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Modeling of variability and mechanisms of megadroughts over the eastern China during the last millennium

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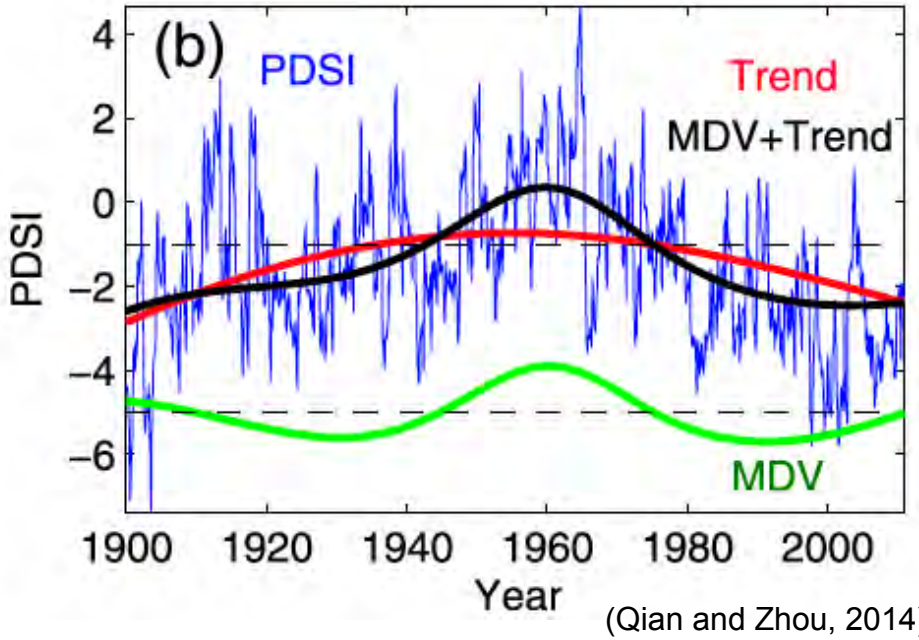
Background

- **What are megadroughts?**
  - Megadroughts are not precisely defined in the literature, but typically refer to persistent drought events with durations longer than a decade (Cook et al., 2016), two decades (Meehl and Hu, 2006), or 35 years (Ault et al., 2016).

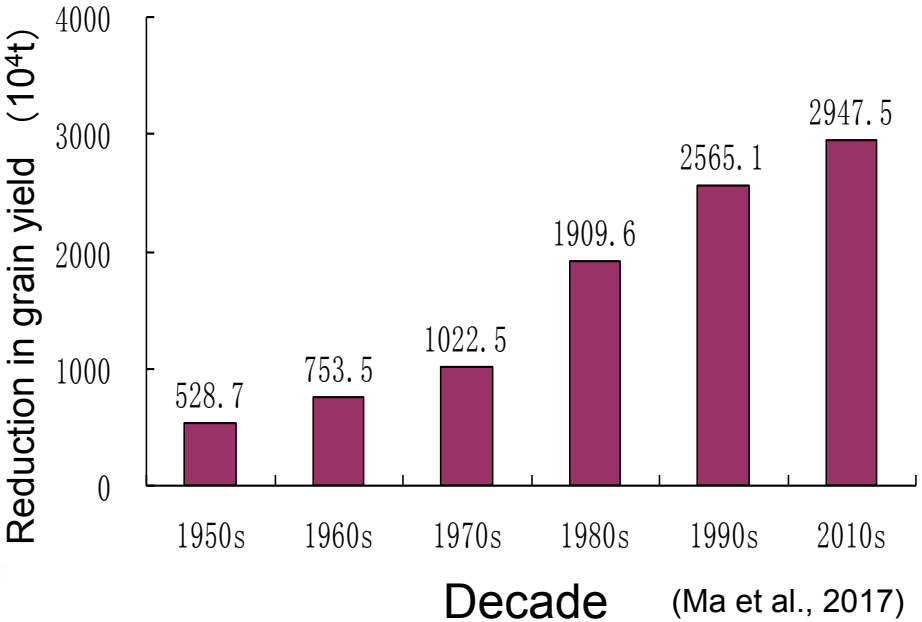
https://inhabitat.com/theres-a-20-50-chance-the-southwest-will-suffer-a-30-year-megadrought-in-the-next-century/megadrought

Evidence of megadroughts over China

- The megadrought over the northern China have persisted for more than five decades, during which the sub-arid area increases 25%.
- Hundreds of cities and millions of people are impacted due to the water shortage.
- The reduction of grain yield caused by megadrought over the northern China has increased from 5287kt (1950s) to 29475kt (2010s).



(Qian and Zhou, 2014)

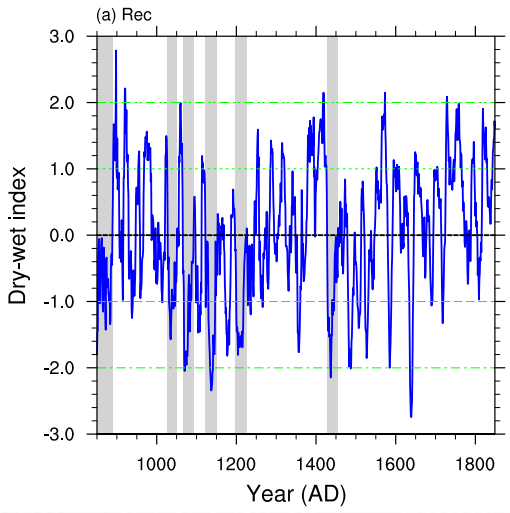


(Ma et al., 2017)

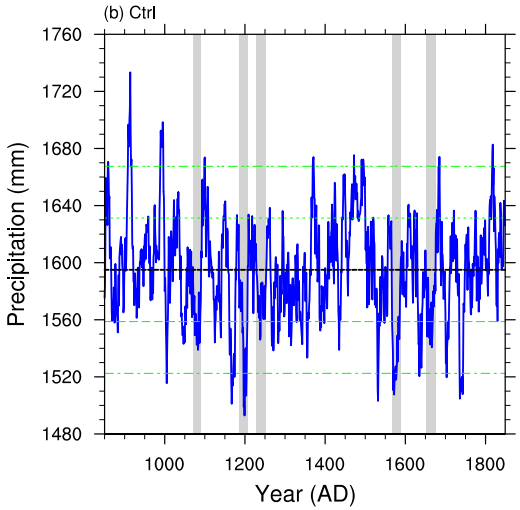
Reconstruction data and model simulations

- **Reconstruction data (Zheng et al., 2006)**
  - Time series of reconstructed dry-wet index averaged over the eastern China (25˚N-40˚N, 105˚E-122˚E) based on Chinese historical documents and instrument measurements (Zheng et al., 2006)
- **Model simulations (CESM-LME) (Otto-Bliesner et al., 2016)**
  - Period: 850-1850
  - Experiments: 1 control run (CTRL), 13 all-forcing experiments (ALL), 3 greenhouse gases emission sensitivity experiments (GHGs), 3 land use and land cover sensitivity experiments (LULC), 4 solar intensity sensitivity experiments (SSI), 5 volcanic eruption sensitivity experiments (VOLC)
  - Resolutions: ~2 degree resolution for atmosphere and land components and ~1 degree resolution in ocean and sea ice components

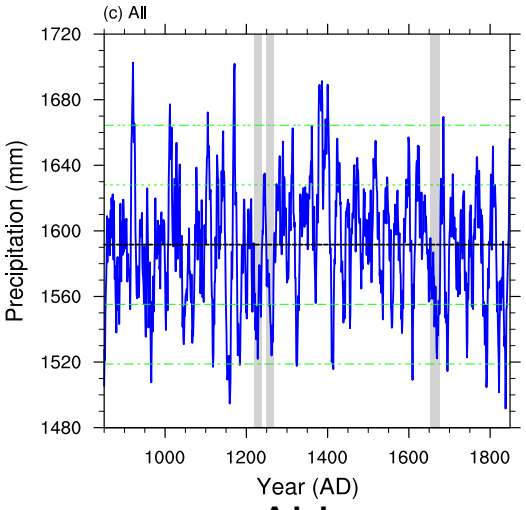
Reconstructed and simulated megadroughts



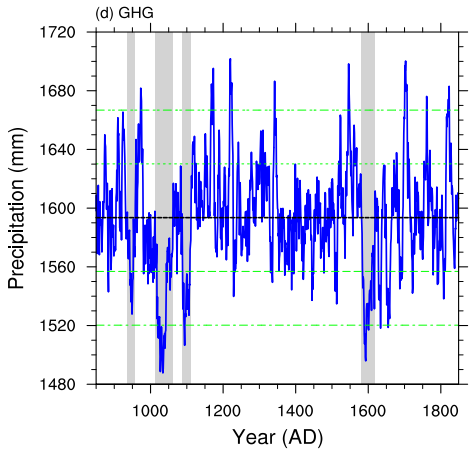
Rec



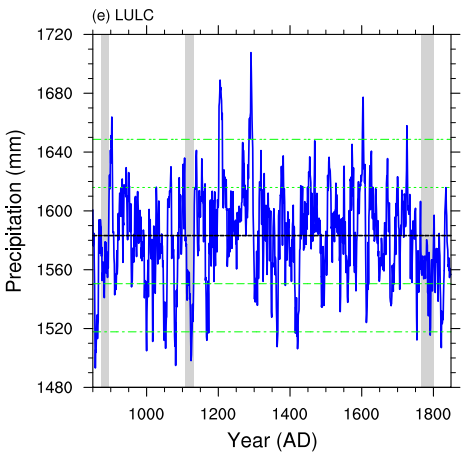
CTRL



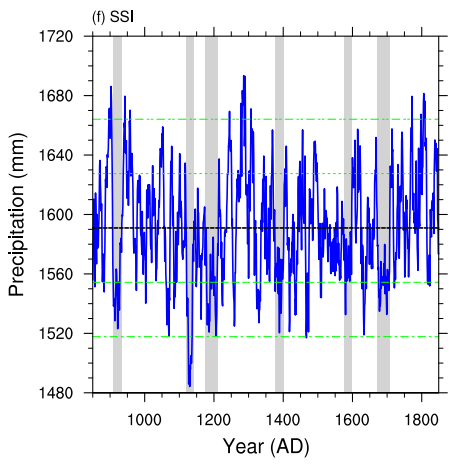
ALL



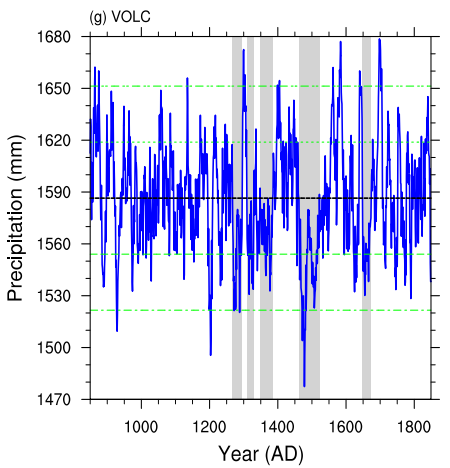
GHG



LULC

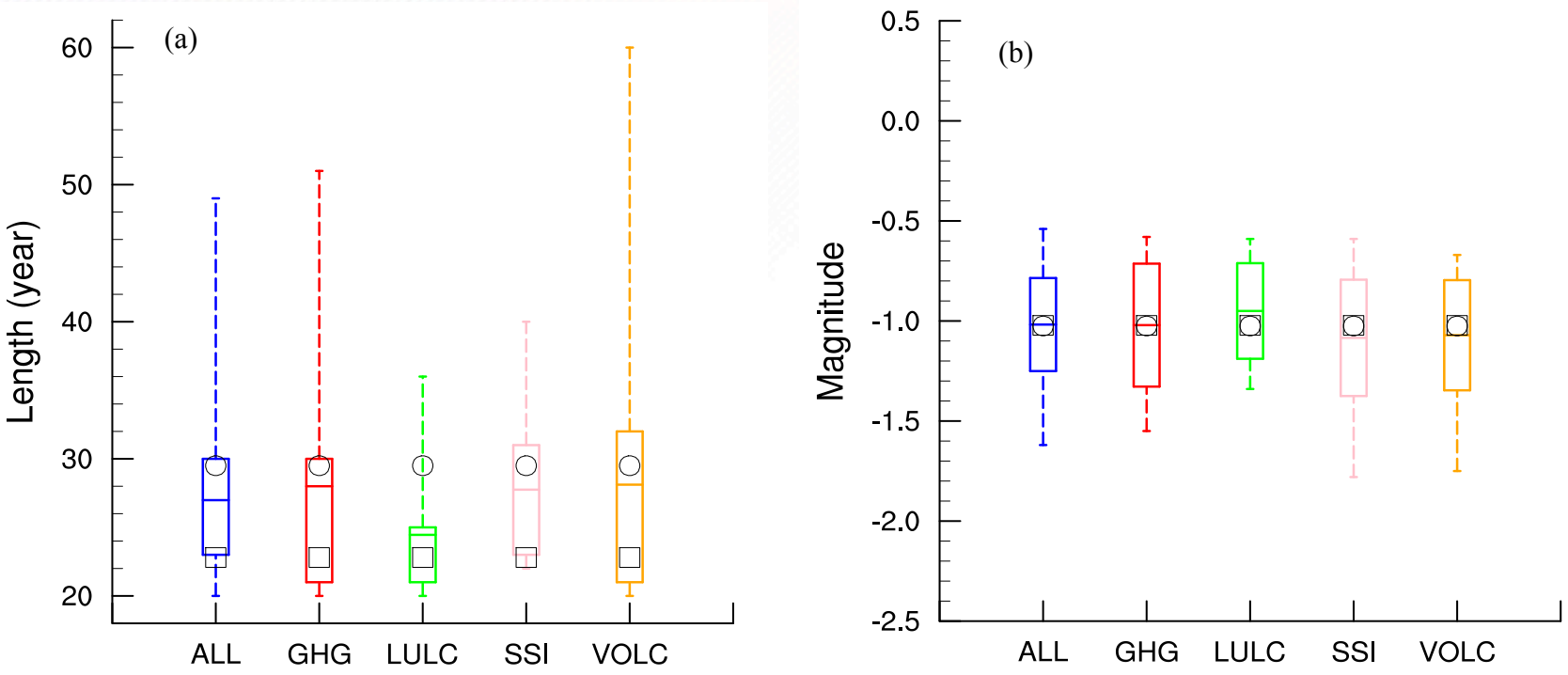


SSI



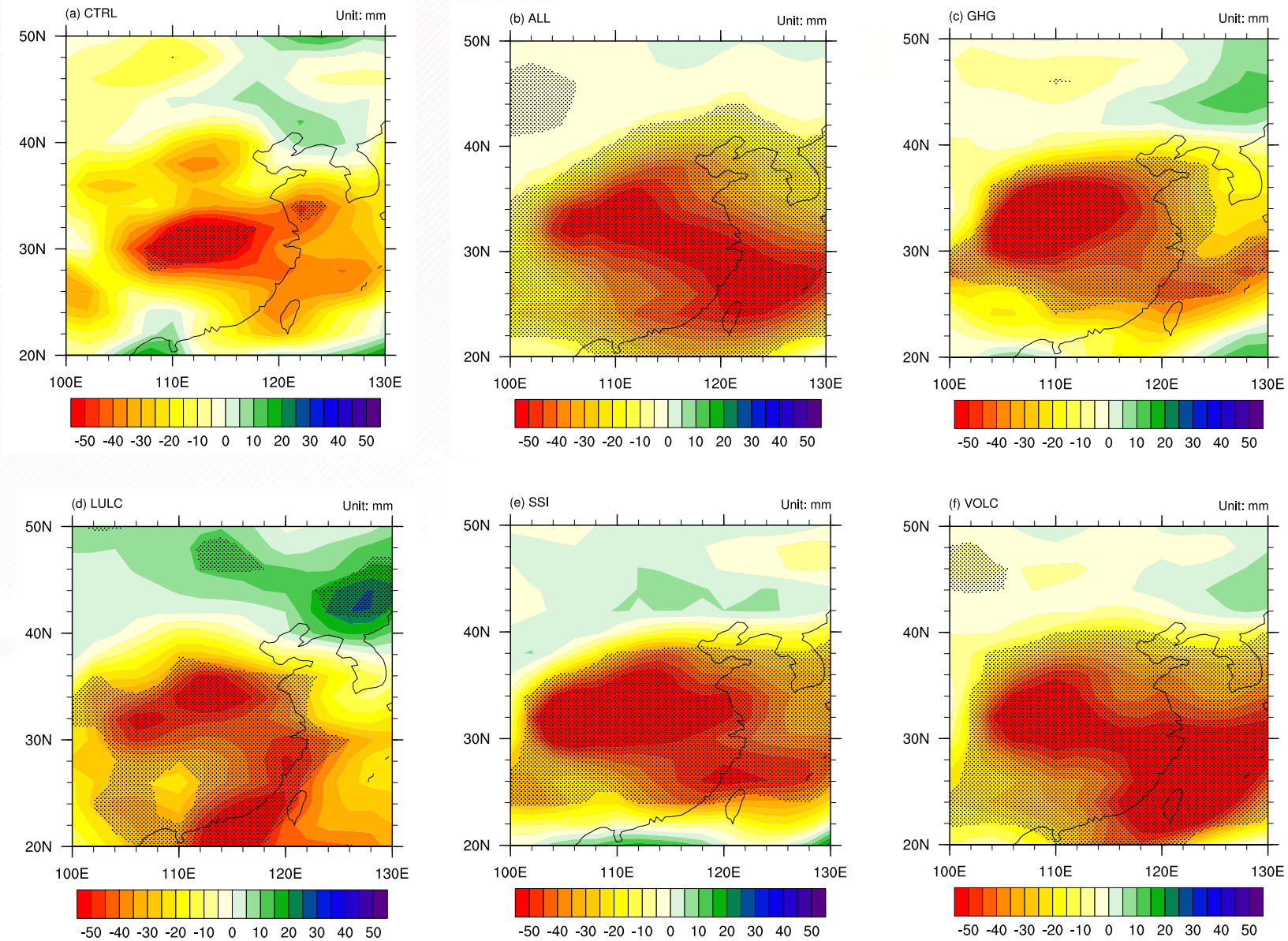
VOLC

Comparison between reconstructed and simulated megadroughts

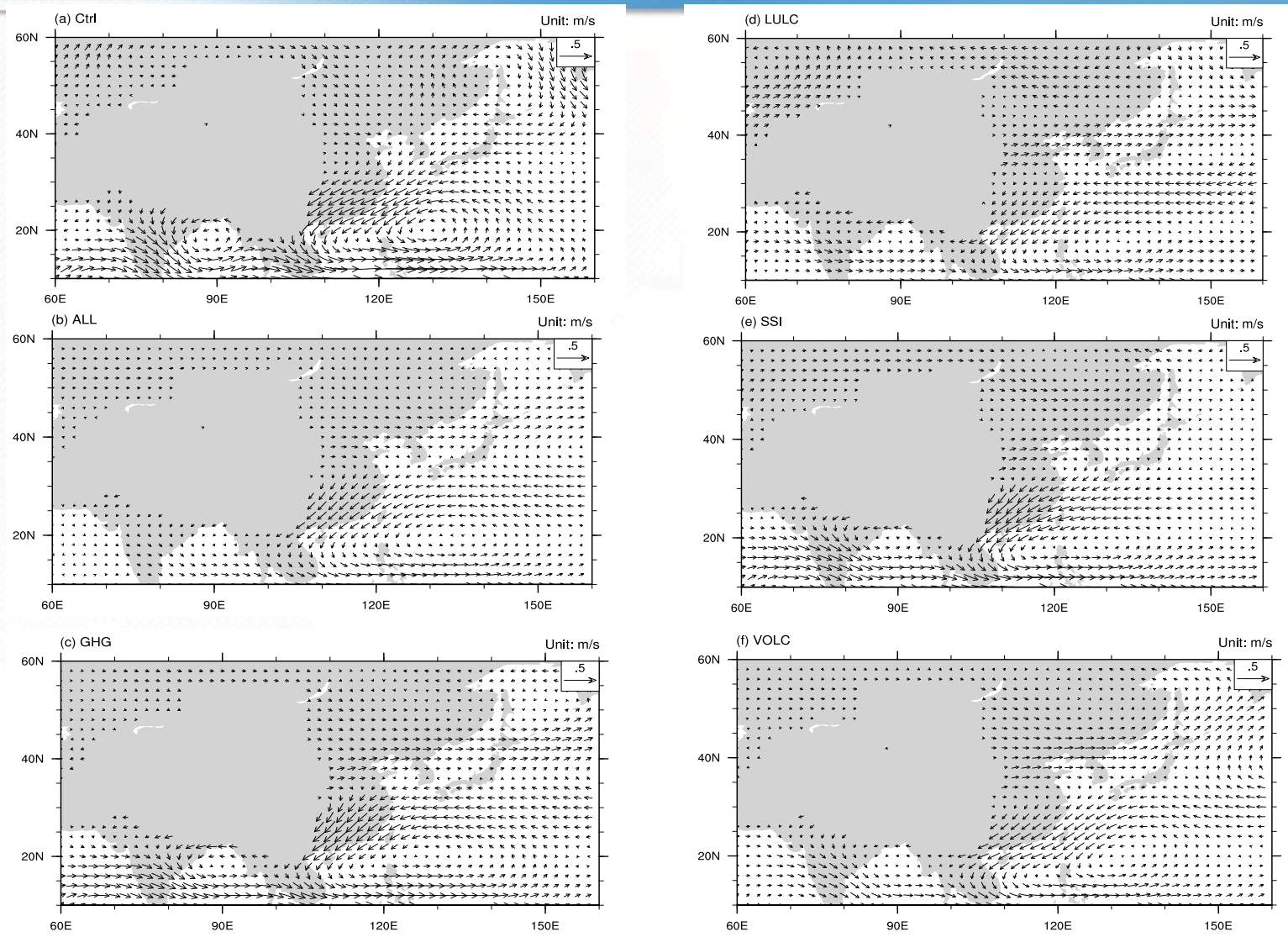


- The mean length of the megadroughts in CTRL is shorter than the reconstruction, while the mean lengths in the forced experiments are closer to the reconstruction.
- The average magnitude of megadroughts in the reconstruction and simulations are about 1 standard deviation below the mean.

Spatial distributions of megadroughts

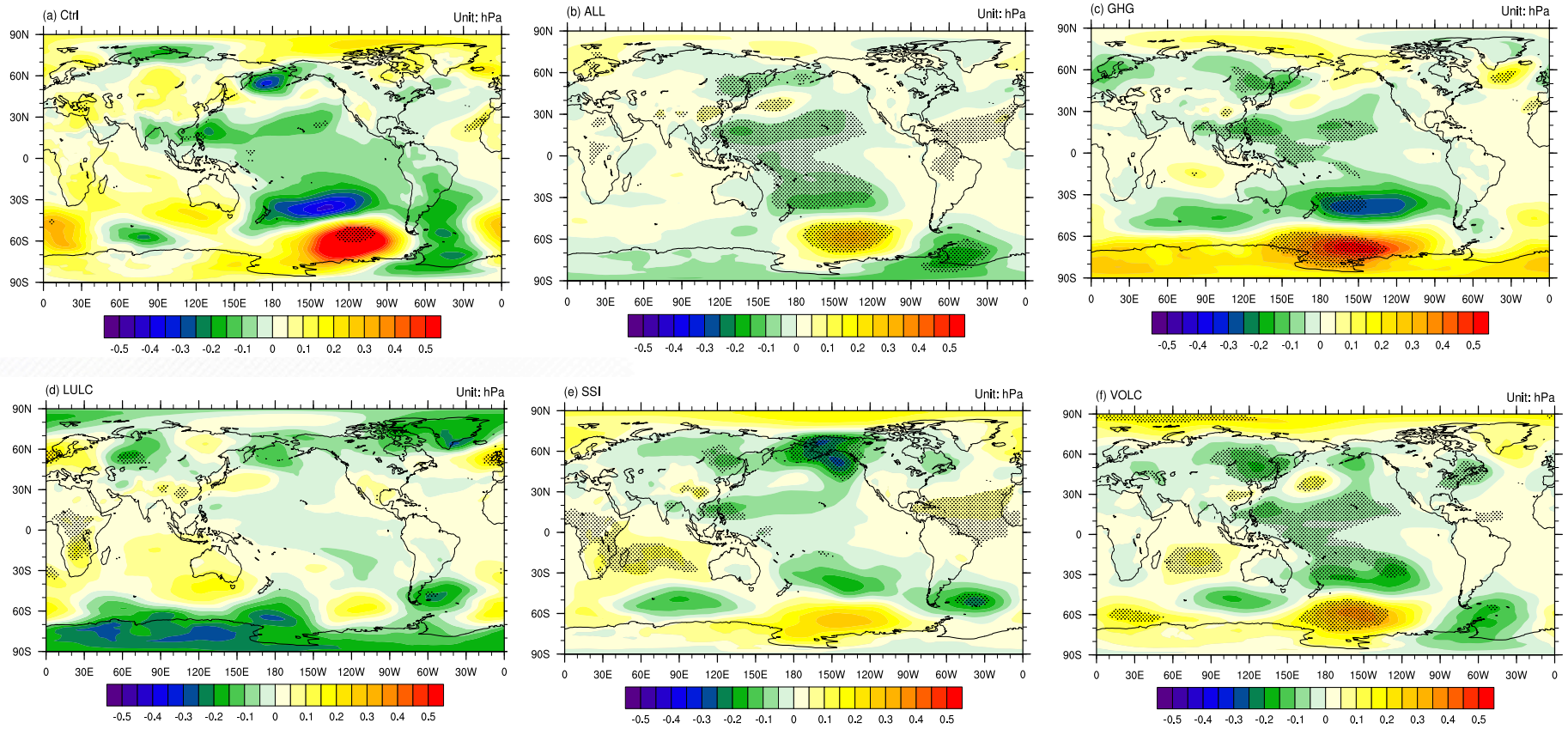


Weakening of EASM during megadroughts



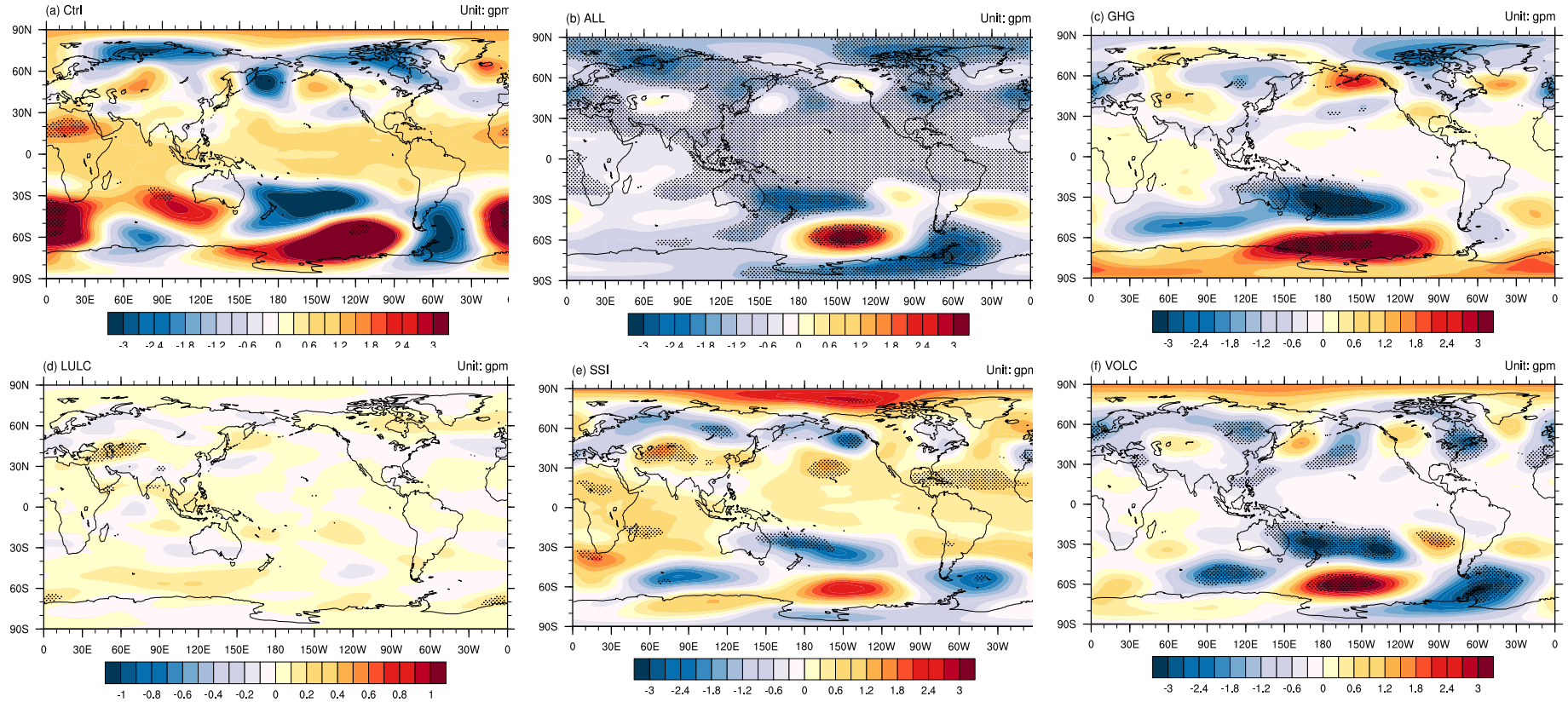
- Consistent with previous studies (e.g., Cook et al., 2010), the megadroughts over the eastern Asia are associated to the eastern Asian summer monsoon failure.

SLP anomalies associated with megadroughts



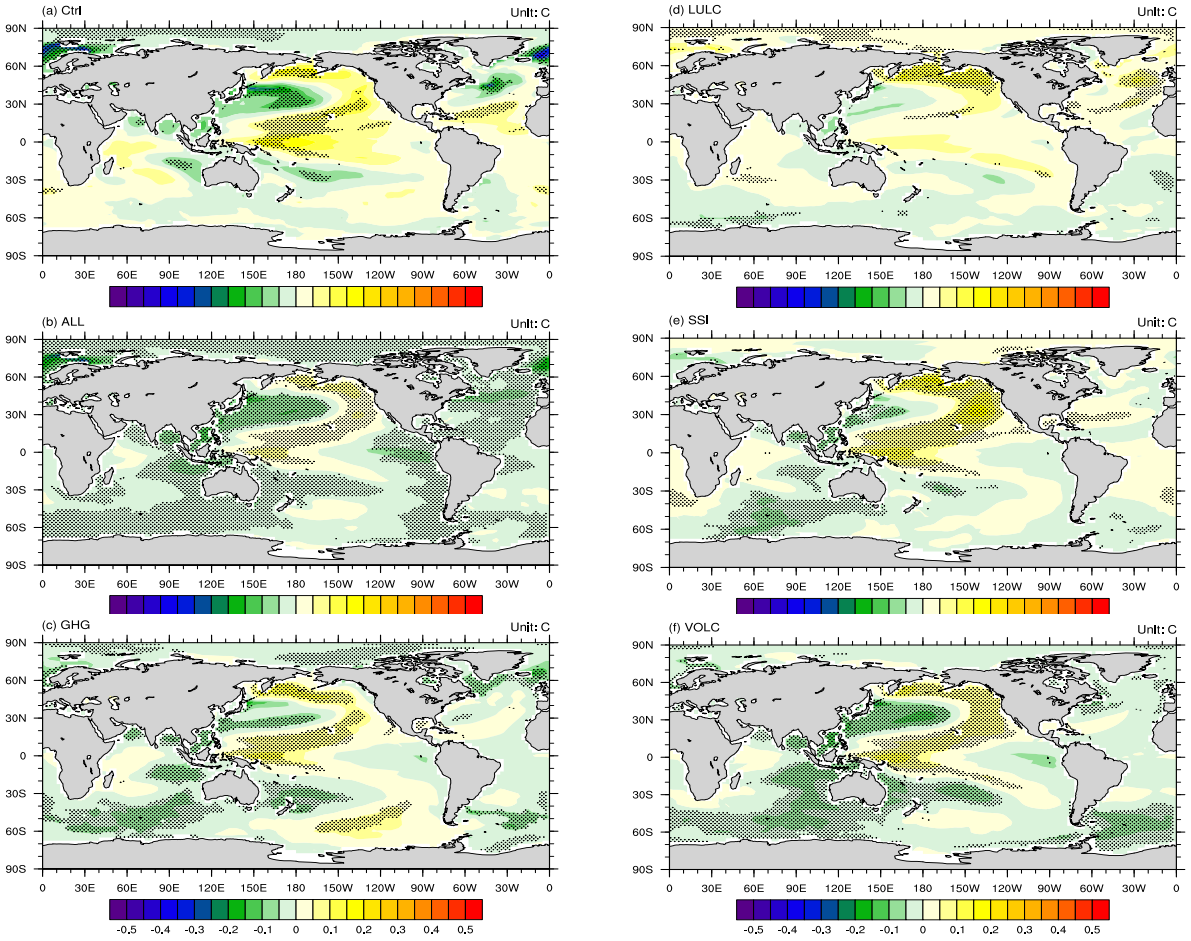
- The spatial distributions of SLP anomalies show a tripole pattern over the eastern Asia.
- This tripole SLP pattern results in weaker EASM, and also directly suppressed precipitation over the eastern China.

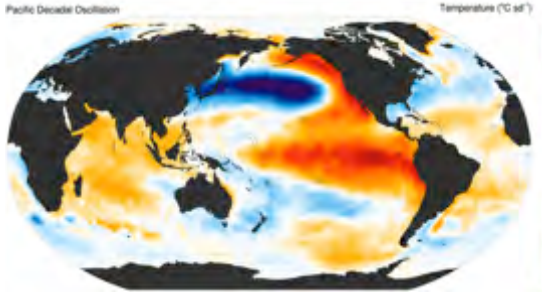
500 hPa geopotential height anomalies



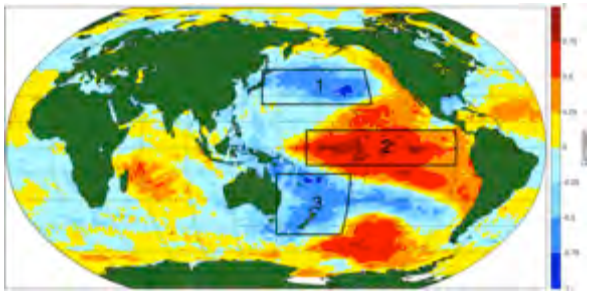
- Similar tripole pattern still exist on middle troposphere (500hPa).
- Combined barotropic and baroclinic patterns are similar to the inter-decadal Pacific-Japan (PJ) pattern (Wu et al., 2016a) confined at the lower troposphere, while, the specific locations of the nodes are different.

SST anomalies inducing the monsoon failure





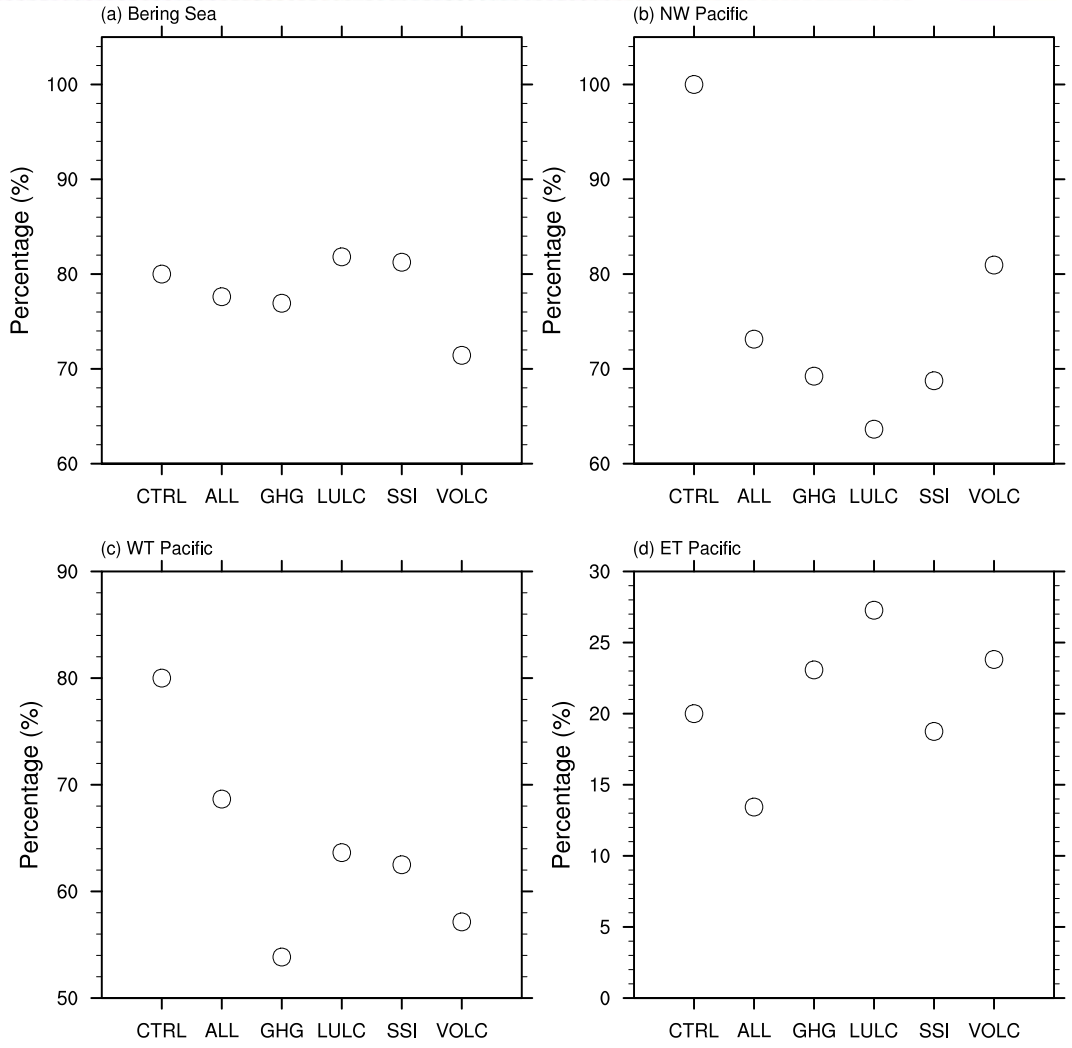
PDO wiki



IPO NOAA

- The SSTA patterns during the megadroughts, are different from the typical PDO or IPO patterns.
- The SSTA pattern includes a tripole SSTA pattern over northwestern Pacific with a La Niña-like SSTA gradient over the tropical Pacific.

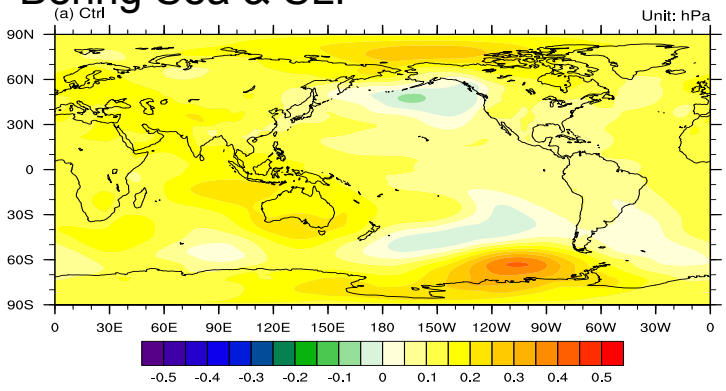
Persistence of the SST anomalies



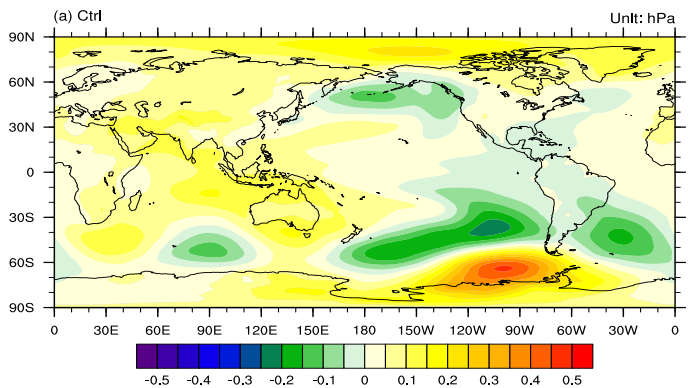
- The SST anomalies over the Bering Sea, NW Pacific, and western tropical Pacific persist through most of the megadroughts, while SST anomalies over the eastern tropical Pacific persist throught only less than 30% of the megadroughts.
- The weakening of EASM are proposed to result from two mechanisms: the direct weakening of land-ocean contrast due to the negative SST anomalies over the South China Sea and eastern Indian Ocean, and the cyclonic circulation anomalies through the La Niña-like SST gradient.

Regression patterns of SLP anomalies to SSTA

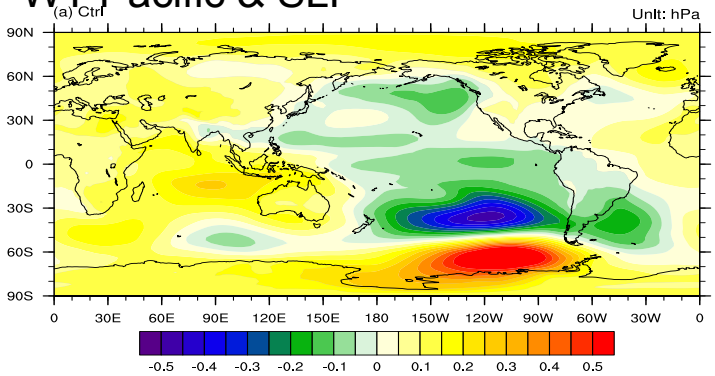
Bering Sea & SLP



NW Pacific & SLP



WT Pacific & SLP



- The SSTA over the Bering Sea and the northwestern Pacific both induce negative SLP anomalies over the northwestern Pacific and positive SLP anomalies over the eastern China.
- The SSTA over the western tropical Pacific induce the negative SLP anomalies over the western subtropical Pacific through Matsuno-Gill pattern (Wang et al., 2000).

Concluding remarks

- The model simulated megadroughts have similar intensity and frequency with the reconstructed megadroughts. However, these simulated megadroughts are not temporally synchronous with the megadroughts found in the reconstructed data, indicating that the internal variability of climate system plays an important role in triggering the megadroughts.
- Compared with CTRL, simulated megadroughts in the forced experiments have closer durations with reconstructed megadroughts.
- An inter-decadal tripole SST anomalies pattern induce a tripole SLP anomalies pattern and a tripole geopotential height anomalies pattern, which result in persistent weaker EASM and reduced precipitation over the eastern China. These patterns are more obvious in the forced experiments.

Thank you!