Dear editor,

Thank you for giving us the opportunity to submit a revised manuscript "Spatial accessibility of emergency medical services under inclement weather: A case study in Beijing, China" for publication in *Natural Hazards and Earth System Sciences*. We appreciate the time and effort that you and the reviewers dedicated to providing feedback on our manuscript and are grateful for the insightful comments on and valuable improvements to our paper.

The notes below provide a point-by-point response to each comment from the referees. The texts with blue font are the reviewer's original comments, the texts with black font are authors' responses. We have incorporated most of the suggestions made by the reviewers. Those changes are highlighted within the manuscript. If there is any question addressed unclearly or unsatisfied, we are always willing to make a second revision based on reviewer's comments. Thank you again for the opportunity to be considered for publication in *Natural Hazards and Earth System Sciences*.

Referee #1

The study looks at the spatial accessibility of emergency medical service facilities in Beijing resolved according to weather situations, days and time-of-the-day. The authors demonstrate an empirical approach for linking spatially resolved accessibility decreases to weather situations, and manage to point out spatial inequalities on a sub-urban level. The approach, despite the reviewer having some reservations regarding certain over-simplifications along the way, shows a way forward to combine empirical data to yield insights into an under-studied topic (EMS accessibility) while shedding light on a dimension of social inequity.

General

1. L 28 not clear at that stage what is meant with « coverage rate ». Is it the total area covered within a 15 mins response time? i.e. 13 % reduction refers to a km2 number? why then « rate » (I do know that it is explained later on in the text, however the abstract should be understandable before this)?

Response: We thank for reviewer's comment. Using "coverage rate" in the abstract may cause confusion to readers, in the revised manuscript, we have rephrased the sentence in Lines 27-29, Page 2:

Under inclement weather scenario, the area in the citywide that could get EMSs within 15 minutes would decreased by 13% compared to normal scenario. And in some suburban townships, the population that could get 15-min EMS would decrease by 40%.

2. L 45-55: It is good that the authors give detailed insight into what parts make up EMS, especially tailored to the case study context. However, there seems to be - strictly speaking - some

inconsistency in the use of the term services: One case includes the transport to the EMS facilities within the service definition (aka, the transportation service), the other case not (only treatment service).

Further, please elaborate how this goes together with the definition in L 72-74: It seems that this definition covers only the case of responders starting out from an EMS facility, getting to the scene, and transferring back to a respective facility (e.g. via ambulance). From the initial description above, the reader might think the authors will cover, however, also the case where patients transfer directly from the scene to an EMS facility (e.g. via private transportation). Hence, it might be good to explicitly mention again that this latter case will not be covered, even though described above for reasons of completeness.

Response: We thank for reviewer's comment. The EMSs includes both pre-hospital and in-hospital services, and in our study, we focus on the accessibility of EMSs (only the transportation part). And we divide the process into 2 parts: one is starting out from an EMS facility and getting to the scene (as in 3.2), the other is transferring the patient from the scene to hospitals (via ambulance, not private transportation, as in 3.3). So, we assume that the patients get the EMSs when the ambulance arrives the scene, and the EMSs is complete when the ambulance transfers the patient to hospital, and both parts were covered in our study. The case where patients transfer directly from the scene to an EMS facility via private transportation was not covered in this study. We apologize for the unclarity, and we mentioned it in the revised manuscript in Lines 193-195, Page 9:

The case where patients transfer directly from the scene to an EMS facility via private transportation will not be considered in this study.

3. L 58: To the non-local reader, it is unclear whether 1.5 to 2 hours response time is significantly longer than normally. One would assume this, but it would be helpful to provide average response times during normal conditions for comparison.

Response: We thank for reviewer's comment. As suggested by the reviewer, we have added the comparison of normal condition in Lines 61-62, Page 3. And this information comes from the same news.

while the transfer time wouldn't be more than 1 hour on usual

4. L 78: Reference to the 2SFCA method?

Response: We thank for reviewer's comment. We have added the reference to 2SFCA methods in Lines 79-80, Page 4:

Chen, X., and Jia, P.: A comparative analysis of accessibility measures by the two-step floating catchment area (2sfca) method, INT J GEOGR INF SCI, 33, 1739-1758,2019.
Kanuganti, S., Sarkar, A. K., and Singh, A. P.: Quantifying accessibility to health care using two-step floating catchment area method (2sfca): a case study in rajasthan, Transportation Research Procedia,

17, 391-399,2016.
Li, M., Kwan, M., Chen, J., Wang, J., Yin, J., and Yu, D.: Measuring emergency medical service (ems) accessibility with the effect of city dynamics in a 100-year pluvial flood scenario, CITIES, 117, http://doi.org/10.1016/j.cities.2021.103314, 2021b.
Luo, W., and Qi, Y.: An enhanced two-step floating catchment area (e2sfca) method for measuring spatial accessibility to primary care physicians, HEALTH PLACE, 15, 1100-1107,2009.

5. L 74-L104: it is good that you provide some literature revolving around the topic of study. However, this very brief listing-style does not make it very clear how those papers are related to the concrete problem statement, or not summarized into coherent areas of challenges, seeming a bit randomly aggregated.

Response: We thank for reviewer's comment. We recomposed the whole part of review in the revised manuscript, please refer to Lines 73-105, Pages 4-5:

The spatial accessibility of EMSs is defined by the travel impedance (distance or time) between service locations and the scene (Guagliardo, 2004). A large body of research on spatial accessibility is concerned with access to hospitals (Luo and Wang, 2003; Mao and Nekorchuk, 2013; Pan et al., 2018; Yang et al., 2020; Yin et al., 2021) and first-aid stations (Hashtarkhani et al., 2020; Jones and Bentham, 1995; Shin and Lee, 2018). To measure the EMSs accessibility, the two-step floating catchment area (2SFCA) method is one of the common methods (Chen and Jia, 2019; Kanuganti et al., 2016; Li et al., 2021; Luo and Qi, 2009). The 2SFCA method considers accessibility to be mediated by not only the distance decay but also the interactions between supply and demand (Chen and Jia, 2019), which is more suitable for normal scenarios. While for studies focusing on the influence of inclement weather on EMSs, people concern more about the transportation situation, instead of the interaction between supply and demand. The coverage analysis method (Coles et al., 2017; Green et al., 2017; Yu et al., 2020) or shortest path analysis method(Albano et al., 2014; Andersson and Stålhult, 2014) are more widely used. These methods could better characterize the reduction of accessibility caused by the road service degradation. For example, Yu et al. (2020) analyzed the accessibility of emergency service in England and identified vulnerability hotspots by quantifying the EMSs coverage of area and population within different time radii under different flood scenarios; Coles et al. (2017) measured the travel time and service area coverage of EMSs in York, UK under flood scenarios by using FloodMap-HydroInundation2D to model flood inundation; Yin et al. (2021) assessed the vulnerability of EMSs to surface water flooding in Shanghai, China by quantifying accessibility in terms of service area, response time, and population coverage, considering four temporal scenarios (nighttime, evening, daytime, and morning–evening peak) of average drive speeds based on a real-time traffic analysis from GPS big data; Andersson and Stålhult (2014) used network analysis methods to generate the shortest paths from hospitals to various administrative areas in Manila, Philippines, and evaluated the impact of different flood events on these paths. Most of these studies assumed that roads are impassable or traffic speed has a certain degree of reduction when the flooded water depth reaches a specific depth, and further evaluated the impact of rainstorm on EMSs accessibility. Due to insufficient recorded traffic data, relatively few studies have been performed to analyze the impact of road access capacity on EMSs *accessibility according to actual traffic speed variation.*

6. Section 3.1:

Could you please elaborate the reason for averaging to daily speeds for the baseline constructions, since you later also look at rush-hours and non-rush-hours specifically?

In a similar line of argumentation, averaging hence-obtained speed reduction rates across all road sections within the city (L220f), seems to conceal congestion hotspots? Please elaborate why this was done and the potential limitations of this.

Also, it is not clear to me from this description, if days are simply divided in a binary manner into inclement and non-inclement weather days, irrespective of the precipitation magnitude? Please elaborate in more detail if this is the case, and what was the reasoning for and potential shortcoming of this.

Response: We thank for reviewer's comment. Actually, we averaged the traffic speed data of the selected period, not of the whole day (as in line 219 and line 221). We apologize for the unclarity, and we added "in the selected period" in Lines 207-215, Pages 10:

The average speed data of the four baseline days ***in the selected period*** *were then averaged as the baseline speed for the given precipitation day, and the traffic speed reduction rate was calculated by eq. (1):*

$$r_c = \frac{v_p - \frac{\sum_{j=0}^{m} v_{d_j}}{m}}{\frac{\sum_{j=0}^{m} v_{d_j}}{m}} \qquad (1)$$

where r_c *is the traffic speed reduction rate* ***in the selected period*** *of the precipitation day to its corresponding baseline days;* v_p *is the traffic speed* ***in the selected period*** *of the given precipitation day;* v_{d_j} *is the traffic speed* ***in the selected period*** *of a baseline day, and m is the number of baseline days. In this case, m equals 4.*

We admit that averaging hence-obtained speed reduction rates across all road sections within the city do conceal the congestion hotspots, which is a limitation of this study. This limitation could be improved in the further study on a small scale based on a higher resolution of precipitation. Nevertheless, averaging could give us the overall impact of precipitation on vehicle speed across the city. And we put Figure 4 to complement the spatially difference and find out the congestion hotspots. We also admit this limitation in Lines 487-492, Pages 25:

However, there are also some limitations in this study. First, we averaged the traffic speed reduction rate of all the roads in the city, as well as the precipitation data, which could conceal congestion hotspots. In further studies, with higher resolution precipitation, along with corresponding traffic data, we could narrow the scale to blocks, pay more attention to local congestions, and analyze the correlation of precipitation and traffic speed on a finer scale.

In this study the days were simply divided in a binary manner into inclement and non-inclement weather days, the reason is that we only got the traffic data of 2019, and there are few days with precipitation. The data does not support an analysis considering precipitation magnitude. In the revised manuscript, we have acknowledged this shortcoming in the discussion section in lines 499-492, page 25:

Due to the data limitation, we could only analyze the EMSs accessibility in 2019, and the precipitation intensity in this year was not quite high. If with more precipitation and traffic data, we could analysis the impact of precipitation magnitude to the traffic and accessibility, instead of divided the days in a binary manner into inclement and non-inclement weather days.

7. Section 3.3: How does aggregation of the population grids to 1000m in a city distort potential travel patterns? Given that the topology of the road network within Beijing is at a much higher resolution, does this aggregation not lead to a very coarse estimation of what roads are taken, and which ones not?

Response: We thank for reviewer's comment. When we run the OD cost matrix analysis for each population grid, we use its centroid as the origin point, not the whole square, so it won't affect the resolution of the topology of the road network. This might be interpreted as a sampling survey. The choice of roads to the nearest hospital won't be greatly impact because the distance to the nearest to the nearest hospital is normally more than 1km in most areas. The reason of aggregation the population grids are mainly reducing the amount calculation, because the OD cost matrix analysis is computationally intensive. We added some explanation in Lines 256-258, Page 12:

This could be interpreted as a sampling method, because we use the centroid point of the grid to represent the other possible starting points in the grid, and we ignored the tolerance caused by the travel time inside the grids.

8. Section 4. Results:

L275-280: It is hard to understand to which scenarios / analysis areas the percentages belong. Do 38 and 40%, resp., refer to the city including suburban areas? And 77 and 83% refer to only the inner city (is that meant by Six Road Ring)? Please phrase it in a way that describes the area analyzed better to a non-local.

Response: We thank for reviewer's comment. The reviewer's comprehension is correct. And we revised the sentences in lines 273-279, page 13:

We divided the city into the inner city and suburban areas along the Sixth Ring Road. Taking the average 15-minute coverage of the area of all Mondays in November as an example: (1) in the whole city (both inner city and suburban), the coverage rate of EMSs is 38.72% in morning rush hours, compared with 40% (±0.3%) in the remaining periods; (2) in the inner city, the coverage rate is 77.37% in morning rush hours, compared with 83% (±0.6%) in the remaining periods.

9. L 283-288: The definition and selection of a precipitation event belongs to the methodology section.

Response: We agree with the reviewer's suggestion, and we moved this part to 2.2.2 in the revised manuscript. Please refer to Lines 155-161 in Pages 7-8.

10. 4.1.1. When I first read that you average out the total precipitation, across the grid cells, I was skeptical whether this conceals local effects, as one might assume that certain parts of the city could hence flood more, and cause over-proportional traffic delays.

Also, I do not see an analysis of total precipitation on traffic speed, which I could imagine has quite an impact (while it is certainly important how strongly it rains in a given hour, it surely also matters how long it rains for causing pluvial flooding). Please elaborate more on both those aspects.

Please also use figure 3 in justifying your assumptions / method, as indeed, it seems that without the (explained) outliers, there seems to be not much of an impact on how much it rains for causing travel reductions? This may be an argument in favor of your decision; however, it is somewhat unintuitive why there is so little effect.

In general, please comment more on the relationship between precipitation and urban pluvial flooding, and limitations of looking only at precipitation data without any hydrological modelling associated with it, that would link precipitation with the actual amount of water on the streets.

Response: We thank for reviewer's comment. First, we averaged the total precipitation because we intended to evaluate the correlation of precipitation and overall traffic speed reduction in the city. And the spatial difference of precipitation was illustrated in Figure 4. We admit that could lead to conceal the local effects. This limitation was mainly due to the lack of high-resolution precipitation data. There are only 175 grids of precipitation data in Beijing, and we couldn't analyze the local effect on that scale. And we added more discussion on that in lines 487-492, page 25:

There are also some limitations in this study. First, we averaged the traffic speed reduction rate of all the roads in the city, as well as the precipitation data, which could conceal congestion hotspots. In further studies, with higher resolution precipitation, along with corresponding traffic data, we could narrow the scale to blocks, pay more attention to local congestions, and analyze the correlation of precipitation and traffic speed on a finer scale.

Second, we apologize for the ambiguity of the precipitation unit. Actually, the index of precipitation we used is the total precipitation during the selected time period, instead of the intensity of precipitation. Because the unit of precipitation we took was mm/2h, and in case that we only focus on the morning rush hours period (7:00-9:00), the index represents the total precipitation in these 2 hours. To avoid confusion, we mentioned it again in lines 287-288, page 13:

The unit of precipitation data is mm/2h, which indicates the total precipitation in the 2 hours of morning rush hours.

Besides, how long it rains was hard to be accurate because the time resolution of precipitation is 0.5 hours, and the morning rush hours period is only 2 hours in total.

Third, Figure 3 shows that there are 4 days that has more speed reduction, and the rest days seems relatively normal. We think the reason of this result is that the days with heavy rain or snow were rare. But when the small rain encountered the specific date, such as teacher's day, the impact would be amplified. The limitation is that we only have one-year traffic data, we believe with a longer time series data, the further results could be more significant.

Fourth, we agree that run a hydrological pluvial flood simulation could better link the precipitation, waterlogging and traffic congestion. However, run a flood simulation need a high-resolution DSM data of the city, which is very hard to get in China. We therefore link the precipitation and traffic directly with the analysis of ground-truth data. And we add some discussion about this in lines 500-503, page 25-26:

Due to the lack of high-resolution DSM data, we didn't run a hydrological flood simulation in Beijing, which could reveal the relationship of precipitation and the actual amount of water on the streets. And this could be improved in the future studies with more high-resolution topographic data.

11. Figure 4 is basically not commented and further analyzed. Please elaborate more, what one can see.

Response: We thank for reviewer's comment. We have elaborated the description of Figure 4 in the revised manuscript in Lines 296-306, Pages 14.

Figure 4 illustrates the spatial difference of traffic speed reduction and distribution of precipitation on precipitation days. A large number of red roads (with traffic speed reduction over 10 km/h) can be observed in the 4 days mentioned above. By comparing the distribution of precipitation and traffic speed reduction on different dates in Figure 4, it can be found that the precipitation in the four days with the most severe speed reduction was moderate, and the precipitation distribution of the whole city was relatively uniform. Compared with other rain days, although the precipitation on July 5, August 9 and September 19 was larger and concentrated in the inner city, the traffic speed reduction of the whole city was not as serious as the four days mentioned above, which may be caused by the decrease of people's willingness to travel with the increase of rain.

Grammar / Style

1. In-line citations are ill-formatted (brackets around them), e.g. L 83, L 90, etc. Please format correctly. Also, some citations are CAPITALIZED.

Response: We thank for reviewer's comment. We have checked and corrected the format of citations.

2. L31: towns new sentence : Furthermore, …

Response: We thank for reviewer's comment. We have corrected the gramma mistake.

3. L 106: Could you briefly explain the term "waterlogging" (e.g. the saturation of ground with water), as it may not be clear to every single reader what is meant by this phenomenon.

Response: As suggested by the reviewer, we have added the explanation in Lines 68-69, Page 4 waterlogging (the phenomenon of a stagnant water disaster in an urban area due to heavy rainfall or continuous precipitation).

4. L145: Rather: "hit" by a rainstorm? They do not malevolently "attack".

Response: We thank for reviewer's comment. We have changed the verb from "attack" to "hit". (Line 56, Page 3)

5. L 145-150: You already gave quite a few examples of hazardous events in the introduction; also, this example does not fit the section "Study area". Please consider to delete it.

Response: We thank for reviewer's comment. We delete it.

6. Section labels are wrong. For instance, after 2.1 and 2.2. on p7, we see another section 2.1 and 2.2. on p8

Response: We thank for reviewer's comment. We have corrected the section labels.

7. L261: The term "population medical accessibility index" is a little bit cumbersome to read and understand. Could you perhaps think of a simpler, more descriptive term?

Response: We thank for reviewer's comment. We have changed the term to "total transfer time" in Lines 259-261, Page 12:

The total transfer time is introduced to quantify the cumulative transfer time for each population grid based on its population size, which is the number of potential users of EMSs.

Referee #2

Summary: This paper presents a study that evaluates the spatial accessibility of emergency medical services during inclement weather, including rain and snow, and measures the impact of precipitation on traffic speeds. It compares the accessibility of emergency services during inclement weather to a baseline value calculated two weeks before the event and two weeks after the event. The results highlight four days when emergency medical service accessibility particularly decreased. The study also shows that snow has a particularly large impact on emergency service accessibility. The study has the potential to provide a scientific basis for discussions with transportation and urban planners to improve access to emergency medical services, particularly in rural areas or areas with unequal conditions.

General comments:

1. The study includes examples of natural hazards and the difficulty of reaching emergency services in a timely manner (L. 55- 63). Can you provide the references for these examples?

Response: We thank for reviewer's comment. We have added the references for the news.

Beijing Evening. (2012). Beijing rainstorm, 120 calls increased by 1/3, trauma and car accident injury increased significantly. Available at: http://news.sohu.com/20120722/n348746024.shtml (accessed 30 August 2021).
Jimu News. (2021). Ambulance was blocked when the rainstorm hit the city in Qujing, Yunnan Province, firefighters transferred the injured boy in a canoe. Available at: https://new.qq.com/rain/a/20210624A0AFSB00 (accessed 30 August 2021).
Shaanxi News. (2019). Ambulance stalled on a rainstorm night, firefighters helped them get to hospital in time. Available at: http://news.cnwest.com/bwyc/a/2019/08/01/17913208.html (accessed 30 August 2021).

2. The study presents several case studies that use different models (L. 70 -104). Could you please summarize the research gaps in this area?

Response: We thank for reviewer's comment. We recomposed the whole part of review in Lines 100-105, Page 5.

Most of these studies assume that roads are impassable or traffic speed has a certain degree of reduction when the flooded water depth reaches a specific depth, and further evaluate the impact of rainstorm on EMSs accessibility. Due to insufficient recorded traffic data, relatively few studies have been performed to analyze the impact of road access capacity on EMSs accessibility according to actual traffic speed variation.

3. The text gives a good description of the resolution of the data used. In line 157, please define "inclement" and "normal" weather in the datasets. Is a little rain already considered bad weather?

Response: We thank for reviewer's comment. In this study, we set a rule that if the precipitation of more than 10 grids in Beijing is greater than 1.5 mm, it is considered an inclement weather scenario. And yes, we include the small rain in the scope of inclement weather, because the overall rainfall intensity was not high in the year of 2019. To make it clear, we have defined it in Lines 155-161, Pages 7-8:

According to the China Meteorological Administration, the moderate rain is defined as the rainfall is 5.0~14.9 mm within 12 hours. We chose intermediate value of interval and average it to each hour. In this study, we set a rule that if the precipitation of more than 10 grids (over 5% area of the city) in Beijing is greater than 1.5 mm in 2 hours, it is considered a precipitation event.

4. Some sentences are very long sentences and compromise readability:

- L. 22 – 25 ("and" is used twice in short succession)
- L. 50 – 55
- L. 74 – 79
- L. 91 – 95
- L. 117- 123
- L. 141 – 145
- L. 366 – 373

Response: Thank you for pointing this out. We have rephrased the long sentences to several short ones.

5. L. 77: Please refer to the correct citation style and do not capitalize references: "Jones and Bentham…".

Response: We thank for reviewer's comment. We have corrected the citations.

6. L. 100: Could you please write out the abbreviation "PF-prone" when it is first mentioned?

Response: We thank for reviewer's comment. PF refers to pluvial flooding, and we have revised it.

7. L. 132: Instead of referencing the link in brackets, please refer to the correct citation style.

Response: We thank for reviewer's comment. We have corrected the citations.

8. L. 145: "Beijing was attacked by a rainstorm…". Could you please paraphrase this sentence?

Response: We thank for reviewer's comment. We have revised the sentence by changing the verb from "attack" to "hit". (Line 56, page 3)

9. L. 162: Section 2 has a wrong numbering of the subsections. Should this be 2.2.1. instead of 2.1, 2.2.2. instead of 2.2?

Response: We thank for reviewer's comment. We did make a mistake in the section labels, and it was corrected in revision.

10. L. 171: Instead of referencing the link in brackets, please use the correct citation style.

Response: We thank for reviewer’s comment. We corrected the citations.

11. L. 183: “third-level grade-A hospitals.” Could you please provide a brief explanation of hospital classifications that might help readers if they are not familiar with it?

Response: We thank for reviewer’s comment. We added the explanation of “third-level grade-A hospitals.” in Lines 169-172, Page 8:

The hospital point data were extracted from the online map point of interest (POI) data of Beijing in 2019. After coordinate correction and deduplication, it contains a total of 630 general hospitals, 76 of which are third-level grade-A hospitals (the highest level in the evaluation system of hospitals in mainland China).

12. L. 255: Could you please write out the abbreviation of “OD”, when it is first mentioned?

Response: We thank for reviewer’s comment. “OD” refers to origin-destination, and we have added it in the revision in Line 251, Page 12.

13. L. 465: Could you rephrase the phrase "we could guess"?

Response: We thank for reviewer’s comment. We rephrased it in lines 497-499, page 25:

Under such precipitation conditions, the EMSs accessibility has been affected to a certain extent, and it would be much more difficult to get timely EMSs under even more extreme inclement weather condition.

- **Figures:**

1. Could you please specify which software tools you used to create the figures?

Response: We thank for reviewer’s comment. Figure 1, Figure 4, Figure 6, Figure 8 and Figure 10 were created in ArcGIS 10.8 and composed in CoreDrawX7. Figure 2 was created in CoreDrawX7. Figure 3, Figure 5 Figure 7 and Figure 9 were created in Excel 2019. We add the explanation in the Method section in lines 185-186, Page 17:

Both service area analysis and OD Cost Matrix analysis are GIS-based, and was done in ArcGIS 10.8.

2. L. 305: Figure 4 is difficult to read. Is it possible to highlight some particular days with observations?

Response: We thank for reviewer’s comment. We added black borders to highlight the 4 special days.

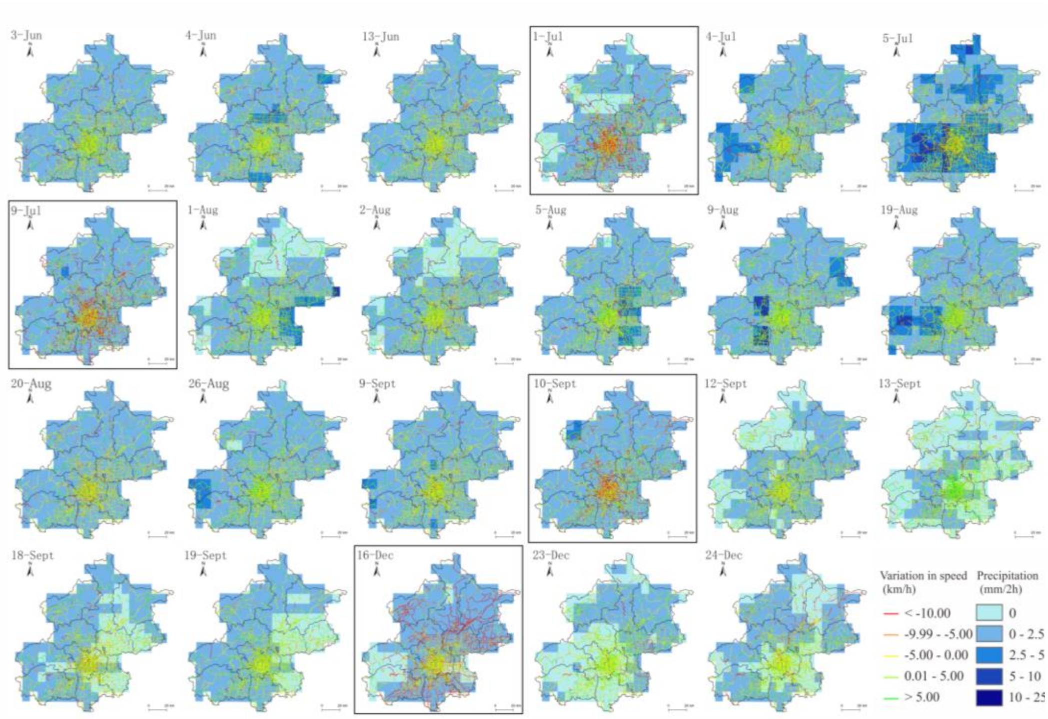


Figure 4. *Variation in drive speed and distribution of precipitation on selected precipitation days (the 4 subfigures with black borders shows the 4 most affected scenarios)*

- **Discussion:**

1. L. 435: In the discussion, it would be good to refer to the previously mentioned studies in the introduction and draw a link: How does this work build on the previously published literature body? Where do the results align, where do they differ?

Response: We thank for reviewer's comment. We have added discussions on this in Lines 474-480, Pages 24-25:

In previous literature, simulation methods were widely used on the research on EMSs accessibility or traffic capacity under inclement weather. The ground-truth traffic data that covers every road in the whole city for a whole year in a row, was hardly used in the previous studies of the impact of weather on traffic and accessibility. And our study could be a good empirical verification in this field of study. The reduction extent of EMSs accessibility was close to previous studies. And we also found that snowfall may have a greater impact, which is hard to find out using flood simulation methods.

2 L. 467: As next steps, you mention that future studies should consider data on "extreme precipitation" events. Are there other data analyses that can be done with the available data?

Response: We thank for reviewer's comment. The lack of traffic data limits the sample size we could analyze. We are trying to obtain a longer time series traffic data, and its corresponding precipitation data. If we could get more samples with bigger precipitation magnitude, we could analyze more extreme scenarios. And we add some discussion about this in Lines 494-496, Page 25:

If with longer time series precipitation and traffic data, we could analyze the impact of precipitation magnitude to the traffic and accessibility, instead of simply dividing the days in a binary manner into inclement and non-inclement weather days.

Specific comments:

1. L. 24: Although it is mentioned in the Abstract, "inclement weather" is quite general. Later, in the introduction, the study refers to "rain or snow" (line 51). How much rain or snow is considered inclement weather, or is a little rain already inclement weather?

Response: We thank for reviewer's comment. We have mentioned it in Lines 155-161, Pages 7-8 in the revision:

According to the China Meteorological Administration, the moderate rain is defined as the rainfall is 5.0~14.9 mm within 12 hours. We chose intermediate value of interval and average it to each hour. In this study, we set a rule that if the precipitation of more than 10 grids (over 5% area of the city) in Beijing is greater than 1.5 mm in 2 hours, it is considered a precipitation event.

2. L. 63 - 65: Since this is a very general context, could you please provide some more references?

Response: We thank for reviewer's comment. Thank you for this comment. We have added the reference to this sentence:

Huber, D. G., and Gulledge, J.: Extreme weather and climate change: understanding the link, managing the risk, Pew Center on Global Climate Change Arlington, 2011.

Stott, P.: How climate change affects extreme weather events, SCIENCE, 352, 1517-1518,2016.

Stott, P. A., Christidis, N., Otto, F. E., Sun, Y., Vanderlinden, J. P., van Oldenborgh, G. J., Vautard, R., von Storch, H., Walton, P., and Yiou, P.: Attribution of extreme weather and climate-related events, Wiley Interdisciplinary Reviews: Climate Change, 7, 23-41,2016.

3. L. 78: Could you please name some references that use the 2SFCA method?

Response: We thank for reviewer's comment. We have added the reference to 2SFCA methods:

Chen, X., and Jia, P.: A comparative analysis of accessibility measures by the two-step floating catchment area (2sfca) method, INT J GEOGR INF SCI, 33, 1739-1758,2019.

Kanuganti, S., Sarkar, A. K., and Singh, A. P.: Quantifying accessibility to health care using two-step floating catchment area method (2sfca): a case study in rajasthan, Transportation Research Procedia, 17, 391-399,2016.

Li, M., Kwan, M., Chen, J., Wang, J., Yin, J., and Yu, D.: Measuring emergency medical service (ems) accessibility with the effect of city dynamics in a 100-year pluvial flood scenario, CITIES, 117, http://doi.org/10.1016/j.cities.2021.103314, 2021b.

4. L. 112 - 113: Could you please state the contribution of the study more clearly?

Response: We thank for reviewer's comment. We have elaborated the contribution of our study in Lines 110-113, Page 5 and in Lines 480-486 Page 25:

Our study provides an approach for evaluating the effectiveness and fairness of EMSs based on ground-truth traffic data, and the results can not only provide reference for the optimization of EMSs in Beijing, but also provide reference cases for other cities, which has a great practical significance. The results from this study provide a scientific reference for city planning departments in Beijing to optimize the site selection of emergency service facilities and get prepared for traffic dispersion on inclement weather. The relevant methods mentioned in this paper can also be popularized and easily applied to other cities once traffic data or empirical formulas regarding the impact of inclement weather on road traffic can be obtained.

5. L. 157: Can you give a brief description of the road network topology?

Response: We thank for reviewer's comment. We have added the description of the road network topology in Lines 135-139, Page 7:

Based on traffic data and meteorological data, we could build a topology road network (using node and edge primitives to describe interconnected linear features (roads) and points (roads junctions) on a map) with transfer time as impendence under inclement weather conditions and corresponding normal weather conditions.

6. L. 203: How many days with precipitation were included in the sample?

Response: We thank for reviewer's comment. There are 19 working days of rainfall and 3 working days of snowfall were selected. To make it clear, we have added the following description in Lines 159-160, Page 8:

The average precipitation of the whole city on each date is averaged by the precipitation of all grids. In 2019, 19 working days of rainfall and 3 working days of snowfall were selected.

7. L. 298: The analysis focuses on specific holidays (July 1st, September 10th). How transferable are the results of your study to other days?

Response: We thank for reviewer's comment. Our study provides a general method to evaluate the EMSs accessibility, it's suitable in both holidays and workdays. These specific days like July 1st or September 10th may affect the traffic flow, which has an amplification effect on the traffic congestion caused by inclement weather. And there could be more days that would change the normal traffic flow, and when they encounter the inclement weather, there are potential risks of decrease of traffic efficiency and EMSs accessibility, which should be given sufficient attention. We have added this in discuss section in lines 467-470, page 24:

Some specific days may affect the traffic flow, which has an amplification effect on the traffic congestion caused by inclement weather. When they encounter the inclement weather, there are potential risks of decrease of traffic efficiency and EMSs accessibility, which should be given sufficient attention.

8. L. 254: “population medical accessibility index”. The term can be a little difficult to understand. Can you briefly explain the term in more detail?

Response: We thank for reviewer’s comment. We changed it into “total transfer time”, which describe the total time would need if every person in this grid did once transfer process.

Technical corrections:

- L. 31: “towns with lower baseline EMS accessibility **are** more vulnerable to inclement weather. Furthermore,”.
- L. 53: For quotations in continuous text, please insert a space in between the text and the reference: “The efficiency of emergency services is highly vulnerable to inclement weather conditions[...], and sometimes block roads completel**y (A**garwal et al., 2006;…”
- L. 152: For quotations in continuous text, please insert a space in between: “Andersson and Stålhult (2014) used network analysis”
- L. 188: How about phrasing the sentence: “The data records present the population size" or “The data records depict the population size…”?
- L. 192: How about phrasing the sentence: “Figure 2 presents” or “Figure 2 illustrates”?
- L. 315: Is it “In which the 15-min EMS coverage rate **reduced** by …”?
- L. 319: “…which **led** to a significant reduction in overall EMS coverage…”
- L. 418: Here, should it be “within the **Sixth** Ring Road extent”? Later, in line 363 and in line 365, the text refers to “within the Sixth Ring road”.
- L. 428: “…were almost no regions where the population medical accessibility index **decreased**.”

Response: We thank for reviewer’s comment. They all have been revised.

Referee #3

This empirical study investigates the impact of inclement weather on the time emergency medical response (EMS) time intervals for the city of Beijing. It is broken into two stages. Firstly, to explore the impact of inclement weather (i.e., precipitation) on traffic and EMS accessibility to come with the worst-case scenarios of the year 2029 (i.e., days including different times per day). Secondly, to evaluate EMS accessibility under the identified worst-case scenario and evaluate the distribution of EMS with particular focus on the difference in population and road network distribution between urban and suburban areas. The study can be useful to identify the scenarios needing improvement to ensure more fair access to EMSs for populated cities. The paper is generally well-written and easy to read but can be improve in terms of clarity.

1. The abstract. It seems to overlook a key impact that seems important from the results: The day of snowfall seems to have more significant impact that the days of rainfall (among the worst-case scenario considered). Can the authors add a mention about this fact somewhere in the abstract.

Response: We thank for reviewer's comment. We added one sentence in abstract in Lines 31, Page 2:

And snowfall has a greater impact on the accessibility of EMS than rainfall.

2. The introduction. In Line 107, Please be specific on what is meant by "The latter". It can be more effectively used to also introduce to lay reader some common terms that will be occurring later, such as "coverage area" and "waterlogging".

Response: We thank for reviewer's comment. We revised the whole paragraph in Lines 73-105, Page 4-5:

The spatial accessibility of EMSs is defined by the travel impedance (distance or time) between service locations and the scene (Guagliardo, 2004). A large body of research on spatial accessibility is concerned with access to hospitals (Luo and Wang, 2003; Mao and Nekorchuk, 2013; Pan et al., 2018; Yang et al., 2020; Yin et al., 2021) and first-aid stations (Hashtarkhani et al., 2020; Jones and Bentham, 1995; Shin and Lee, 2018). To measure the EMSs accessibility, the two-step floating catchment area (2SFCA) method is one of the common methods (Chen and Jia, 2019; Kanuganti et al., 2016; Li et al., 2021; Luo and Qi, 2009). The 2SFCA method considers accessibility to be mediated by not only the distance decay but also the interactions between supply and demand (Chen and Jia, 2019), which is more suitable for normal scenarios. While for studies focusing on the influence of inclement weather on EMSs, people concern more about the transportation situation, instead of the interaction between supply and demand. The coverage analysis method (Coles et al., 2017; Green et al., 2017; Yu et al., 2020) or shortest path analysis method(Albano et al., 2014; Andersson and Stålhult, 2014) are more widely used. These methods could better characterize the reduction of accessibility caused by the road service degradation. For example, Yu et al. (2020) analyzed the accessibility of emergency service in England and identified vulnerability hotspots by quantifying the EMSs coverage of area and population within different time radii under different *flood scenarios; Coles et al. (2017) measured the travel time and service area coverage of EMSs in York, UK under flood scenarios by using FloodMap-HydroInundation2D to model flood inundation; Yin et al. (2021) assessed the vulnerability of EMSs to surface water flooding in Shanghai, China by quantifying accessibility in terms of service area, response time, and population coverage, considering four temporal scenarios (nighttime, evening, daytime, and morning–evening peak) of average drive speeds based on a real-time traffic analysis from GPS big data; Andersson and Stålhult (2014) used network analysis methods to generate the shortest paths from hospitals to various administrative areas in Manila, Philippines, and evaluated the impact of different flood events on these paths. Most of these studies assumed that roads are impassable or traffic speed has a certain degree of reduction when the flooded water depth reaches a specific depth, and further evaluated the impact of rainstorm on EMSs accessibility. Due to insufficient recorded traffic data, relatively few studies have been performed to analyze the impact of road access capacity on EMSs accessibility according to actual traffic speed variation.*

3. What platform was used to "Combining the topology road network with medical facility locations and the distribution of the population, we could further analyze the spatial accessibility to EMSs." Was this work GIS based? What was the tool employed?

Response: We thank for reviewer's comment. In this study, we used ArcGIS 10.8 to run the analysis. We added that in the method section in Lines 185-186, page 9:
Both service area analysis and OD Cost Matrix analysis are GIS-based, and was done in ArcGIS 10.8.

3. Line 162: the sub-section numbering here down to line 189 is missing a third digit. I suppose it should be 2.2.1, 2.2.2, 2.2.3 and 2.2.4.

Response: We thank for reviewer's comment. We apologize for the mistake in the section labels, and it was corrected in revision.

Methodology.

1. As in any study, there should some assumption made by the authors and aspects that were not addressed. A mention of these would be useful.

Response: We thank for reviewer's comment. In this study, we have these assumptions in lines 187-195, page 9:

1. *The ambulances move at the average speed all the time and would always take the shortest path in space.*
2. *In network analysis, the location of facilities is approximately considered to be on the nearest road point vertically.*
3. *In OD analysis, we use the centroid as the origin point to represent the whole grid, and the shortest path to hospital is the same within the grid.*

4. *The prehospital EMSs is divided into two parts: the ambulances depart from the first-aid station to the scene and from the scene to the nearest hospital. The case where patients transfer directly from the scene to an EMS facility via private transportation will not be considered in this study.*

2. Line 232: Is there any citation that you can use to justify the choice of the 15-minute arrival time?

Response: We thank for reviewer's comment. In previous study, considering various response time targets, three service zones lying within 8-, 12-, and 15-minute travel are specified for each individual EMS station. And the coverage areas all decreased under the impact of flood. So, we chose 15-minute arrival time. In the revised manuscript, we added the reference:

Yin, J., Yu, D., and Liao, B.: A city-scale assessment of emergency response accessibility to vulnerable populations and facilities under normal and pluvial flood conditions for shanghai, china, ENVIRON PLAN B-URBAN, 48, 2239-2253, http://doi.org/10.1177/2399808320971304, 2021

5. Line 255: please define OD. Does it stand for Origin-Destination?

Response: We thank for reviewer's comment. Yes, "OD" refers to origin-destination, and we added it in Lines 250-251, Page12:

The shortest transfer time is calculated by the OD (Origin-destination) cost matrix analysis method.

6. Line 258-259: More discussions on the calculation cost is welcome so one can justify the rationale behind increasing the resolution from 100 and 1000 m. How much would this impact the predictions vs. reduce the cost for the analysis?

Response: We thank for reviewer's comment. The choice of roads to the nearest hospital won't be greatly impact because the distance to the nearest to the nearest hospital is normally more than 1km in most areas, so increasing the resolution would not affect the overall pattern of spatial difference of accessibility, but would the cost of calculation would reduce to 1/100, because every grid needs to calculate the shortest route and transfer time to every hospital. After the aggregation of population grids, there are about 25,000 origin points, and we need to calculate the shortest travel path between every origin point and hospital and select a closest hospital for each origin point. The calculation can be done in about 10~15 minutes for each scenario. If we don't do the aggregation, the number origin points would be about 2,500,000, so the calculation would be more than 1000 minutes.

7. Line 265: there is always a mention of a grid. Should this be meaning that the analysis was GIS based?

Response: We thank for reviewer's comment. The analysis is GIS based. We have added this information in Lines 184-185, Page 9:

Both service area analysis and OD Cost Matrix analysis are GIS-based, and was done in ArcGIS 10.8.

6. Line 306: Figure 4 deserves a discussion as such in 4.1.1 before moving to 4.1.2 and quoting it there. I guess it was used to support further the choice for the days considered as worst-case scenario.

Response: We thank for reviewer's comment. We add some elaboration in lines 296-299, page 14:

Figure 4 illustrates the spatial difference of traffic speed reduction and distribution of precipitation on precipitation days. A large number of red roads (with traffic speed reduction over 10 km/h) can be observed in the 4 days mentioned above. By comparing the distribution of precipitation and traffic speed reduction on different dates in Figure 4, it can be found that the precipitation in the four days with the most severe speed reduction was moderate, and the precipitation distribution of the whole city was relatively uniform. Compared with other rain days, although the precipitation on July 5, August 9 and September 19 was larger and concentrated in the inner city, the traffic speed reduction of the whole city was not as serious as the four days mentioned above, which may be caused by the decrease of people's willingness to travel with the increase of rain.

7. Line 331: "The results demonstrate …" what results? Any figures I should be looking at? Or, from which equation? Are you talking about the "coverage rates". Please specify.

Response: We thank for reviewer's comment. The results refer to the spatial difference of population coverage. We added a new figure to illustrate it better. The new figure has 2 rows, using the first row minus the second row is the variation that Figure 6 (the order number becomes Figure 7 now) shows, as can be found in Page 17:

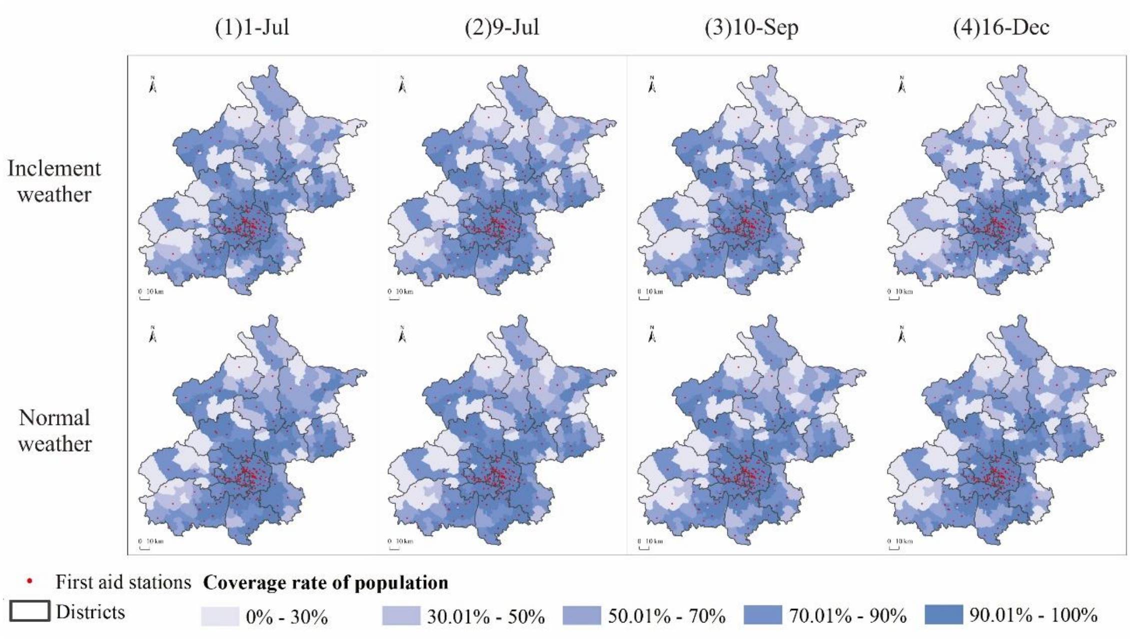
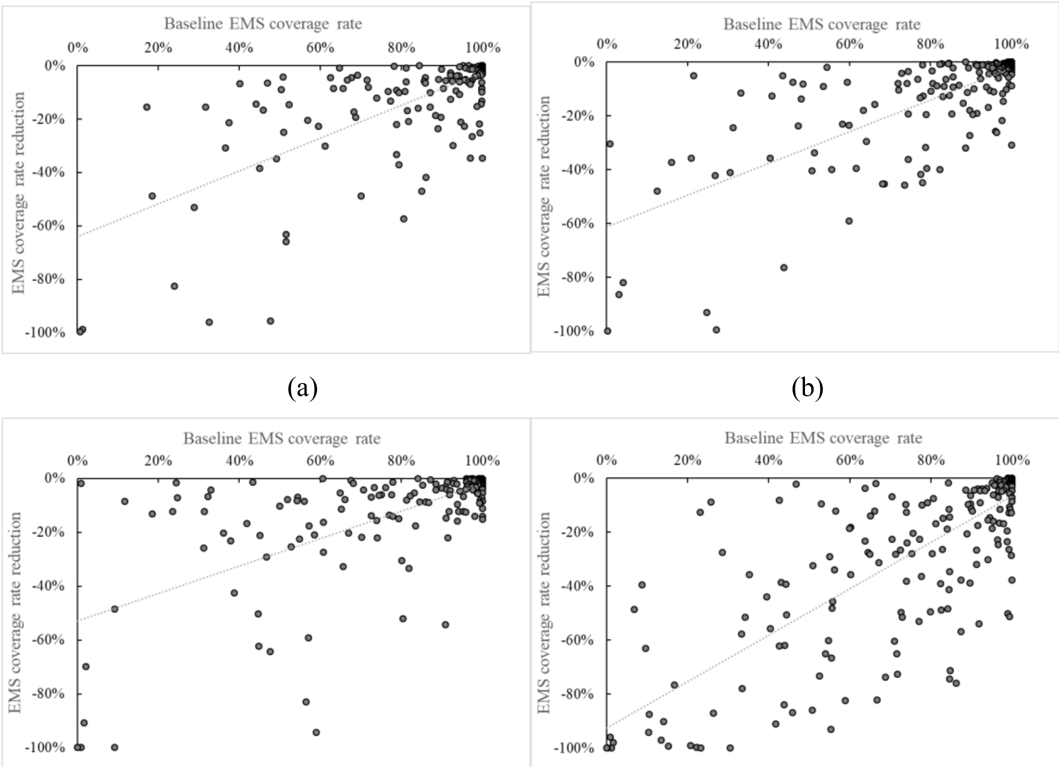


Figure 6. The EMSs coverage rate of population in townships under the inclement weather condition and normal weather condition on 1st July, 9th July, 10th September and 16th December

8. Line 359: The clarity of the sub-figures in Figure 7 can be significantly improved. Same for Figure 8.

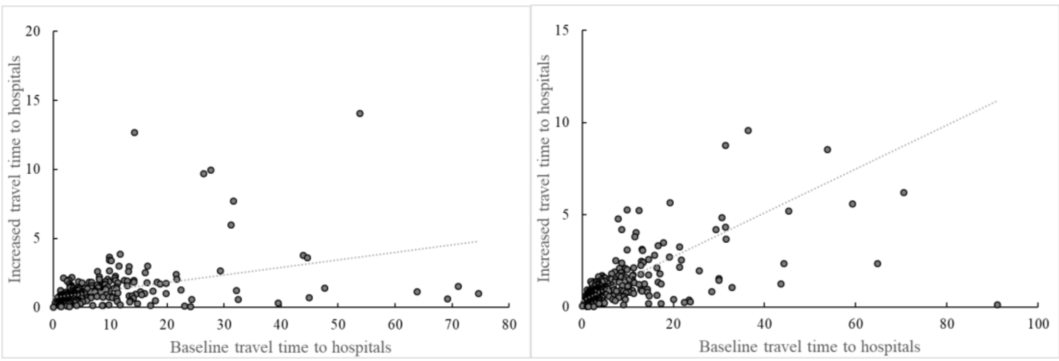
Response: We thank for reviewer’s comment. We have enlarged the font in the figures to make it clearer. The figure number changed in the revision of manuscript.



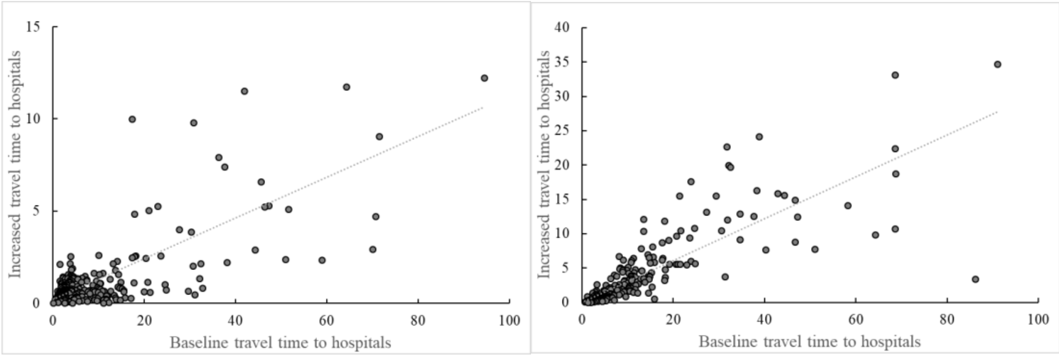
(a) (b)

(c) (d)

Figure 8. The correlation between the baseline EMS coverage rate of population and its reduction percentage in inclement weather. (a) 1st July, (b) 9th July, (c) 10th September, and (d) 16th December



(a) (b)



(c) (d)

Figure 10. The correlation between the baseline transfer time to hospitals and the increased transfer time in inclement weather. (a) 1st July, (b) 9th July, (c) 10th September, and (d) 16th December

9. Overall, the snowfall seems to have the greatest impact and it useful to highlight in key locations including the abstract and conclusions. This could be hinting at the fact that such a study is more of relevance to cities affected by snowfall.

Response: We thank for reviewer's comment. We have added that in abstract and conclusions in Lines 31-32, page 2 and Lines 460-461, page 24:

And snowfall has a greater impact on the accessibility of EMSs than rainfall.
Besides, snowfall has a greater impact on EMSs accessibility than rainfall.