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Interactive comment

Interactive comment on "High resolution global grids of revised Priestley-Taylor and Hargreaves-Samani coefficients for assessing ASCE-standardized reference crop evapotranspiration and solar radiation" *by* Vassilis G. Aschonitis et al.

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Comment R1.1: I appreciate the Editor to give me a chance to review an interesting and valuable paper. I found some merits in the both methodology and results. In my opinion, this paper has a good potential to be published in the journal. However, I have also some concerns on the different parts of the manuscript. If only the author(s) address carefully to all of my comments, I'll recommend publication of the manuscript

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Discussion paper

in the journal.

Response: We would like to thank the reviewer for the constructive comments. We followed his suggestions for improving the manuscript. Our responses to specific comments are given below. We also suggest the reviewer to check carefully the responses to the comments of Reviewer 2, since his suggestions led to substantial changes in the manuscript.

Comment R1.2: What was the criterion to select the stations? Why the USA and Australia? Are they covering all climates?

Response: The reasons for choosing the CIMIS-database of California (USA) and AGBM database of Australia are: - The first database includes stations from California-USA and it was selected because: a) it has been used as a basis for the development of Hargreaves-Samani method (Hargreaves and Samani, 1985; Hargreaves and Allen, 2002) and CIMIS method (Snyder and Pruitt, 1985, Snyder and Pruitt, 1992) and b) provides a dense and descriptive network of stations for a specific region that combines coastal, plain, mountain and desert environments (Table 1, Fig.1a in the manuscript). The second database includes stations from Australia and it was selected because the stations network covers a large territory with large variety of climate classes (Table 1, Fig.1b in the manuscript), but also because the Priestley-Taylor method has been calibrated for locations of eastern Australia (Priestley and Taylor, 1972). For the stations of AGBM database, the selection of stations was performed in such way in order to cover all the possible existing Köppen climatic types and elevation ranges of Australian continent (Table 1 in the manuscript). (see text in Page 9, lines 25-35, Page 10, lines 0-5)

- Additional reason for choosing these two databases was that they provide a large number of stations with complete data for estimating ASCE-ETo covering large observation periods before and after the year 2000 (Table 1 in the manuscript). This was a prerequisite in this study because the rasters of the new coefficients were developed based on mean monthly climatic parameters of 1950-2000. Thus, using stations with many available data after 2000, we could prove that the derived coefficients also work for current conditions. (see text in Page 10, lines 8-10)

- We have to mention that the combination of the databases provided a wide range of the mean monthly values of the parameters used for the ETo estimations (this is an additional reason for their selection). The general statistics of the aforementioned parameters are also given in Table R1 below, which was included in the supplementary material as Table S1 (reference for Table S1 exist in the text in Page 10, line 24). In order to show the high variability in the parameters of the validation dataset, we provide frequency diagrams of mean monthly Tmax, Tmin, Rs, RH%, u2 and P are given below in Fig.R1a,b,c,d,e,f, respectively.

- Taking into account the last column of Table 1 (Köppen-Geiger classification), we provided the climatic classification of each station. According to Table 1, from the 140 stations, 9 belong to A Köppen-Geiger group (tropical/megathermal), 69 to B group (Arid/semi-arid), 59 to C group (temperate/mesothermal) and 3 to D group (continental/microthermal). We believe, that apart from the D group, the number of stations for the rest climatic groups are enough for validating the results. As concern the D group, we couldn't find more stations with adequate data inside the aforementioned databases. Other databases, which may provide data for stations from other parts of the world, were not used in order to fully exploit the two aforementioned databases but also to give the opportunity to other scientists to test our revised coefficients for their territories using other complete databases and not selected stations from various databases. Many existing databases of observed data may show differences in the methods used for measuring and presenting data. Such differences were also observed in the CIMIS and AGBM databases and they were used to justify many uncertainties observed during the implementation of this work (see response to comment R2.3 of reviewer 2 and the new section in the discussion with title "Uncertainties in the data used for calibrating and validating the revised coefficients of P-T and H-S methods". It would be difficult to identify such uncertainties using stations from multiple databases.

Table R1. General statistics* of the mean monthly observed values of climatic parameters from the 140 stations of California-USA and Australia that participate in the estimation of reference evapotranspiration with the ASCE method.

[TABLE R1, PLACE HERE]

*The statistics are based on 1680 values (140 stations × 12 months)

Fig.R1 Frequency diagrams (number of monthly values) based on the mean monthly data of the 140 stations of CA-USA and Australia for a) maximum temperature Tmax, b) minimum temperature Tmin, c) solar radiation Rs, d) relative humidity RH, e) wind speed u2 at 2 m height and f) precipitation P. The frequencies are based on a total number of observations equal to 1680 (140 stations × 12 months).

[FIGURE R1, PLACE HERE]

Comment R1.3: Lns 7-8, cite also these three useful papers to enhance the literature: - Selecting the best model to estimate potential evapotranspiration with respect to climate change and magnitudes of extreme events. - Temporal analysis of reference evapotranspiration to detect variation factors. - Analysis of potential evapotranspiration using limited weather data.

Response: The proposed citations were added at the proposed locations in the text and in the references list.

Comment R1.4: Lns 15-16, cite also these two useful papers to enhance the literature: - Application of new mass transfer formulae for computation of evapotranspiration - Ability of Box-Jenkins Models to Estimate of Reference Potential Evapotranspiration (A Case Study: Mehrabad Synoptic Station, Tehran, Iran)

Response: The proposed citations were added at the proposed locations in the text and in the references list.

Comment R1.5: In the last paragraph of the Introduction, the authors should clearly mention the weakness point of former works (identification of the gaps) and describe the novelties of the current investigation to justify us the paper deserves to be published in this journal.

Response: The most significant novelty of the study is that provides, for the first time, global maps of revised coefficients for the P-T and H-S evapotranspiration methods and revised coefficients for the H-S radiation formula. Such attempt has never been made in the past at the global scale, despite the fact that many studies for recalibrating the respective coefficients have been presented for many parts of the world. The final maps allow the comparison of the revised coefficients among regions under a common base since they were built using common datasets and using the same technique (Eqs.7), while they provide a global overview of the variation in these coefficients. Other novelties of the study are: âĂć the development of global maps for the revised coefficients for P-T and H-S evapotranspiration methods for tall reference crop. âĂć the development of global maps for the possible mean annual error, when the P-T and H-S are applied using the standard coefficients of the original methods (maps of MAD% parameter, Fig.4b,c,d in the manuscript). These maps provide information about the uncertainty when the standard H-S and P-T methods are used. These maps were also combined to derive a new map (map of DMAD parameter, Fig.5a in the manuscript), which indentifies the optimum locations for the application of the standard H-S and P-T formulas based on their proximity to the results of ASCE for short reference crop. The DMAD map is an important tool, which can give a solution when someone has to choose between the two methods. âĂć the proposal of a method for deriving annual coefficients for the P-T and H-S methods. The procedure described by the set of Eqs.7, which estimates the partial weighted averages of the coefficients based on their monthly values, is a newly proposed method that can be easily applied in GIS environment, while it provides a solution when annual coefficients have to be derived under a common base for many stations or for global applications using raster data. This technique is proposed as an alternative of optimization methods, which are difficult to be incorporated in GIS environment (see more details about this comment in Page 18, lines 13-24 and the respective subsection of the discussion). The method calibrates the basic coefficients without modifying or adding parameters in the original P-T and H-S equations. Finally, we have to stress that the aim of the study is to provide tools for facilitating the estimation of ETo and solar radiation for regions (especially those of developing countries), which face serious shortage of climatic data and not to propose the revised coefficients as an alternative method for regions, which have complete meteorological stations that provide detailed sets of all climatic variables. Of course, the use of such stations to validate the coefficients is the only solution. All the aforementioned aspects related to the novelties and the aims of the study are included in brief in the revised paragraph at the end of the introduction.

Comment R1.6: Compare the results with modified/calibrated H-S and P-T models presented by other researchers in all of the world (particularly in the USA and Australia).

Response: The requested task is quite difficult and there are many problems of comparability since either the majority of authors have modified the initial form of H-S and P-T models and not only the main coefficients, but also because the majority of the works provide H-S and P-T models, which are calibrated for regions outside California and Australia. For example, the popular recalibrated Priestley-Taylor model of Abtew (1996) for Florida-USA uses a recalibrated coefficient equal to 1.18, which is almost equal to our revised coefficient (1.17 from 0.5 degree resolution), but the model gives bad results in the validation procedure because Florida has a completely different environment from California and cannot cover the climatic variation of Australia stations. Other examples are the modified Makking model and other models given by Castañeda and Rao (2005), which were calibrated only for one station of southern California using 4 years of observations and the modified Hargreaves-Samani models and other models of Azhar and Perera (2011), which were recalibrated for three stations of southeastern

Australia with very few years of observations. Similar problems were observed for too many other cases that we examined using a large list of models provided by Valipour (2015a,b; 2017) and Valipour et al. (2017) and by models obtained from the works cited in the introduction. Thus, it is unfair to examine the accuracy of such models using the complete validation dataset (both California and Australian stations), while it is not feasible in the context of this article to examine one by one all the modified models published in the international literature. Of course, the analysis of modified H-S and P-T models calibrated for other parts of the world was rejected from the beginning because the validation dataset does not include stations from these regions. The only models, which are absolutely comparable are the modified H-S models by Droogers and Allen (2002) because they have been calibrated using global datasets. In order to partly satisfy the request of the reviewer, we selected some models of reduced parameters, which have similar or additional requirements from the standard H-S and P-T models. The final selected models were also those who showed a) the best performance after examining an extremely large list of models using both California-USA and Australia stations data and b) a good performance to other studies using other datasets. The comparison with such models will also contribute to verify the value of our coefficients as alternative options for ETo estimations with fewer variables. Based on the aforementioned observations, the following 8 models were selected for comparisons with the standard and re-adjusted H-S and P-T models: 1. Two modified models of H-S by Droogers and Allen (2002) where the second one uses precipitation as additional parameter. The models were based on calibrations using global data. 2. Three models of reduced parameters given by Valiantzas (2013a,b; 2014) that were calibrated using 535 stations from Europe, Asia, Africa. The first model uses temperature and radiation data, while the other two use temperature, radiation, and humidity data. The models have been tested for California (Valiantzas, 2013c) and Australia conditions (Ahooghalandari et al., 2017). 3. Two models of reduced parameters by Ahooghalandari et al. (2016) calibrated using 18 stations from various locations of Australia. The models use temperature and relative humidity data. Ahooghalandari et al. (2017) also made recalibration of Valiantzas equations and other models but for a restricted region of Western Australia considering 8 stations, and for this reason these modified versions were not used. 4. The Copais model of Alexandris et al. (2006) that uses temperature, radiation and humidity data. The model was calibrated/validated using data from Greece, California and Oregon-USA, while it has shown a very good response to many other regions of the world including Australia (Ahooghalandari et al., 2017). The aforementioned observations and the description of the additional models used for comparisons were added as a new paragraph in the page 10 (lines 32-35) and 11 (lines 0-25) together with the new Table 2, which gives the equations of the additional models. The results of the models were added in Page 14 (lines 25-35), and 15 (lines 0-15). The comparisons of the models were included in new Fig.8 and their statistics in the new Table 5.

Comment R1.7: The Discussion section should be broken to sub-sections for better understanding of readers.

Response: we followed the suggestion of the reviewer and the discussion section was broken to sub-sections.

Comment R1.8: Explain the variations of the spatial extent of the major climatic groups CGs from Köppen-Geiger climate map.

Response: The variations of the spatial extent of the major climatic groups CGs from Köppen-Geiger climate map, which are given in the first column of Table 4 in the revised manuscript, are results obtained from the respective raster Köppen-Geiger climate map of Peel et al. (2007) and they are described in detailed in their article. We believe that is beyond the scope of the paper to discuss the observed % of CGs in the map of Peel et al. (2007) (keep in mind that % values are re-adjusted after excluding Antarctica and they are slightly different from those given by Peel). If the reviewer means to explain the results of the other columns of new Table 4 (i.e. why for example the typical H-S method is better from the typical P-T method in more arid environments or why P-T is better in more humid environments) the explanation is based on the fact that the standard H-S method was calibrated for the conditions of California, which include arid and semi-arid environments, while the standard coefficient 1.26 of Priestley-Taylor method was obtained based on experiments of more humid environments. This justification was added in the text (see Page 13, lines 8-11).

Comment R1.9: Discuss the comparison of the average and standard deviation of RMSEs of the validation dataset between different pixel Resolutions more thoroughly.

Response: The comparison between different pixel resolutions was removed based on the objections of Reviewer 2. Reviewer 2 suggested not to use the resolutions below 0.5 degree due to interpolation limitations in the initial raster data for solar radiation, humidity and wind speed, which were at 0.5 degree. See comments of Reviewer 2. All the manuscript was revised from the beginning using only the results of 0.5 degree resolution.

Comment R1.10: What are the strategies/recommendations to reduce uncertainties in this study?

Response: a new subsection was added in the Discussion. See the new subsection with title "Recommendations for reducing the uncertainties when the re-adjusted coefficients of P-T and H-S models are used".

Comment R1.11: At the end of the manuscript, explain the implications and future works considering the outputs of current study.

Response: we added new text about it (see the last paragraph in the Conclusions section)

Comment R1.12: The quality of the language needs to improve by a native English speaker for grammatically style and word use.

Response: We examined carefully the language, and English corrections were made with the help of native English speaker.

Other major corrections made in the text: 1. Some affiliations changed because some authors were transferred to other institutions or because one of the Institutions changed name. 2. The abstract reformed in order to be more descriptive. 3. Any analysis related to finer resolutions below 0.5 degrees was removed from the text following the comments of reviewer 2. For this reason, the 30 arc-sec resolution maps given in Figs.2,3,4,5,6,7 were substituted with the ones of 0.5 degree resolution with respective changes in the range of values in their legends. Any discussion about the comparison of different resolutions was also removed from the discussion section. Additionally, all the results and tables changed based on 0.5 degree resolution. Similar changes were also made in the supplementary material. The only reference about the finer resolutions is given in section 5. Data availability, where we added the following text: "Apart from the 0.5 degree resolution raster datasets, the database contains the same datasets at finer resolution (30 arc-sec, 2.5 arc-min, 5 arc-min and 10 arc-min). These finer datasets are provided in order to cover the observed resolution range in the initial climatic data (e.g. the temperature data of Hijmans et al. (2005) are provided at 30 arc-sec resolution). The finer resolutions were produced using bilinear interpolation on solar radiation, humidity and wind speed data of Sheffield et al. (2006). This interpolation method is not the most appropriate for such purposes. The data of finer resolutions can only be used as a tool to assess uncertainties associated to temperature variation effects within a 0.5 degree pixel or to estimate average values of the coefficients for larger territories in order to capture a better representation of the coastlines or islands that do not exist in 0.5 degree resolution (use of values from individual pixels is not recommended). A complete list of the datasets is provided in the Table S5." 4. Reviewer 2 also commented that the manuscript is quite long. For this reason we removed the accuracy analysis by splitting the stations based on their elevation, and we also removed the Taylor diagrams analysis since the criteria that we give in Table 5 are more than enough. 5. The Discussion section was completely reformed based on the comments of Reviewer 1. 6. We added another 8 models of short reference crop evapotranspiration for comparative purposes after the request of Reviewer 1. 7. An error was found in the coordinates of Australian station Paynes Find station (A-69) of the validation dataset and the associated coefficients extracted from the specific coordinates. The position of the station was corrected in Fig.1 and any information related to the station was corrected. An additional arithmetic error was found and corrected in the ETo ASCE estimations of Australian stations. We performed a detailed check for all stations data, all the calculations/equations used for rasters development, all the calculations/equations used for analyzing stations data.

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Please also note the supplement to this comment:
http://www.earth-syst-sci-data-discuss.net/essd-2016-59/essd-2016-59-AC1-supplement.pdf

Interactive comment on Earth Syst. Sci. Data Discuss., https://doi.org/10.5194/essd-2016-59, 2016.

Parameter	T_{max}	T_{min}	R_s	RH	u_2	P	ET_o ASCE-short	ET_o ASCE-tall
Unit	°C	°C	MJ m^{-2} d^{-1}	%	m s^{-1}	mm $month^{-1}$	mm $month^{-1}$	mm $month^{-1}$
Average	25.3	11.4	18.8	56.4	2.6	41.5	138.4	190.5
Minimum	5.3	-7.2	4.9	19.0	0.9	0.0	17.9	26.2
Lower quartile	19.7	6.5	13.5	45.5	1.8	11.7	82.2	112.7
Upper quartile	31.1	15.8	24.4	68.2	3.2	50.6	186.9	254.2
Maximum	41.2	26.3	30.1	90.3	6.8	470.4	377.5	563.8
Range	**35.9**	**33.5**	**25.2**	**71.3**	**5.9**	**470.4**	**359.6**	**537.6**
Standard deviation	7.1	6.4	6.5	15.4	1.0	51.5	69.5	98.9
Coeff. of variation %	28.11%	56.13%	34.32%	27.36%	37.05%	123.90%	50.17%	51.93%

Fig. 1. TABLE R1

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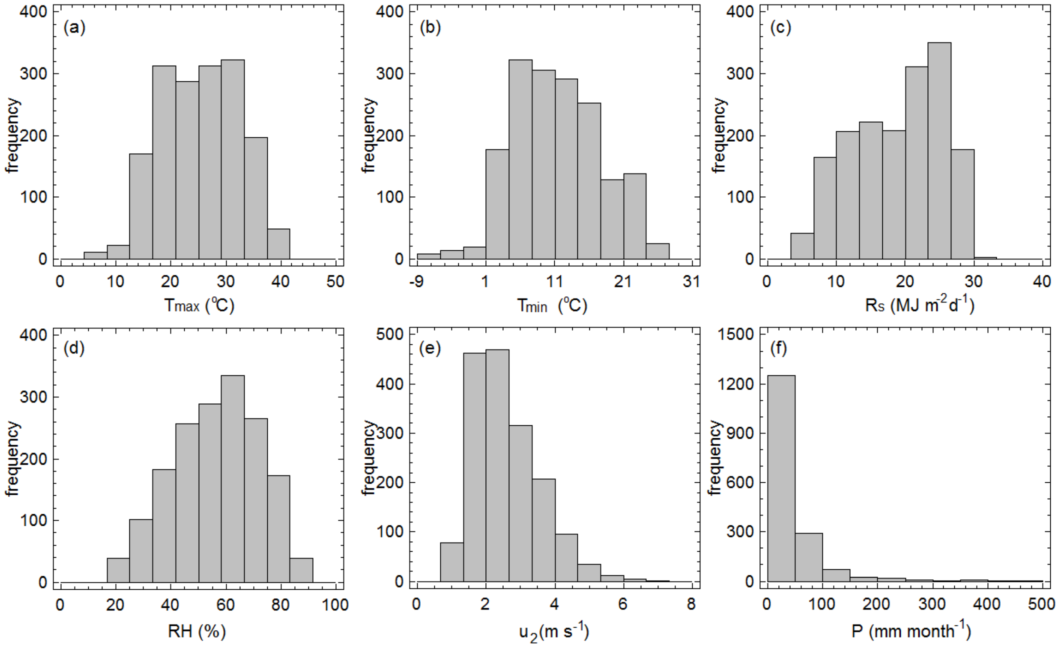

Fig. 2. FIGURE R1

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