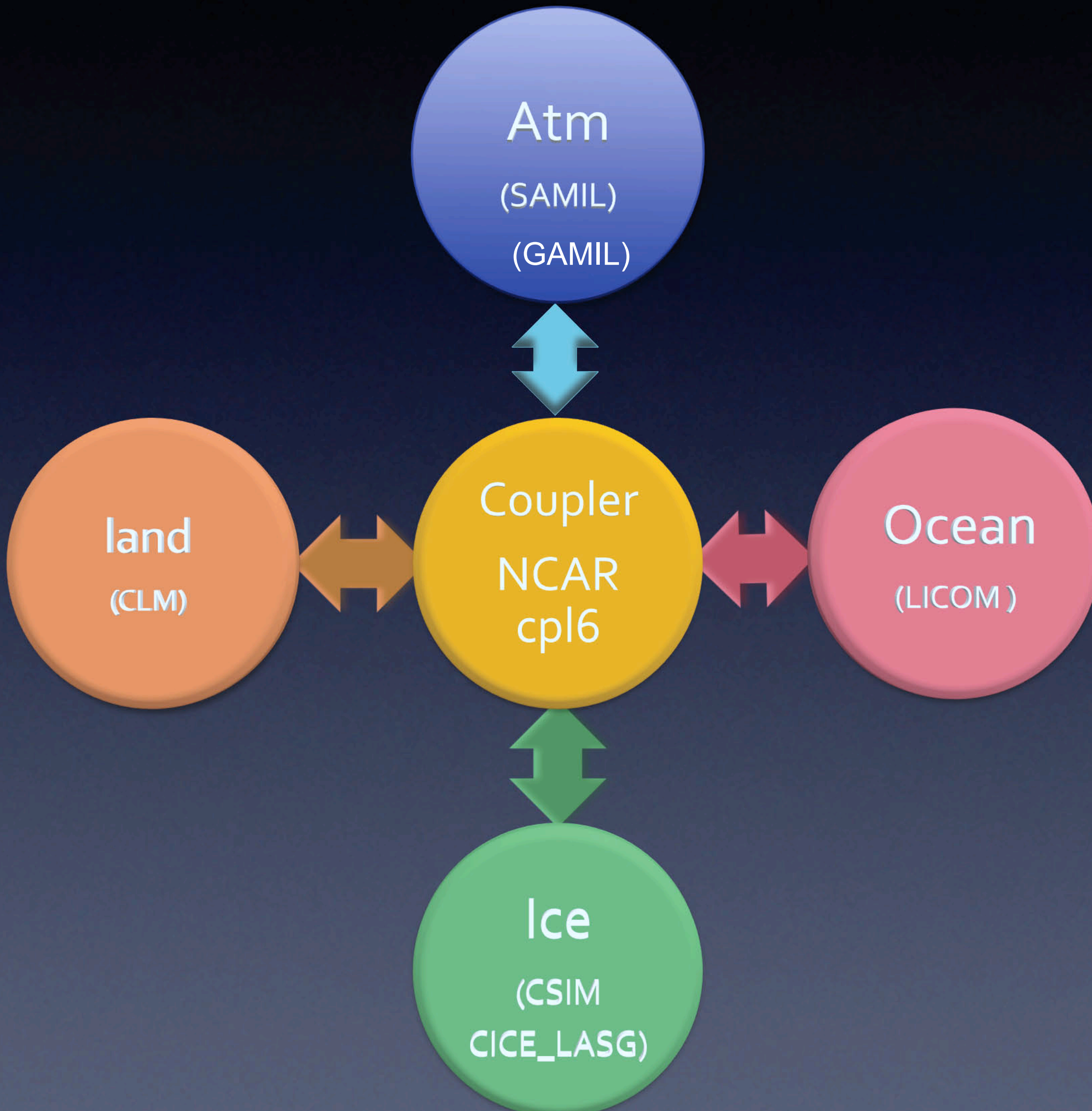
Flexible Global Ocean Atmosphere Land System Model



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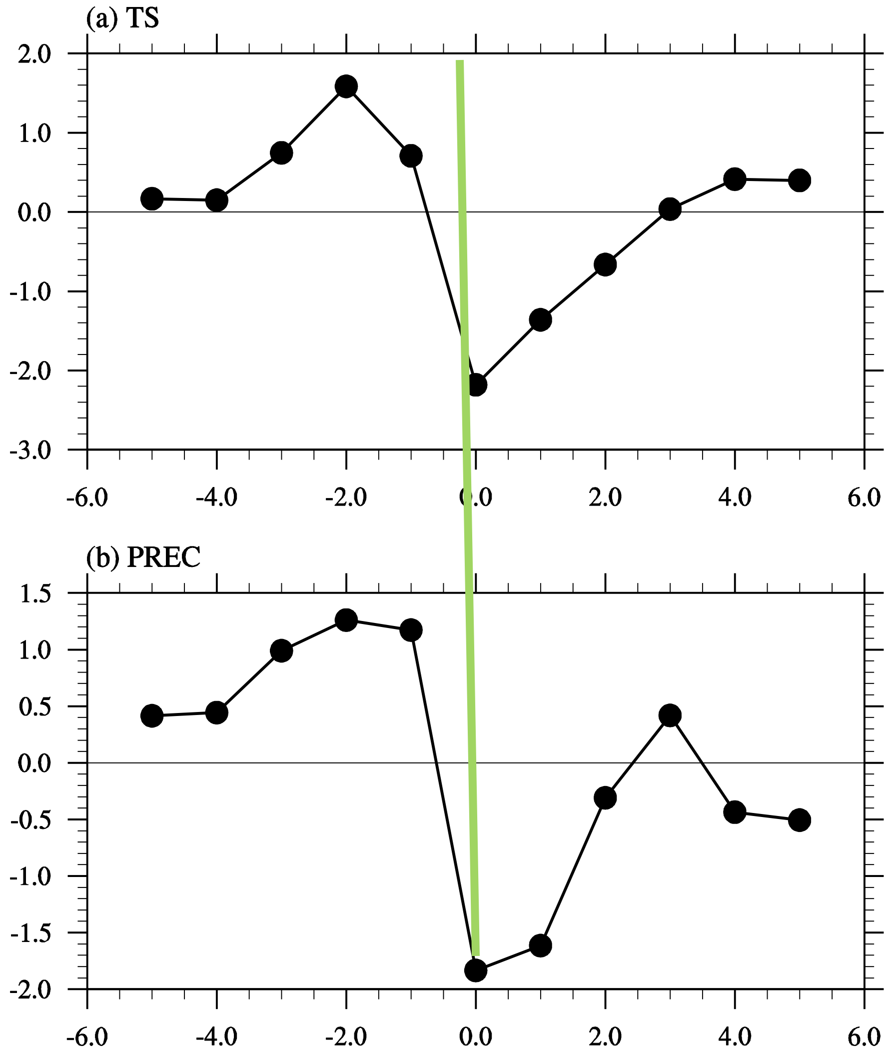
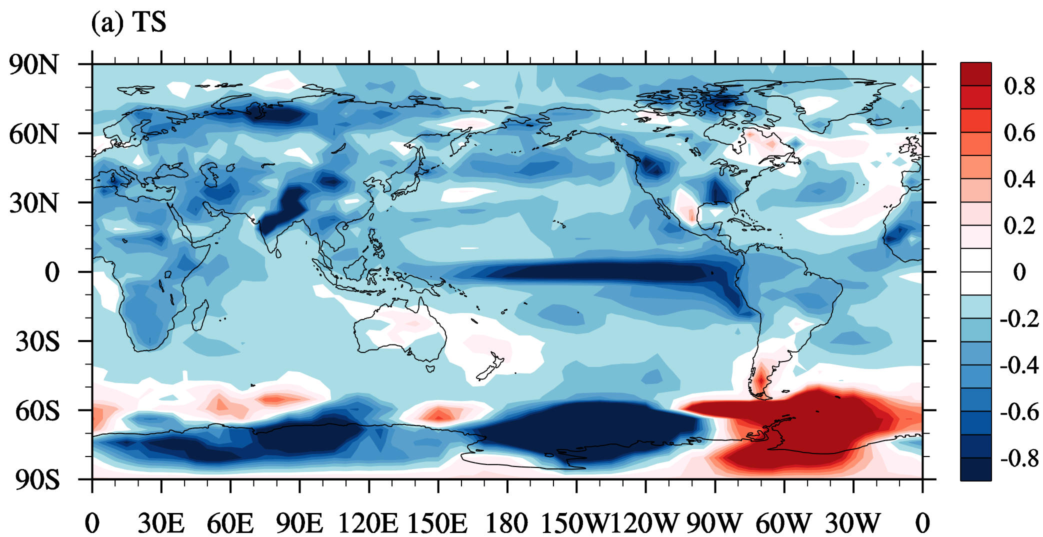
Zhou et al. 2013, Springer Press

Temporal pattern of global mean temperature and precipitation anomalies in LASG/IAP model FGOALS-gl

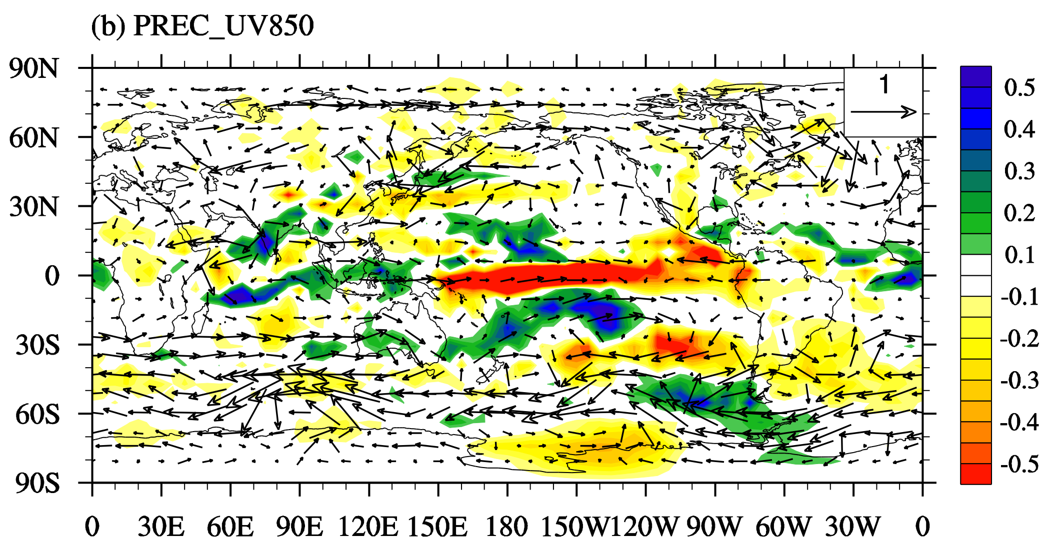


A peak global cooling and precipitation decrease occur in the volcanic eruption year, after which they slowly returns to pre-eruption levels.

Spatial patterns of global temperature and precipitation anomalies in LASG/IAP model FGOALS-gl

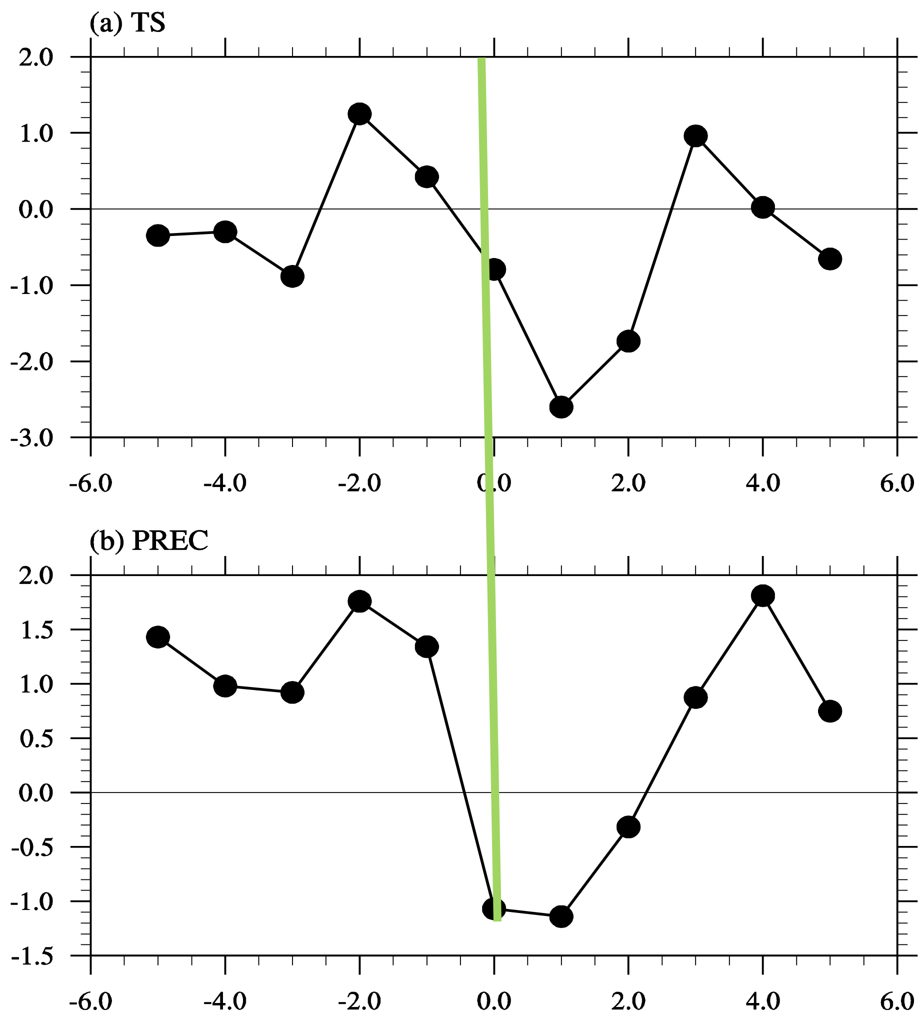


- Strong cooling over NH land and tropical eastern Pacific.
- Cooling over the land is stronger than that over the ocean.



- Not well-shaped.
- Negative precipitation anomalies are seen in the tropical and subtropical regions.

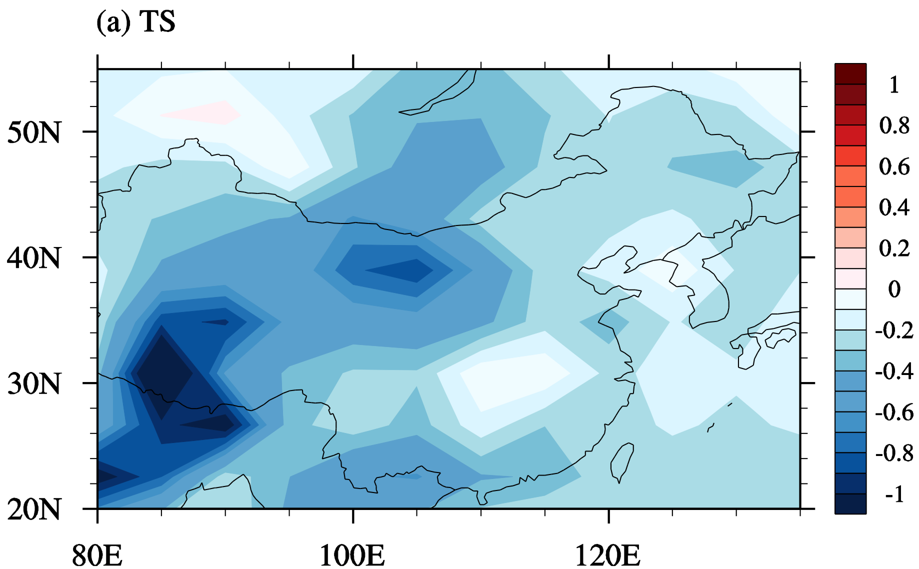
Temporal pattern of temperature and precipitation anomalies over East Asia in LASG/IAP model FGOALS-gl



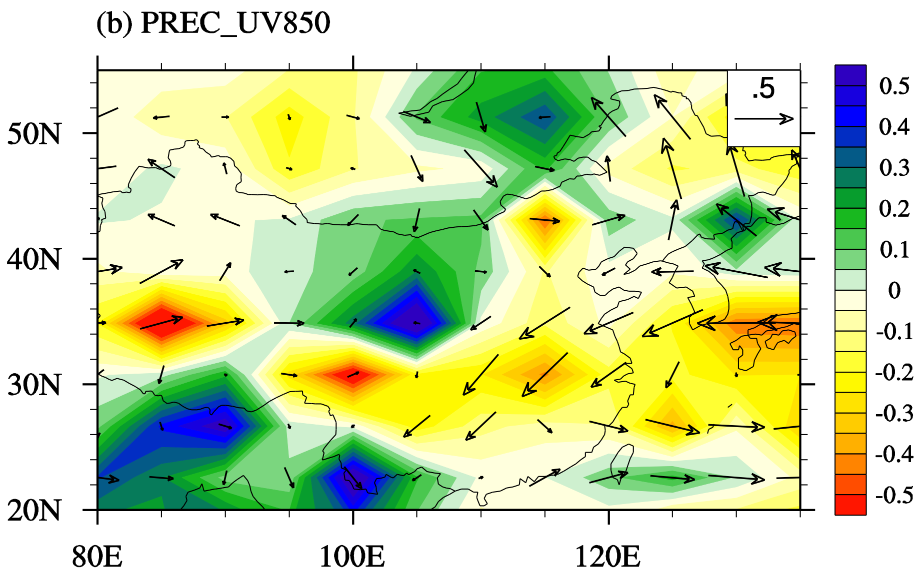
Strongest cooling is seen one year later.

Largest reduction in precipitation is seen in the eruption year and one year after.

Spatial patterns of temperature and precipitation anomalies over East Asia in LASG/IAP model FGOALS-gl



- Coherent cooling is seen over the EA continent and the tropical ocean.



- Weakened summer monsoon wind.
- Coherent reduction of prcp over the entire East China.

Summary

- The largest reduction of global mean SAT and precipitation anomalies appears in the volcanic eruption year and one year later.
- The cooling in the northern hemisphere is stronger than that in the southern hemisphere. The cooling over the land is stronger than that over the ocean.
- There exists a general decreases of prcp in the tropical and subtropical regions one year later after the eruption.
- Cooling anomalies are seen over East China in the first summer after the eruption. The East Asian continent is dominated by northerly wind anomalies. Entire E China saw a coherent reduction of summer rainfall.
- Changes of EASM circulation after the volcanic eruptions are dominated by the land-sea thermal contrast change.

LASG

THANKS

www.lasg.ac.cn/staff/ztj