Dear Editor and Reviewer,
Thank you very much for the constructive suggestions on our paper entitled "A New Method for Calculating Highway Blocking due to High Impact Weather Conditions". They are very helpful for improving the manuscript. We have revised the manuscript accordingly. We sincerely hope that you will find this version acceptable to be published in Natural Hazards and Earth System Sciences.

Best regards.

Yours sincerely,
Duanyang Liu (Corresponding Author)
Nanjing Joint Institute for Atmospheric Sciences (NJIAS)
E-mail: liuduanyang@cma.gov.cn;

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Manuscript Title: A New Method for Calculating Highway Blocking due to High Impact Weather Conditions

Responses to Reviewer #1

General comments

This manuscript evaluated the characteristics of the highway-blocking event data in terms of meteorological conditions and spatiotemporal distribution. A 5-level classification of highway blocking was proposed. Finally, the authors developed a highway load index as a weighted average of a set of selected parameters to represent the loss due to highway blocking. The general methodology was promising but certain clarification is needed. The discussion was detailed while some rationale of critical decisions needs to be further elaborated. The conclusions were valid and provided insights for transport management authorities. Some editing for the English language is required throughout the manuscript.
The manuscript presents a study on a topic within the scope of the Natural Hazards and Earth System Sciences (NHESS). I would recommend this manuscript for publication after addressing the following comments with critical discussions and clarifications.
RESPONSE: Thank you for your suggestions.

Specific comments

1、The highway-blocking features in Figure 2

- *The inner circle was not explained in the manuscript. Was there any causal relationship between the features of inner and outer circles?*
- *Four main weather factors (i.e., fog, rainfall, snow, ice) were used in Table 1. However, ice was not shown in Figure 2, although it is mentioned in Line 170: "The highway blocking caused by snowfall (snow cover) and icing also accounts for 17% and 2%, respectively."*
- *It is recommended to improve the pie chart by enlarging the circle and adding the indication line.*
- *The discussion was around the four main weather factors. Please confirm that event caused by other weather factors were removed from the database.*

RESPONSE: Revised.The inner pie graph of figure 2 is deleted.

2、The cluster analysis

- *It is recommended to elaborate on how the method was used in this study after the mathematical equations. For example, it is inferred from section 3.3 that the number of clusters were decided to be five, corresponding to the five levels? It is unclear what the input vectors were, were they 2-dimensional (i.e., blocking mileage and blocking time) or only the meteorological factors?*

RESPONSE: Revised. Firstly, the blocking mileage is used as the initial judgment condition of severity. Then, using equatoin 2, the blocking events caused by different meteorological factors are clustered. the blocking mileage, blocking time and response time in different high-impact weathers asl the input vectors

in the calculations. Finally, the severity of the blocking events is determined according to the size of the clustering centers.

- *What are the uncertainties of the clustering centers in Table 2? What is the sensitivity of the clustering centers with respect to the meteorological factors?*

RESPONSE: Revised.

The "uncertain center" in the K-means algorithm mainly refers to the fact that at the beginning of the algorithm, the centers of the clusters (i.e., the centers of the clusters) are randomly selected, first the number of clusters K needs to be determined, and then K data points are randomly selected from the dataset to be the initial center of the clusters. The selection of these initial centroids is random and there are no fixed rules or criteria.

Such uncertain centers are selected by categorization only by calculating the blocking intensity expressed by blocking time * blocking mileage, and all blocking events occur because of weather factors, so sensitivity analysis cannot be performed.

- *Related to the previous point, as shown in Figure 6, the distribution of the 5-level highway blocking is dominated by Level 1 and Level 3, while Levels 4 are limited. Are these caused by the thresholds?*

RESPONSE: Revised.

This was analyzed by a clustering algorithm, in which the clustering of blocking intensities showed a low distribution of high-level blocking events; usually disasters in which a specific long period of time and a wide range of meteorological hazards do not often occur in daily life.

This is a presentation of the clustering results, sudden and prolonged disasters are not common, so the high level of highway blockage is less, in most cases, small-scale unexpected weather affects the smoothness of the traffic, but the highway management will also be able to deal with the problem as soon as possible, when it comes to the natural disasters of high intensity and wide range of the highway management can't unblock the traffic as soon as possible, therefore the intensity of the blockage events in this case will be very high, so the high level of the clustering results will be highlighted and present a scanty number of results.

- *Notation is unclear for xi' and C(i')=k*

RESPONSE: Revised.

- *Equation 2 "armin" should be "argmin"*

RESPONSE: Revised.The inner pie graph of figure 2 is deleted.

3、The highway load index

- *The construction of highway load index was a weighted average of a set of selected indicators. This approach was similar to the widely used index construction using the principle component analysis (PCA). PCA takes advantage of multicollinearity and combines the highly correlated variables into a set of uncorrelated variables. In this study, the selected parameters were correlated, such as ΔTFload the load capacity of freight transport for per kilometer and TFload the total freight transport, Δ load the number of people for per kilometer and load the number of people. Please elaborate on why those parameters are selected and how the multicollinearity issue is addressed.*

RESPONSE: Revised. The CRITIC method is an objective evaluation method based on the comparative strength of the evaluation indicators, which fully utilizes the objective attributes of the data itself to carry out scientific evaluations. The CRITIC method takes into account the size of the variability of the indicators while also taking into account the correlation between the indicators. This means that it not only focuses on the volatility of individual

indicators, but also takes into account the mutual influence and conflict between indicators, thus improving the comprehensiveness and accuracy of the evaluation. Therefore, we chose the composite and unit indicators for evaluation, which are also more suitable for this method.

- *What were the impacts of highway blocking levels and high-impact weather conditions on the highway load index? If possible, please discussion on the disaggregation of the highway load index to highway blocking levels and high impact weather conditions.*

RESPONSE: Revised. We carry out the assessment of the carrying pressure per unit length of road in different areas by calculating the highway loading index, and when it carries more transportation tasks, more losses will be incurred in the event of a blockage.

- *Were the results aggregated across all the weather conditions? Some results for fog conditions are shown in Figure 8. What were the patterns for the other three weather conditions?*

RESPONSE: Revised.

In the result part, we introduce the calculation process of the new calculation method in detail. In the discussion part, we choose the typical high impact weather for detailed discussion.

By carrying out this new calculation method proposed, we have analyzed and calculated all four types of catastrophic weather, and because the results are too lengthy, we have selected the fog weather blocking loss distribution, which has the highest percentage, for a demonstration. If needed, we can analyze the damage caused by the remaining three hazardous weather types of weather in a presentation and discussion.

- *In Figure 8, given fog conditions, Jiangsu, Hebei, Henan and Sichuan show high levels of damage in terms of four economic indicators. Since most of the highway blocks were due to fog weather, it is expected in Figure 7 that these provinces would have a high level of highway load. However, the highest highway load occurred in Guangdong and Jiangsu only. Line 308-309: "No highway-blocking events caused by dense fog occur in Guangdong Province". What is the driving indicator behind the high level of highway load in Guangdong?*

RESPONSE: Revised. Add this sentence: Guangdong Province, as an economically developed province in China, and near the sea has many harbors. Guangdong province highway and other infrastructure construction for a long time, basically covering the entire province, not only to bear the pressure of the port cargo to inland, but also to bear the pressure of the entire province manufacturing transportation. So the highway load in Guangdong are in the high level.

4、It is understood from Line 68-69: "Taiwan, Hong Kong and Macao are not included in this study due to the lack of data", which is also reflected in Table 1, 5 and 7 and Figure 3. However, for Figures 7 and 8, there were results for Tibet and Taiwan (coloured map). Please clarify how the results for Tibet and Taiwan are computed given that no data was available.

RESPONSE: Figures 7 and 8 are Revised. In Figures 7 and 8, the results for Tibet and Taiwan (white, no data)

5、The CRITIC weigh method

- *The methodology was introduced in Section 2.3.2 and equation3-4 explained the computation*

of some key parameters. It is unclear which correlation coefficient rij is used, Pearson correlation coefficient?

RESPONSE: Equation3-4 and the key parameters are Revised.

Contrast intensity, expressed as a standard deviation, indicates the dispersion degree of an indicator. The larger the standard deviation is, the greater the dispersion degree is, the larger the differences between samples are, and the larger the assigned corresponding weights are. The standard deviation *S* can be expressed in Eq. (3).

$$S_j = \sqrt{\frac{\sum_{i=1}^{p}\left(x_{ij}-\frac{1}{n}\sum_{i=1}^{n}x_{ij}\right)^2}{n-1}} \quad \textbf{(3),}$$

where x_{ij} denotes the data processed by standard deviation, S_j the standard deviation of the *j*th indicator, *n* the total number of samples, and *p* the total number of indicators.

Correlation is expressed as the correlation coefficient between indicators. The stronger the correlation between indicators is, the higher the repetition rate of information expression. Therefore, the corresponding weights of the indicators can be reduced to a certain extent. The correlation coefficient *R* can be expressed in Eq. (4).

$$R_j = \sum_{i=1}^{p}(1-r_{ij}) \quad \textbf{(4),}$$

where, R_j indicates the correlation coefficients of the *j*th indicator with the other indicators, and r_{ij} denotes the correlation coefficient of the *i*th indicator with the *j*th indicator.

- *The result in Table 6 showed extra parameters however they are not discussed or explained in the main text. What was the importance of these parameters? What were the implications on the weights?*

RESPONSE: In the CRITIC weighting method, although the standard deviation, as a measure of the intensity of comparison, reflects the magnitude of the difference in the values of the same indicator between different evaluation objects, i.e., the volatility, the magnitude of the standard deviation is not the only factor that directly determines the magnitude of the weights. The determination of weights also needs to take into account the conflicting nature of different indicators, i.e., the correlation between them.

Specifically: when an indicator has a large standard deviation but also a high correlation with other indicators, its weight may be weakened by a high correlation (i.e., low conflictivity).

Conversely, when an indicator has a low correlation with other indicators (i.e., high conflictivity), although not the largest standard deviation, its weight may be relatively high because of the unique information it provides.

We therefore present both mutability and standard deviation in a table.

- *Line 131-135: "Contrast intensity, expressed as a standard deviation, indicates the dispersion degree of an indicator. The larger the standard deviation is, the greater the dispersion degree is, the larger the differences between samples are, and the larger the corresponding weights are." Suggested large standard deviation S leads to larger weights. However, this trend was not reflected in Table 6.*

RESPONSE:

In the CRITIC weighting method, although the standard deviation, as a measure of the intensity of comparison, reflects the magnitude of the difference in the values of the same indicator between different evaluation objects, i.e., the volatility, the magnitude of the standard deviation is not the only factor that directly determines the magnitude of the weights.

The determination of weights also needs to take into account the conflicting nature of different indicators, i.e., the correlation between them.

Specifically: when an indicator has a large standard deviation but also a high correlation with other indicators, its weight may be weakened by a high correlation (i.e., low conflictivity).

Conversely, when an indicator has a low correlation with other indicators (i.e., high conflictivity), although not the largest standard deviation, its weight may be relatively high because of the unique information it provides.

6、*What is the time span of the data introduced in Section 2.2 Data source? What is the time resolution of the data, which is related 10-day window and hourly distribution in Figure 5?*

RESPONSE: Revised. Add sentences:

Highway blockage data comes from Highway Monitoring & Emergency Response Center, and the data recording process and specifications are in accordance with the "Information Reporting System for Highway Traffic Blockage of the Ministry of Transportation and Communications of the People's Republic of China" issued by the Ministry of Transportation and Communications of the People's Republic of China.The dataset contains 16 indicators: province name, submitting department, route name, route number, starting and ending pile number (Highway pile numbers are usually combined with the milestone system and are expressed in K kilometers ± meters. That is, along the direction of the road, the pile number at the starting point is k0+000, and one pile number is marked every certain distance (such as 100 meters), and the corresponding place is marked), reasons of highway blocking, blocking mileage (the distance of the highways blocking), status, blocking type, information event classification, site description, disposal measure, time of finding blockage, submitting time, expected recovery time, and actual recovery time. Since highway blocking information is submitted by manual statistics, there is a possibility of manual statistical errors. Therefore, all data were pre-corrected with a time series correction and then verified based on the cause of the blockage and the meteorological data of the station at the time, among other things. Quality control resulted in the retention of 95% of valid data.

7、*Terminology and notations are not consistent.*

- *Level 4 is referred to as the severe level between Line 245 and Line 265, where it is labelled as serious in Table 2*

RESPONSE: Revised. Table 2 five levels are recommended to be labelled as "slight-mild-moderate-severe-extreme".

- *Please add notations TFload, GDPtrans, Pload and EP in the caption of Figure 8*

RESPONSE: Revised. Table 2 five levels are recommended to be labelled as "slight-mild-moderate-severe-extreme".

- *"ice" vs "icing"*

RESPONSE: Revised.

- *Equation 6 "GDPtrans the added value of the GDP generated by transportation" vs Table 5 " " unit "100 million yuan/km" which is normalised by length vs Table 7 " " unit "Ten thousand"*

RESPONSE: Table 5, table 7 Revised..

8、The English language needs to be improved. Some editing for the English language is required throughout the manuscript due to too many mistranslations or mistakes. The authors must seek the help of a native English-speaking person.

- *Line 55-56: "The ability to estimate highway traffic demand caused by the highway blocking*

during adverse weather events; therefore, it is critically needed." needs to be rephrased.

Response：Revised. Therefore, there is a critical need to improve the ability to estimate highway traffic, caused by the highway blocking during adverse weather events.

- *Table 2 five levels are recommended to be labelled as "slight-mild-moderate-severe-extreme".*

Response：Revised.

- *Line 188-190: "There are large seasonal differences in highway blocking in various regions of China due to differences in geographical environment and climatic characteristics (Fig. 4a), and high-impact weather types (Fig. 4b), such as dense fog, snowfall (snow cover), rainfall (road slippery) and icing, are also various."*

Response：Revised. "There are large seasonal differences in highway blocking in various regions of China due to differences in geographical environment and climatic characteristics (Fig. 4a), and high-impact weather types (Fig. 4b), such as dense fog, snowfall (snow cover), rainfall (road slippery) and icing, etc."

- *Line 232-235: "This study only considers the evaluation of road traffic by the blockage itself, and does not consider the basic resources of the road network and the impact of secondary disasters. If the road network resources are large, then the blocking may have little impact on the local road network, which is not considered in the blocking degree." What do the road network resources refer to?*

Response：Revised. the road miles per unit area, the higher the density of road network per unit area, the more abundant road network resources.

9、Clarification is generally needed to better explain the motivation of critical decisions in this study.

- *Line 23-24: "Results suggested that the highway losses caused by dense fog was the main contributor for highway blocking conditions and occur at about 43%." 43% of what, the loss or the occurrence rate?*

RESPONSE: Revised. These lines are deleted.

- *Line 81-82: "...follow the criteria of the Highway Traffic Blocking Information Submitting System of the Ministry of Transport of the People's Republic of China (2018, No. 451)." What are the criteria?*

RESPONSE: Revised. The highway-blocking events data obtained from the Ministry of Transport of the People's Republic of China (Fig. 1a) follow the criteria of the Highway Traffic Blocking Information Submitting System of the Ministry of Transport of the People's Republic of China (2018, No. 451;https://www.hunan.gov.cn/xxgk/wjk/zcfgk/202007/t20200730_e1c6436a-6aff-43d0-9c74-c0822311b8db.html).

- *Line 89-90: "Therefore, all data were corrected in advance for spatio-temporal sequences, and the quality control was then carried out according to blocking causes and site descriptions, etc. 95% of the valid data is filtered out". Please elaborate on what are the correction procedure and quality control as large amounts of data are filtered out.*

RESPONSE: Revised. Therefore, all data were pre-corrected with a time series correction and then verified based on the cause of the blockage and the meteorological data of the station at the time, among other things. Quality control resulted in the retention of 95% of valid data.

- *Line 165: "α, β, γ, δ, ε, ϵ, θ, ϑ and μ are the corresponding coefficient values of each parameter." It is recommended to clarify that they were weights computed from the CRITIC method and referred to Table 6 as well.*

RESPONSE: Revised. α, β, γ, δ, ε, ϵ, θ, ϑ and μ are the corresponding coefficient values of each parameter, these parameters will be computed according the above data, and these will be detailed calculated in the results part.

- *Line 231-232: "we select the blocking mileage (the distance of the highways blocking), blocking time and response time as the most crucial reference indicators." Why choose these three parameters? It is not clear where the response time is used in this study. What are the sensitivities of the results if more or less indicators were used?*

RESPONSE: Revised. blocking mileage (the distance of the highways blocking), blocking time and response time are three characteristic quantities that reflect highway blocking, so we use three indicators for analysis.

- *Line 236-238: "Firstly, the blocking mileage is used as the initial judgment condition of severity. Then, the blocking events caused by different meteorological factors are clustered. Finally, the severity of the blocking events is determined according to the size of the clustering centers." It is very unclear what is the procedure here and how the clustering was actually carried out.*

RESPONSE: Revised. Firstly, the blocking mileage is used as the initial judgment condition of severity. Then, using equatoin 2, the blocking events caused by different meteorological factors are clustered. the blocking mileage, blocking time and response time in different high-impact weathers asl the input vectors in the calculations. Finally, the severity of the blocking events is determined according to the size of the clustering centers.

- *It is stated in Lines 280-290 that the normalised economic indicators were used in Equation 8. Thus, the notation in Equation 6 and 8 should be unified. For example, Hd is the highway density, but it should be normalised highway density. Please confirm.*

Response: All the economic indicators were normalised before used.

- *Table 3 and 4, what does "/" indicate? No data or no obvious factors?*

Response: Revised. "/" assumes that there are no blocking events of this type at this level.
The data were standardised at the pre-processing stage, where Equation 6, which was used in the methodology presentation, is a methodological scenario and is therefore represented using Arabic letters. Equation 8 is a presentation of the final calculations.

Minor comments

10、 Please provide the link or reference to the data sources in Section 2.2.

Response: Revised. The highway-blocking events data obtained from the Ministry of Transport of the People's Republic of China (Fig. 1a) follow the criteria of the Highway Traffic Blocking Information Submitting System of the Ministry of Transport of the People's Republic of China (2018, No. 451; https://www.hunan.gov.cn/xxgk/wjk/zcfgk/202007/t20200730_e1c6436a-6aff-43d0-9c74-c0822311b8db.html)
.

11、 Table 2 "type" is not sorted from A to E. Is there any specific reason or is it the cluster type that is not associated with the level?

Response: The type from A to E are deleted.

12、 Provinces in China are mentioned throughout the manuscript to discuss the highway blocking distribution due to high-impact weather conditions. Therefore, a map of provinces with labels is needed to facilitate the discussion.

Response: Revised.

13、 Please add the subplot labels (e.g., (a) and (b)) to the figure, or use Left and Right in the caption

Response: Revised.

14、 Line 54 please introduce HIW acronym before using it in the text. The first time you use the term, put the acronym in parentheses after the full term.

Response: Revised. The HIW acronym introduced in Abstract.

15、 Figure 5 Left subplot a: results for Anhui was missing while results for Anhui was available in subplot b

Response: Revised.
