Author's Response

We sincerely thank the Editor and two referees for their careful assessment of our work and for the constructive suggestions. We have revised the manuscript to improve its clarity, organization, and scientific presentation, and have rechecked the figures, tables, and language where necessary. In addition, we have added one more funding source, which was omitted in the first edition. All modifications are shown in the tracked-changes file. Below, we address the referees' comments point by point and indicate the corresponding changes. For clarity, our responses are highlighted in blue.

Reviewer#1

This paper presents a valuable and comprehensive study on the climatology, variability, and trends of Mesoscale Convective Systems (MCSs) over the Asian Monsoon Region (AMR) from 2001 to 2023. The manuscript is well-written and concise, making it a pleasure to read. There remain a few points that require further clarification and polish.

We thank the reviewer for the thoughtful and constructive comments on our manuscript. The suggestions have helped us clarify several aspects of the methodology and improve the presentation of our results. Our detailed responses are provided below.

Major comments:

1. The authors use a simplified spatial-temporal overlap method to associate hazards with MCSs: if a hazard event occurs within the "impact area" of an MCS on the same day, it is considered MCS-associated. While operationally straightforward, this approach introduces significant uncertainties and potential overestimation of MCS contributions, particularly for hazards with different spatial and temporal scales.

1.1 The MCS impact area is defined via a circumscribed circle of the MCS's bounding rectangle (Fig. 2), which may not accurately represent the true spatial extent of convective hazards.

Thank you for this comment. We agree that representing the MCS impact area using the circumscribed circle of the bounding rectangle is a simplified geometric approximation and may not fully capture the real spatial extent of a convective hazard. This approach was adopted to provide a consistent and operational definition of the MCS influence area for large-scale, long-term statistical analyses

involving systems with diverse morphologies and movement characteristics. Because the brightness temperature data used to identify and track MCSs in this study have a temporal resolution of 30 min, the systems may move substantially between successive observation times. As a result, weather impacts such as precipitation may occur slightly outside the instantaneous cloud boundary defined at the 30-min temporal resolution. The cloud-mask-based definition could therefore underestimate the spatial extent associated with the MCS.

It should also be noted that the primary objective of this study is to examine the regional-scale statistical relationships between MCS activity and convective hazards rather than to establish precise event-level attribution. In addition, the available hazard datasets are generally reported at daily temporal resolution and aggregated at administrative-unit scales, which limits the possibility of establishing precise event-to-event correspondence at finer spatial and temporal scales. Therefore, this method is used as a practical approximation for regional climatological analyses. In the revised manuscript, we have further clarified these methodological limitations and emphasized that the results should be interpreted as statistical associations at regional and climatological scales rather than precise event-scale attribution at Lines 397–409.

We also conducted a supplementary comparison using a more conservative cloud-mask-based definition of the MCS impact area. The comparison (Fig. R1) shows that the choice of impact-area definition mainly affects the absolute magnitude of MCS-related precipitation, whereas the overall spatial distribution pattern remains broadly similar between the two definitions. In general, the circumscribed-circle-based definition yields larger precipitation amounts than the cloud-mask-based definition, which is consistent with its broader spatial coverage. These results suggest that, although the exact magnitude of MCS-related precipitation is sensitive to the definition of the impact area, the overall spatial pattern of MCS-related precipitation remains broadly similar between the two definitions. In the revised manuscript, we have clarified the potential effects of this methodological choice on the precipitation statistics and explicitly acknowledged its limitations at Lines 96–103.

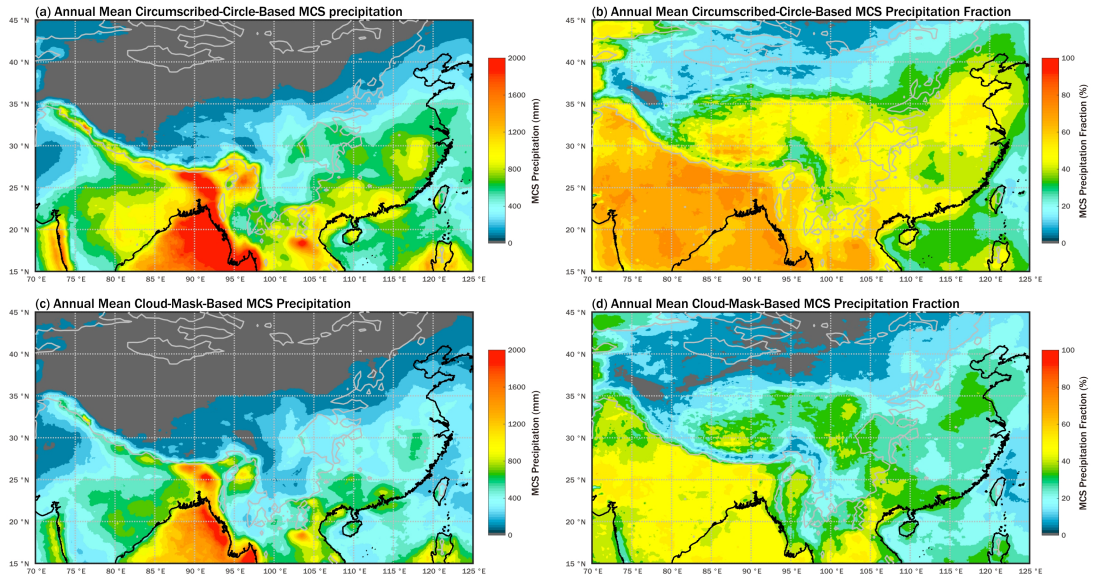


Figure R1: Annual mean spatial distributions of (a) circumscribed-circle-based MCS precipitation, (b) circumscribed-circle-based MCS precipitation fraction, (c) cloud-mask-based MCS precipitation, (d) cloud-mask-based MCS precipitation fraction. The black solid line represents the coastline, and the gray solid line represents the 1000 m elevation contour. Color shading indicates: annual mean (a, c) cumulative MCS precipitation (mm) and (b, d) MCS precipitation fraction (%).

1.2 The analysis uses daily resolution for all hazards. MCSs evolve rapidly (lifetimes of hours), and associating a daily-aggregated hazard with an MCS that may have occurred only briefly within that day can lead to false positives. This is especially problematic for short-lived events like tornadoes.

Thank you for this important comment. We agree that the mismatch in temporal resolution between the daily-scale hazard records and the half-hourly MCS tracks may introduce uncertainty in temporal matching. Therefore, the daily-scale matching method may, to some extent, overestimate the association between MCSs and hazard events. We would like to clarify that the attribution analysis conducted in this study is intended to assess the statistical attribution between hazard occurrence and MCS activity at regional and climatological scales, rather than to establish a strict causal attribution for each individual hazard event. Specifically, our analysis aims to determine whether severe convective hazards, such as hail and tornadoes, are more likely to occur in the presence of MCS activity at the daily scale, and to further quantify the occurrence probability of these hazards under MCS-impacted conditions.

On this basis, we conducted supplementary analyses for heavy rainfall events (HREs) and strong wind events (SWEs), respectively. For HREs, we redefined and recalculated MCS-HREs based on half-hourly MCS precipitation (MCSP). Specifically, we first accumulated half-hourly MCSP to obtain the daily MCS-related precipitation, and defined cases with daily accumulated MCSP $\geqslant$ 50 mm as

MCS-HREs. We then further analyzed the MCS-HRE fraction and the interannual trend in MCS-HRE frequency. The results (Fig. R2) show that the daily-scale method used in the manuscript does indeed overestimate the MCS-HRE fraction to some extent. Nevertheless, the spatial patterns of the MCS-HRE fraction and the interannual trend in MCS-HRE frequency derived from the two methods are generally consistent. For the ECAS, the MCSP-based trend in MCS-HRE frequency is 0.080 days yr^{-1} (5.04% yr^{-1}), compared with 0.097 days yr^{-1} (3.79% yr^{-1}) obtained using the daily-scale method. Both trends pass the two-tailed Student's t-tests at the 95% confidence level.

For MCS-SWEs, we used the hourly station observations available for 2016–2022 to calculate the MCS-SWE fraction during this period using both the daily-scale method described in the manuscript and the hourly-scale method. In the hourly-scale method, the unit of analysis remains a station day: for a station day with an observed SWE, if the station was covered by the MCS impact area within ±1 h of the SWE observation time, this station day was identified as an hourly-scale MCS-SWE. The results (Fig. R3) show that the daily-scale method results in a higher estimate of the MCS-SWE fraction than the hourly-scale method: under the daily-scale method, 46.7% of SWEs were identified as MCS-related events, whereas this fraction decreased to 32.8% under the stricter hourly-scale method. This difference is reasonable because the daily-scale method only requires an SWE to occur on a day with MCS activity and therefore applies a relatively loose temporal constraint, whereas the hourly-scale method requires MCS influence near the SWE observation time and thus imposes a stricter temporal constraint on the correspondence between SWE occurrence and MCS influence. Meanwhile, although the daily-scale method overestimates the magnitude of the MCS-SWE fraction, the spatial distribution patterns derived from the two methods remain broadly consistent, which indicates that the temporal matching scale mainly affects the estimated magnitude of the MCS-SWE fraction rather than its primary spatial distribution characteristics.

Therefore, we believe that this difference in temporal scale mainly affects the precise event-level correspondence between hazard occurrence and MCS activity, but does not materially affect the overall conclusions of this study regarding the regional and climatological statistical relationship between MCS activity and severe convective hazards. Although the MCSP-based method applies a more restrictive criterion for defining MCS-HREs, we retained the daily-scale method in the main analysis to maintain methodological consistency across different types of weather hazards. Meanwhile, to avoid overstatement, we have further emphasized this methodological limitation at Lines 397–409 of the

revised manuscript and clarified that the related results should be interpreted as daily-scale statistical attribution at regional and climatological scales, rather than as a causal attribution for each individual hazard event.

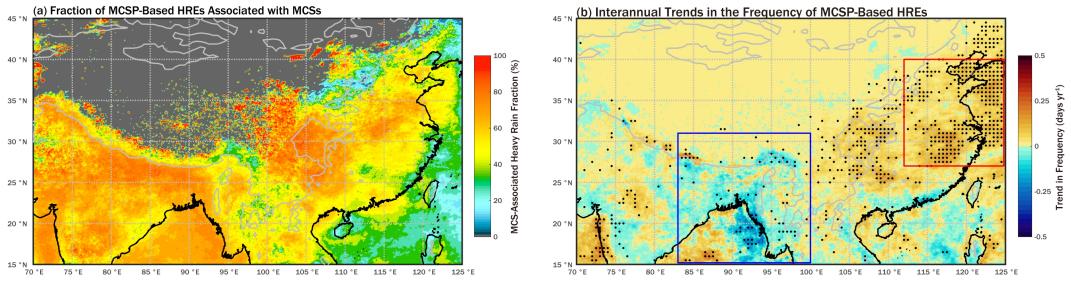


Figure R2: Spatial distribution of MCSP-based (a) MCS-HRE fraction, (b) interannual trend of MCS-HREs. The black solid line represents the coastline, and the gray solid line represents the 1000 m elevation contour. The color shading indicates the annual mean number of MCS-HRE fraction for (a) and annual trend of MCS-HREs (unit: days yr^{-1}) for (b). The black dots indicate regions with statistical significance at 5 % level, as determined by a two-tailed Student's t-test. The blue box indicates the range of BoBCR in this study, and the red box indicates the range of ECAS in this study.

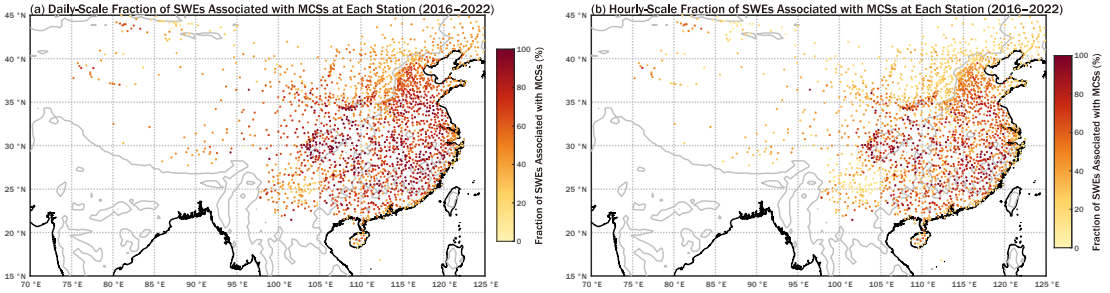


Figure R3: Spatial distribution of (a) daily-scale and (b) hourly-scale MCS-SWE fraction. The black solid line represents the coastline, and the gray solid line represents the 500 m elevation contour. The dots represent meteorological station locations. The color shading of dots indicates the number of MCS-SWE fraction.

2. The identification of MCSs relies heavily on Tb thresholds (233 K for CCAs, 225 K for cold cores) and an area threshold of 3000 km². While the authors justify these thresholds based on precipitation efficiency and computational trade-offs (Fig. 3), the sensitivity of the results to these choices is not thoroughly tested. The authors are not advised to pick "the best" set of thresholds, but at least they need to provide the error bars of their results.

Thank you for this valuable suggestion. In response to this comment, we conducted additional threshold sensitivity tests to assess the robustness of the main results to parameter selection. Considering the computational cost of MCS identification and tracking over a large domain and long time period, we limited this analysis to the ECAS region for 2001–2023.

Specifically, we performed MCS identification and tracking over the region 110°–127°E, 25°–42°N, which is slightly larger than the ECAS domain (112°–125°E, 27°–40°N). We then carried out a

one-at-a-time sensitivity analysis, in which only one threshold was varied in each test while the other thresholds were fixed at their reference values. The reference thresholds were set to a CCS threshold of 225 K, a duration threshold of 3 h, an overlap ratio threshold of 0.15, and an area threshold of 3000 km², consistent with those used in the manuscript. We separately tested CCS thresholds of 220 and 230 K, duration thresholds of 2 and 4 h, overlap ratio thresholds of 0.10 and 0.20, and area thresholds of 2000 and 4000 km². For each threshold setting, we calculated the interannual trends of the metrics such as MCSD and MCSH over the ECAS region to evaluate the sensitivity of the results to threshold selection.

For the cold-cloud threshold (233 K), we did not conduct an additional sensitivity analysis of the same type, primarily because the identification of cold-cloud systems is relatively insensitive to changes in this threshold. As shown in Fig. 3b of the manuscript, the number of identified cold-cloud systems remains nearly unchanged across the 230–245 K threshold range.

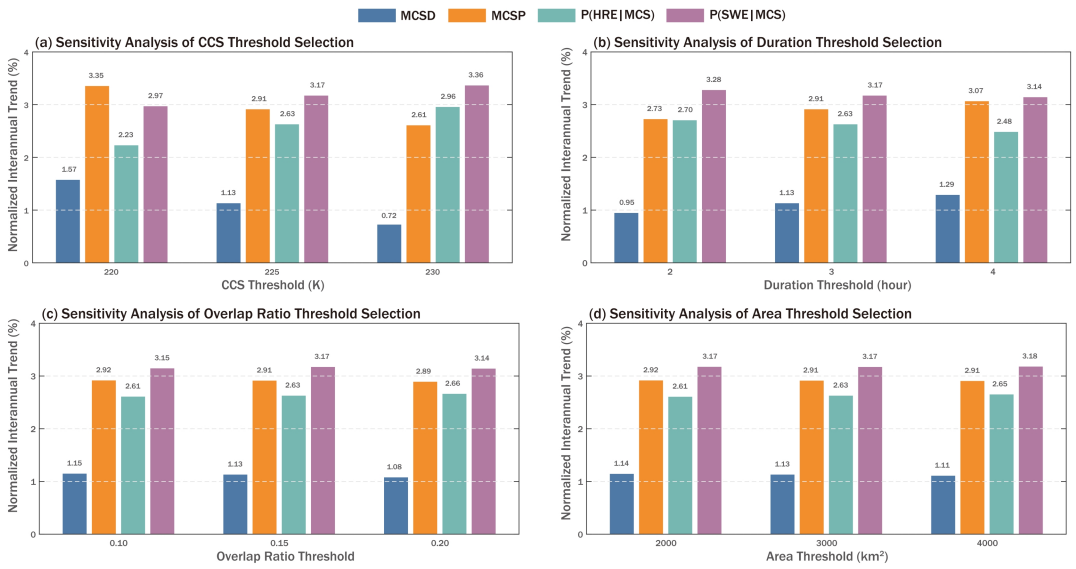


Figure R4: Sensitivity of the normalized interannual trends of MCSD, MCSP, *P*(*HRE*|*MCS*) and *P*(*SWE*|*MCS*) to (a) CCS threshold, (b) Duration threshold, (c) Overlap-ratio threshold, (d) Area threshold. All displayed trends are significant at the 5% level according to a two-tailed Student's t-test.

Figure R4 compares the normalized interannual trends of four representative metrics under different threshold perturbations, where the normalized trend is defined as the ratio of the interannual trend to the corresponding multi-year mean over 2001–2023. The results show that the CCS threshold and the duration threshold have relatively larger impacts on the results, particularly on the normalized interannual trends of MCSD and MCSP. Moreover, these results appear to suggest that MCSs with more active convective characteristics (i.e., lower cloud-top temperatures) and longer durations tend to

exhibit larger upward trends in their precipitation impacts, as illustrated in Fig. R4a, b. Figure R5 further summarizes the sensitivity of the normalized interannual trends of all key metrics to threshold selection. Although the trend values differ across threshold settings, all metrics retain upward trends, supporting the robustness of the main conclusions of this study to threshold selection.

Tables R1 and R2 further list the trend values and normalized trends of the key metrics in the manuscript under different threshold settings. The main differences arise in a few specific threshold settings, under which the interannual trends of some metrics do not reach statistical significance at the 5% level based on a two-tailed Student's t-test. For example, under the threshold combination of a CCS threshold of 230 K, an overlap ratio threshold of 0.15, a duration threshold of 3 h, and an area threshold of 3000 km², the interannual trend of MCSH is not significant at the 5% level.

Table R1: Interannual trends of MCSD, MCSH, MCSP, and MCSPF under different threshold settings. Values in parentheses denote the ratio of the trend to the corresponding multi-year mean. Underlined values indicate trends that are not statistically significant at the 5% level according to a two-tailed Student's t-test.

CCS threshold (K)	Overlap ratio threshold	Duration threshold (hour)	Area threshold (km^2)	MCSD (day yr^{-1})	MCSH (hour yr^{-1})	MCSP (mm yr^{-1})	MCSPF (pp yr^{-1})
225	0.15	3	3000	1.20(1.13%)	2.54(1.57%)	15.27(2.91%)	0.83(1.91%)
220	0.15	3	3000	1.36(1.57%)	2.83(2.10%)	15.18(3.35%)	0.88(2.39%)
230	0.15	3	3000	0.83(0.72%)	2.08(1.22%)	14.31(2.61%)	0.73(1.59%)
225	0.15	2	3000	1.05(0.95%)	2.45(1.45%)	14.86(2.73%)	0.78(1.72%)
225	0.15	4	3000	1.30(1.29%)	2.59(1.68%)	15.42(3.07%)	0.85(2.05%)
225	0.10	3	3000	1.22(1.15%)	2.56(1.58%)	15.31(2.92%)	0.83(1.91%)
225	0.20	3	3000	1.12(1.08%)	2.43(1.53%)	14.99(2.89%)	0.80(1.87%)
225	0.15	3	2000	1.22(1.14%)	2.58(1.59%)	15.40(2.92%)	0.83(1.91%)
225	0.15	3	4000	1.17(1.11%)	2.49(1.56%)	15.11(2.91%)	0.82(1.90%)

It should be noted that, to ensure comparability among the threshold sensitivity experiments, the supplementary analysis was conducted using the same identification domain and statistical window settings across all tests. Therefore, even though the reference-threshold experiment used the same threshold parameters as the main analysis in the manuscript, the corresponding results from the present

sensitivity analysis differ slightly from those reported in the manuscript. This difference mainly arises from the adjustment of the identification domain rather than from changes in the thresholds themselves, and therefore does not affect the overall conclusions of the threshold sensitivity assessment. We have included the above sensitivity analysis results in the Supplement and added the corresponding description to the revised manuscript at Lines 148–150 and Lines 494–499.

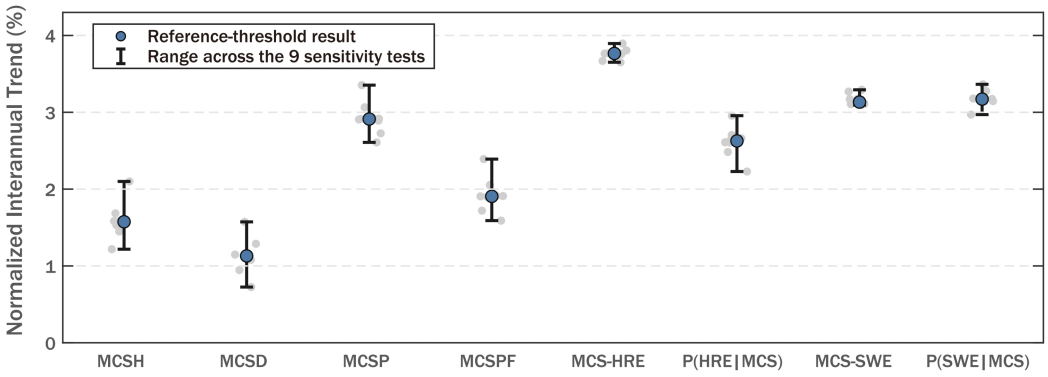


Figure R5: Sensitivity of key metrics to threshold perturbations. Gray dots represent the individual values obtained from the 9 tests. The reference-threshold results are obtained using a CCS threshold of 225 K, an overlap ratio threshold of 0.15, a duration threshold of 3 h, and an area threshold of 3000 km². Error bars indicate the minimum-to-maximum range across the 9 sensitivity tests.

Table R2: Interannual trends of MCS-HRE, *P*(*HRE*|*MCS*), MCS-SWE, and *P*(*SWE*|*MCS*) under different threshold settings. Values in parentheses denote the ratio of the trend to the corresponding multi-year mean. Underlined values indicate trends that are not statistically significant at the 5% level according to a two-tailed Student's t-test.

CCS threshold (K)	Overlap ratio threshold	Duration threshold (hour)	Area threshold (km²)	MCS-HRE (day yr⁻¹)	*P*(*HRE*|*MCS*) (pp yr⁻¹)	MCS-SWE (mm yr⁻¹)	*P*(*SWE*|*MCS*) (pp yr⁻¹)
225	0.15	3	3000	0.097(3.77%)	0.063(2.63%)	0.071(3.13%)	0.062(3.17%)
220	0.15	3	3000	0.096(3.90%)	0.062(2.23%)	0.066(3.27%)	0.061(2.97%)
230	0.15	3	3000	0.096(3.67%)	0.067(2.96%)	0.074(3.09%)	0.065(3.36%)
225	0.15	2	3000	0.096(3.65%)	0.063(2.70%)	0.073(3.11%)	0.063(3.28%)
225	0.15	4	3000	0.097(3.81%)	0.061(2.48%)	0.072(3.29%)	0.062(3.14%)
225	0.10	3	3000	0.097(3.77%)	0.062(2.61%)	0.071(3.11%)	0.061(3.15%)
225	0.20	3	3000	0.097(3.77%)	0.065(2.66%)	0.071(3.17%)	0.061(3.14%)
225	0.15	3	2000	0.097(3.76%)	0.062(2.61%)	0.072(3.17%)	0.062(3.17%)
225	0.15	3	4000	0.097(3.76%)	0.064(2.65%)	0.070(3.12%)	0.062(3.18%)

Minor comments:

1. The delineation of the "AMR" domain warrants clarification. As currently defined (Line 185), it encompasses South Asia while omitting Japan and the Korean Peninsula in East AMR. To avoid confusion and improve geographical precision, refining the terminology for this study region would be beneficial.

Thank you for the suggestion. We agree that referring to the analysis domain simply as “AMR” may be imprecise. In the revised manuscript, we have described it more precisely as a selected study domain within the broader Asian monsoon region at Line 87.

2. Line 21. Change “upward” to “increasing”.

Thank you for the suggestion. We have replaced “upward” with “increasing” at Line 22 and revised similar expressions elsewhere in the revised manuscript.

3. Line 62. This statement is true maybe only for China.

Thank you for pointing this out. We agree that this statement is too broad. In the revised manuscript, we have rephrased the sentences at Lines 66–68 to improve precision and avoid overgeneralization.

4. Figures 1 and 2. The two figures can be merged.

Thank you for this suggestion. We have merged Figures 1 and 2 in the revised manuscript.

5. Line 83. The precipitation attribution does not make sense. Assuming a squall line passing through, the diameter of influence would be the length of the linear system.

Thank you for this comment. We agree that for elongated systems such as squall lines, a diameter-based definition may overestimate the effective influence area and thus lead to over-attribution of precipitation to MCSs. We have addressed this issue in more detail in our response to Major Comment 1.1 and clarified this limitation in the revised manuscript at Lines 96–103.

6. Line 107. Please keep consistent in putting space between number and unit.

Thank you for pointing this out. We have systematically checked and corrected the spacing between numbers and units throughout the revised manuscript.

7. Line 107. Just say “CCAs with cold cores”.

Thank you for this suggestion. We have revised the text to “CCAs with cold cores” in the revised manuscript at Line 127.

8. Line 111. Any sensitivity tests on varying overlapping thresholds?

Thank you for this suggestion. We have conducted sensitivity tests using different overlapping

thresholds, as detailed in our response to Major Comment 2. We have briefly summarized the main conclusions of the sensitivity analysis in the revised manuscript at Lines 494–499.

9. Line 112. Same, any sensitivity in duration thresholds?

Thank you for this suggestion. We have conducted sensitivity tests using different duration thresholds, as detailed in our response to Major Comment 2.

10. Line 155. The authors may list the possible data sources of the reports.

Thank you for this suggestion. In the revised manuscript, we have added a brief description of the possible data sources at Lines 180–182 for clarity.

11. Line 188. How are TCs removed, both spatially and temporally?

Thank you for this comment. In removing TCs that were mistakenly identified as MCSs, we considered both temporal coincidence and spatial overlap. Specifically, for each identified MCS, we examined its spatial extent at each time step throughout its lifetime. If, at any time, the MCS overlapped with a 500-km-radius circle centered on the contemporaneous TC center, it was classified as a TC mistakenly identified as an MCS and removed from the analysis. We have added the relevant description to the revised manuscript at Lines 210–214.

12. Line 191. Then how is this product matched to the hourly IMERG rainfall data?

Thank you for this comment. The IMERG rainfall product used in this study has a half-hourly temporal resolution. Therefore, no additional temporal aggregation was required when matching it with the MCS product. Spatially, precipitation pixels within the circumscribed circle of the bounding rectangle of the MCS region were classified as MCS-related precipitation.

13. Line 196. The accumulated MCS-hour would be interesting too.

Thank you for this helpful suggestion. We agree that accumulated MCS-hour could also be an informative metric for characterizing local MCS activity. In this study, however, we used MCSD because the wind, hail, and tornado datasets employed are mostly available at daily resolution, making MCSD more directly comparable to the hazard records used in the analysis. In addition, daily-based metrics provide a more straightforward basis for examining the statistical relationships between MCS occurrence and hazardous weather. We have emphasized the potential value of accumulated MCS-hour in the revised manuscript at Lines 406–409.

14. Lines 189-214. The authors may summarize all the MCS metrics into a table.

Thank you for the suggestion. we have added a summary table of all MCS metrics to the Supplement

(Table S1).

15. Line 232. Where are the “some areas” located?

Thank you for this comment. The “some areas” here refer to the region between 32 °N and 34 °N and between 87 °E and 102 °E, corresponding to the eastern Tibetan Plateau. We have specified this more clearly in the revised manuscript at Line 252.

16. Line 296. How about “fraction” instead of “proportion” to be consistent with MCSPF.

Thank you for this suggestion. We have replaced “proportion” with “fraction” in the revised manuscript for consistency with MCSPF.

17. Line 328. There is an inherent misalignment in the temporal resolution of the two key datasets: daily hazard reports versus half-hourly MCS tracks. This leads to an approximation where any hazard on the same day is linked to an MCS, even if it preceded the MCS initiation (e.g., hail before MCS onset). It is suggested that the authors more clearly articulate this as a methodological limitation, discussing its potential to dilute the specificity of the association between MCSs and convective hazards.

Thank you for pointing out this issue. We agree that the difference in temporal resolution between daily hazard records and half-hourly MCS tracks may introduce uncertainty into the assessment of the association between MCS activity and hazards. Accordingly, we have explicitly added this methodological limitation in the revised manuscript and clarified its potential influence on the interpretation of the related results at Lines 397–404.

18. Line 362. What about the seasonality?

Thank you for this comment. We separately analyzed the trends for the warm and cold seasons. The results (Fig. R6) show that the overall trend patterns are broadly similar between the two seasons, with the main difference being the spatial extent of the areas that pass the significance test. Following the reviewer’s suggestion, we have added a brief discussion of these seasonal differences in the revised manuscript at Lines 432–434 and provided the corresponding figures for the warm and cold seasons in the Supplement for reference.

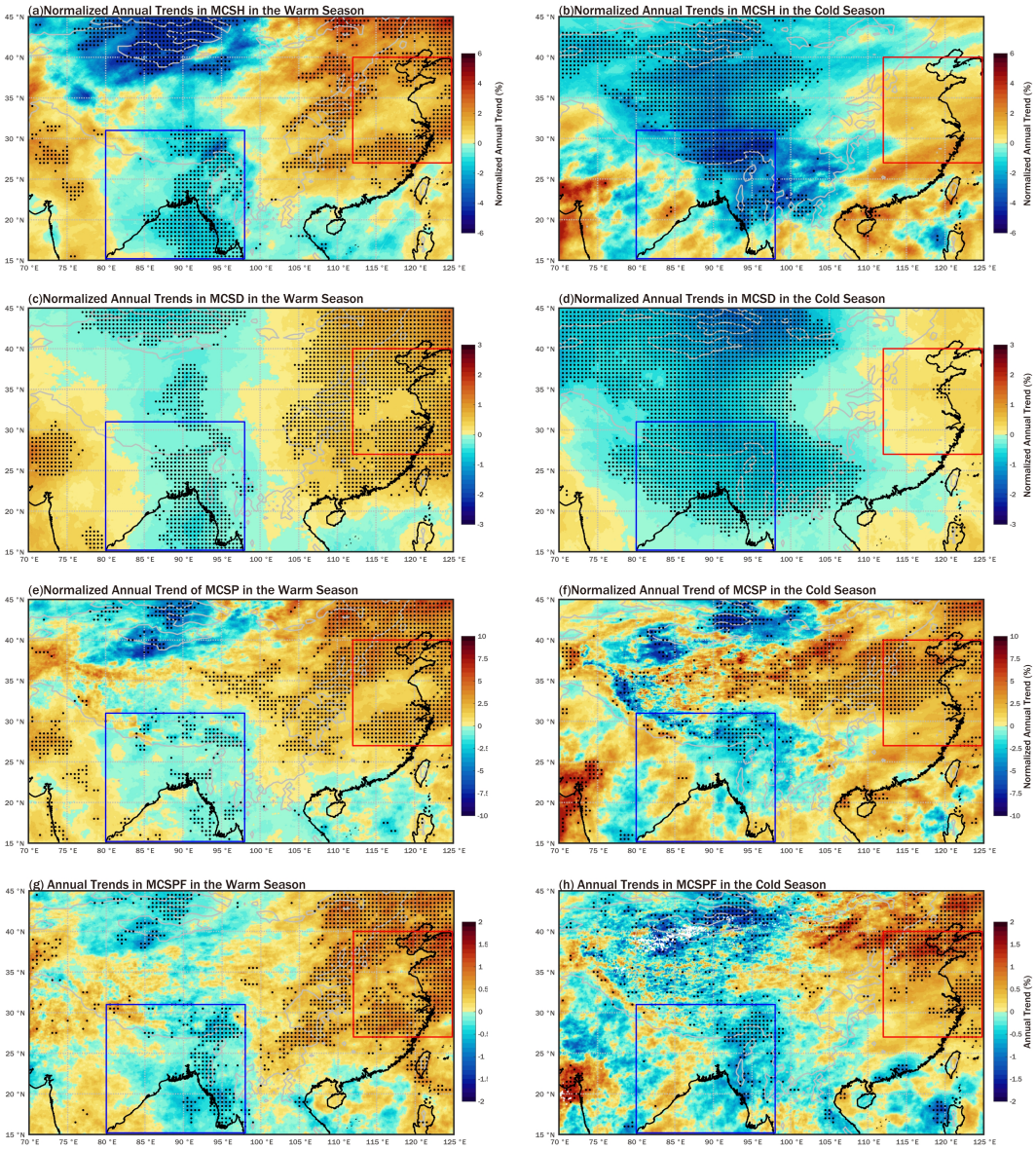


Figure R6: Spatial distribution of the interannual variations of (a, b) MCSH, (c, d) MCSD, (e, f) MCSP, and (g, h) MCSPF, with warm-season results shown in the left column and cold-season results in the right column. The black solid line represents the coastline, and the gray solid line represents the 1000 m elevation contour. The color shading in (a - f) denotes the normalized annual trend, which is the ratio of the interannual trend of each grid to its annual mean value (unit: % yr^{-1}); color shading in (g, h) denotes the annual trend (unit: pp yr^{-1}). The black dots indicate regions with statistical significance at 5% level, as determined by a two-tailed Student's t-test. The blue box indicates the range of BoBCR in this study, and the red box indicates the range of ECAS in this study.

Reviewer#2

Summary: The authors present a multi-faceted study of MCSs and their associated hazards across the AMR. The authors use various datasets, both satellite and land based, to examine the frequency of MCSs, the hazard production of MCSs, and trends in MCSs across the region. I generally fine the manuscript well written and adding some interesting information to the body of literature of MCSs in the region. However, I do have a few comments about the analysis and the use of land-based observations. While these I do not think rise to the level of major revisions, they are close. I defer to the editor in making this decision. I am happy to read the paper again.

We thank the reviewer for the insightful and constructive comments. We have carefully considered all points raised and provide our detailed responses below.

Recommendation: Minor Revisions

Minor Comments (Comments are not listed in order of importance):

1. First, I would like to apologize to the authors on the lateness of this review. Between conferences and classes, it slipped through the cracks. My apologies.

We thank the reviewer for the time and effort devoted to reviewing our manuscript and for the helpful comments provided.

2. Section 1: There need to be some spaces between certain words and the parenthetical citations that follow.

Thank you for pointing this out. We have checked and corrected this formatting issue throughout the revised manuscript.

3. Section 1: Please state your hypotheses for this manuscript. This is critical to the scientific processes and will greatly improve the motivation for the scientific analysis that follows.

Thank you for this valuable suggestion. We agree that clearly stating the scientific hypotheses of this study would help strengthen the motivation and logical framework of the manuscript. We have added a statement of these hypotheses at Lines 68–75 of the revised manuscript.

This study is guided by two main hypotheses. First, given the close association between MCS activity and the occurrence of weather-related hazards (Hu et al., 2020; Schumacher and Rasmussen, 2020), this study aims to quantify the strength of this statistical association within the study region and characterize its regional and seasonal differences. Second, considering that MCS activity and its statistical association with weather-related hazards may vary over time and exhibit statistically

significant interannual trends under changing climate, this study further analyses the interannual variations and trends in MCS activity and MCS-associated hazards across the AMR. It should be noted that, attributing the trend, if there is any detectable signal, to climate change is beyond the scope of this study.

4. Lines 115: A think a bit more clarification on the heavy precipitation threshold here is needed. Is the 20 mm/hr a rate or an accumulation threshold? The prior means this could be achieved in a sub-hourly timeframe, where 20m mm of rainfall did not actually fall in an hour (i.e., 5 mm fell in 15-minutes). If it is an accumulation, meaning 20 mm rainfall actually fell in an hour, please indicate. This also needs to be discussed for the HRE criteria.

Thank you for this valuable comment. The precipitation data used in this study are half-hourly snapshot estimates. According to the documentation of the V07 data product, "The term 'snapshot' for half-hourly estimates reflects the fact that individual satellite overpasses are the basis for these data, and that the resulting satellite estimates are not 'instantaneous', but represent an interval that can exceed an hour." Therefore, this variable should not be strictly interpreted as an instantaneous rain rate, but rather as an indicator of the intensity of precipitation sustained over a certain time interval, derived from precipitation estimates within that interval. In this study, heavy precipitation was identified using a threshold of 20 mm hr^{-1}, equivalent to 10 mm of accumulated precipitation in 30 minutes. For HRE identification, this variable was further used in the statistical analysis to estimate daily accumulated precipitation, and a day with daily accumulated precipitation exceeding 50 mm was classified as an HRE. We agree that this treatment should be described more clearly in the manuscript. In the revised version, we have clarified the interpretation of this variable at Lines 108–111.

5. Throughout: The severe wind, hail, and tornado reports are likely quite biased by population. This is a known problem in severe weather hazards databases across the globe. I believe some more discussion (and caveats) about this needs to be included in terms of understanding the results. The attempt to look at this in terms of prefectures still likely is biased by population, as prefecture size is also dependent on local population.

Thank you for pointing this out. We agree that this issue does exist, particularly for hazard records such as hail and tornado events. For example, the hail and tornado records used in this study are mainly derived from the Yearbook of Meteorological Disasters in China. Due to possible observational biases in sparsely populated areas, as well as the potential underreporting of weak-intensity events in the

yearbook itself, the spatial distributions of hail and tornado events, as well as their statistical associations with MCSs, may be affected to some extent. In the revised manuscript, we have further emphasized these potential data biases at Lines 401–409 and clarified that the related results represent statistical associations obtained under the current observational and reporting conditions, rather than a strict attribution of the mechanisms responsible for hazard occurrence.

6. Section 3.2: Was any attempt to examine the characteristics as a function of seasonality made? This seems to be a pretty important aspect of the analysis, given the seasonality of the monsoon circulation. This might also help with supporting the conclusion in lines 235-238.

Thank you for this comment. We agree that examining these characteristics from a seasonal perspective is important, particularly given the pronounced seasonality of the monsoon circulation. We conducted a preliminary analysis of their seasonal variations, although these results were not presented in detail in the original manuscript.

The seasonal variations in MCS characteristics (Fig. R7) show that, over the Tibetan Plateau, MCSH and MCSP are in relatively good agreement in the warm season. In contrast, although both MCSH and MCSD are high in the cold season, MCSP remains very low, suggesting that the combination of low temperatures and high elevation in this region may contribute to an overidentification of MCSs. We have added the corresponding figures showing the seasonal differences to the Supplement and provided additional discussion of these differences at Lines 256–259 of the revised manuscript.

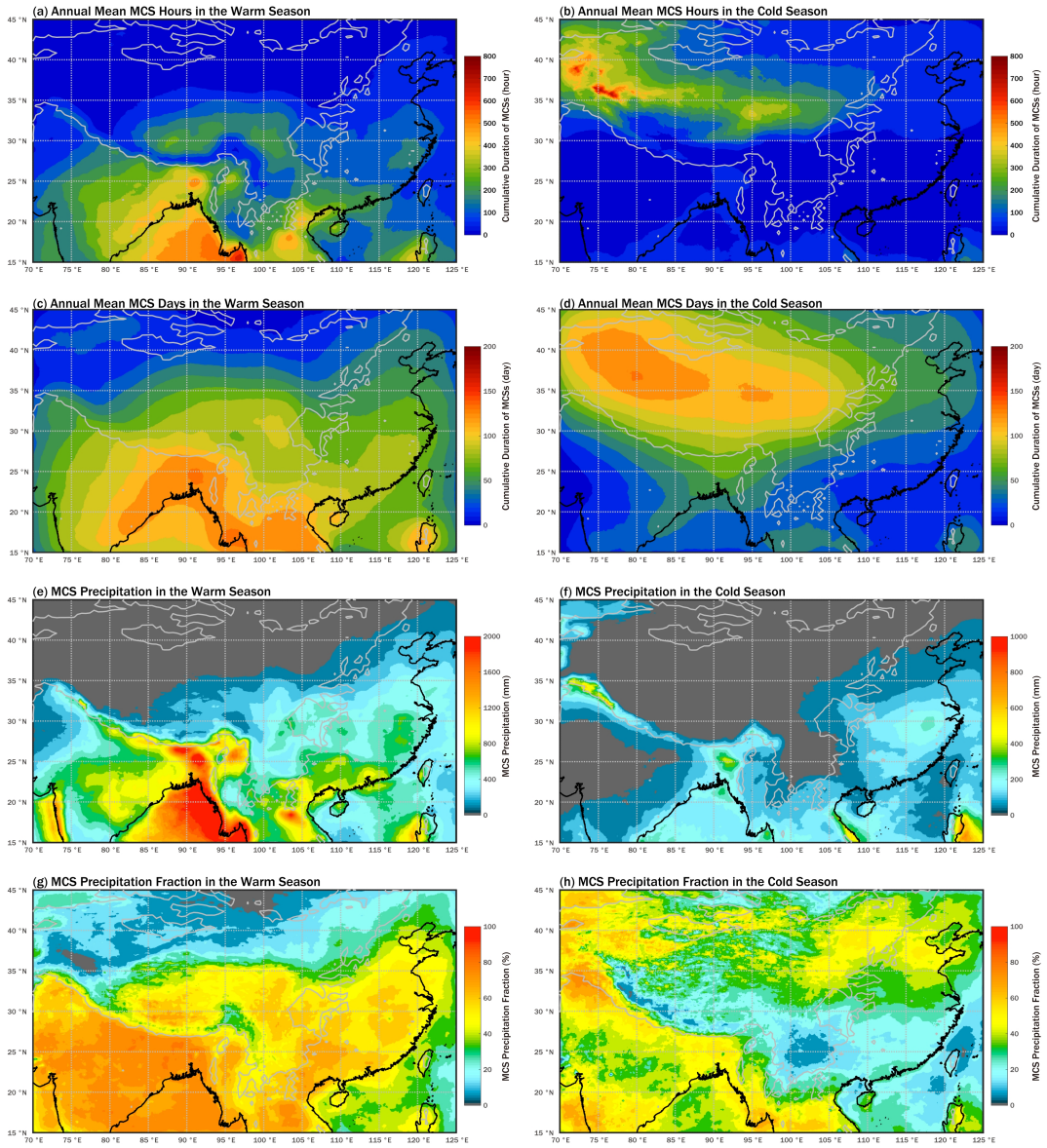


Figure R7: Annual mean spatial distributions of (a, b) MCSH, (c, d) MCSD, (e, f) MCSP, and (g, h) MCSPF, with warm-season results shown in the left column and cold-season results in the right column. The black solid line represents the coastline, and the gray solid line represents the 1000 m elevation contour. Color shading indicates: annual mean (a, b) cumulative MCS duration (hours), (c, d) number of MCS days (days), (e, f) cumulative MCS precipitation (mm), and (g, h) MCS precipitation fraction (%).

7. Section 3.3: Please make sure it is clear these results are over a certain region for a given time and should not necessary be generalized to other regions. They can be compared to similar analyses in other regions on the globe.

Thank you for this comment. We agree that these results are specific to the study region and period. We have clarified this point at Lines 392–396 in the revised manuscript.

8. Line 322-327: I am not sure this is correct/can be justified based upon what is presented. We know that descending rear-inflow jets in MCS can cause severe wind. These clearly depend on rainfall characteristics and background thermodynamics/moisture profiles.

Thank you for this comment. We agree that the mechanisms responsible for severe winds in MCSs are complex and involve both internal storm dynamics and environmental thermodynamic conditions. We also agree that the interpretation in Lines 322–327 may have been stated too strongly given the results presented. Our original intention was to highlight the spatial correspondence between SWE occurrence and regions with pronounced topographic transitions, rather than to attribute the mechanism directly to topographic effects. In the revised manuscript, we have revised the relevant sentences at Lines 353–357 to make this interpretation more cautious and to clarify that topography may modulate MCS-SWE occurrence.

9. Section 3.3.3: Choosing a daily timescale for the tornado and hail events associated with MCSs does not seem valid. We know in convective scenarios that, within a diurnal cycle, we often see upscale growth from discrete isolated convection to MCSs. This analysis does not, to my understanding, account for the fact that these discrete cells could be producing the main hazards. This is even more true since it is aggregated on the prefecture level and is again compounded by the population bias in the hail/tornado data. This is probably my most major comment and almost warrants a major revisions decision. The only reason I am not, is I think this section can be removed from the manuscript and it still be publishable.

Thank you for this important comment. We agree that the reviewer has raised a more fundamental issue: given the temporal and spatial resolution of the available tornado and hail records, our analysis cannot distinguish whether the reported hazards occurred during the early stage of discrete convection or during the later stage after organization into an MCS, and therefore cannot support strict event-level attribution.

In response to this comment, we have revised the relevant statements in the manuscript to make clear that this analysis is intended to describe the statistical correspondence between MCS activity and hail/tornado records at the regional climatological scale, rather than to provide a strict hazard-attribution analysis. In addition, expressions such as “associated with MCSs” have been replaced with more neutral wording, such as “occur on MCSDs,” and terms such as “trigger,” which may suggest direct causation, have been removed.

On the basis of these revisions, we would prefer to retain this section in the revised manuscript. This is because the currently available tornado and hail records in China are generally limited to daily resolution and are typically reported at the prefectural level, and therefore do not support more precise

event-level matching. Under this practical limitation, the analysis can still be used to characterize the statistical correspondence between MCS activity and these two types of hazard records at the regional and climatological scales, thereby providing supplementary information for understanding their broader statistical relationship. To avoid misinterpretation, we have further clarified its scope and limitations at Lines 401–406 in the revised manuscript.

10. Figure 7: This figure is very channeling to see. The dots and the terrain overplotting blend together. Please find a way to make this clearer.

Thank you for this suggestion. We have revised the original Figure 7 to improve its readability. In addition, for consistency in presentation, we made corresponding adjustments to the original Figure 12. As the number of figures was adjusted during revision, the original Figures 7 and 12 are now presented as Figures 6 and 11, respectively. The updated figures are shown below and have been used to replace the original figures in the revised manuscript.

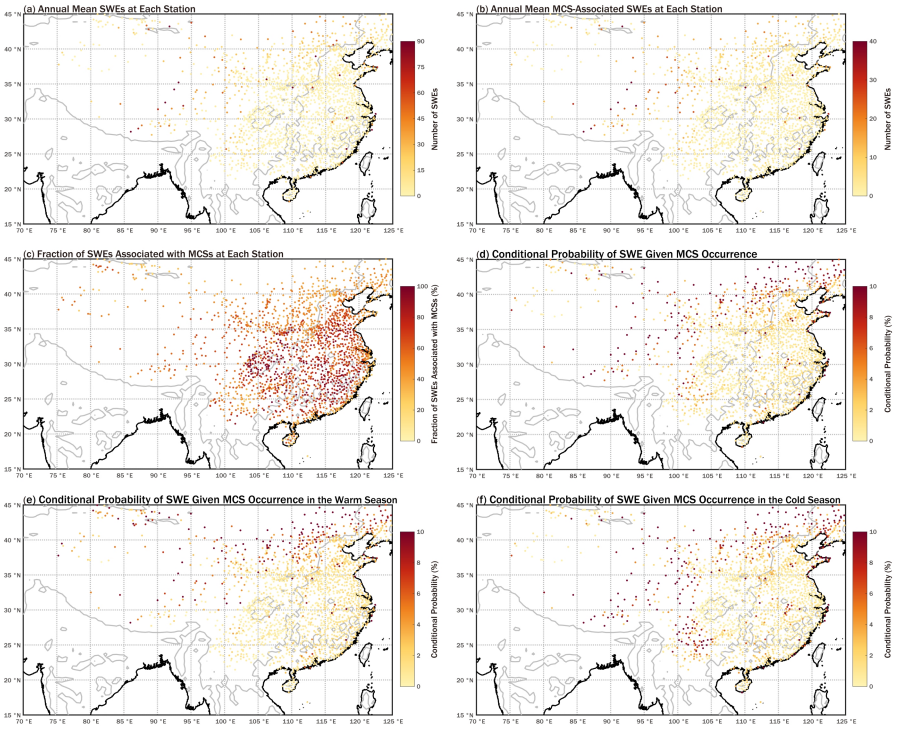


Figure R8 (Figure 6 in the revised manuscript): Annual mean spatial distributions of (a) SWEs, (b) MCS-SWEs, (c) MCS-SWE proportion, and P(SWE|MCS) for (d) the whole year, (e) the warm season, and (f) the cold season. The black solid line represents the coastline, and the gray solid line represents the 500 m elevation contour. The dots represent meteorological station locations. The color shading of dots indicates the annual mean number of events (days) for (a) and (b), the fraction of events associated with MCSs (%) for (c), and the conditional probability (%) for (d)–(f).

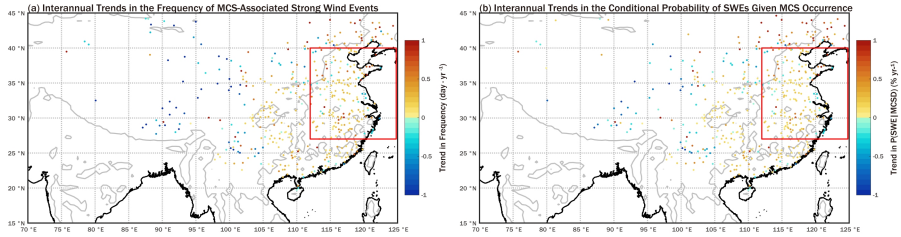


Figure R9 (Figure 11 in the revised manuscript): Spatial distribution of interannual variation of (a) MCS-associated SWEs, (b) P(SWE|MCS). The black solid line represents the coastline, and the gray solid line represents the 500 m elevation contour. The dots represent meteorological station locations. The color shading of dots in (a) denotes the annual trend of MCS-SWEs (unit: day yr^{-1}). The color shading in (b) denotes the annual trend of P(SWE|MCS) (unit: % yr^{-1})). Stations that do not pass the significance test are not shown in this figure. The red box indicates the range of ECAS in this study.