The ITCZ seesaw response to hemispherically asymmetric thermal forcing

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Overview

- Previously, the ITCZ location has been linked to atmospheric cross-equatorial energy transport, with greater southward energy transport corresponding to a northward ITCZ shift. This mechanism has been proposed to explain the ITCZ seasonal migration and the precipitation interhemispheric dipole pattern seen in paleoclimate proxies.
- However, in coupled GCMs with a dynamic ocean, the change in oceanic energy transport compensates atmospheric energy transport change when a hemispherically asymmetric thermal forcing is imposed in the Pacific; consequently, the ITCZ barely moves.
- **We point out that although the ITCZ location changes very little, the relative strength of the ITCZ versus the SPCZ changes dramatically in response to climate forcing of realistic magnitude. This seesaw behavior in ITCZ/SPCZ precipitation may be more relevant for explaining paleoclimate proxies and making projections for future climate change.**

Methods

- Model: CESM 1.2 with 2-degatmosphere, 1-deg ocean.
- Simulation period: 100-200 years.
- Experiment design: Opposite surface heat fluxes (warming/cooling) are added in the northern and southern subtropical Pacific to mimic hemispherically asymmetric thermal forcing.

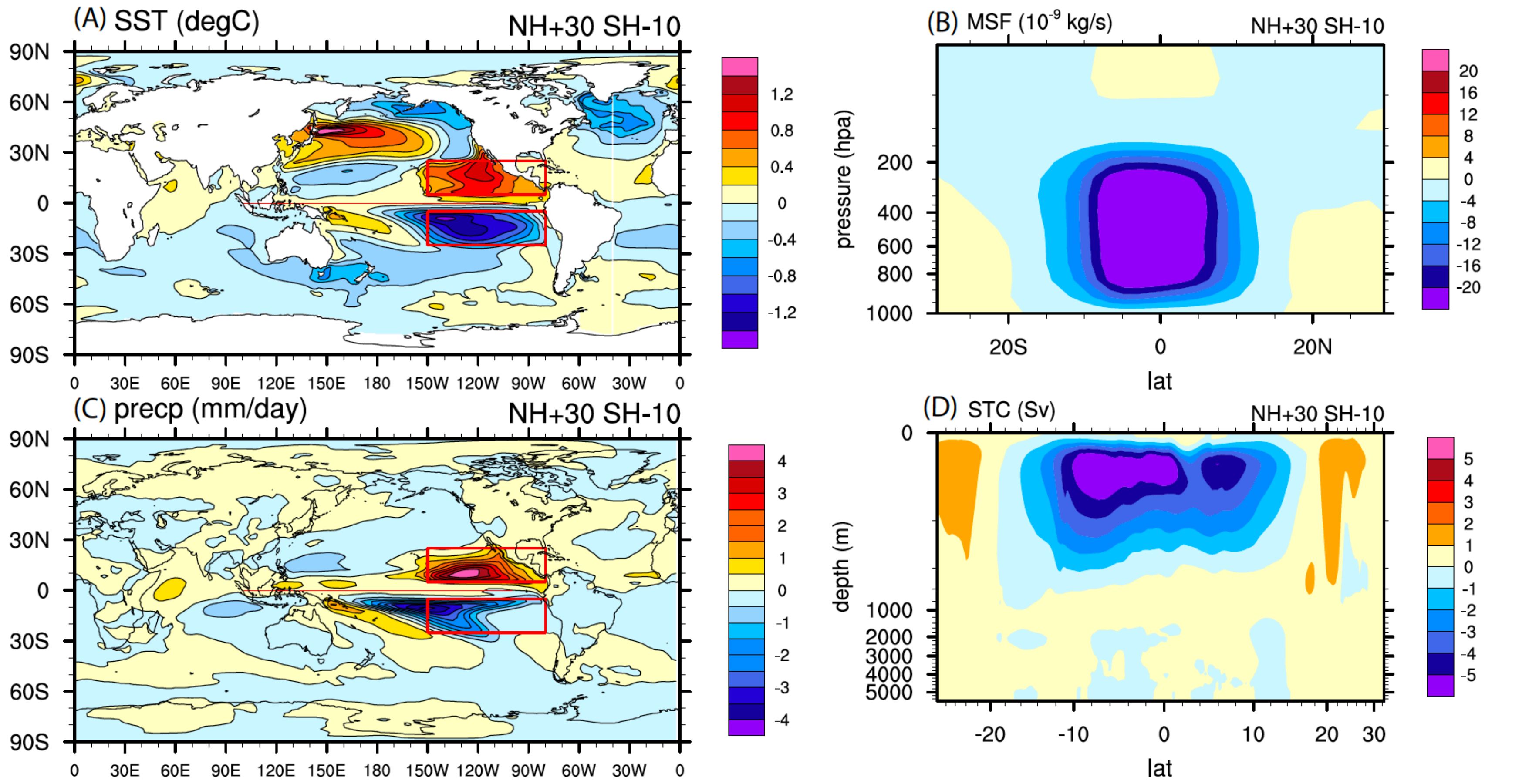

Fig.1 Example of changes in mean climate in one of the perturbation experiments. (A) SST and (C) precipitation changes in response to heat flux anomalies added in the marked boxes, and corresponding changes in (B) atmospheric mass stream function and (D) oceanic volume stream function. In this particular example, 30 W/m^2 and -10 W/m^2 are added to the north and south box, respectively.

Results

- **Even with strong surface heat fluxes forcing, both the ITCZ and SPCZ locations barely change (their shifts are smaller than the model horizontal resolution).**
- ITCZ and SPCZ *locations* are defined by the climatological precipitation centroid in the northern tropical Pacific ([0-20°N, 100°W-280°W]) and the southern tropical Pacific ([0-20°S, 100°W-280°W]), respectively. ITCZ and SPCZ *strengths* are defined as the climatological area-weighted precipitation in the northern and southern tropical Pacific, respectively.
- Earlier studies defining the ITCZ location as a broader tropical precipitation centroid (within 20°S-20°N) *aliased* strength changes into location changes.

Acknowledgement

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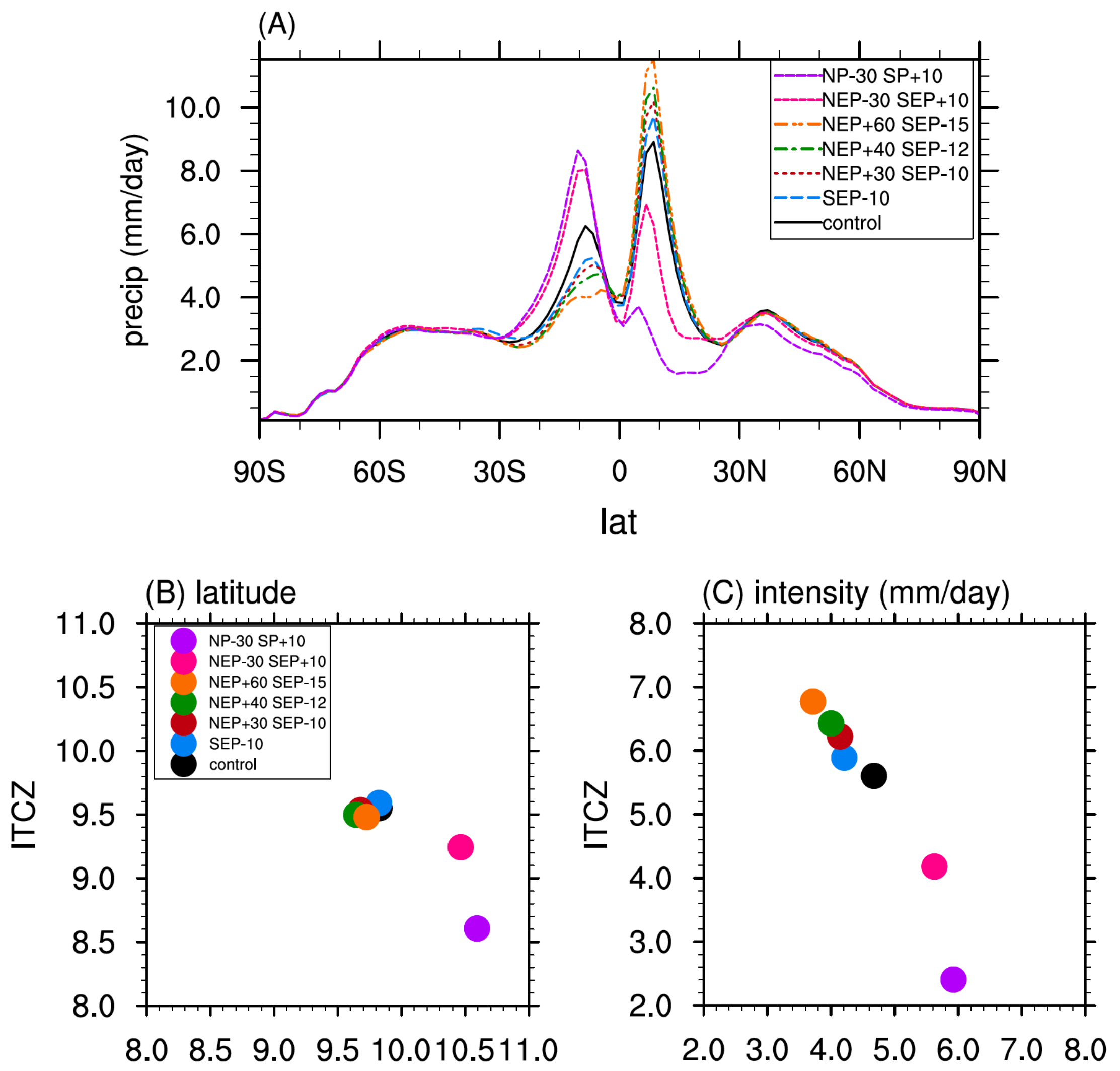

Fig. 2 (A) Zonal mean precipitation as a function of latitude. (B) Latitudinal position and (C) precipitation intensity of the ITCZ and SPCZ response. Zonal average is taken over the Pacfic Ocean between [100E-80W]. Note the large changes in precipitation intensity while only a modest meridional migration of the ITCZ and SPCZ.

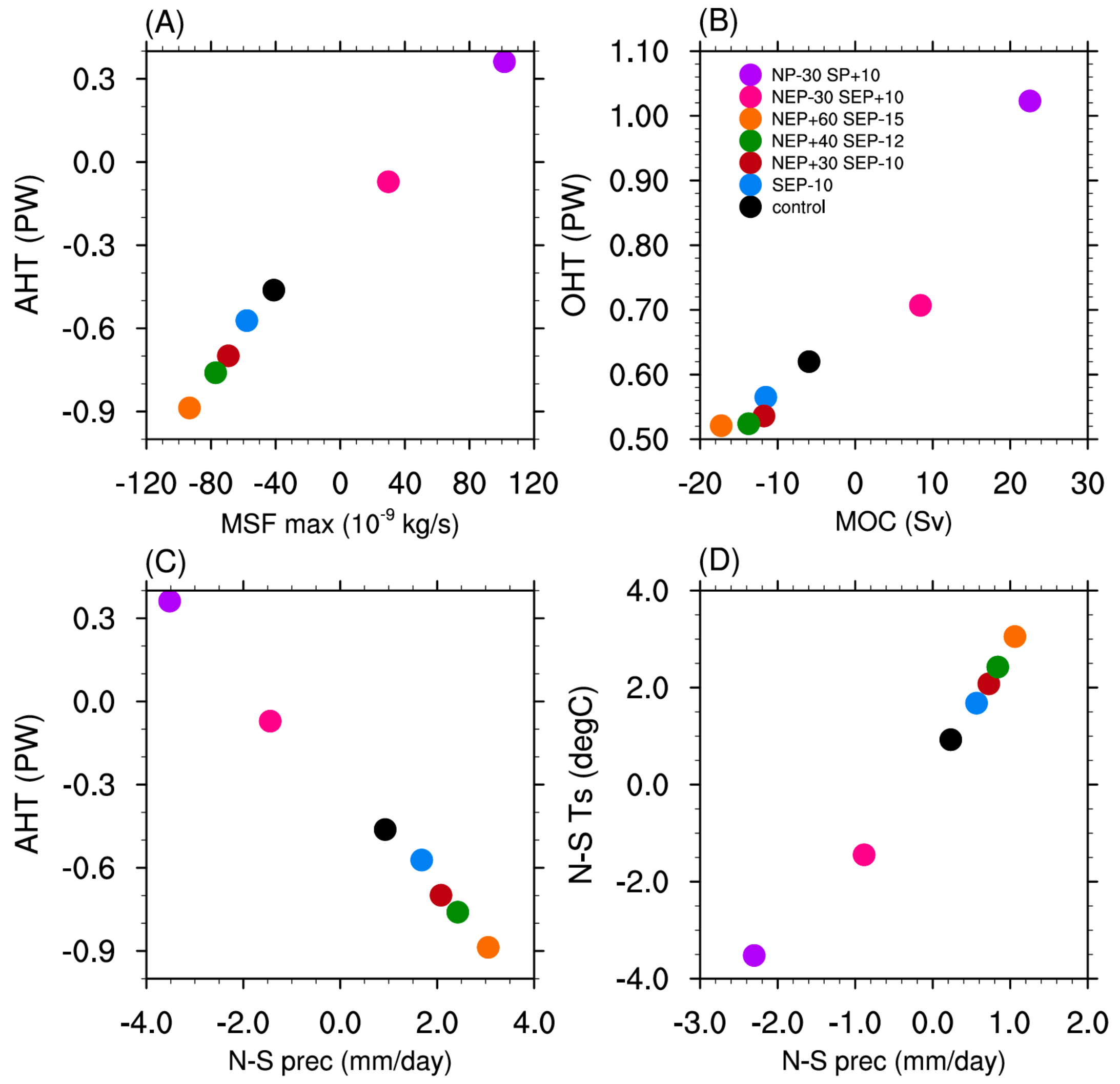

Fig. 4 (A) Atmospheric energy transport across the equator versus maximum northward mass transport across the equator; (B) Oceanic energy transport versus maximum northward volume transport across the equator; (C) Atmospheric energy transport across the equator versus precipitation asymmetry; (D) Surface temperature asymmetry versus precipitation asymmetry.

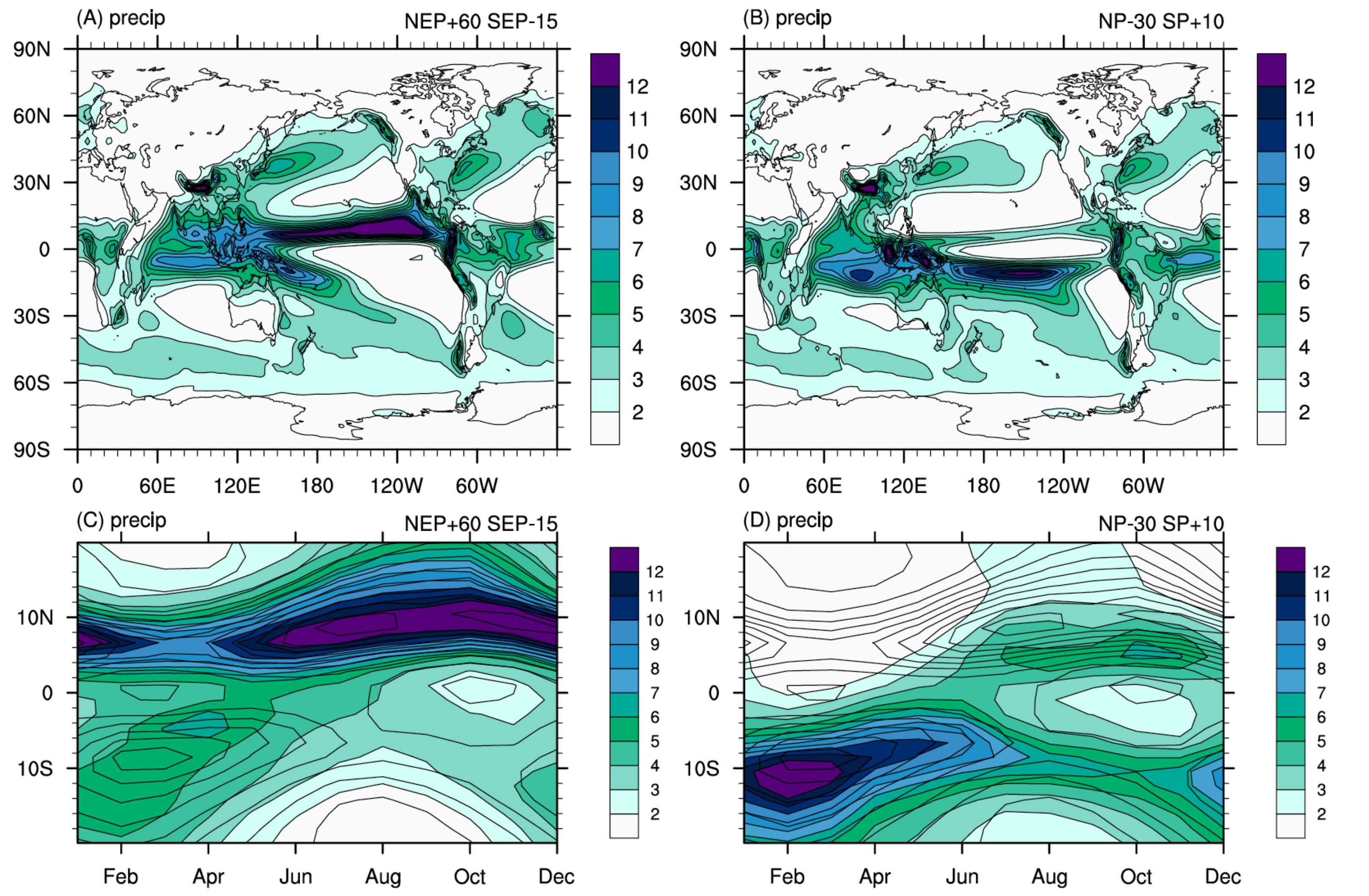

Fig. 3 Mean precipitation field and precipitation seasonal cycle under strong perturbation forcings. (A, B) Annual-mean precipitation fields and (C, D) the seasonal cycle of zonal mean Pacific precipitation (color) in two perturbation experiments with strong forcing. Panels (A) and (B) are for the NEP+60/SEP-15 run where the double ITCZ is *eliminated* by the imposed forcing while panels (C) and (D) are for the NP-30/SP+10 run where the SPCZ and ITCZ *swap* their roles.

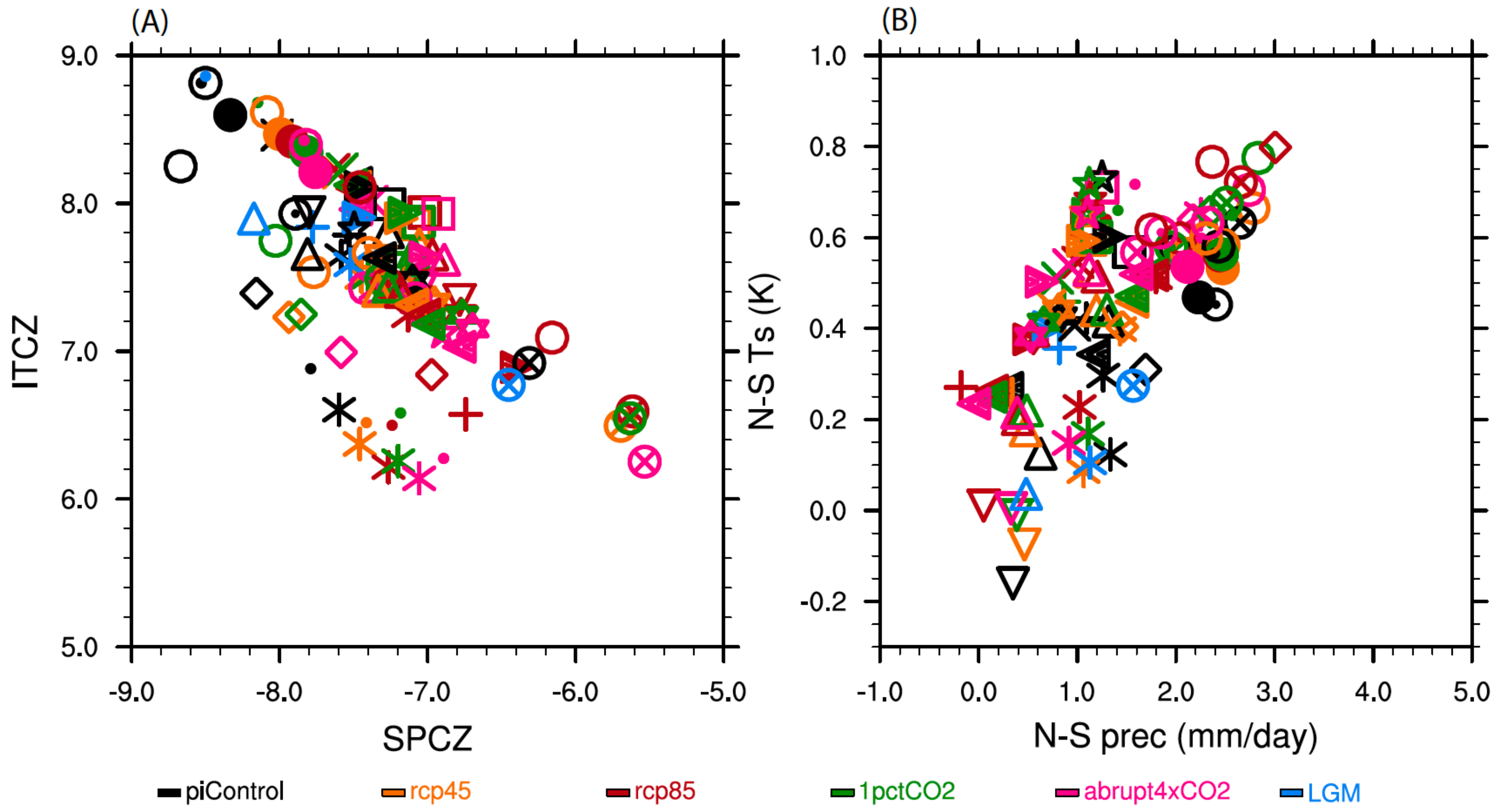

Fig. 5 Changes in the ITCZ and SPCZ characteristics across different climate simulations in the CMIP5 dataset. (A) The latitudinal position of the ITCZ versus the SPCZ and (B) the north-south gradient in near surface temperature versus the north-south gradient in precipitation. Precipitation and temperature indices are calculated for the region of [100E, 80W; 15S, 15N] and the last 50 years of each simulation.

Conclusion

- Interhemispheric climate forcing in the tropical Pacific at timescales much longer than interannual does not induce significant ITCZ shifts, largely due to the compensating effect of ocean heat transport.
- However, relatively small changes in atmospheric heat transport still result in significant changes in cross-equatorial mass transport, modulating precipitation intensity between the northern and southern tropical Pacific.
- **The seesaw behavior of the ITCZ/STCZ could explain paleoclimate proxies and have implications for future climate change.**