9TH GLOBAL ENERGY AND WATER EXCHANGES OPEN SCIENCE CONFERENCE

The relative contribution of large–scale circulation and local soil moisture to summer precipitation over Asian mid–low latitudes

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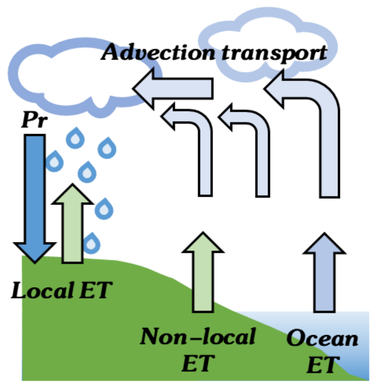
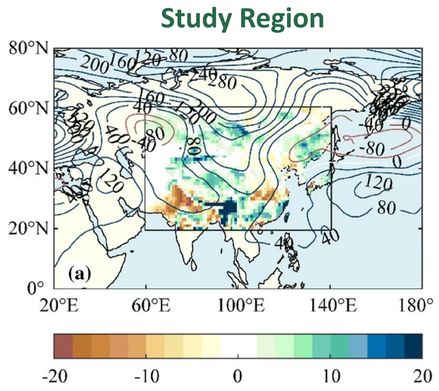
Introduction

- Water vapor sources of land precipitation (Pr) include large-scale atmospheric circulation transport and local land evapotranspiration (ET)
- This study adopts a dynamic adjustment approach based on constructed circulation analogs (DA-CCA) to isolate the contribution of atmospheric circulation to summer Pr over Asian mid-low latitudes during 1980–2019 quantitatively
- On the basis of the study of climatology, an application to a case of extreme precipitation in China is conducted

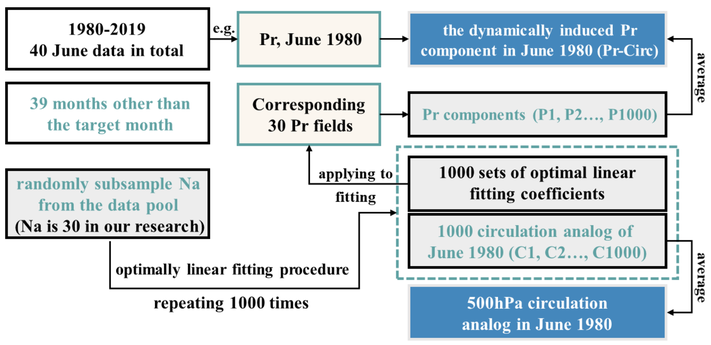


Data & Method

Study Region



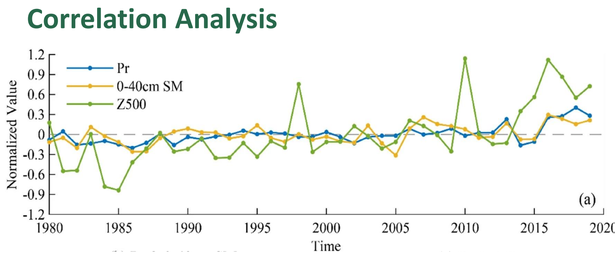
A dynamic adjustment approach based on constructed circulation analogs (DA-CCA)



- **Datasets**: monthly GLDAS Noah v2.0/2.1 and ERA5 Reanalysis, 0.25×0.25 deg
- **Study Period**: June - August, 1980-2019
- After DA-CCA, the Pr is divided into Pr-Circ (reflecting the effect of large-scale circulation) and Pr-Res (considered to represent land surface processes)

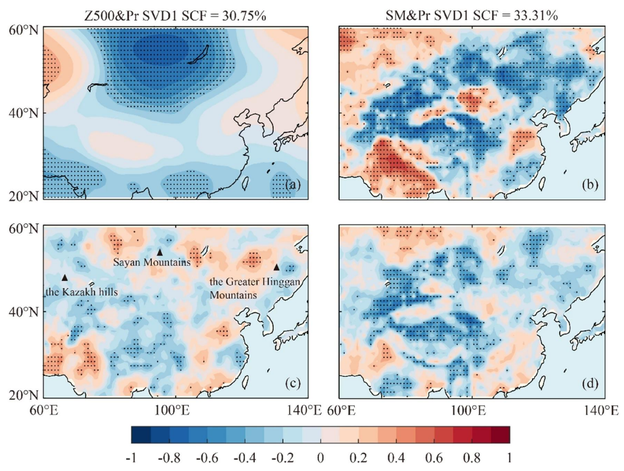
Results & Discussion

Correlation Analysis



- The summer Pr is strongly associated with both the 500hPa geopotential height (Z500) and antecedent soil moisture (SM)

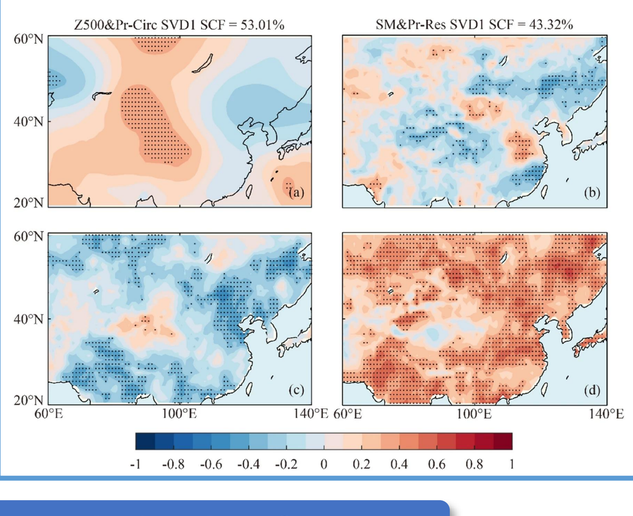
Fig 1. The normalized annual time series of the MJJ SM, JJA Pr and Z500 averaged over Asian mid-low latitudes



- In SVD analysis, the significant region of heterogeneous correlation represents the key area of the interaction between the two variable fields
- The regions with significant Pr-SM and Pr-Z500 correlation are not independent

Fig 2. The heterogeneous correlation coefficients of the first SVD modes (a, c) between the JJA mean Z500 and Pr and (b, d) between the previous SM in the and Pr over Asian mid-low latitudes from 1980 to 2019. The dotted areas are statistically significant at the 5% level

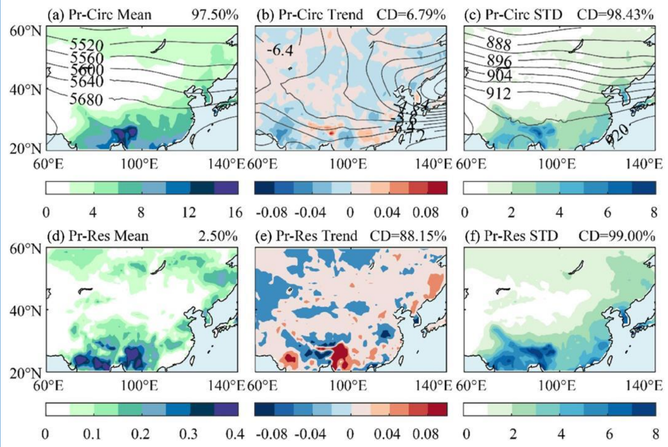
To separate the contributions of large-scale circulation and local ET to Pr, the DA-CCA approach is used to decompose the contributions into two parts, Pr-Circ and Pr-Res. And the SVD method is again used to analyze the relationships between Z500 and Pr-Circ and between SM and Pr-Res.



- The key SM-Pr feedback areas are mainly located in northeast China and the northern Indian Peninsula
- While the key influencing area of Z500 on Pr anomaly shows a "- + -" tripole pattern in the mid-latitude region

Fig 3. Similar to the above figure, but for the heterogeneous correlation coefficients of the first SVD modes (a, c) between the JJA mean Z500 and Pr-Circ and (b, d) between 0-40 cm SM one month in advance and Pr-Res

Quantification of component contributions



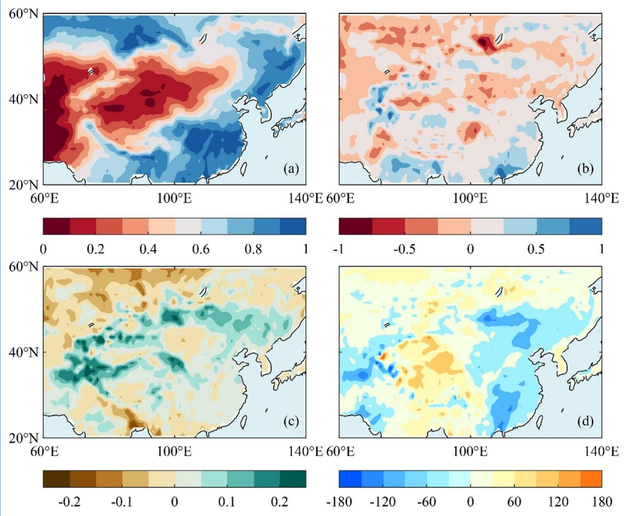
- Atmospheric circulation determines the magnitude of summer Pr
- Pr-Res reflects the local land-atmosphere coupling effect and dominate the trend of Pr, and both components are equally important to the interannual variability of Pr

Fig 4. (a) Climatological mean, (b) trend and (c) STD of JJA Pr-Circ (color shading; mm/day, and trend unit is mm/a) and constructed circulation analog (contour; gpm) over Asian mid-low latitudes. Panels in (d, e, f) are same as those in (a, b, c) but for Pr-Res (color shading; mm/day)

Physical mechanism of Pr-Res trend

ET (SM) affects the distribution of land surface available energy between sensible and latent heat fluxes, which can be quantified by the evaporation fraction (EF). Based on this concept, the study area can be divided into two parts according to the evaporation limitation conditions: water-limited and energy-limited regions.

$$EF = \frac{Latent\ heat\ flux}{Surface\ available\ energy}$$



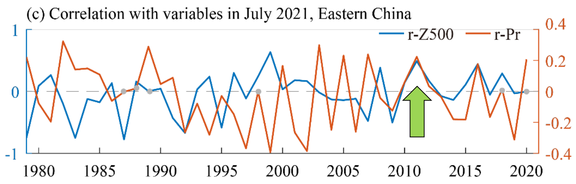
- In the water-limited region, the significant soil wetting trend is conducive to the enhancement of SM-ET feedback, resulting in the increasing in Pr-res
- Besides, the sensitivity of Pr-Res to the SM reduction is stronger than that of SM enhancement in the water-limited region

Fig 4. (a) Climate mean state and (b) trend of the JJA evaporation fraction (EF, dimensionless) over Asian mid-low latitudes from 1980 to 2019. Trend of the (c) MJJ 0–40 cm SM (m3/m3/a) and (d) JJA land surface available energy (W/m2/a) from 1980 to 2019

Application in a recent extreme event

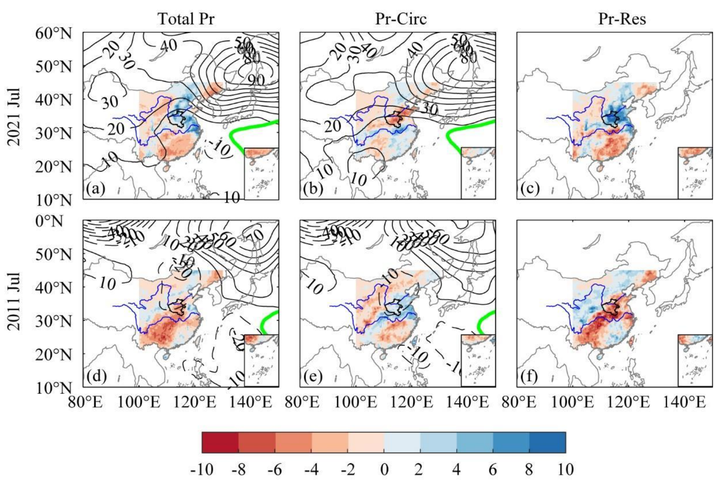
Comparison of precipitation in two July months under similar circulation in eastern China

- **Case:** '7·21' rainstorm in Henan, China in 2021
- **Datasets**: CN05.1 and ERA5, 0.25 deg
- **Study Period**: July, 1979-2021



- Between 1979 and 2020, the years with the most similar Pr and those with the most similar Z500 pattern to 2021 do not coincide

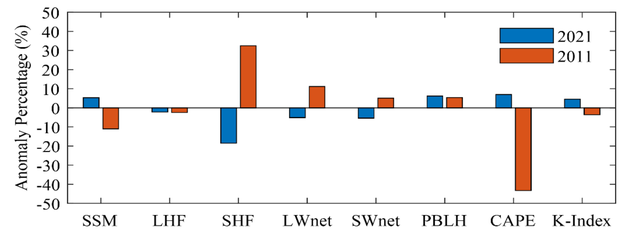
Fig 5. The spatial correlation coefficients of Z500 (blue line) and Pr (orange line) in eastern China between July 2021 and July during 1979–2020



- The Pr-Res significantly enhances the intensity of extreme Pr in July 2021

Fig 6. (a, c) Pr anomaly (shadings, units: mm/day) and Z500 anomaly (contours, units: gpm), (b,e) (shadings, units: mm/day) and constructed circulation analog of Z500 anomaly (contours, units: gpm), (c, f) Pr-Res (shadings, units: mm /d) over eastern China in July 2011 and July 2021. The black solid (dashed) line represents the positive (negative) geopotential height anomaly, and the green contour indicates that the Z500 is 5880 gpm

The role of land surface anomalies in '7·21' Henan rainstorm



- Processes conducive to rainfall formation: The enhanced ET reduces the sensible heat flux, then strengthens the convective instability energy thought affecting the atmospheric relative humidity and the boundary layer height

Fig 7. Anomaly percentage of land surface and near-surface convection factors in July 2021 and July 2011 in Henan Province relative to the July climatology during 1979-2021

Conclusion & References

- Atmospheric circulation determines the magnitude of summer land precipitation, while the residual components reflect the land-atmosphere coupling effect and dominate the precipitation trend, and both are equally important to the interannual variability of precipitation
- In '7·21' Henan rainstorm, the land surface thermal anomaly superimposed enhances the intensity of extreme precipitation by enhancing the land-atmosphere feedback
- The analysis of July precipitation evolution from 1979 to 2021 in eastern China shows that the extreme precipitation anomaly is mainly reflected in the strong interannual variability of the residual component, emphasizing the important influence of the local thermal effect on extreme summer precipitation

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[2] Chen, Y., Wang, A., Zhi, R., Feng, G. 2023. Contributions of Large-Scale Circulation and Local Land–Atmosphere Interaction to Precipitation in Eastern China: Investigation on Influencing Factors of the July 2021 Heavy Precipitation Event in Henan Province. Chinese Journal of Atmospheric Sciences (with English Abstract), 47(2): 551–566.