Reply to Anonymous Referee #2

In this paper, the authors study observed extreme precipitation in the Loess Plateau in China, derived from 87 meteorological stations in the period 1961 to 2015. They find that while there was a decreasing trend in mean precipitation in general, the trend in extreme precipitation frequency, intensity, and severity was increasing in parts of the study area. They further find a correlation of extreme precipitation thresholds with soil erosion hazards that regularly happen in this area. They apply multifractal theory and a segmentation algorithm to derive thresholds of extreme precipitation, and state that this method is superior to non-parametric methods that use fixed absolute values or percentiles to define the extreme precipitation threshold. The structure of the paper and the language is clear.

Reply: Thank you very much for your favorite consideration and detailed suggestions. We have studied all the comments carefully and have made corrections. The responses below are the details of the plan to revise the manuscript.

This analysis in an area that is exposed to hazards related to extreme precipitation is certainly valuable. It further promotes an advanced statistical analysis method based on multifractal theory, that many potential readers are probably not familiar with, including myself. The presentation of the method is at some points confusing, and it has not become entirely clear to me what makes the multifractal method superior to the more common methods from reading the manuscript. I recommend that the authors could improve the manuscript in a major revision, by a better motivation and explanation of the analysis method, and by some additional analysis. In the following, I separate my comments into major and minor points.

Major points:

1. Many readers may be unfamiliar with the theory of multifractals, therefore I recommend to make the explanation in the Methods section somewhat more “didactial”. I understand that it is only possible to provide a very brief outline of the theory in the paper, but I think it might be possible to present the method in a way that allows readers to grasp the general idea, and make them aware of this new method. The more interested reader can then be drawn to book by Lovejoy and Schertzer.

Reply: The methodology was introduced in more details.

Here are some specific issues:

1a) Eq. (1): What would be L and l in this specific case of station measurements? Why is lambda the density of stations? I thought you apply the method to each station individually, so I would rather expect it is something like the measurement interval?

Reply: Thanks for your detailed comment. The λ is scale or resolution of the time series of observed precipitation. We mean that φ_λ is precipitation intensity at scale λ, i.e. accumulated rainfall depth. I am sorry for my mistake in brackets in Line 103. λ is indeed the measurement interval as you meant. Here, l is the number of the embedded time series at scale λ. For example, for a data series of daily precipitation with length of L = 1024 days, if we defined l = 128, then

λ=8, φ_λ is the maximum precipitation accumulated at 8 days.

The sentences were rewritten.

1b) I don't really understand what "singularity" means in this context. Could you give a simple explanation in your own words, if this is possible in a few sentences? Which values can gamma take?

Reply: The "singularity" means the maximum of precipitation in this paper, and generally, γ_s >0. It will be explained in detail in the revision of this manuscript.

1c) Eq. (3): Is q an integer defining the order of the moment?

Reply: Yes, it was explained in the Revision.

1d) Similar to 1b: Can you give some more explanation what the mulitfractal index alpha means? For example, what does it mean if alpha<1 versus alpha>1? In Eq. (4) and Eq. (6) it looks like that alpha is written with a "'" ("prime"). Is this a typo?

Reply: The multifractal index, α, quantifies the distance of the process from monofractality. When α = 0, the process is monofractal, whereas α = 2 means the divergence of data moments. For time series, 0 < α <1. According to universal multifractal by Tessier et al. (1994) and Lovejoy and Schertzer (2013), α' is the multifractal index related to α, $1/\alpha + 1/\alpha' = 1$.

These parameters were introduced in the Revision.

Lovejoy, S., Schertzer, D., 2013. The weather and Climate: emergent laws and multifractal cascades. Cambridge University Press.

Tessier, Y., Lovejoy, S., Schertzer, D., 1994. Multifractal analysis and simulation of the global meteorological network. Journal of applied meteorology, 33(12): 1572-1586.

1e) l. 135: Is the interval space d a parameter? How is it selected?

Reply: The parameter d is an interval that was used to gradually remove extremes in the EPT determining procedure, and the d was set 1 mm/d.

1f) Eq. (7): Define and explain mu_L, mu_R, s_D.

Reply: The parameters μ_L, μ_R, and s_D were defined.

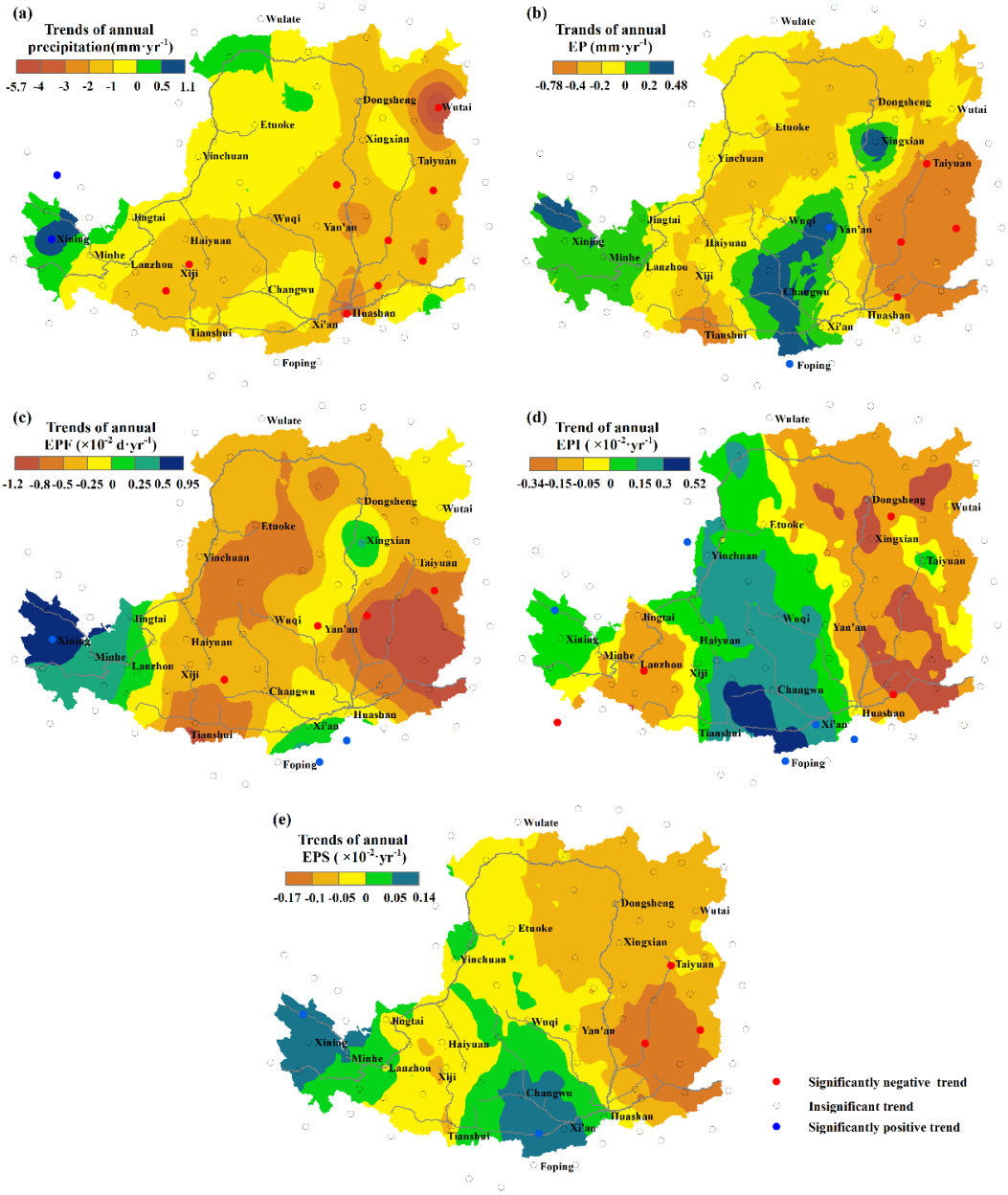
1g) Eq. (8): Should it be P(tau) instead of P(t) here? Otherwise I don't understand the meaning of this equation.

Reply: Yes, thanks for your careful work. The parameter was corrected as you noted.

2. The trend calculation in section 4.3 is certainly an important result of your paper. Therefore, I strongly recommend to perform significant tests for ALL indices shown in Fig. 4, including the mean precipitation. Why did you use significance level p<0.1 for EPI, and p<0.05 for EPS? It would be better to use the same significance level for all indices. It would also be good to mark regions with significant trends in all panels. One possibility would be to mark all stations with positive significant trends with blue dots, all stations with negative significant trends with red dots, and all stations with insignificant trends with black dots.

Reply: According to this comment, stations with significant trends were marked in Figure 4.

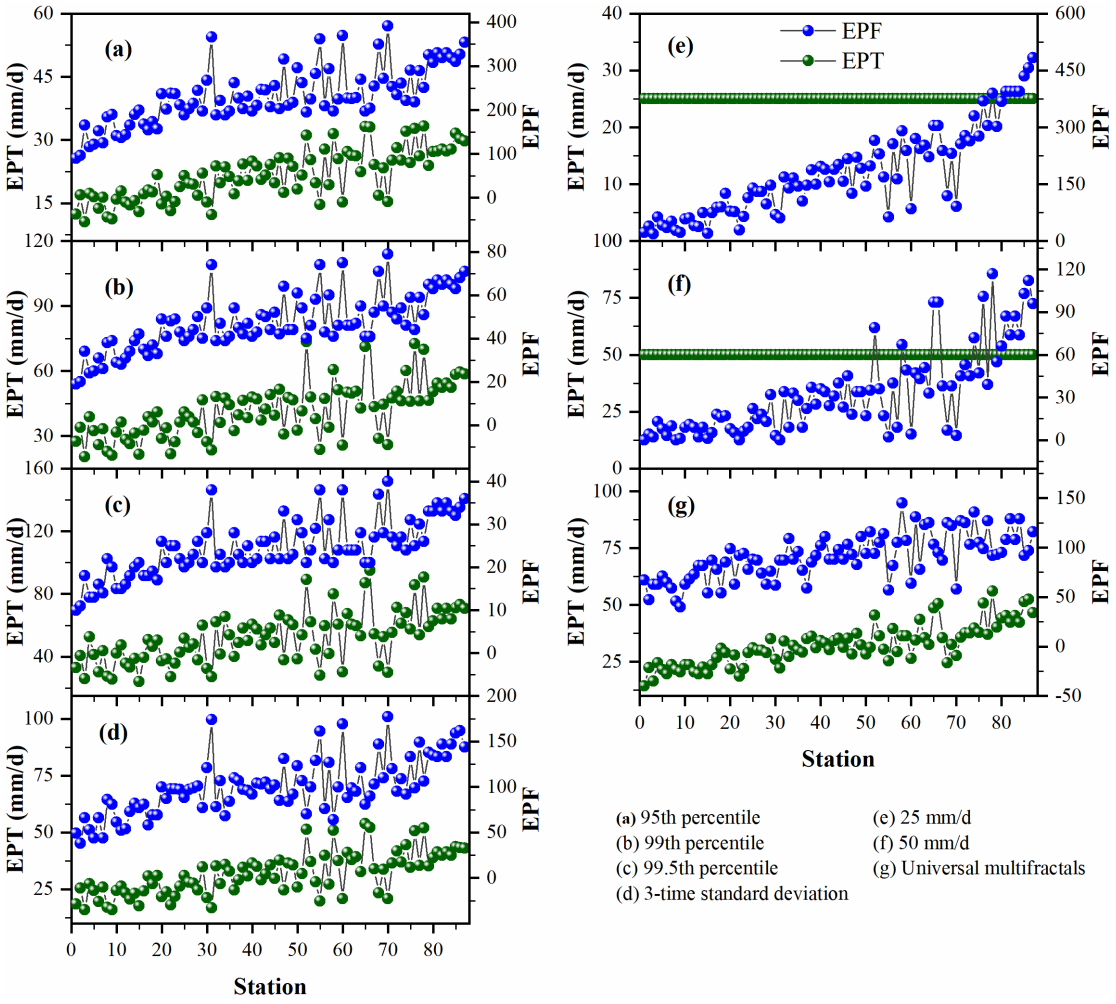
To show more stations with higher trends, the significance level of 0.1 was selected. The replotted Figure 4 is shown below



3. I think the claim that the mutifractional method is superior to the more common analysis methods it is not yet clearly justified. There should be a direct comparison of the non-parametric methods with the multifractal method, especially for the results shown in section 5.2. In Fig. 8, can you add a panel with the EPTs calculated from the multifractal method, and explain the differences to the others? The "standard deviation method" shown in panel 8f comes out of nowhere, please define it. It is not explained anywhere yet. Could you also show the goodness-of-fit numbers for the EP distributions from the multifractal results, and compare them to the non-parametric methods shown in Fig. 9? You could mark them in the panels in Fig. 9, or list them in a table.

Reply: A figure for EPT determined by multifractal method was added in Figure 8, as shown

below. The 3 times standard deviation method was briefly introduced. The goodness-of-fit of EP events determined by universal multifractals in individual stations show very high passing rates, 100%, as shown in the Table 1 below.



Tabel 1. Passing rates of goodness-of- fit test for EP events determined by universal multifractals method.

Function	K-S test (%)	A-D test (%)	C-S test (%)
Weibull	100	100	100
GPA	100	100	100
GEV	100	100	100
Gumbell	100	100	100
Exponential	100	100	100
Gamma	100	100	100

Minor points:

4. Definition of the EP indices (Section 2.3): The abundance of symbols is confusing here. The EP severity EPS is called EPSI in Table 1, Fig. 3f, and probably other places. Plase use the same acronyms everywhere. It is also confusing that EPI and EPT are called P_I and P_T, respectively, in Eq. (9). Better use EPI and EPT in Eq. (9). In Eq. (11), P_F is not defined. It is the same as EPF, I assume, so you can also better use EPF here.

Reply: Sorry for my carelessness. The acronym of EP severity was uniformly defined as EPS in the Revision. According to this comment, these parameters used in Eqs. (9) and (11) were replaced by their acronyms.

5. Eq (11): How sensitive are the results for EPS to the choice of k1 and k2? (See Fig. 3f, Fig. 4e)

Reply: The EPS is the combination of both EPF and EPI. Different values of k1 and k2 will result in different values of EPS in a pixel and hence the spatial variation of EPS. The values of k1 and k2 was set according to IPCC [2007].

6. l. 84/85: "For precipitation, a scaling break ... roughly two weeks." What does this sentence mean? Could you be more precise?

Reply: Studies of the scaling property of precipitation using multifractals showed that the scaling break of precipitation from one station does not always equal to those form the other stations around the world. Generally, the scaling break ranges from several days to about 1 month around the world, with an average about 2 weeks.

7. The index EP as shown in Fig. 4b is not given in Table 1. Or do you mean MEP here?

Reply: MEP is mean annual EP; it is used in spatial variation presentation. Figure 4b shows the trends of annual EP in spatial.

8. l. 236: "... the annual EPF changed by -0.6 to +0.5 days,..." Where are these numbers from? They are not given in the figure. Is this the totlt trend for the whole time series?

Reply: Yes, the “-0.6 to +0.5 days” were total changes of EPF over the past 55 years. These were calculated by multiplying slopes by years. The sentence was rewritten.

9. l. 273: "According to the average sea level pressure and winds at the 1000 hpa level..." This does not seem to make sense. Either you can give the air pressure at a given height level, or the geopotential height at a given pressure level.

Reply: Thanks for your suggestion. The sentence was rewritten.

10. l. 334/335: "It can be seen... lower percentiles". This seems trivial. Either remove this sentence, or write something like: "Trivially, thresholds are smaller...."

Reply: The sentence was rewritten as this comment suggested.

11. Figs. 3 and 4: Why are there different station names shown in different panels? For example, the Xiji station is mentioned in connection with panel 4e, but it is not shown in this panel. So one has to find it in one of the other panels.

Reply: These labels had been listed to describe the regions with different values or trends.

According to this comment, we have listed same station labels in all these figures.

12. The tropical cyclone situation shown in Fig. 6c and 6d: Do these maps show mean fields for the whole day, or an instantaneous situation?

Reply: Yes, these maps show mean fields for the whole day. This information was added.

Small corrections:

l. 19: "scarce" (instead of "scare")

Reply: The word was corrected.

l. 167: "1" should be subscript in "k1".

Reply: We corrected it.

l. 193: There is no Fig. 2b

Reply: The figure should be Fig. 2. We corrected it.

l. 194: Link is not accessible to me.

Reply: The website was changed to be http://data.cma.cn/. It was revised.

l. 255: "... and EPS had a negative *trend in* annual..." and in the following line "... LP area with negative *trend in* annual..."

Reply: Thanks. The sentences were corrected.

l. 332: "...parametric and non-parametric...

Reply: Sorry for my carelessness. The two words were corrected.