The Initiation and Rainfall Characteristics of Warm-season MCSs over the South China Coast

Chenli Wang[1,2], Xingchao Chen[2*], Kun Zhao[1*] and Chin-Hsuan Peng[2]

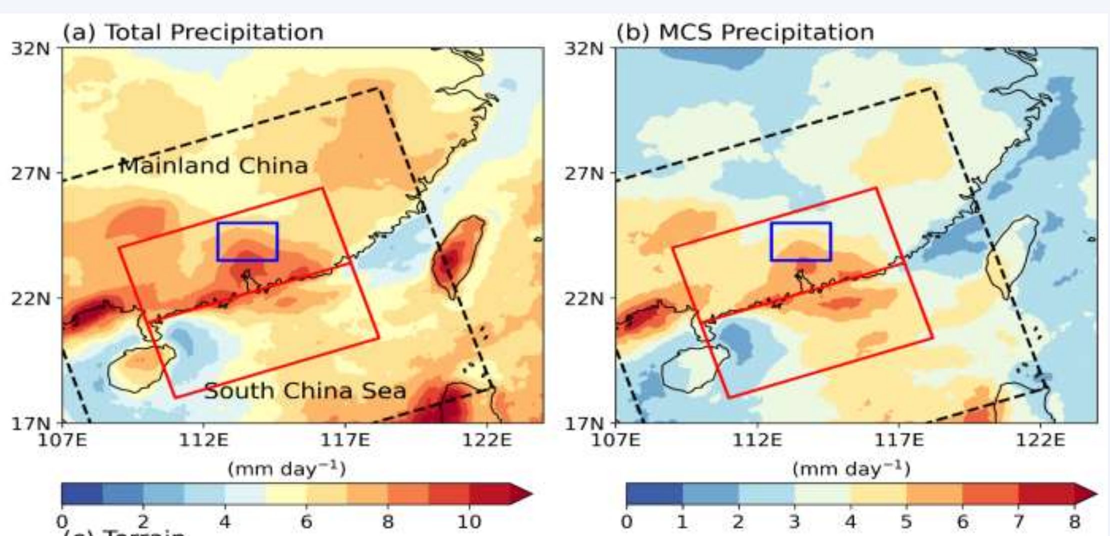
[1]Key Laboratory of Mesoscale Severe Weather/MOE and School of Atmospheric Science, Nanjing University, Nanjing, and State Key Laboratory of Severe Weather and Joint Center for Atmospheric Radar Research of CMA/NJU, Beijing, China

[2]Department of Meteorology and Atmospheric Science, and Center for Advanced Data Assimilation and Predictability Techniques, The Pennsylvania State University, Pennsylvania, USA

ABSTRACT

The South China coast (SCC) experiences frequent heavy rainfall during the warm season (May-September). Using 20 years of satellite observations and cloud tracking, this study highlights that **mesoscale convective systems (MCSs)** play a pivotal role in generating precipitation. Locally initiated MCSs contribute more to SCC warm-season precipitation than propagating MCSs from outside of the study region. The **extreme local MCSs** are prone to initiate near the coastline. The favorable environments are characterized by stronger geopotential gradient, moisture transport, and convective available potential energy (CAPE). The low-level prevailing onshore wind carrying warm-moist airflow, which converges and generates updrafts due to land-sea contrast and coastal terrain, is crucial to the initiation, growth and propagation of convections.

Objective classification analysis further shows that the majority of warm season precipitation (>80%) occurs under three low-level typical **synoptic circulation patterns**: the southerly monsoon pattern (P1), the southwesterly monsoon pattern (P2), and the low-level vortex pattern (P3). The initiation and rainfall characteristics of MCSs are strongly modulated by the background synoptic circulations.



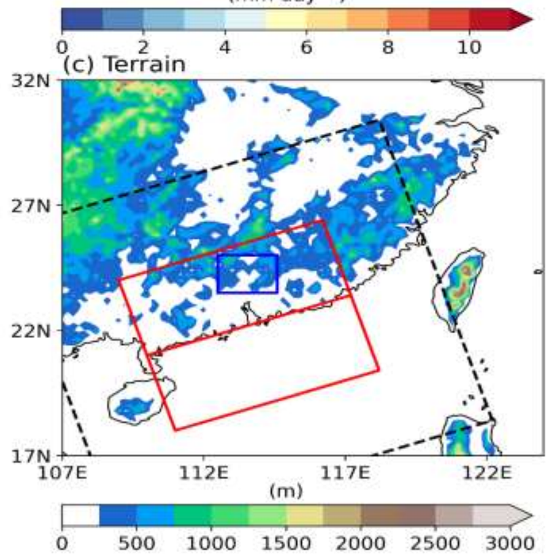


Figure 1. The daily mean (a) total and (b) MCS precipitation over the 2001-2020 warm-seasons. (c) Terrain height.

1. Warm-season rainfall concentrates near the coastline;
2. MCSs contribute for ~70% total rainfall.

DATA AND METHOD

- The 0.1°×0.1° hourly global (60°S–60°N) MCS dataset developed by Feng et al. (2021) during 2001-2020 is used to study warm season MCS rainfall characteristics over the SCC.
- The hourly 0.25° × 0.25° ERA5 is utilized to analyze the dynamic and thermodynamic environments.
- The obliquely rotated principal components analysis in T-mode (PCT) is applied to the daily averaged 925-hPa geopotential height for the classification of synoptic circulation patterns.

RESULTS

(1) Rainfall is Dominated by Local MCSs

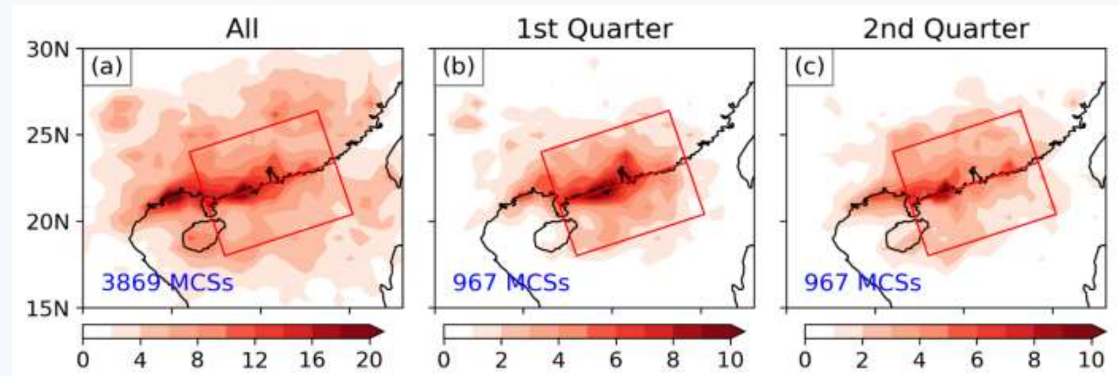
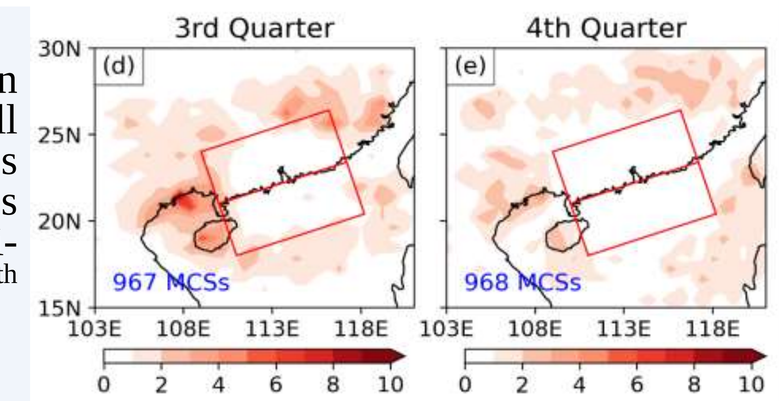
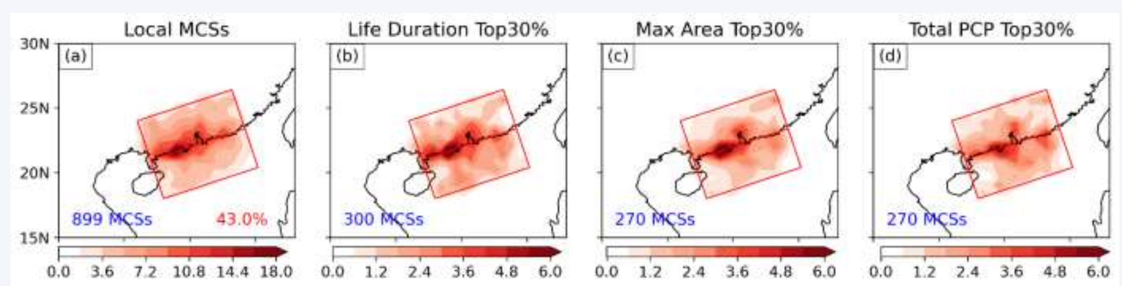


Figure 2. Initiation frequency of (a) all contributing MCSs and (b)-(e) MCSs with rainfall contribution in the 1st-4th quarter.





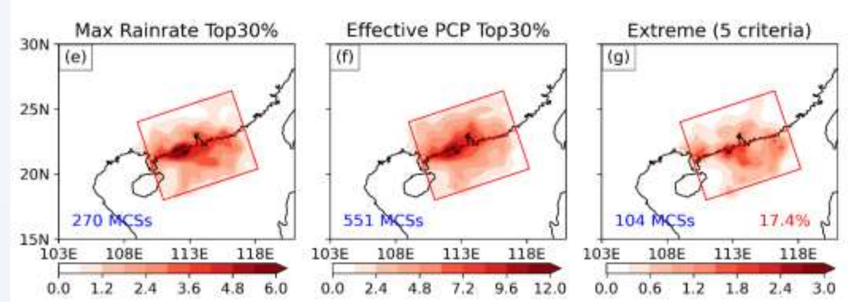


Figure 3. Initiation frequency of local MCSs with different criteria.

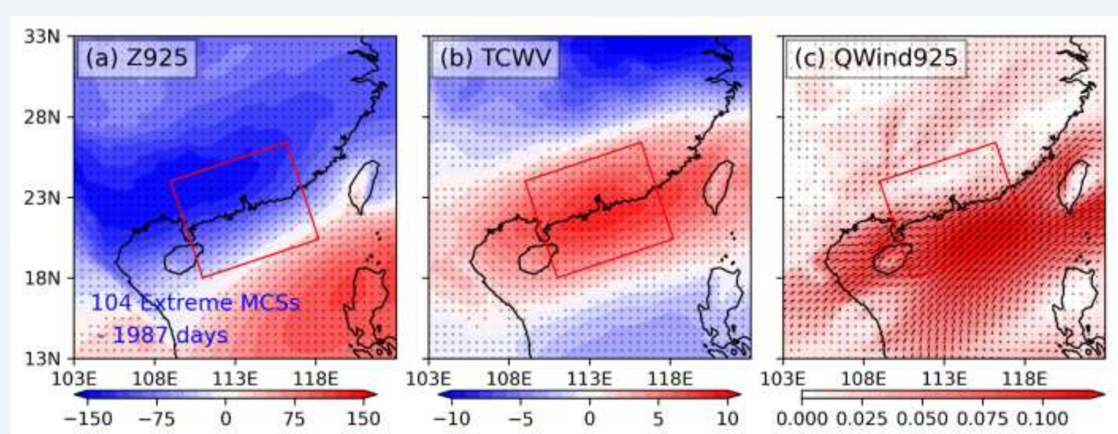


Figure 4. Anomalous (a) geopotential height at 925-hPa, (b) total column water vapor, and (c) moisture transportation at 925-hPa during extreme local MCSs compared with that during days without local MCSs.

1. Warm-season rainfall amount is more effectively contributed by locally initiated MCSs over the SCC;
2. The initiation frequency of extreme local MCSs, defined by top 30% duration, maximum area, maximum rainrate, total and effective rainfall contribution, concentrates near the coastline;
3. The environments of extreme MCSs are characterized by stronger geopotential height gradient, onshore moisture transport, and CAPE (not shown).

(2) Case Study of Extreme Local MCS

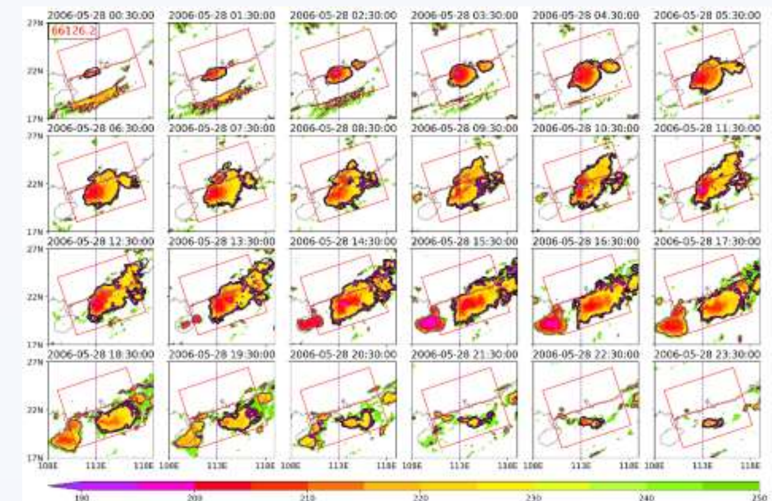


Figure 5. Hourly evolution (LST) of a typical extreme local MCS.

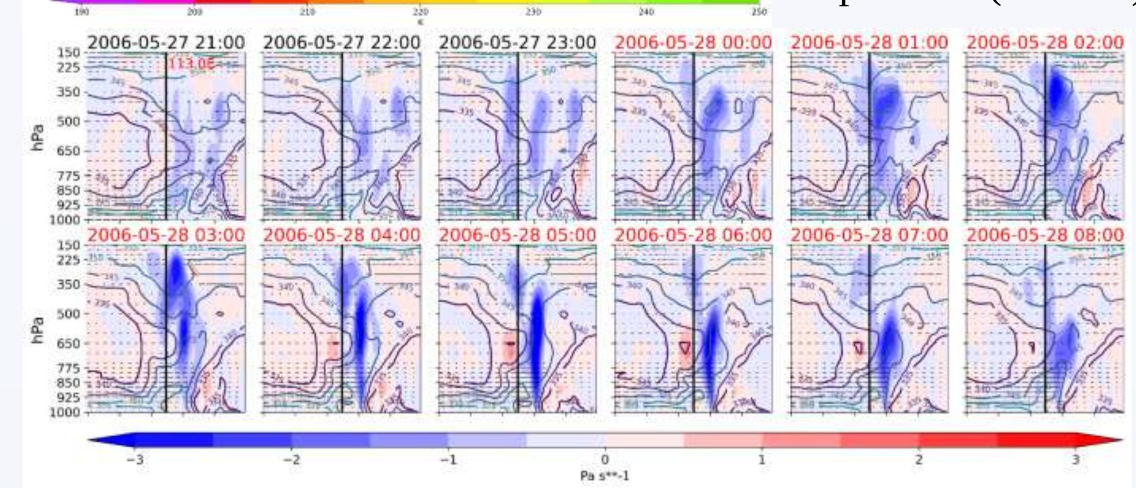


Figure 6. Hourly evolution of horizontal wind (vector), vertical velocity (shading), and equivalent potential temperature (contour).

The low-level onshore winds with warm-moist airflow and corresponding updrafts are important.

(3) Synoptic Control on MCSs

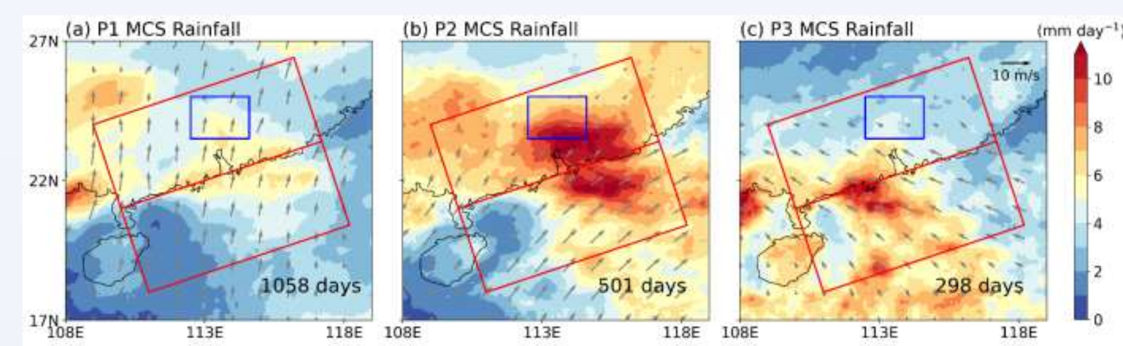


Figure 7. The daily mean MCS rainfall and 925-hPa wind field under (a) Pattern 1, (b) Pattern 2 and (c) Pattern 3.

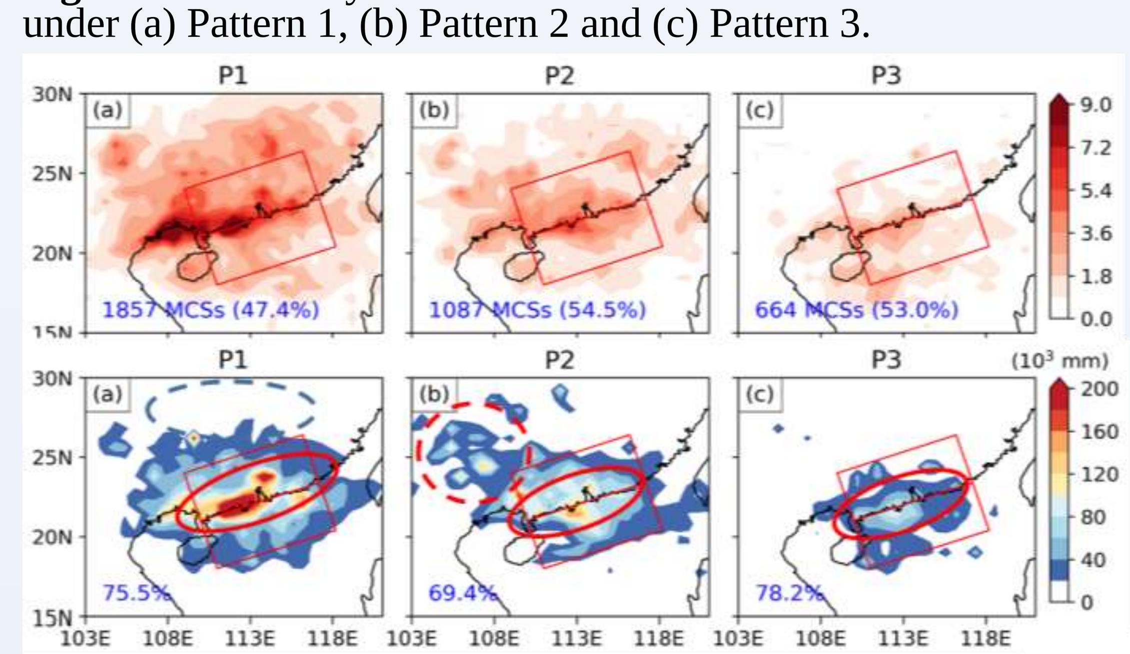


Figure 8. The (upper row) original and (bottom row) rainfall-contribution-weighted initial frequency of contributing MCSs under three typical patterns.

1. Synoptic circulation patterns determine the spatial distributions of MCS rainfall through the coastal convergence of prevailing wind;
2. Locally initiated MCSs contributes most effective rainfall (70-78%) under all three typical patterns, while there are some disparities between patterns.

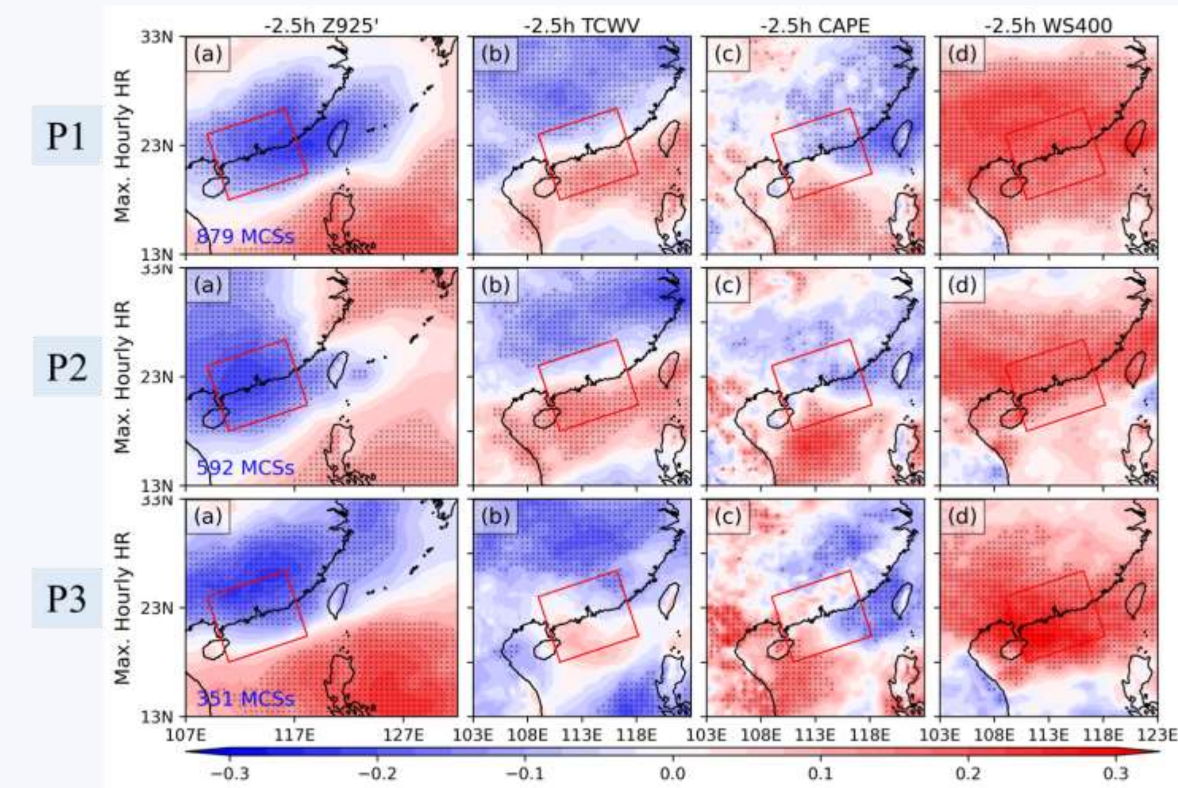


Figure 9. Correlation coefficients between the pre-MCS environments and the maximum hourly heavy rainfall amount of MCSs under three typical patterns.

Intensified gradient promotes stronger moisture transport, higher offshore moisture content, higher upstream CAPE, and stronger deep-layer wind shear can lead to local MCSs with stronger rainfall and larger rainfall area (not shown).

CONCLUSIONS

- Using the cloud tracking and classification dataset, we found that the MCS contributes for the most warm-season rainfall over the SCC.
- The composite favorable environments for extreme local MCSs are characterized by stronger geopotential gradient, moisture transport, and CAPE. The low-level warm-moist onshore wind generates convergence and updraft, affecting the initiation, growth and propagation of MCS.
- The typical synoptic circulation patterns significantly determine the initiation and rainfall characteristics of MCSs through the interactions between prevailing onshore winds and local land-sea contrast and terrain.

REFERENCES

Wang, C., Chen, X., Zhao, K., & Peng, C. Synoptic Control on the Initiation and Rainfall Characteristics of Warm-season MCSs over the South China. Submitted to *Journal of Geophysical Research: Atmospheres.*

Wang, C., Zhao, K., Huang, A., Chen, X., & Rao, X. (2021). The Crucial Role of Synoptic Pattern in Determining the Spatial Distribution and Diurnal Cycle of Heavy Rainfall over the South China Coast. *Journal of Climate, 34*(7), 2441-2458. https://journals.ametsoc.org/view/journals/clim/34/7/JCLI-D-20-0274.1.xml

Feng, Z., Leung, L. R., Liu, N., Wang, J., Houze Jr, R. A., Li, J., et al. (2021). A Global High-Resolution Mesoscale Convective System Database Using Satellite-Derived Cloud Tops, Surface Precipitation, and Tracking. *Journal of Geophysical Research: Atmospheres*, *126*(8), e2020JD034202. https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020JD034202

CONTACT INFORMATION

Chenli Wang, chenliwang@smail.nju.edu.cn