Editor Decision: Reconsider after major revisions (further review by editor and referees) (30 Apr 2018) by Piero Lionello

Comments to the Author:

Dear Authors,

Considering the comments of the reviewers and the online public discussion, your manuscript is returned to you for a major revision and it will be sent again to the reviewers.

You are required to provide

1) A revised version of the manuscript, where all changes are marked	The final version of manuscript was attached. All changes were explained in this file and were determined in the main article by using blue color.
2) An accompanying letter, where you explain point wise all changes that you have made to the text as response to the comments of the reviewers.	All changes were explained in this file and were determined in the main article by using blue color.
I anticipate that your replies to the comments of reviewer 1 are not convincing. The revised version of the introduction is not sufficient to responded to the reviewer's request for improving it, I cannot find in the text that you have tentatively uploaded the improved explanation of the overall goals of your study and the main new scientific findings are not sufficiently clear.	The introduction and main goal were rewritten. We hoped the changes have made the introduction suitable.
This negative comment applies also to the abstract, where you write that "The results of this study will be helpful for planning, designing, and management of hydraulic structures and water resources projects in the study area", without providing in it clear information to support this claim.	This sentence was mentioned just as a suggestion at the end of the abstract. Therefore it was deleted from the text and the abstract was rewritten. We hoped the changes have made the abstract suitable.
I find the uploaded text AC4 where you reply to reviewer 2 hard to be read, as line breaks are not used to separate the different comments. Please, take care to avoid this problem when providing the accompanying letter mentioned above in point 2).	We are sorry for this problem. Responses to reviewers are mentioned in this file.
In general, please make sure labels are readable when the figures are reduced to printed size. This is certainly the case for figure 1 included in AC4, that I do not understand whether you mean to insert in the main article or it is just provided as an answer to reviewer 2.	Figure 1 was redrawn. The attached figure in AC4 is just provided as an answer to reviewer 2, and it is not used in the main article.
Further add to your paper a large scale map showing the area of study, whose location would, otherwise, be unclear to readers not familiar with the geography of IRAN.	The new version of figure was added to text.

Looking forward to your revised version.

Piero Lionello

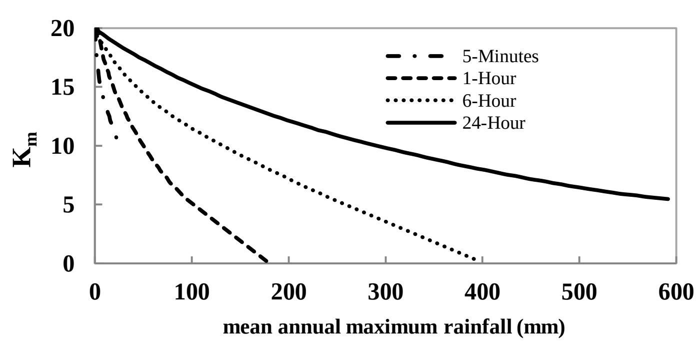
Probable Maximum Precipitation Estimation in a Humid Climate

The paper focuses on estimating and comparing Probable Maximum Precipitation (PMP) values from different statistical and physical methods. The statistical methods considered were Hershfield and Modified Hershfield methods, and the physical method used was the convergence method. The manuscript is interesting, and it deserves publication in the NHESS journal. However, the authors need to do a major revision to address some issues and to improve the paper in terms of organization, flow, content, and grammar.

The authors wish to thank the editors and reviewers for their time in effort in reviewing our manuscript. We hope the changes listed have made the manuscript suitable for publication and we look forward to your response.

Response to Reviewer 1:	
Major comments:	
The main paragraph in the introduction is considerably long and not clear about its message. It is also weak in terms of flow. Furthermore, the authors list a large number of studies; however, the strengths, deficiencies, and implications of the cited references to your work are not mentioned and how these findings are relevant to your work. The review of the literature should be presented in a way that the readers can understand what has been done related to the topic in the past and build the argument why your contribution is a valuable extension of the previous work. A one-line summary that may not be even relevant to your approach is not sufficient.	The text was revised and irrelevant citations were removed.
2) The overall goal of the study is not well defined. I suggest considering the following items in introducing the goals of this study: a. Do you claim that PMP calculations are not available in that region? Or you think that the current estimates need to be revisited? b. Furthermore, explain why you are estimating the PMP24 from both statistical and physical methods? c. Do you intend to compare the results obtained from the two and specify which is the better method? In any case, the authors should make their intentions of the study clearer. d. The authors also need to describe the statistical metric(s) and measure(s) which should be employed to identify the superior method.	a. There are many regions in various parts of the world for which PMP has never been estimated. Qareh Su basin is one of these regions. On the other hand, the accuracy, or reliability, of an estimate, fundamentally depends on the amount and quality of data available and the depth of analysis. Procedures for estimating PMP cannot be standardized. They vary with the amount and quality of data available, basin size and location, basin and regional topography, storm types producing extreme precipitation, and climate (WMO, 2009). b. In some cases, it is appropriate to make parallel estimates using more than one method, followed by comprehensive analysis in order to acquire reasonable PMP estimates. Therefore, the aim of this study is the estimation of PMP by using two main methods such as statistical methods and physical methods. c. The results of the statistical method are affected by maximum annual 24-h precipitation, while the results of the physical method are affected by dew point temperature, wind speed and direction, air pressure, and precipitation. Because of the results of both method are affected by different factors, comparison of two methods are not investigated. Also, the results of statistical method are point PMP, while physical method provided the areal PMP. Nevertheless, performance criteria were used to a brief comparison. d. Performance criteria as a new section were added to manuscript. The result of them was added to results and discussion.
3) The methodology section is very brief. More detailed explanation of the methods and equations are required in order to allow the reproducibility of the implemented approaches. Furthermore, the purpose of some of the equations and calculations is not described and the reader could not understand how they contribute to the overall estimation approach. The general flow of the methodology section also needs to be improved.	The required description was added to the text.
4) The results section must highlight the main findings from each figure and table.	Due to changes in the results and discussion section, we hope the manuscript suitable.
Minor comments:	
P3L2: This is more suitable for the beginning of the introduction.	This sentence was moved to the first section of the manuscript.
P3L11: How is that basin important? Is it important in terms of water supply? Or it has geopolitical importance?	Qareh-Su basin is located in Golestan province in the northern parts of Iran with a

	humid climate. The Qareh-Su basin, with nearly 1760 km2 area is one of the most important basins in the north of Iran. This area is important from the viewpoint of the existence of different cities and villages, population densities, industrial and agricultural centers, flood, and watershed management schemes. 8% of the surface water (equal to 100 million cubic meters) in Golestan province is derived from the Qareh-Su basin. There are two main dams including Kowsar and Shast kalateh to supply water demand of agricultural and residential land located in this area. Also, it is one of the most flood-prone areas that has suffered severe floods throughout its long history, so that in recent years, many people have died in destructive floods. Over the period 1951–2013, the annual average precipitation in this basin is 596 mm.
Figure 1: What are the "+" signs in the map? It should be mentioned in the legend. Also, Include the map of Iran, in a larger regional context, in the corner of this figure and demonstrate the location of this basin. Additionally, mention the elevation unit beside "DEM". The "d" letter in the legend is overlapped with the basin boundaries.	The "+" signs in the map were used as a grid of ticks. The newer version of Figure 1 already added to the manuscript.
P3L13: For which period? Last 30 years?	Over the period 1951–2013, The annual average precipitation in this basin is 596 mm.
P3L14: Air pressure? Vapor pressure? Saturated vapor pressure?	It was air pressure. It was revised.
P2L13: Are these climatological data taken from the only synoptic station available in your study? If so, please mention it.	The required data such as air temperature and rainfall were taken from available climatological, hydrometric (Rain gauge station) and synoptic stations in the study area, but dew point temperature data was taken from an available synoptic station in the study area which is called Gorgan station.
P3L14: The sampling frequency and the calculation time-steps should be mentioned. For instance, whether the stations provide hourly values? Or daily? Or for the wind speed data, in what elevation is the wind speed measured? 10m or 2m? It would be good to present this information in a table.	Required information was added to the text.
Table 1: Also mention the average annual precipitation in each of these stations.	The average annual precipitation in each of these stations was added to the manuscript.
P4L2: Do you mean the "Annual maximum series"? Does it also work with the "Peak Over Threshold" extreme series?	It means maximum depth of 24-hour precipitation in each year.
P4L2: What does this frequency factor mean?	K_m is then the number of standard deviations to be added to obtain PMP.
P4L3: Are the "Km" values from the chart method based only on the average extreme value and duration? Are the charts similar for the eastern and western US?	According to (WMO, 2009, page 65, Figure 4.1), Km was shown as a function of rainfall duration and mean of annual series (Hershfield, 1965). Yes.
P4L5: Do you mean "The United States"?	Yes. This was revised in manuscript.
P4L5: Why did they modify it? What was wrong with the original approach?	The original approach was not wrong. It was first thought that K_m was independent of rainfall magnitude, but it was later found to vary inversely with rainfall: the value of 15 may be too high for areas of generally heavy rainfall and too low for arid areas." Because of the study area is a wet area, the value of K_m for wet areas is too high, and therefore revised approach was used to obtain the appropriate value of K_m. In order to calculate the K_m, the equation 2 was used. Then the maximum value of K_m was considered as $K_{m\text{-envelope}}$ and was used to calculation of PMP_{24}. The K_m values in standard approach were obtained from Equation 5, based on 24-h K_m chart (WMO, 2009; Hershfield, 1965). These curves obtained from 2700 stations over the USA, while in revised approach, frequency factor was obtained from observed rainfall over the study area and stations. The frequency factor in revised approach is more reasonable, for it was obtained based on real occurred rainfall over the study area and the result of corresponding PMP is closer to real occurred rainfall over the study area. Reduction of K_m in revised approach is not a reason to refuse standard approach; this shows that the standard approach estimates the PMP with more caution while estimating appropriate value of K_m is leading to decrease the cost of structures that affected by PMP.
P4L2-L5: The sentence is too long. Also needs grammar revisit.	The sentence was revised.

<table>
<tr><td></td><td>K_m is frequency factor as a function of duration and average of annual maximum rainfall (the maximum depth of 24-hour precipitation in each year). In other words, K_m is then the number of standard deviations to be added to obtain PMP. In this approach, K_m is calculated by K_m charts which were extracted based on records of rainfall from around 2700 stations in the climatological observation of the United States of America (WMO, 2009).</td></tr>
<tr><td>P4L7-L10: It turns out that only the first equation is used! What is the second equation then used for?</td><td>The second approach is based on the first approach theory. The main difference between these approaches is K_m. in the first approach; K_m was obtained from the empirical chart, while in the second approach K_m is obtained from the actual rainfall in each station and considers the maximum value of K_m as a regional value of K_m for all stations.</td></tr>
<tr><td>P4L7: Is the Xmax, a single value? Is it the grand maximum, or a time series?</td><td>X_{max} is a single value for each station and it is maximum depth of rainfall in period of 1951-2014.</td></tr>
<tr><td>P4L12: What are the differences between these methods? Why did you choose the “convergence” method?</td><td>The best and the most reliable procedure to estimate the PMP is usually the physical method, which is divided into two procedures, i.e., the orographic and convergence models. The convergence model is used for PMP estimate in Mid-Latitude regions. It is based on the physical characteristics of storms. In convergence model storm physical features such as moist and warm air and movement of moist and warm air, on the basis of dew point temperature and wind speed and wind direction of any storm should be considered.</td></tr>
<tr><td>P4L18: Did you also consider the discharge data? If so, mentioned it in the data section. If not, how did you estimate the maximum discharge?</td><td>Yes. Maximum 24-hours rainfall data was used to determine the date of occurrence the most severe and widespread storms. Then the maximum daily and instant discharge data were used to ensure the date of occurrence storms by comparing Maximum 24-hours rainfall data and maximum daily and instant discharge data. Because of discharge data and rainfall data have a close correlation.</td></tr>
<tr><td>P4L21: What is the purpose of doing “Moisture maximization” and “Wind Maximization”? Are they parts of the convergence model? Or they are different PMP calculation methods? From section 2.3 it turns out to be so; however, it seems to be a different PMP estimation method according to P4L23.</td><td>You are right. This is typo mistake. It was revised as “The storm maximization factor is calculated by the moisture maximization factor multiplied by wind maximization factor. The moisture maximization method is one of the acceptable procedures to maximize the rainfall values associated with severe storms (Rakhecha and singh, 2009).”</td></tr>
<tr><td>P5L1-L14: How are the FM and MW used? It is not clear from the text that why they are calculated?</td><td>Finally, PMP id determined by the precipitation depth R (found using DAD curves) multiplied by moisture maximization and wind maximization factors based on Eq. (5).
$$PMP = FM \times MW \times R$$</td></tr>
<tr><td>P5L21: How was this equation calculated? If this is a polynomial function fitted to the point data, it needs to be shown.</td><td>In this study, the equation of each curve was extracted based on R^2. Extracted equation are mentioned below:


K_m charts that were extracted by authors</td></tr>
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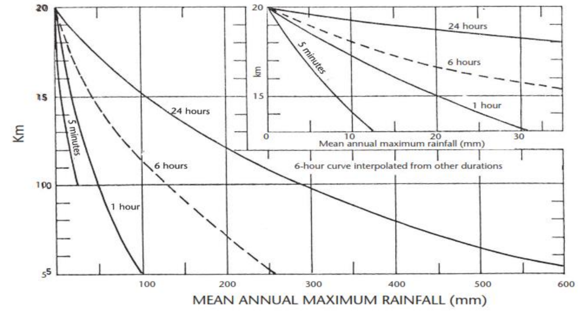
<td>


K_m charts (WMO, 2009)

Equations of frequency factor (K_m) that were extracted by authors

<table>
<tr><th>Duration</th><th>Equation</th><th>(R^2)</th></tr>
<tr><td>5-Minutes</td><td>$K_m = -0.0008 \times x^3 + 0.0414 \times x^2 - 0.8951x + 19.214$</td><td>0.9896</td></tr>
<tr><td>1-Hour</td><td>$K_m = -5 \times 10^{-6} \times x^3 + 0.0017 \times x^2 - 0.2744x + 19.825$</td><td>0.9987</td></tr>
<tr><td>6-Hour</td><td>$K_m = -4 \times 10^{-7} \times x^3 + 0.0003 \times x^2 - 0.1029x + 19.172$</td><td>0.9984</td></tr>
<tr><td>24-Hour</td><td>$K_m = -5 \times 10^{-8} x^3 + 8 \times 10^{-5} x^2 - 0.052x + 19.794$</td><td>0.9998</td></tr>
</table>
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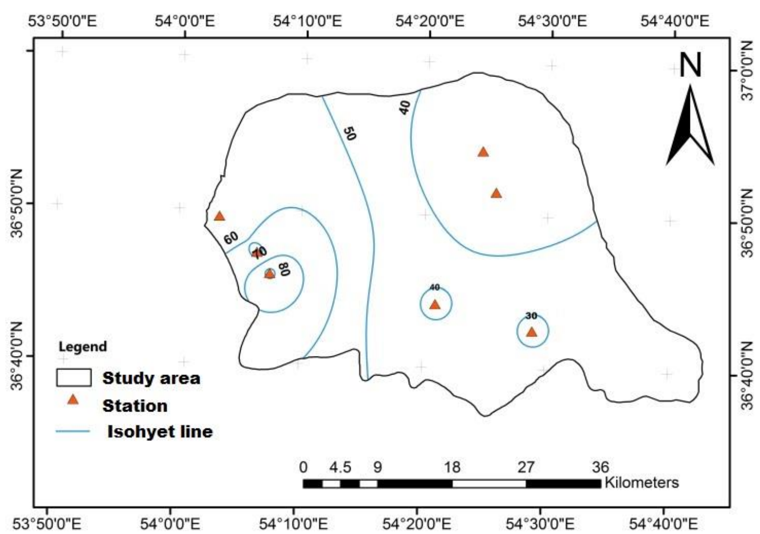
<tr>
<td>P5L26: The application seems to be of limited use for other regions given the fact that information from limited gauges in one basin is considered in its development.</td>
<td>This application can be used in each region. It can calculate PMP by the standard and revised approaches in each region without any limitation.</td>
</tr>
<tr>
<td>P6L1: What are the summary of findings from Table 2? What are the differences and what are the sources?</td>
<td>Required description was added to the text in line 14-18 (Page 6).</td>
</tr>
<tr>
<td>P6L1: Km values and PMP24 values from the standard and modified approaches are considerably different. Which one is more accurate? How is the better approach determined?</td>
<td>Required description was added to the text in line 1-2 and 5-6 (Page 7).
Even based on performance criteria including MAE, MSE, RMSE, MAPE, r, and R^2, physical method is more accurate than statistical method and revised approach is better than standard approach. Corresponding values of these performance criteria are mentioned below:
Statistical comparison between $(P_{24})_{max}$ and estimated PMP_{24} values
<table>
<tr><th>Method</th><th>MAE</th><th>MSE</th><th>RMSE</th><th>MAPE</th><th>r</th><th>R^2</th></tr>
<tr><td>Standard</td><td>258.2</td><td>69090.5</td><td>262.9</td><td>241.7</td><td>0.8</td><td>0.63</td></tr>
<tr><td>Revised</td><td>64.36</td><td>4311</td><td>65.7</td><td>61.2</td><td>0.9</td><td>0.86</td></tr>
<tr><td>Physical</td><td>7.1</td><td>50.4</td><td>7.1</td><td>4.7</td><td>-</td><td>-</td></tr>
</table>
</td>
</tr>
<tr>
<td>P6L2: The isohyetal maps also show significant differences between the PMP24s. How do you discuss and justify this issue?</td>
<td>Spatial distribution of PMP in standard approach is affected by Km values. After modification of Km by using the maximum of 24 hours precipitation, the spatial distribution of PMP was drawn.</td>
</tr>
<tr>
<td>P6L6: How did you characterize these storms? What measures did you consider in selecting these 8 storms?</td>
<td>First observed rainfall data during 1981-2013 was sorted descending and all observed rainfalls that have the higher depth than Mean 24-hour precipitation was selected. Then the top 8 observed rainfalls are selected so that the Mean 24-hour precipitation depths of 24-hour rainfall in all stations are higher than Mean 24-hour precipitation. Then the date of each storm was checked by maximum daily and instant discharge data. It should be noted that the criteria used for selection of the rainstorms are mostly based on the severity of the storms.</td>
</tr>
<tr>
<td>Table 3: How many days did each of these storms last?</td>
<td>Due to the aim of study that is the calculation of 24-hour PMP, the duration of all storms is 24-hours.</td>
</tr>
<tr>
<td>P6L9: What interpolation method has been used to generate Figure 4?</td>
<td>In order to show the spatial distribution of precipitation, the precipitation gradient versus elevation was investigated. In each storm that the gradient of precipitation versus the elevation was significant, the isohyet maps were drawn in ArcGIS software using the Digital Elevation Model (DEM) and the gradient of the precipitation equation, otherwise, the IDW (Inverse Distance Weighted) method would be used. In DAD curves, the areas bounded by isohyet lines were calculated by GIS.</td>
</tr>
<tr>
<td>P6L13: What do you understand from table 4 and table 5?</td>
<td>The steps of physical PMP estimation are mentioned in table 4 & 5. Dew point was</td>
</tr>
</table>

	considered as the moisture inflow into storms. Therefore, Maximum persisting 12-hr dew point was used to calculate the moisture maximization factor. Maximum persisting 12-hr wind speed was used to approximate wind maximization factor and precipitation efficiency. Then the storm maximization factor was calculated by using the moisture maximization factor and wind maximization factor in table 4. In table 5, physical PMP was calculated by using average rainfall and storm maximization factor (PMP Factor) for each storm.
P7L4: This section is supposed to discuss the physical method. Discussion ion the statistical method should go to section 3.1.	Discussions were transferred to section 3.1.
P7L4: For the physical method, is there only one PMP value for the whole basin? Why the physical method gives a different value for each storm, but the statistical method gives one fixed value for the entire period?	Yes, the result of the physical method is areal PMP (this is an average PMP value for the study area), while the results of statistical methods are point PMP (a particular value for each station). In physical method, each storm is representative of the severest storm that is possible leads to PMP.
P8L14: You compared two statistical methods and the results showed that they lead to considerably different PMP estimates. You did not make any comparison between the different physical methods to show how their results would compare.	There are two main methods to estimate PMP including physical method & statistical method. Among all statistical methods, Hershfield method is more common and convenient that has two standards and modified approaches. Manual of WMO has recommended this method for PMP values in particular regions that long-term rainfall data are available (WMO). Also, the best and the most reliable procedure to estimate the PMP is usually the physical method that was investigated in this study. It is necessary mentioned that physical method (convergence model) was selected based on geographical characteristics of the study area which is more applicable in this area.
P8L15: Why the statistical method gives different PMP values for different locations; however, the physical method gives a single value for the whole basin. It turns out that the PMP values from the statistical method change only in space dimension, but those from the physical method change only in the time dimension.	The results of statistical method are based on rainfall in each station that is related to mean and standard deviation 24-hour rainfall, and Km. So that the result of the statistical method for each station in a basin is different. While the results of physical method are based on physical characteristics of storm that effect on an extensive area.

Thank you again for your time and effort and for helping us to improve the manuscript.

Response to Reviewer:

<table>
<tr><td colspan="2">Reviewer 2</td></tr>
<tr><td>P1L12: At first, define the variable and then use the abbreviation (e.g. frequency factor; K_m).</td><td>Required description was added to the text.</td></tr>
<tr><td>P2L14-17: Too many citations..., without commenting their research
Improve the syntax of the sentence.</td><td>This sentence was corrected.
The sentence was corrected.</td></tr>
<tr><td>P3L16: ... of 33 years ranging from ...</td><td>It was corrected.</td></tr>
<tr><td>P4L4&5: Improve the syntax of the sentence.</td><td>It was corrected.</td></tr>
<tr><td>P5L22: Previously, you have mentioned that Km is replaced by $K_{envelope}$ value. Now you use equation 5.Please clarify this point.</td><td>It was first thought that K_m was independent of rainfall magnitude, but it was later found to vary inversely with rainfall: the value of 15 may be too high for areas of generally heavy rainfall and too low for arid areas.” Because of the study area is a wet area, the value of K_m for wet areas is too high, and therefore revised approach was used to obtain the appropriate value of K_m. In order to calculate the K_m, the equation 2 was used. Then the maximum value of K_m was considered as $K_{m\text{-}envelope}$ and was used to calculation of PMP_{24}. The K_m values in standard approach were obtained from Equation 5, based on 24-h K_m chart (WMO, 2009; Hershfield, 1965). These curves obtained from 2700 stations over the USA, while in revised approach, frequency factor was obtained from observed rainfall over the study area and stations. The frequency factor in revised approach is more reasonable, for it was obtained based on real occurred rainfall over the study area and the result of corresponding PMP is closer to real occurred rainfall over the study area. Reduction of K_m in revised approach is not a reason to refuse standard approach; this shows that the standard approach estimates the PMP with more caution while estimating appropriate value of K_m is leading to decrease the cost of structures that affected by PMP.</td></tr>
<tr><td>P6L2: Discuss the differences between the two approaches.</td><td>The second approach is based on the first approach theory. The main difference between these approaches is K_m. in the first approach; K_m was obtained from the empirical chart, while in the second approach K_m is obtained from the actual rainfall in each station and considers the maximum value of K_m as a regional value of K_m for all stations.</td></tr>
<tr><td>P6Section3-2: The authors should provide the Spatial distribution of rainfall PMP24 based on physical method, as they have done regarding the other two statistical procedures.</td><td>The spatial distribution of PMP_{24} based on physical method was followed by the Spatial distribution of storm that occurred at 10/29/1993. Also, physical PMP result is an average depth for basin. Figure shows the spatial distribution of storm 10/29/1993.


</td></tr>
<tr><td>P8L1: Improve the syntax of the sentence.</td><td>The sentence was revised.</td></tr>
<tr><td>P8L1-6: This a repetition found also in section "Material and Methods"</td><td>The sentence was revised.</td></tr>
<tr><td>P8L23: The authors should provide statistical metrics such as R2, RMSE, MAE and probability of detection (POD), false alarm ratio (FAR) and critical success index (CSI). These metrics are important to verify the results obtained by the two applied procedures.</td><td>Common criteria for rainfall such as (MAE, MSE, RMSE, MAPE, r, and R^2 was added to the text. Other criteria were not used because it was used for radar-based rainfall. Even based on performance criteria including MAD, MSE, RMSE, MAPE, R, and R2, physical method is more accurate than statistical method and revised approach is better</td></tr>
</table>

	than standard approach. Corresponding values of these performance criteria are mentioned below:

Statistical comparison between $(P_{24})_{max}$ and average estimated PMP_{24} values

Method	MAE	MSE	RMSE	MAPE	r	R^2
Standard	258.2	69090.5	262.9	241.7	0.8	0.63
Revised	64.36	4311	65.7	61.2	0.9	0.86
Physical	7.1	50.4	7.1	4.7	-	-

Thank you again for your time and effort and for helping us to improve the manuscript.