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大气科学和地球流体力学数值模拟国家重点实验室

The Global Monsoon Response to Volcanic Eruptions in the CMIP5 Past1000 Simulations and Model Simulations of FGOALS

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PAGES2k-PMIP3 Hydroclimate Workshop, New York

1-3 Jun, 2016

Outline

- Motivation and Methods
- GM precipitation responses following large volcanic eruptions
- The monsoon-desert coupling mechanism exist following large volcanic eruptions
- IAP/LASG model simulation
- Summary

Motivation

- Large, explosive volcanic eruptions are known to be a leading cause of natural climate change on a range of time- scales.
- Previous studies pay much attention on the regional scale monsoon changes following the eruptions. However, changes in the regional monsoons cannot be fully understood unless we considered within a global perspective.
- The present study deals with the global monsoon (GM), the integral of all regional monsoon systems. This broader perspective allows us to view changes in the total system due to the stratospheric aerosols.
- The main motivation of this study is to investigate the GM response to volcanic eruptions and understand the mechanisms for the GM response following the eruptions.

Data and methods

- Two alternative volcanic data sets are provided for the past1000-simulations in the CMIP5. It is up to the groups to choose the Gao et al. (2008) or the Crowley et al. (2008) reconstruction for their last millennium simulation.
- For the model response, eruptions with peak global mean AOD>0.05 whose aerosol clouds affected both hemispheres were chosen.
- we used 'epoch analysis', which involves averaging across the precipitation response to several volcanic eruptions in order to reduce internal variability and make the volcanic influence clearer.
- Significance of the average precipitation response to volcanic eruptions was assessed using a Monte Carlo

Definition of GM domain

Following Wang and Ding (2008), the GM domain was defined by the local summer-minus-winter precipitation rate exceeding 2.0 mm/day and the local summer precipitation exceeding 55% of the annual total. Here the local summer denotes May through September (MJJAS) for the Northern Hemisphere (NH) and November through March (NDJFM) for the Southern Hemisphere (SH).

Major water budget components

A moisture budget analysis is used based on Endo and Kitoh (2014),

$$\delta P = \delta E + \delta DY + \delta TH + \delta NL + \mathrm{Res}$$

$$\delta DY = -(\left\langle \delta\overline{\omega}\partial_p\overline{q} \right\rangle + \left\langle \delta\overline{V}.\nabla\overline{q} \right\rangle)$$

$$\delta TH = -(\left\langle \overline{\omega}\partial_p\delta\overline{q} \right\rangle + \left\langle \overline{V}.\nabla\delta\overline{q} \right\rangle)$$

$$\delta NL = -(\delta\left\langle \overline{\omega'\partial_p q'} \right\rangle + \delta\left\langle V'.\nabla q' \right\rangle)$$

ω denotes pressure vertical velocity; V is the horizontal wind; q is the specific humidity; δ (•) is the climatological difference between the perturbed and unperturbed climate; < > is the vertical integration from surface to100 hPa.

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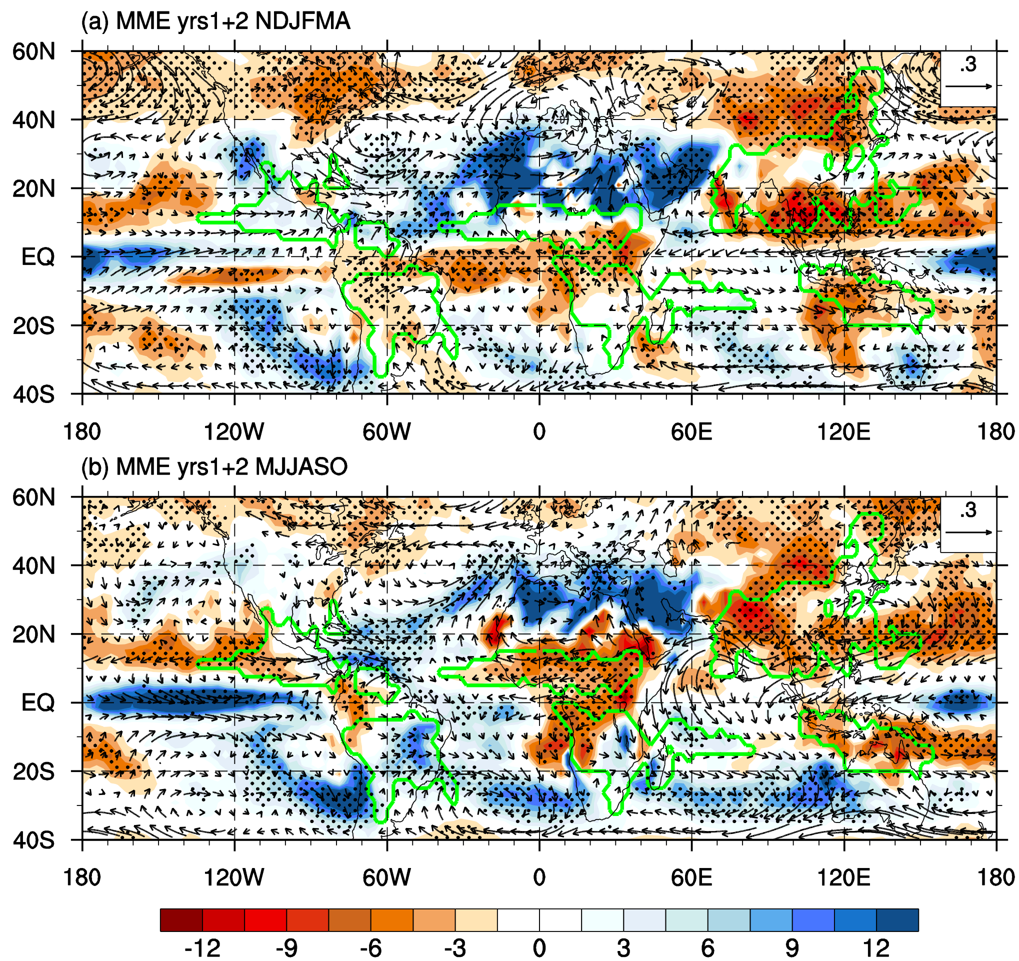
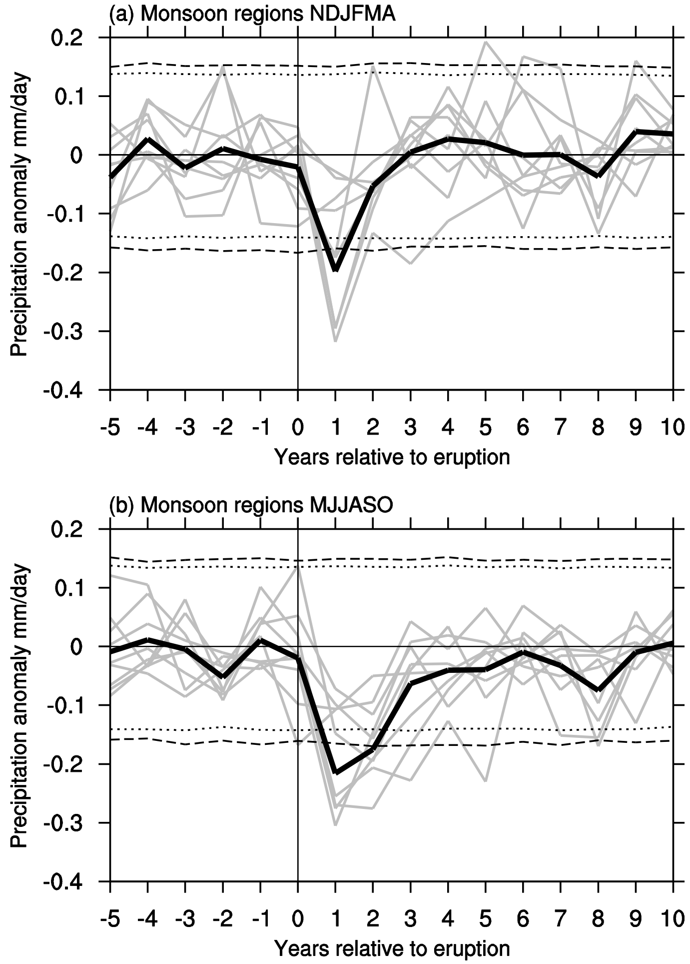
GM precipitation responses following large volcanic eruptions



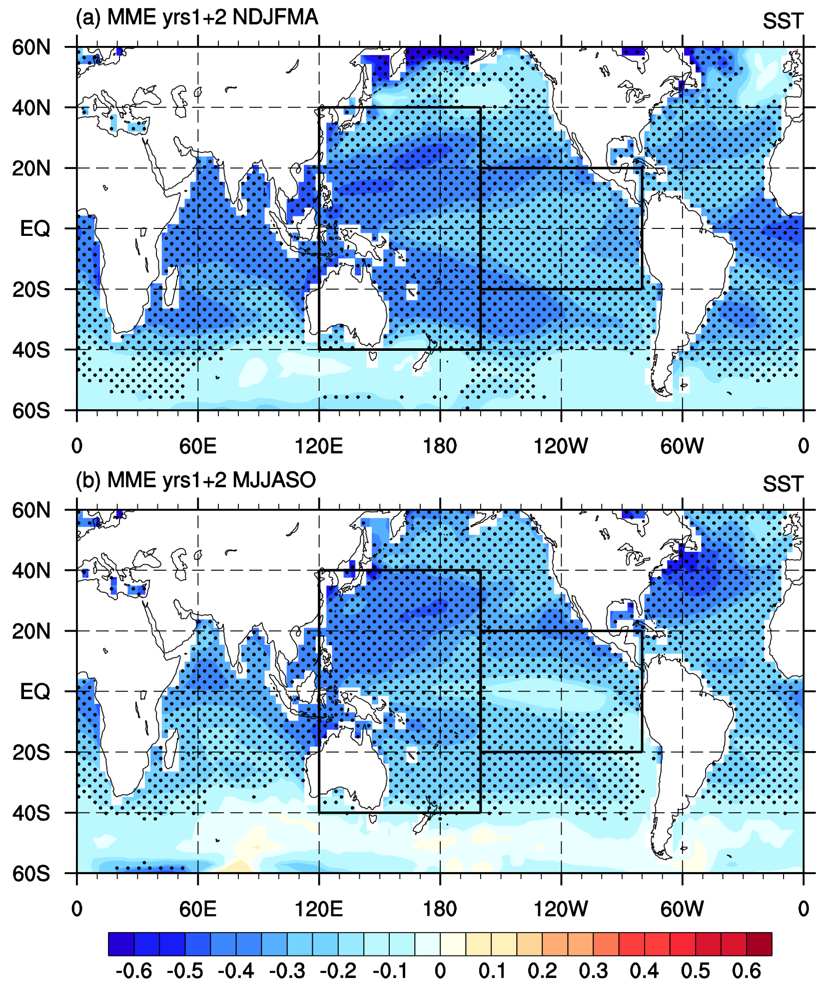
The monsoon regions exhibit drying in their respective warm season. There are also some grid cells that get significantly wetter, but to a lesser extent.

The temporal pattern of the precipitation response in the GM regions

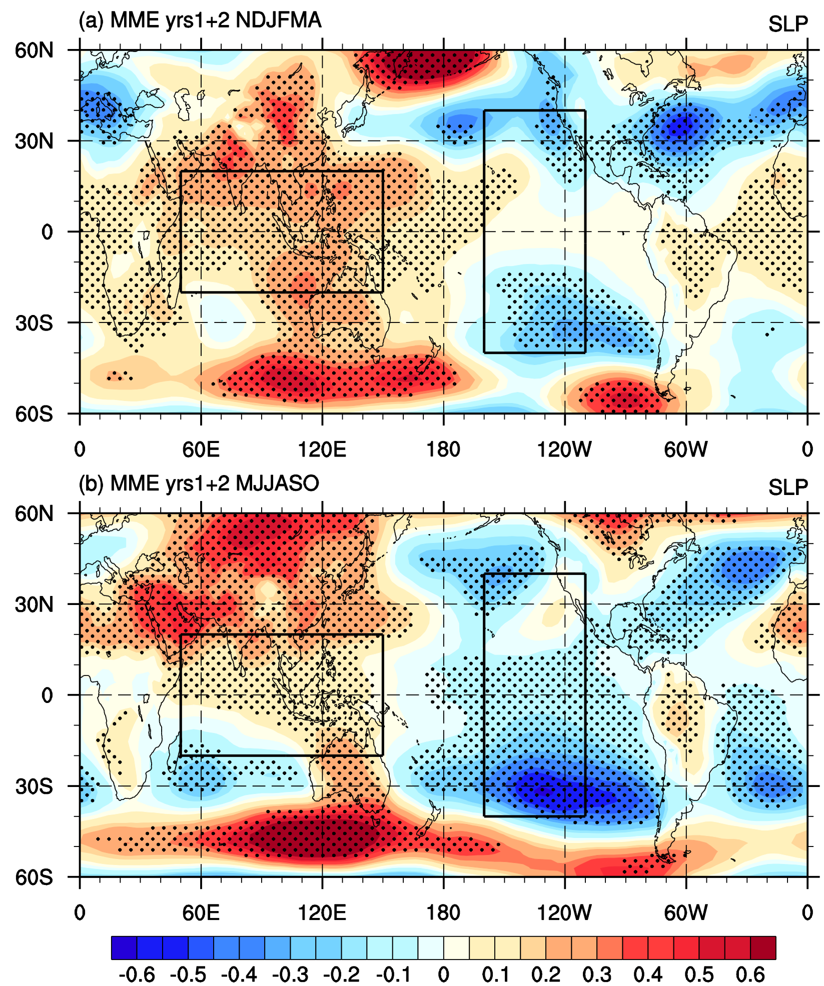


A significant decrease in monsoon rainfall can be seen in the SH monsoon regions (South American, African and Australian monsoon regions) in austral summer and in the NH monsoon regions (Asian, African and North American monsoon regions) in boreal summer in Year 1 and Year 2.

What drives the decreased GM precipitation following the eruptions?



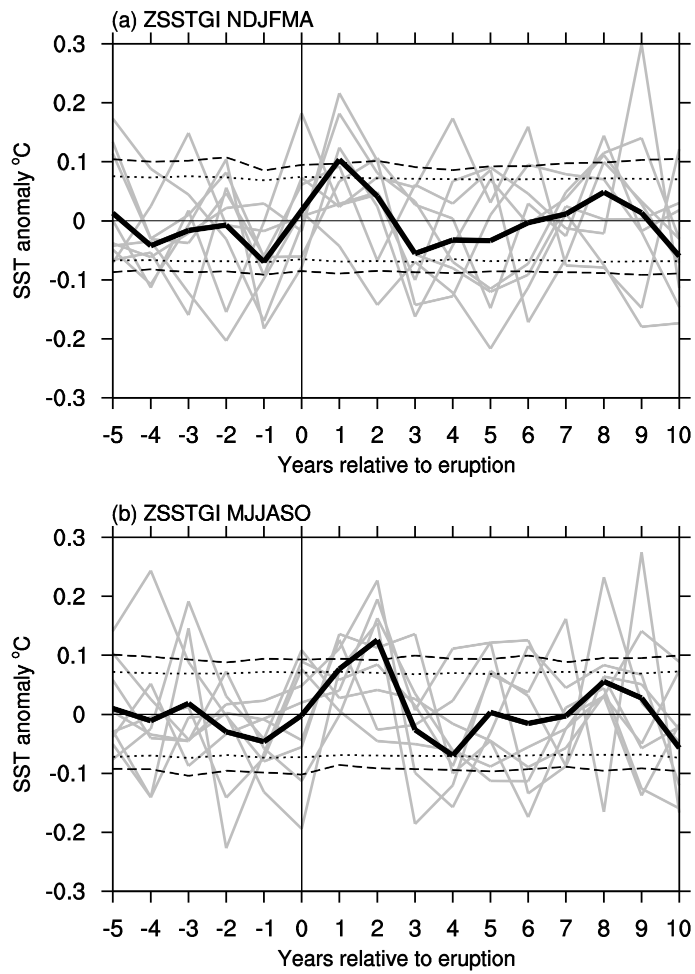
The SST features a zonal temperature gradient with stronger cooling in the western Pacific than that in the eastern Pacific.



The corresponding SLP features a lowering SLP in the eastern Pacific and rising SLP in the western Pacific.

The broad scale east–west asymmetry in Pacific SST represented by a zonal SST gradient index (ZSSTGI)

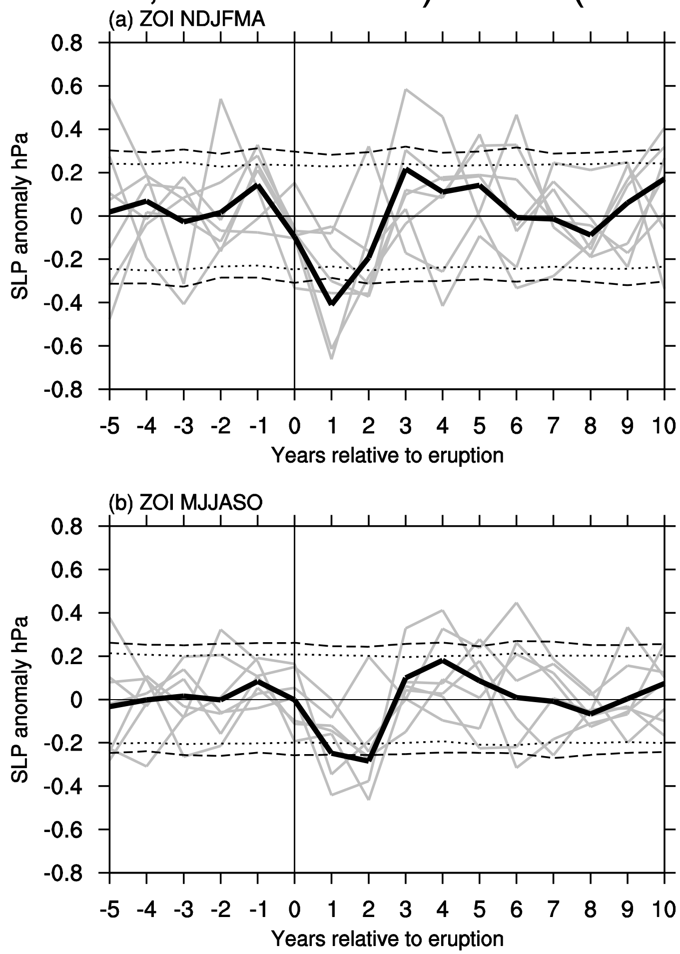
ZSSTGI = SST (20S-20N, 160W-80W) –SST (40S-40N, 120E-160W)♪



There is a peak warming following the eruption year and 2 years after, indicating a significant El Nino-like response to explosive volcanic forcing over the last millennium.

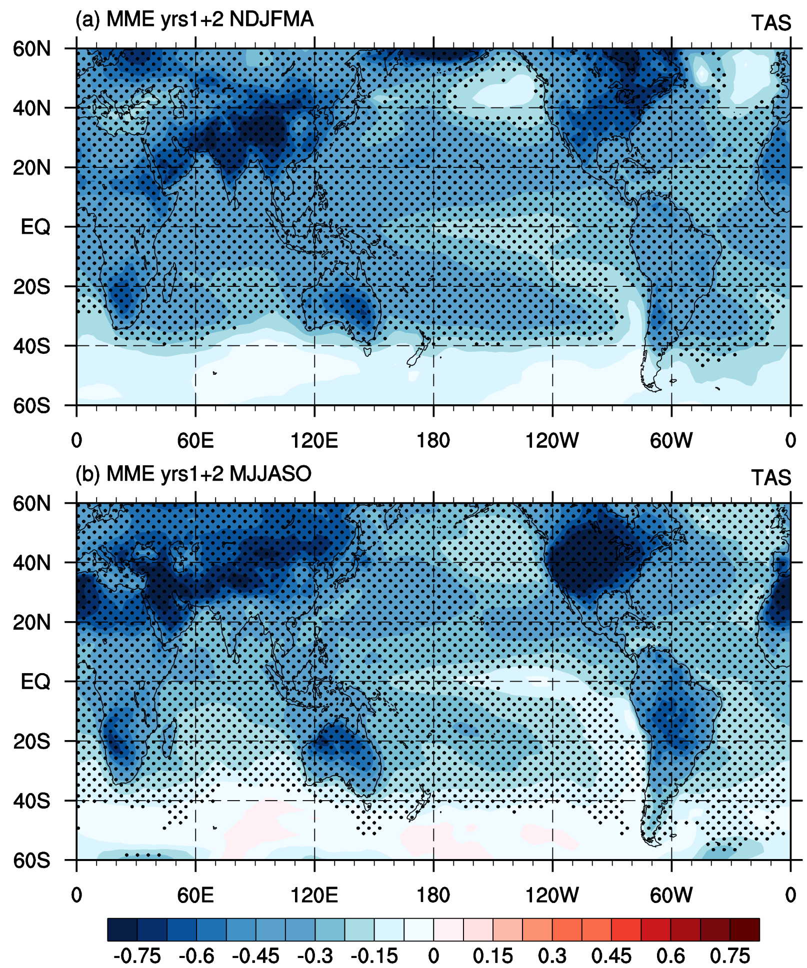
The east–west asymmetry in SLP field depicted by an Indo-Pacific zonal oscillation index (ZOI)

ZOI = SLP (40S-40N, 160W-110W) –SLP (20S-20N, 50E-150E)



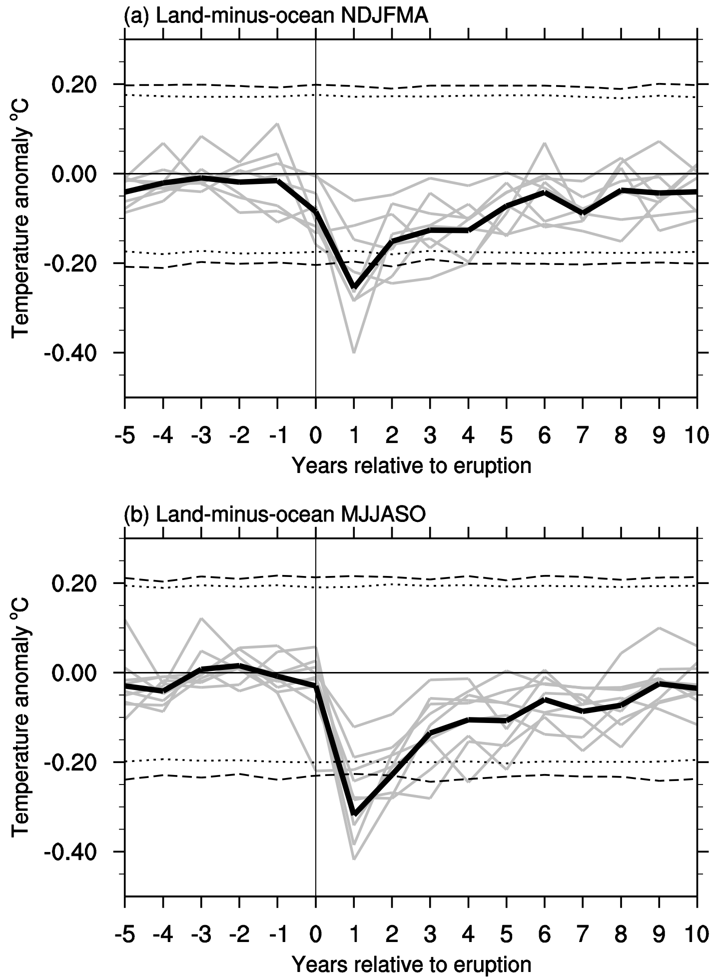
The reduced zonal temperature gradient across the Pacific induces lowering SLP in the EP where the two subtropical Highs straddle the equator. This will weaken the trades which transports and converges moisture into the eastern hemisphere monsoon regions, thereby leading to the reduced GM precipitation.

Besides the SST anomalies, to what extent does the surface air temperature (SAT) contribute to GM precipitation change after large volcanic eruptions?



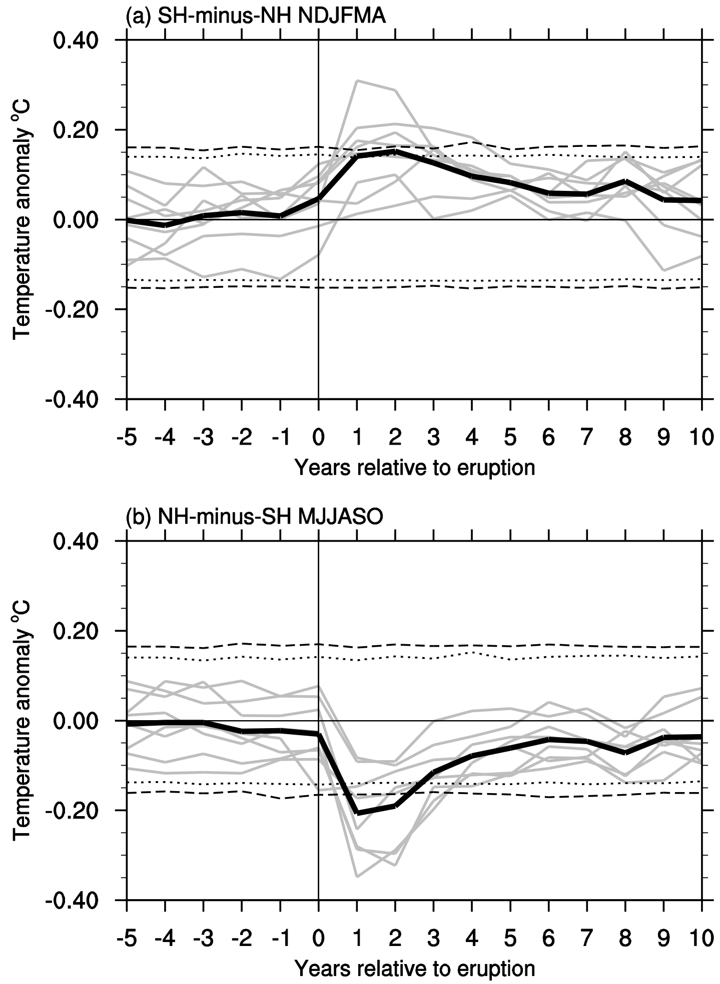
There are two prominent characteristics, i.e., the cooling over the land areas is stronger than that over the oceanic areas and is stronger in the NH than that in the SH.

The temporal patterns of land-minus-ocean temperature



The decreased land–ocean thermal contrast prevails in both the NH and the SH, suggesting that this factor weakening both NH and SH monsoons.

The temporal patterns of hemispheric temperature differences



The NH surface cooling is much greater than the SH cooling, which reduces cross-equatorial pressure gradients that drive low-level cross-equatorial flows from the SH to the NH, weakening NH monsoon.

On the contrast, the SH–NH contrast exerts an opposing effect on the SHSM.

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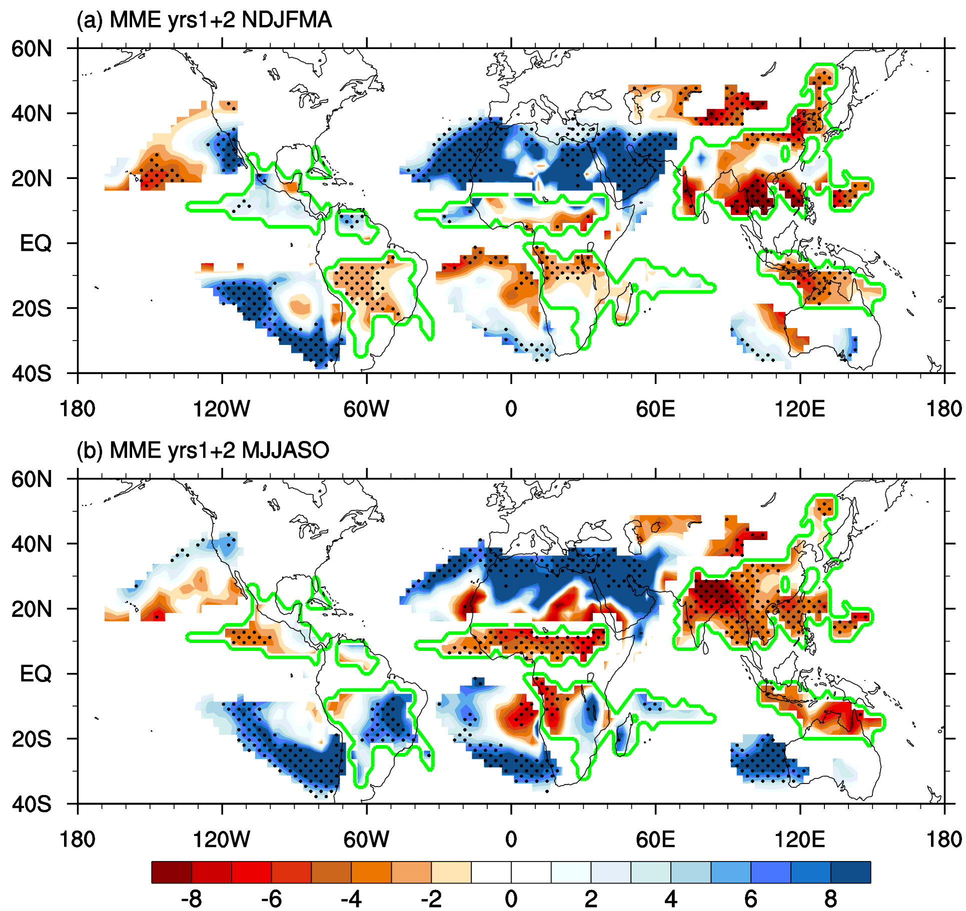
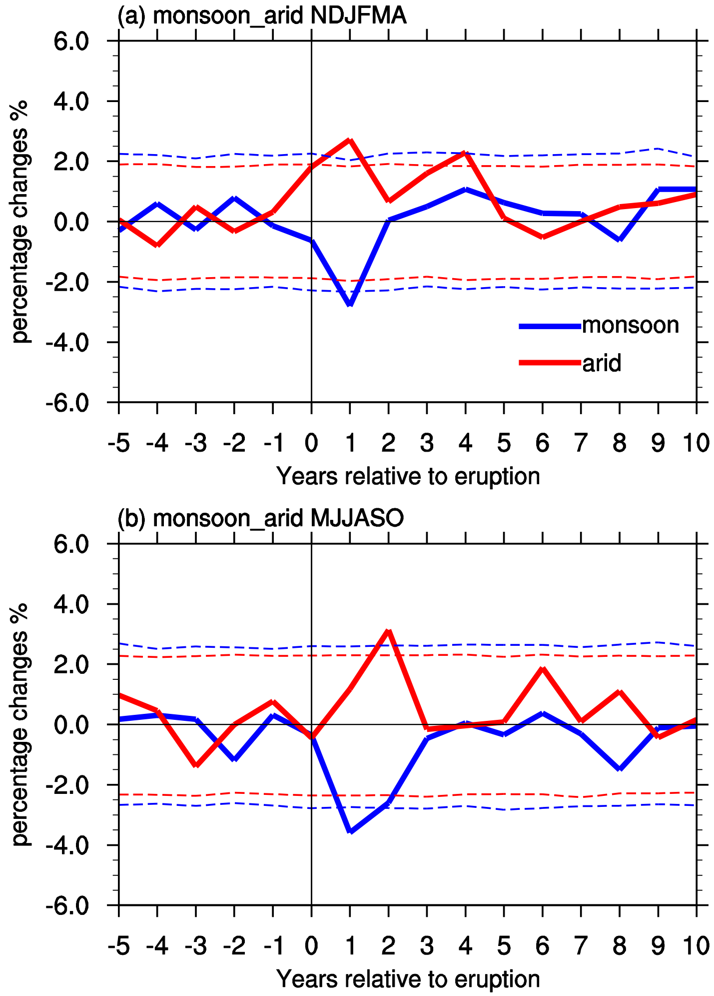
The spatial patterns of precipitation response following eruptions in the global monsoon regions and adjacent arid regions



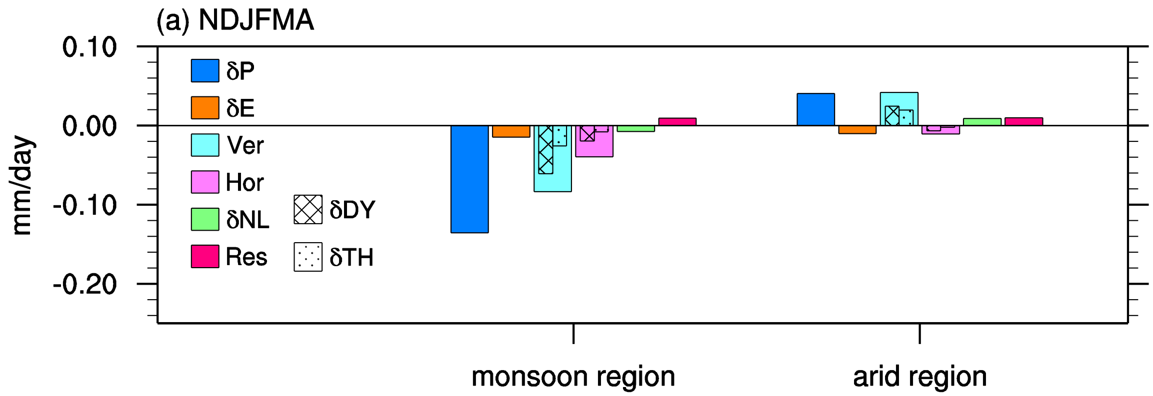
The summer monsoon rainfall shows decreasing anomaly across the majority of the regional monsoon regions. In contrast to a weakened global local summer monsoon precipitation, most arid and semiarid desert or trade wind regions, located to the west and poleward of each monsoon region, show wetting anomalies.

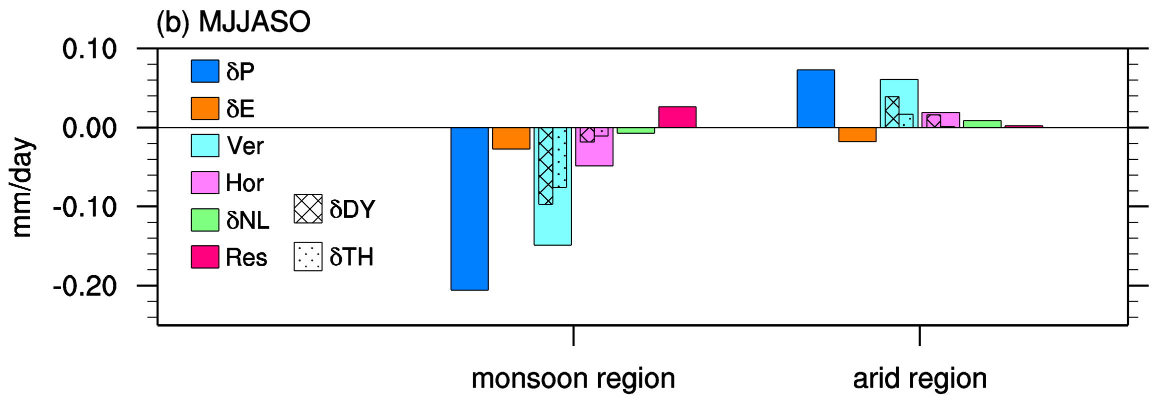
The temporal evolution of precipitation response over the monsoon and non-monsoon regions



The monsoon domain show a clear significant precipitation decrease for both seasons. In contrast, the adjacent dry regions exhibit a smaller but significant increase in precipitation.

The GM precipitation differences between the monsoon domain and the adjacent arid regions, along with the water budget terms





The dynamic and thermodynamic terms equivalently dominate the change of precipitation, while the non-linear term can be neglected. The vertical component dominates the dynamic and thermodynamic bars, whereas the magnitudes of the horizontal component are much smaller than the vertical component.

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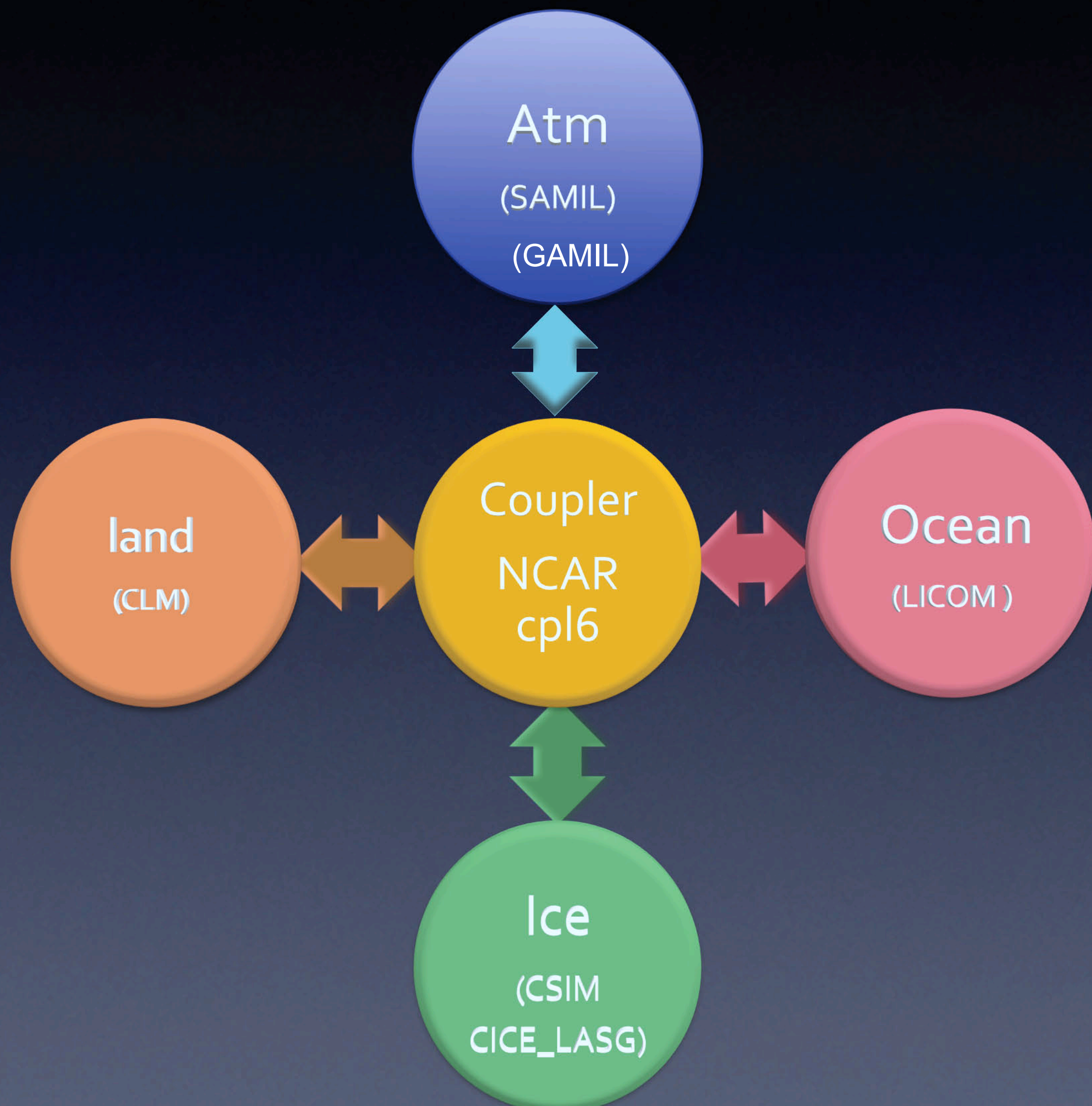
Flexible Global Ocean Atmosphere Land System Model



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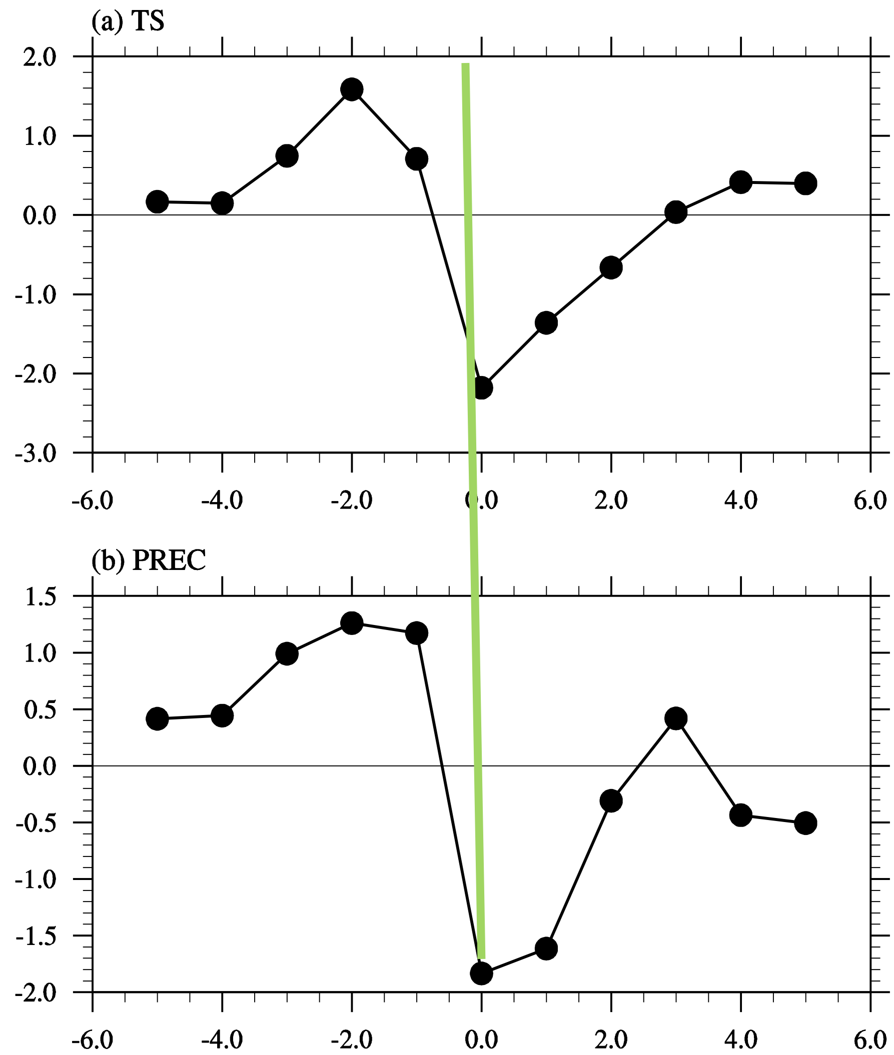
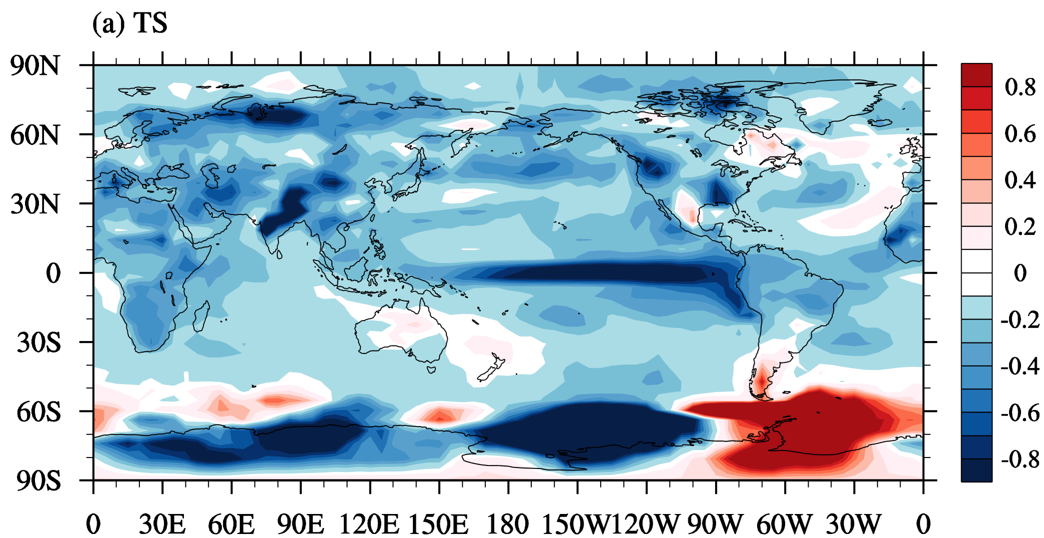
Zhou et al. 2013, Springer Press

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

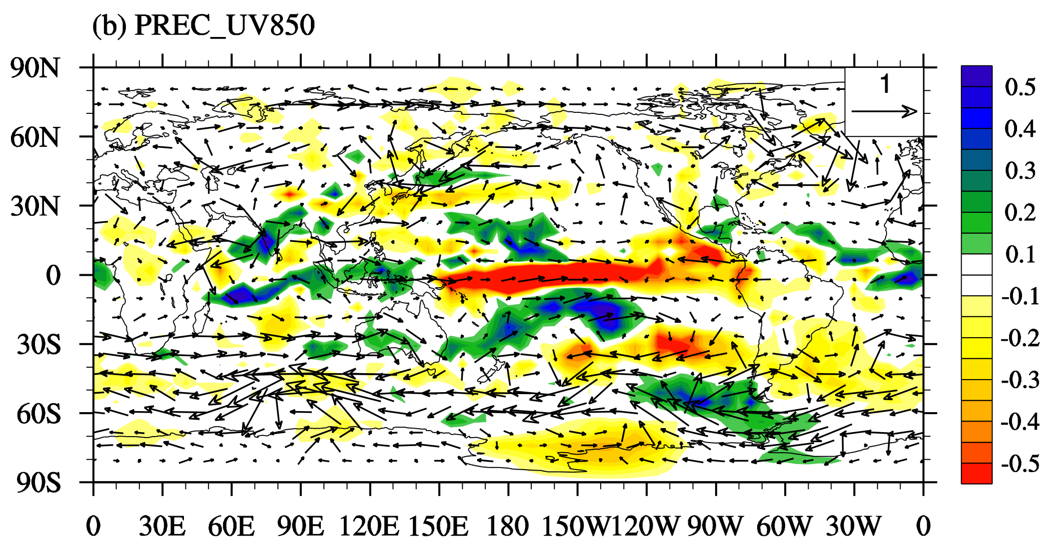


A peak global cooling and precipitation decrease occur in the volcanic eruption year, after which they slowly returns to pre-eruption levels.

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

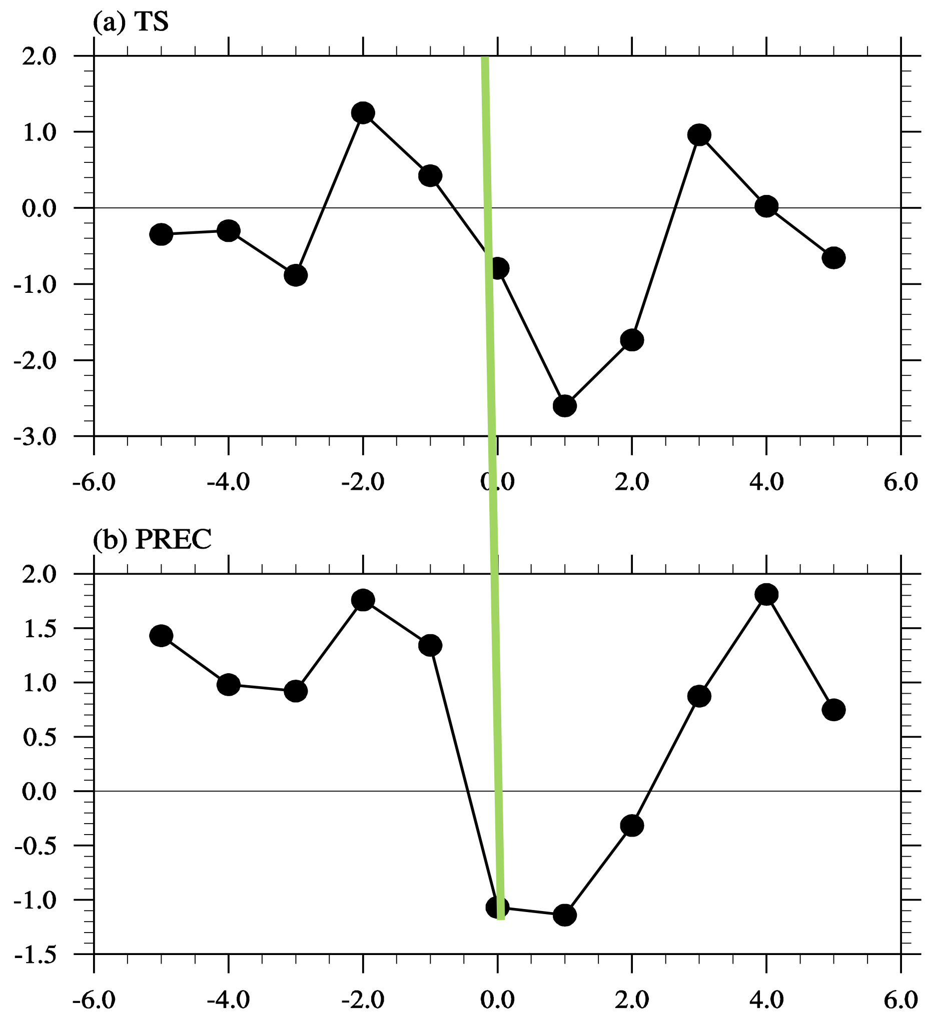


- Strong cooling over NH land and tropical eastern Pacific.
- Cooling over the land is stronger than that over the ocean.



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

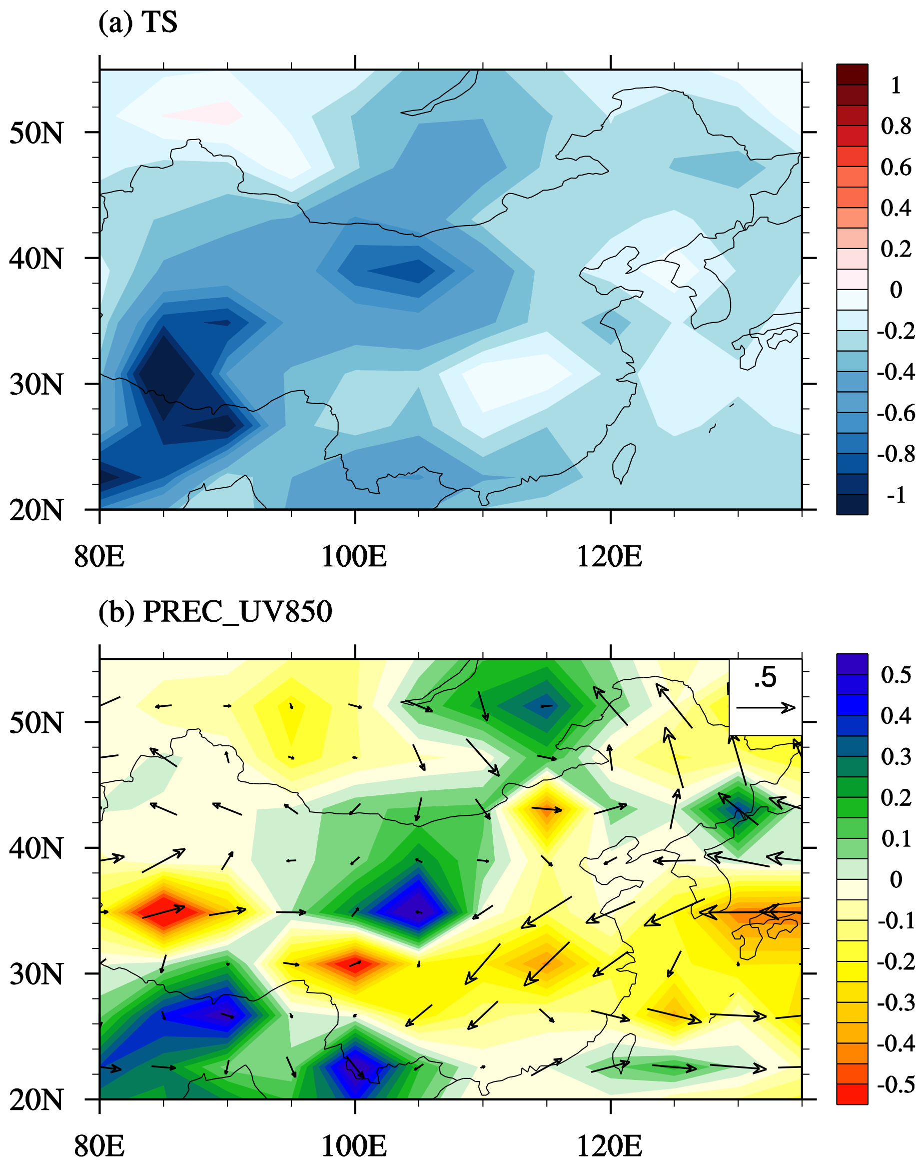
Temporal pattern of temperature and precipitation anomalies over East Asia in LASG/IAP model FGOALS-gl



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 summer monsoon rainfall shows a general decreasing anomaly across the majority of the regional monsoon regions following large eruptions. In contrast to a weakened global local summer monsoon precipitation, most arid and semiarid desert regions, located to the west and poleward of each monsoon region, show wetting anomalies.
- This zonal SST gradient across the Pacific induces lowering SLP in the EP where the two subtropical Highs straddle the equator. This will weaken the trades which transports and converges moisture into the eastern hemisphere monsoon regions, thereby leading to the reduced GM precipitation.
- The ‘‘cold land-warm ocean’’ and ‘‘cold NH-warm SH’’ mechanisms can explain why the NH monsoon has a strong reduction, while only the ‘‘cold land-warm ocean’’ lead to a weak SH monsoon.
- The water budget analysis indicate that the change of the dynamic and thermodynamic terms equivalently dominate the change of precipitation. The vertical component dominates the dynamic and thermodynamic bars, whereas the magnitudes of the horizontal component are much smaller than the vertical component.

THANKS

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