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Atmospheric Measurement Techniques
Discussions
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Interactive comment on "McClear: a new model estimating downwelling solar radiation at ground level in clear-sky conditions" *by* M. Lefèvre et al.

M. Lefèvre et al.

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General comment. We thank the reviewer for his deep review of our text. Several mistakes in expression of our results were outlined by the reviewer. The revised text will be much clearer and more precise.

General comments

COMMENT. The authors claim that their 'results are much better than those from state-of-the art models'. Comparisons demonstrate that McClear performs indeed better than HelioClim-3v3, but there may be other clear-sky models around. I am at least aware of one: the SICCS algorithm described by Greuell et al. (2013) follows a similar approach for clear-sky SSI modelling as McClear, and appears to achieve similar

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Interactive Discussion
Discussion Paper

results. The authors should thus withdraw their claim.

ANSWER. We agree to withdraw the claim (in abstract and conclusion). Note that the comparison with the SICCS publication is uneasy without extensive work because Greuell et al. (2013) performed comparisons with BSRN data averaged over 1 h limited to the year 2006 and that only 3 BSRN stations are common to both works. We agree that the SICCS algorithm may perform similarly. This will be mentioned in the revised version, the reference will be added.

Note that the final objective of Geuell et al. is to discuss "the calculation and the validation of a data set of surface solar incoming radiation" (§60 in their paper). The SICCS data set is available on the Web. Differently, the goal of our paper is to discuss a clear-sky model that exploits MACC data as inputs, and as noted in the conclusion, that anyone may invoke it for any part of the world and get time-series of irradiances under clear sky for several years within minutes. The process is made on-the-fly and the time period extents together with the extension of the MACC data set.

Specific comments

COMMENTS. P3368, L9: I haven't seen the word abaci in this context before. It seems to be a term invented by the authors, but why not use the word look-up table (LUT), which I am sure most readers are familiar with. I strongly suggest to remove the term abaci.

ANSWER. An abacus is a table for computation. It was already used by Greeks and Romans. Many abaci were computed and printed for a long time for their use in engineering. Look-up tables (LUT) were introduced in computer vision to display images in the 70's. At that time, they were a means to reduce the content of RGB images into 64 or 256 possible colors for the display. Then, LUT were used in segmentation / classification of multi-bands images, where the input vector was converted into a taxon. Since the 90's, LUT and abacus have the same meaning. We will make this clearer in the text. Using the word "abacus" is a means to recognise the work made by our ancestors; LUT is nothing new. The term “abaci” was used in presentations made during the project MACC to the consortium (approx. 100 researchers), the EC and its reviewers, and users of the MACC products and nobody shows any surprise.

We will write in the abstract: “by adopting the abaci, also known as look-up tables, approach combined with interpolation functions”. This will also be reported in page 5, line 8.

COMMENT. P3368, L14-18: Theses sentences are somewhat hard to read, because they contain two radiation components in combination with two limits (lower and upper). I suggest to write in one sentence the correlation coefficient, bias and RMSE for global radiation, then in a second sentence the values for direct radiation. By the way, I don’t think mentioning the correlation coefficients is useful here: the large dynamic range of radiation almost automatically yields a high correlation, as is indeed stated by the authors in their manuscript.

ANSWER. We agree and made changes as shown below. We have kept the correlation coefficients as we believe that one may be surprised not to find them.

A new fast clear-sky model called McClear was developed to estimate the downwelling shortwave direct and global irradiances received at ground level under clear skies. It is a fully physical modelling replacing empirical relations or simpler models used before. It exploits the recent results on aerosol properties, and total column content in water vapor and ozone produced by the MACC project (Monitoring Atmosphere Composition and Climate). It accurately reproduces the irradiance computed by the libRadtran reference radiative transfer model with a computational speed approximately 105 times greater by adopting the abaci, or look-up tables, approach combined with interpolation functions. It is therefore suited for geostationary satellite retrievals or numerical weather prediction schemes with many pixels or grid points, respectively. McClear irradiances were compared to 1 min measurements made in clear-sky conditions at several stations within the Baseline Surface Radiation Network in various climates. The

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Interactive Discussion

Discussion Paper

bias for global irradiance is comprised between 6 and 25 W m 2. The RMSE ranges from 20 W m 2 (3% of the mean observed irradiance) to 36 W m 2 (5%) and the correlation coefficient ranges between 0.95 and 0.99. The bias for the direct irradiance is comprised between 48 and +33 W m 2. The RMSE ranges from 33 W m 2 (5%) to 64 W m 2 (10%). The correlation coefficient ranges between 0.84 and 0.98. This work demonstrates the quality of the McClear model combined with MACC products, and indirectly the quality of the aerosol properties modeled by the MACC reanalysis.

COMMENT. P3368, L18-19: Remove the sentence 'These results : : : models.' (see general comments).

ANSWER. Done.

COMMENT. P3369, L8: What is meant by 'a suitable supplement to rare long-term SSI measurements'? Please clarify.

ANSWER. We rephrase it: Given the scarcity of long-term SSI measurements made at ground level, several authors mention that satellite-derived SSI may supplement these measurements (Ba et al. 2001; Blanc et al. 2010; Cano et al. 1986; Darnell et al. 1996; Diabaté et al. 1988; Elias, Roujean 2008; Lefèvre et al. 2007; Posselt et al. 2012; Raschke et al. 1987; Schiffer, Rossow 1985; Schmetz 1989).

COMMENT. P3369, L12-13: What is meant by 'the clear-sky model'? A radiative transfer model? And which one? And does the clear-sky model set the upper limit of the SSI? I would say the upper limit would be given by an 'empty' atmosphere. Please clarify.

ANSWER. We rephrase: Hereafter, a model estimating the SSI under clear-sky is called a clear-sky model. As it describes the SSI in a cloud-free atmosphere, it estimates a realistic upper limit of the SSI (Gueymard 2012; Long, Ackerman 2000).

COMMENT. P3371, L20: I don't count 10 parameters. Clarify.

ANSWER. Thank you for this remark. The original text was confusing. The new text is:

AMTD

6, C1732–C1756, 2013

Interactive Comment

Inputs to McClear are the solar zenith angle, the ground albedo and 6 parameters describing the optical state of the atmosphere: âĂć total column content of ozone and water vapour, âĂć vertical profile of temperature, pressure, density, and volume mixing ratio for gases as a function of altitude taken in the AFGL data sets (see Sect 3.2), âĂć aerosol optical depth (AOD) at 550 nm, Angstrom coefficient, and aerosol type: urban, continental clean, continental polluted, continental average, maritime clean, maritime polluted, maritime tropical, antarctic, and desert (see Sect. 3.4), and other parameters describing the geographical location and the time: âĂć latitude, longitude and elevation above mean sea level (a.s.l.) of the site of interest, âĂć period of time requested, âĂć integration period, also known as the summarization period, of the radiation: 1 min, 15 min, 1 h, 1 d, âĂć time sampling step, usually identical to the integration period.

COMMENT. P3371, L23: ‘atmospheric profiles’: of what?

ANSWER. vertical profile of temperature, pressure, density, and volume mixing ratio for gases as a function of altitude taken in the AFGL data sets

COMMENT. P3371, L27: This seems a duplication. Only one height should be necessary. What is meant by altitude? The height above mean sea level? We’re dealing with radiation at the surface, so why the elevation above the ground?

ANSWER. We rewrote the text: “Altitude of the ground level and elevation above the ground are both needed because the 6 clear-sky parameters are computed in the MACC analysis for a very smooth terrain and therefore represent the atmospheric properties for this atmospheric column. The altitude of this smooth terrain model may differ from the elevation of the more local site of interest and the SSI should be corrected, assuming that the difference in SSI between the local elevation and the smooth terrain is equivalent to the difference in SSI between a similar elevation above ground level, i.e. in the atmosphere, and the smooth terrain. The correction is explained in Sect. 3.3.”

COMMENT. P3373, L10-12: What is ‘obey the uniform law’? Do you mean ‘have a uniform distribution'? Does this mean that the water vapour column PDF is assumed to be uniform?

ANSWER. We thank the reviewer to underline this point. This point was also mentioned by Reviewer #1. Indeed, we forgot to mention that we were modelling the marginal distribution, and not the distribution of the properties themselves. The text is now: “The optimization was done for each of the 10 inputs listed above. A Monte-Carlo technique is applied to randomly generate sets of inputs to libRadtran within the 10D-space, with the exception of the current parameter which is regularly sampled with a small step. The optical properties were selected by considering their observed marginal distribution. More precisely, the uniform distribution is chosen as a model for marginal probability for all parameters except aerosol optical thickness, Angstrom coefficient, and total column ozone. The chi-square law for aerosol optical thickness, the normal law for the Angstrom coefficient, and the beta law for total column ozone have been selected. The parameters of the laws are empirically determined from the analyses of the observations made in the AERONET network for aerosol properties and from meteorological satellite-based ozone products.”

The uniform distribution means that any value in the random selection has the same statistical weight.

COMMENT. P3374, L2: Do you mean Eq. (4)?

ANSWER. Yes.

COMMENT. P3374, L5: Shouldn't the sky albedo S be independent of the surface albedo. Please explain.

ANSWER. Yes, S is independent of the surface albedo. We have better explained as follows:

The formula of Vermote et al. (1994, 1997): KT(ïĄšg) = KT(ïĄšg = 0) / (1 - ïĄšg S) (4) describes the change in KT as a function of the ground albedo ïĄšg and the

AMTD
6, C1732–C1756, 2013

Interactive Comment

Full Screen / Esc

Printer-friendly Version

Interactive Discussion

Discussion Paper

atmospheric spherical albedo S. ïĄšg s an input while S is unknown. In principle, S can be computed knowing KT for any value of ïĄšg using Eq. (4). Actually, better results are attained if S is computed for two values of ïĄšg: 0.1, and 0.9 using Eq. (4), and then is linearly interpolated/extrapolated for the actual ïĄšg: a = [S(ïĄšg=0.9)-S(ïĄšg=0.1)] / 0.8 (5) b = S(ïĄšg=0.1) - 0.1 a S = a ïĄšg + b

COMMENT. P3374, L9-10: What if the water vapour column exceeds 100 kg/m2? This is certainly possible in the Tropics.

ANSWER. Actually, we use interpolation / extrapolation functions. Therefore, the upper values of the node points are not upper limits for the computation of the clear-sky irradiance. This is clarified in the text.

COMMENT. P3374, L13-14: Why are two heights necessary? (see earlier comment)

ANSWER. See previous answer. We have also changed the text in Sect 3.3.

“The 6 inputs from MACC are given for grid nodes, which are separated by approximately 100 km. A very smooth elevation model is used in MACC analyses and each node has a known local mean elevation above mean sea level (asl). The MACC-equivalent elevation for the local site under concern is computed by linear interpolation of the MACC elevations of the 4 neighboring grid nodes. Then, interpolation in clearness index is made for this MACC-equivalent elevation using the two closest nodes “site elevation” in the abaci. If the actual elevation of the local site is less than the MACC-equivalent elevation, the clearness index is set to that corresponding to the MACC-equivalent elevation. Otherwise, an additional linear interpolation/extrapolation is performed using the nodes “elevation above ground level”

COMMENT. P3375, L5: Please explain shortly what these three parameters are.

ANSWER. The text is now:

The MCD43C1 and MCD43C2 data, derived from MODIS images, are 16-day composites provided as a level-3 product projected to a 0.05° grid in latitude/longitude. They

AMTD

6, C1732–C1756, 2013

are produced every 8 days with 16 days of acquisition, where the given date is that of the first day of the 16-days period. These data sets contain three model parameters, called fiso, fvol, and fgeo (Schaaf et al. 2002). fiso describes the isotropic part of the bidirectional reflectance distribution function (BRDF); the two other parameters are linked to the viewing and illuminating geometry to describe the anisotropic part of the BRDF. The directional hemispherical reflectance (DHR) -also known as black-sky albedo- and the bihemispherical reflectance (BHR) -also known as white-sky albedo- (e.g. Schaepman-Strub et al. 2006) are computed from the BRDF using formulas in Schaaf et al. (2002).

COMMENT. P3375, L2: Is the MCD43C2 product gap filled? If not, what do you do in case of gaps? Also, I believe the MCD43C2 product is snow-free. What do you do in case of snow?

ANSWER. No, the MCD43C2 product is not gap filled. In case of gap, we were looking at valid data in a time window. In unsuccessful, we were using averaged values, computed for a given month with all valid data over the period 2004-2011. If no averaged value was available, then the computation of the SSI was not performed.

Yes, the MCD43C2 product is snow-free. Presence of snow is not accounted for, which may induce errors in the diffuse irradiance in some cases. This will be mentioned in the revised text.

Actually, we have made extensive tests in the past months comparing the SSI obtained with an "instant" ground albedo from MODIS, and that obtained with averaged ground albedo. The difference is very small, of order of 1 W/m2. The proposed text is now:

In a practical manner, once a request is made for a given site, the three BRDF parameters fiso, fvol, and fgeo are taken from the closest MCD43C1 or MCD43C2 grid point. Then, Eq. (8) is solved for KT for each minute of the day. The difference between the MCD43C1 and MCD43C2 products is that MCD43C2 is a snow-free version of MCD43C1. Both products exhibit gaps in time and space. Two approaches have been tested to palliate the lack of data. In the first approach, the three BRDF parameters were taken from MCD43C2 product for the previous, current and following months for the current day. They were interpolated in time for each minute of the day, taking into account the possible absence of data. Sometimes, data may not be available for three months in a row. In these cases, the parameters were replaced by their mean values computed for the given month over the period 2004-2011. Over the ocean, fiso was set to 0.02 (Wald, Monget 1983) and the two parameters to 0. Several gaps in space and time were still observed. Presence of snow is not accounted for and this may induce errors in the diffuse irradiance in some cases. The second approach consists in computing mean values of the three BRDF parameters from MCD43C1 product for each of the twelve months of the year over the period 2004-2011. Ecah mean value was allotted to the mid day of each month. The values for the current day were computed by linear interpolation using the current month and that before or after depending on the case. A great deal of efforts has been made on the completion of data which are missing mostly in water-covered areas. The "Land Cover Type" product is also a MODIS product using the same grid than MCD43C1. It allows the identification of pixels containing water and the proportion of water in this pixel. Let W denote the binary mask for water; W=1 if the pixel has been classified as "water" at least once for the given month during the period 2001-2009 covered by the "Land Cover Type" product, and is 0 otherwise. Let P be the average proportion of the water. The typical triplet fW=(fiso, fvol, and fgeo) for water areas was defined by the mode of the valid triplets (fiso, fvol, and fgeo) for water pixels comprised between latitude 45° and latitude 45°. fW was allotted to each unknown water pixel for which P=1. Then, if a water pixel exhibited a valid triplet f and a proportion of water P less than 1, f was replaced by a linear combination P fW + (1-P) f. A moving average of +/- 1 month was applied followed by a median filter of 11x11 pixels to fill gaps. This two-steps filtering was repeated but with a window of +/- 2 months. The, a median filter of 21x21 pixels was applied. Still unknown were a few pixels in the middle of the ocean, extreme southern part of the Antarctic Ocean, and Greenland. They were treated manually and were allotted the mean value of the

AMTD

6, C1732–C1756, 2013

Interactive Comment

triplets f averaged in their neighbourhood. When compared to ground-based measurements of the SSI as discussed later, both approaches gave the same results with very small differences not taking into account the gaps. The second approach is used in the following. It has the advantage that is makes easier the implementation of McClear.

COMMENT. Section 3.2: Atmospheric profiles of what? Please clarify.

ANSWER. These are vertical profiles of temperature, pressure, density, and volume mixing ratio for gases as a function of altitude. The text has been changed.

COMMENT. Section 3.3: I don't understand the altitude correction. Please explain more clearly.

ANSWER. The text is now:

The 6 inputs from MACC are given for grid nodes, which are separated by approximately 100 km. A very smooth elevation model is used in MACC analyses and each node has a known local mean elevation above mean sea level (asl). The MACC-equivalent elevation for the local site under concern is computed by linear interpolation of the MACC elevations of the 4 neighboring grid nodes. Then, interpolation in clearness index is made for this MACC-equivalent elevation using the two closest nodes "site elevation" in the abaci. If the actual elevation of the local site is less than the MACC-equivalent elevation, the clearness index is set to that corresponding to the MACC-equivalent elevation. Otherwise, an additional linear interpolation/extrapolation is performed using the nodes "elevation above ground level".

COMMENT. P3379, L14: Please include the definition of air mass.

ANSWER. Done in the revised text. Cannot appear here as Equations do not show in this answer box.

COMMENT. Section 4: I strongly suggest to clarify this algorithm with concrete data, for example by showing a time series of which various parts are disregarded because of either of the three criteria. Can you comment on the percentage of measurements

AMTD
6, C1732–C1756, 2013

filtered out on the basis of Eq. (9)? Does that vary between the BSRN stations?

ANSWER. We have rewritten the text to clarify that the first constraints (Eq. 9) are those recommended by BSRN, and not ours, and to better explain our filtering for obtaining clear-sky values.

We wrote "Two filters have been applied on the remaining BSRN data in order to retain reliable clear-sky instants. The first one was a constraint on the amount of diffuse irradiance with respect to the global irradiance since the direct irradiance is proeminent in case of clear-sky. Only those minutes for which Ediff/Eglo < 0.3, i.e. when the diffuse component is much less than the direct one, have been retained."

We then explained the second filter "The second filter dealt with the temporal variability of the irradiance. If there is no cloud, the sky should be clear for a long period. Checking this would avoid cases of broken clouds or noticeable spatial heterogeneity around the site if ergodicity is assumed. The first step of this filter was to retain only periods with enough measurements that have passed the first filter. A given instant t, expressed in min, was kept only if at least 30% of the 1 min observations in both intervals [t 90, t] and [t, t+90] have been retained after the first filter."

before going to the Equations, including that for air mass. Fig. 3 displays a time-series of Eglo for the selected clear-sky instants in the year 2005 in Payerne, in black circles. Payerne experiences a large number of clear skies during the year and many instants are selected. In this graph are also drawn the clear-sky instants selected by the algorithm of Long and Ackerman (2000), in light grey crosses. One may see that they are differences between the results. The proposed algorithm presents less low values of Eglo than that of Long and Ackerman and offers more confidence in the fact that the instant is clear.

COMMENT. P3379, L19-20: How much more restrictive is this algorithm compared to existing ones? This is important because the more restrictive, the better the validation scores will probably become. Thus this should be taken into account when making intercomparisons.

ANSWER. See Figure above. We agree with the Reviewer that selecting clear-sky values is a delicate matter. We have to be sure not to retain cloudy skies and we should not be too restrictive in order to get enough values to represent the various cases of clear –sky.

COMMENT. P3381, L9: What does 'compact' mean here?

ANSWER. This part has been rewritten.

COMMENT. P3381, L25: I am surprised that there is no clear trend of the validation statistics of, for example, EËĘglo with the solar zenith angle. For larger angles, EËĘglo will decrease. At the same time the air mass increases and thus the absorption by ozone and water vapour. With more absorption one would also expect more uncertainty in the absorption. Thus, I would expect the RMSE to increase with the solar zenith angle in absolute terms, and certainly in relative terms. Can the authors comment on this? I strongly suggest to illustrate some of the dependences in a Figure.

ANSWER. The bias and RMSE exhibit complex shapes as a function of the solar zenith angle. As a whole, the RMSE has a tendency to decrease with the solar zenith angle. Four graphs are provided that depicts the changes in bias and RMSE with the solar zenith angle for the global and direct irradiances. These are now Figs 12 to 15.

COMMENT. P3381, L27-28: Isn't this a consequence of the smaller solar zenith angle in summer (see previous comment)? Please explain.

ANSWER. We do not have any clear explanation. As seen in the new graphs, the bias is not a simple function of the solar zenith angle. This cannot explain alone the observation.

COMMENT. P3382, L2: Is there any explanation for the very poor correlation for Xianghe, both for global and direct radiation? Any issues with the BSRN measurements for this station? I am surprised that, while the correlation for Xianghe is very low com-

AMTD

6, C1732–C1756, 2013

Interactive Comment

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Interactive Discussion

Discussion Paper

pared to other stations, but the RMSE does not stand out. Can this be explained? Could you include a scatter plot?

ANSWER. Thanks to the remark of the Reviewer, we have better investigated this point. We found that low correlation coefficients may be explained by the limited range of values taken by the clearness indices because only clear-sky is dealt with and do not necessarily imply poor performance. We have discussed better the case of Xianghe and provided four scatter density plots (now Figs 8 to 11).

Figures 8 to 11 are scatter density plots between BSRN data and McClear estimates for respectively Eglo, Edir, KT, and KTdir for Xianghe. Xianghe is a rural city but under the influence of the air pollution in Beijing (Wang, Zhao and Li, 2011). It is also the seat of an AERONET station, which shows that the fine mode is very often encountered. An overall good fit is observed between estimates and observations for both Eglo and Edir. The relative bias is small: -1% for Eglo and -3% for Edir, as well as the RMSE: 5% and 10%. The squared correlation coefficients are large for the global: 0.91 but low for the direct: 0.74, meaning that 91% and 74% of information contained in Eglo and Edir is well explained by McClear. Aerosol types estimated by McClear are mostly "urban" by far, then "desert" and then "continental polluted" in agreement with AERONET observations. Wang, Zhao and Li (2011) found that the aerosol optical depth estimated by MODIS and further assimilated in the MACC analyses is greater than that observed by the AERONET instrument. This may explain the underestimation of Edir by McClear. The range of values for KT and KTdir are very limited (Figs 10 and 11). As a consequence, the correlation coefficients are low. The bias is small: -1% for KT and -4% for KTdir, as well as the RMSE: 5% and 11%.

COMMENT. P3385, L5-8: Please remove this statement (see earlier comments).

ANSWER. The statement has been removed and has been replaced by: "Comparisons with state-of-the-art clear-sky models show that McClear offers similar or better performances."

In addition, in the previous section, we wrote a paragraph on the SICCS "Greuell, Meirink and Wang (2013) have developed a method for the retrieval of hourly means of the SSI using Meteosat images. MACC data are inputs to their method. Comparaisons were made with several BSRN stations for the year 2006 for clear-sky cases and all skies. Though the period is not similar and that comparaisons were made on an hourly basis rather than 1 min, performances can be compared for the bias for the three common sites: Palaiseau, Carpentras, and Payerne. Both models provide similar results for both Eglo and Edir."

COMMENT. P3385, L16-20: What is the reason for mentioning this reference? If the RMSE estimate of 10-15% represents a theoretical limit due to spatio-temporal mismatching. How can the present results then be (far) below that limit?

ANSWER. The proposed limits have been defined by Zelenka et al. from a series of experiments in Switzerland, US Northeast and Amazonia. The present results may be below these limits. Nevertheless, this discussion has been withdrawn. More detailed work should be done to discuss our results in the light of this publication which was not dealing with 1 min values. As the basis of the reasoning is the variability expressed as structure functions, also known as variograms, it is very sensitive to the sampling step of the data.

Technical comments. ANSWER. All the following technical comments have been taken into account.

P3368, L4: McClear implements : : : A model does not implement something; scientists do that. Please rewrite.

P3368, L13: in several stations -> at several stations

P3370, L1: is -> has been

P3370, L4: performances -> performance

P3370, L5: Suggest to change 'published similar works' to 'the existing literature'.

AMTD
6, C1732–C1756, 2013

P3370, L7: Swap denote and Ediff.

P3370, L9: Remove the brackets.

P3370, L10 and furtheron: Subscript the 0 in E0.

P3371, L4-5: ‘e.g. 15 min values over a year’ can be omitted.

P3371, L16: resolution -> solution

P3371, L20: MCClear -> McClear

P3371, L22: in -> of

P3372, L5: summarization period -> integration time

P3372, L10: twice ‘available’.

P3372, L25: Suggest to replace ‘decrease as much as possible’ by ‘minimize’

P3373, L16: What are ‘spatial’ missions?

P3375, L24: Remove ‘as’.

P3377, L8: watersoluble -> water soluble

P3378, L4: in -> of

P3379, Eq. (9): As stated here the left-hand side should equal 1.08 or 0.92 (for the first line). I’m sure the authors mean the interval between those numbers, so please correct.

P3380, L13: coefficient is -> coefficients are. Also add ‘respectively’ in this sentence

P3380, L29: add ‘of SSI’ after ‘estimates’

P3381, L3: increase -> increases

P3384, L16: than -> that, and ‘figures of merit’ -> ‘statistics’?

AMTD

6, C1732–C1756, 2013

Interactive Comment

P3384, L20: of -> in

P3385, L5: comparaisons -> comparisons

Table 7: The percentage symbol is missing for the relative RMSE for Sede Boqer.

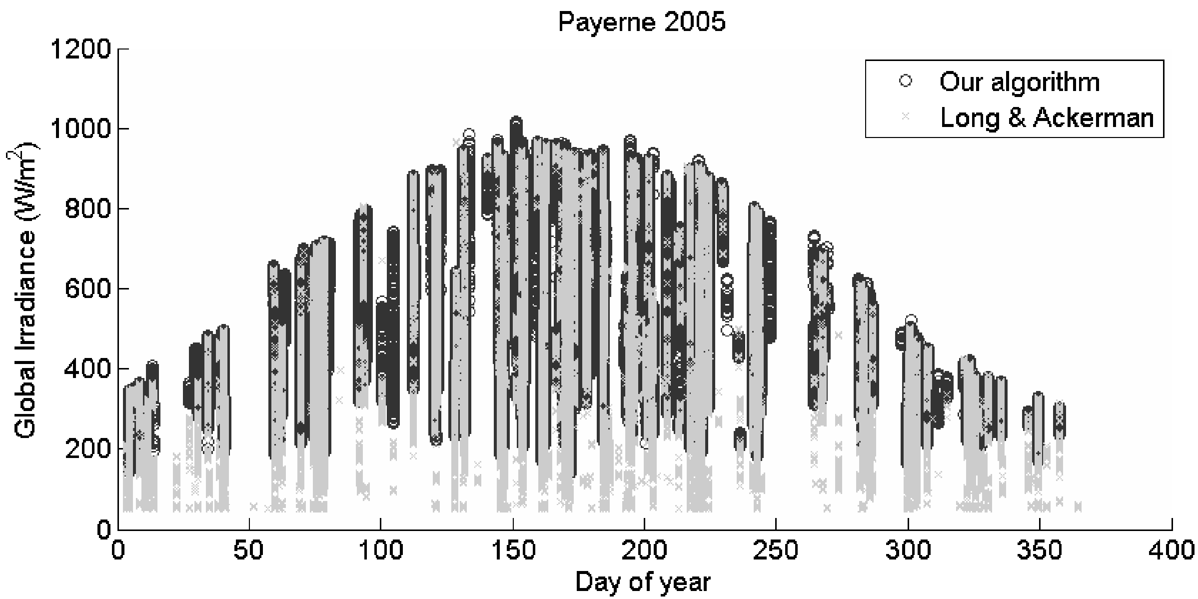
Fig. 2: What is GHI?

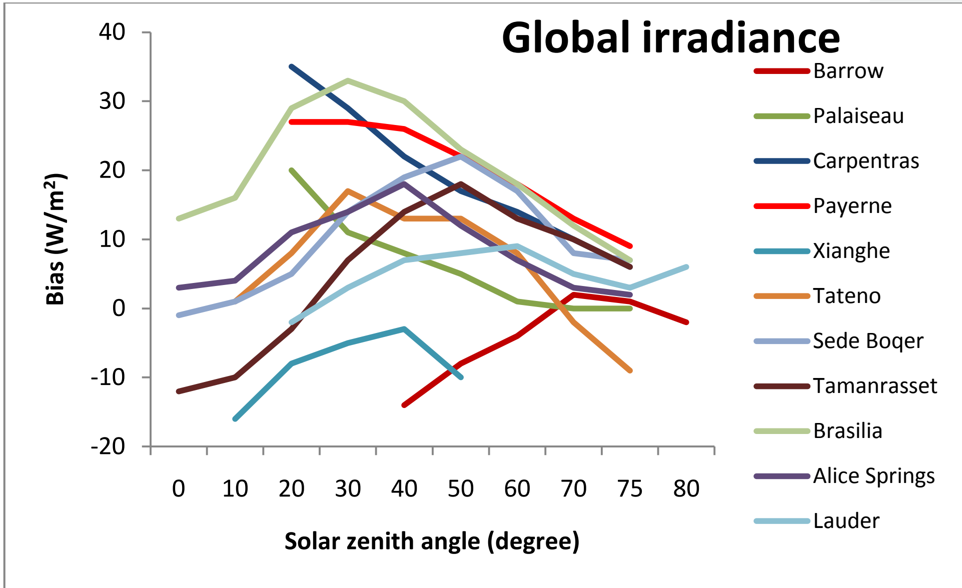
Fig. 3: Add one more digit to the densities at the right of the colorbar. Same for Figs. 4 and 6.

Fig. 5: Please add same statistics as in Figs. 3 and 4 in the plot. Also in Fig. 6.

Reference Greuell W., J. F. Meirink, and P. Wang (2013), Retrieval and validation of global, direct, and diffuse irradiance derived from SEVIRI satellite observations, J. Geophys. Res. Atmos., 118, 2340–2361, doi:10.1002/jgrd.50194.

Interactive comment on Atmos. Meas. Tech. Discuss., 6, 3367, 2013.

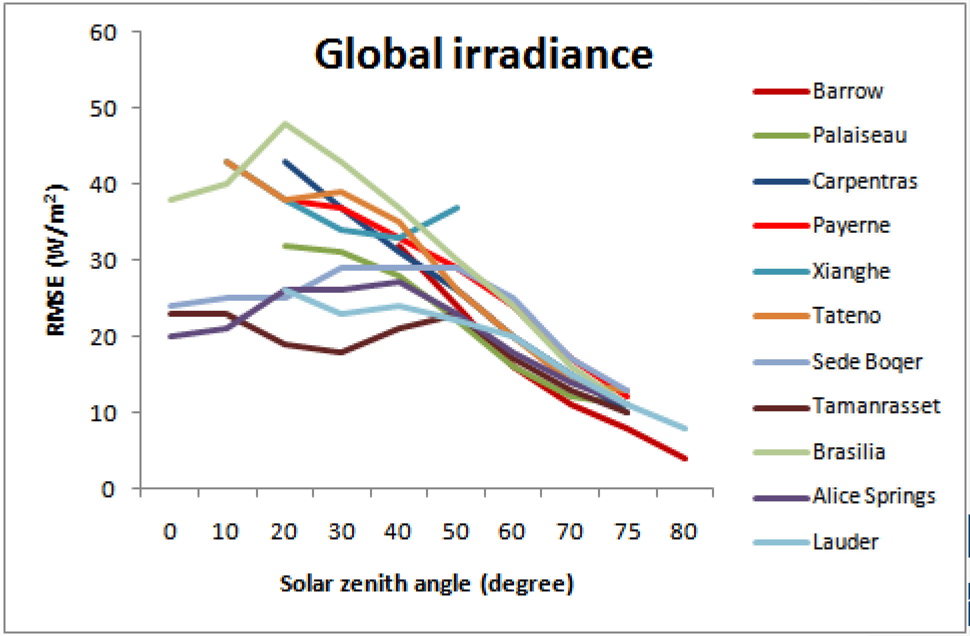

Payerne 2005
Our algorithm
Long & Ackerman
Global Irradiance (W/m2)
Day of year
0
200
400
600
800
1000
1200
0
50
100
150
200
250
300
350
400

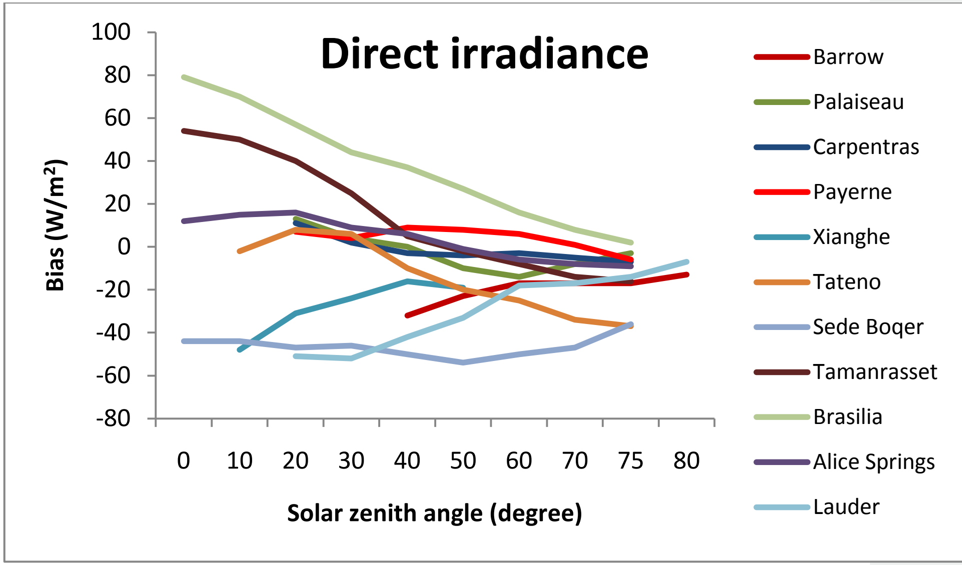

Global irradiance
Bias (W/m²)
40
30
20
10
0
-10
-20
0
10
20
30
40
50
60
70
75
80
Solar zenith angle (degree)
Barrow
Palaiseau
Carpentras
Payerne
Xianghe
Tateno
Sede Boqer
Tamanrasset
Brasilia
Alice Springs
Lauder

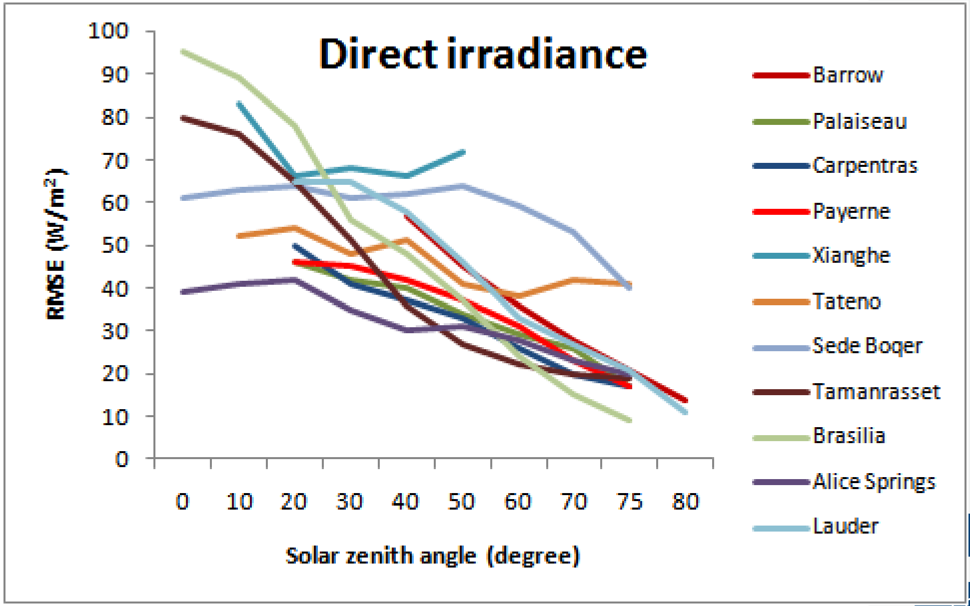
AMTD

6, C1732–C1756, 2013

Interactive Comment

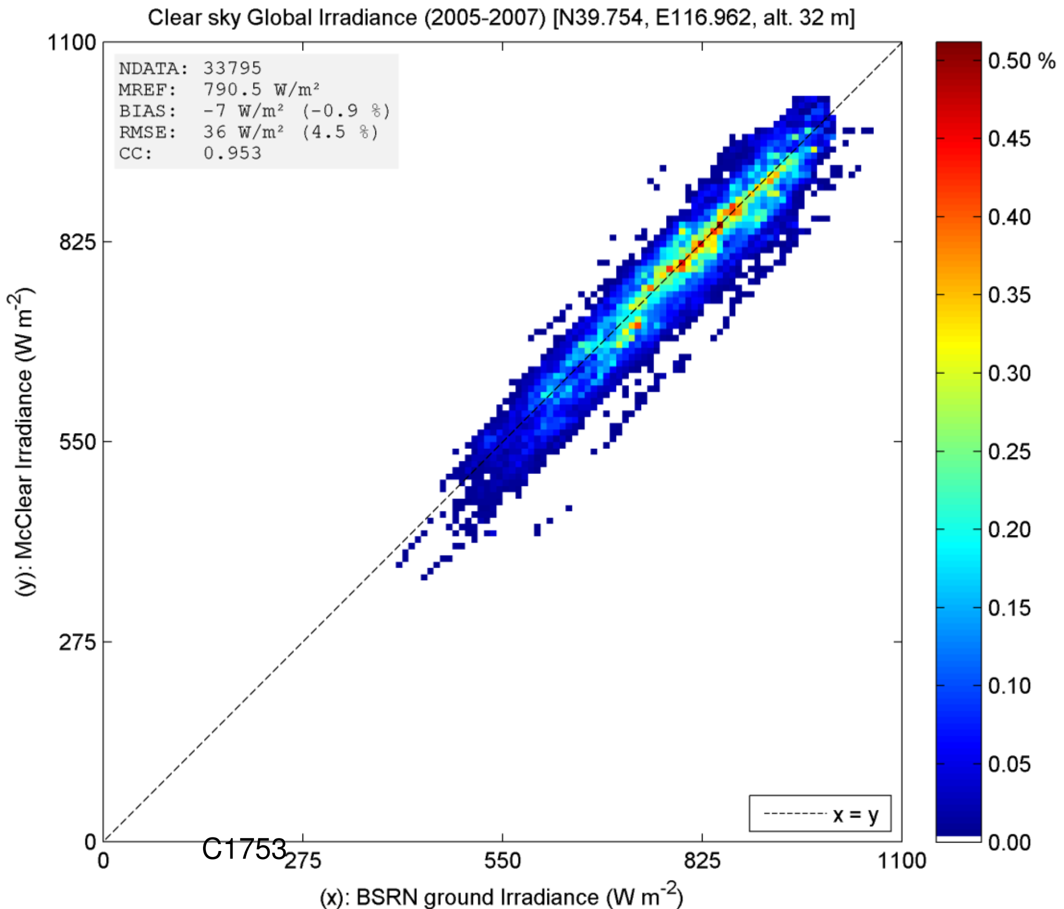


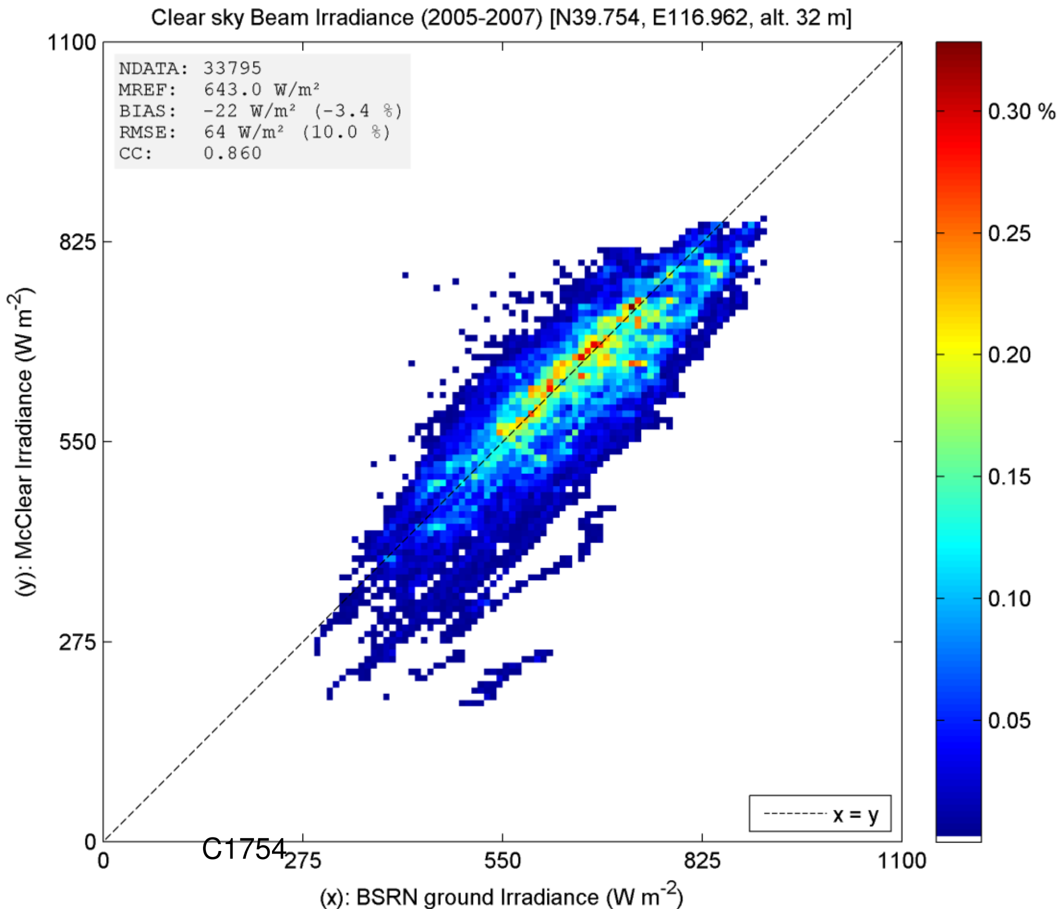

Direct irradiance
Bias (W/m²)
100
80
60
40
20
0
-20
-40
-60
-80
0
10
20
30
40
50
60
70
75
80
Solar zenith angle (degree)
Barrow
Palaiseau
Carpentras
Payerne
Xianghe
Tateno
Sede Boqer
Tamanrasset
Brasilia
Alice Springs
Lauder

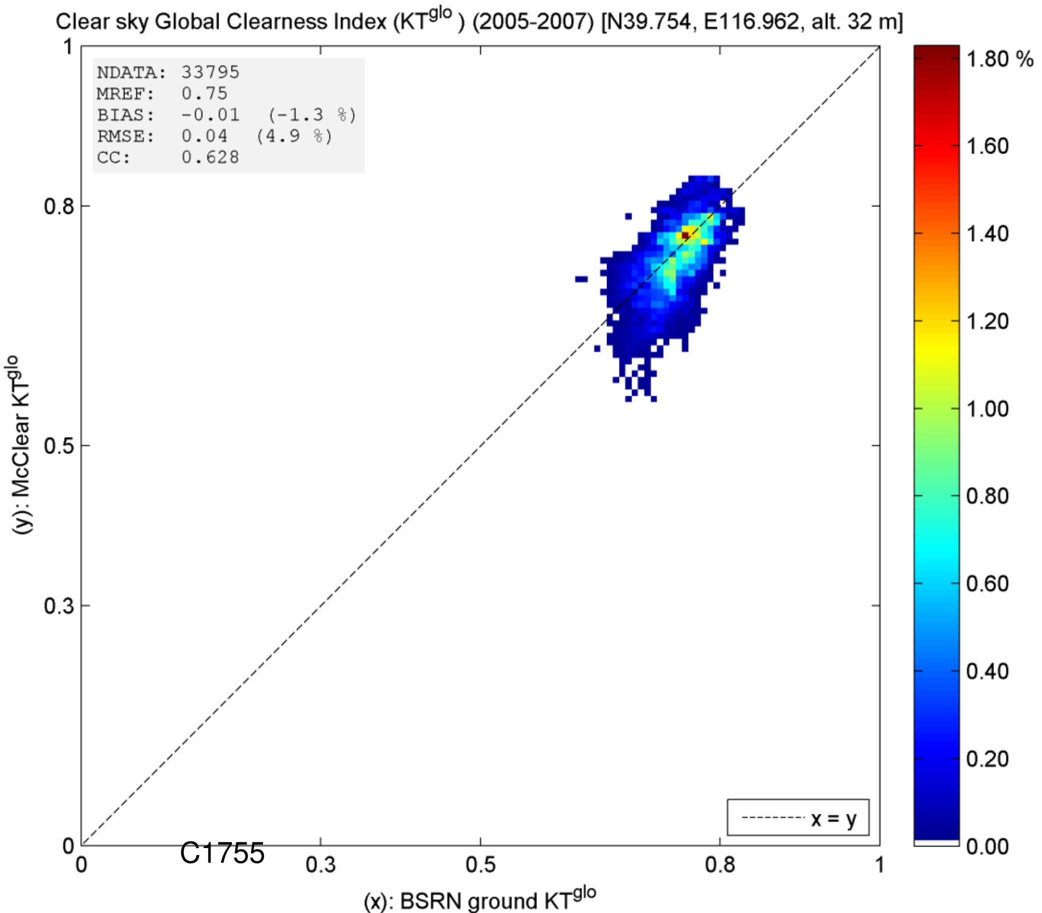


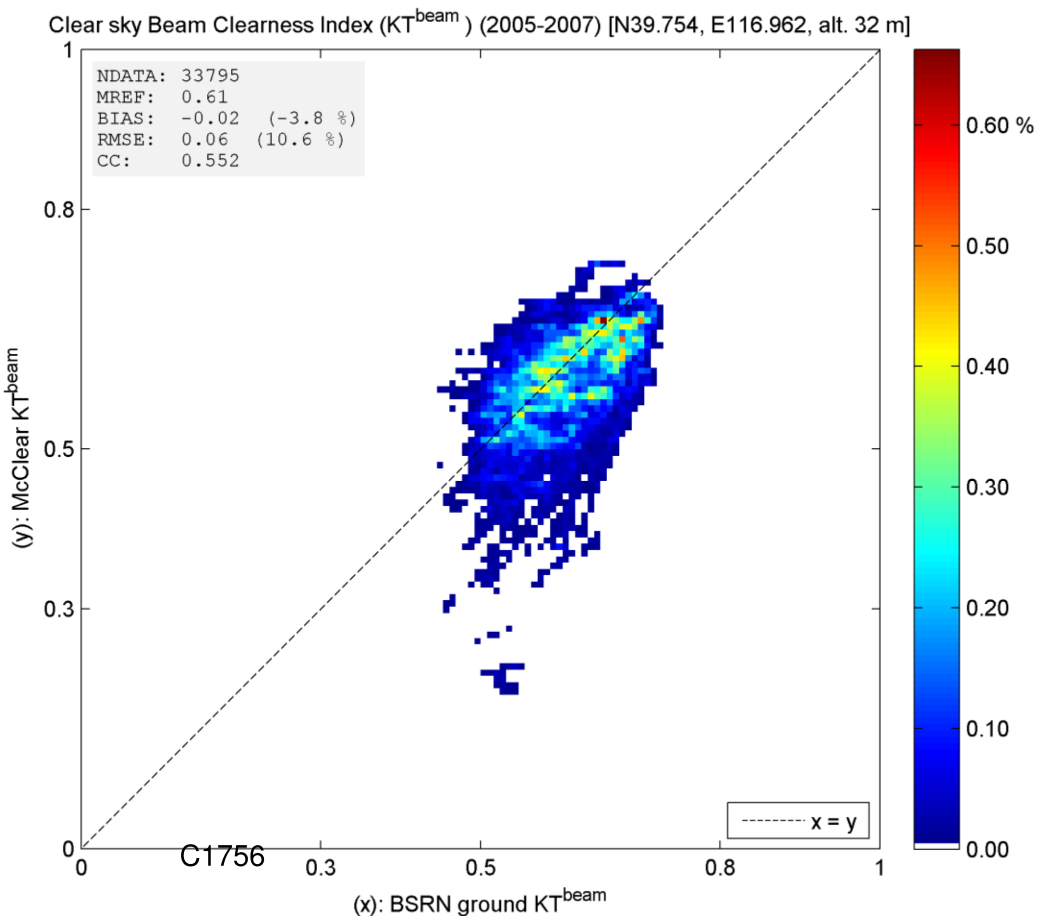
AMTD
6, C1732–C1756, 2013

Interactive Comment


Clear sky Global Irradiance (2005-2007) [N39.754, E116.962, alt. 32 m]
NDATA: 33795
MREF: 790.5 W/m²
BIAS: -7 W/m² (-0.9 %)
RMSE: 36 W/m² (4.5 %)
CC: 0.953
x = y
(y): McClear Irradiance (W m-2)
(x): BSRN ground Irradiance (W m-2)
0
275
550
825
1100
0.50 %
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00


Clear sky Beam Irradiance (2005-2007) [N39.754, E116.962, alt. 32 m]
NDATA: 33795
MREF: 643.0 W/m²
BIAS: -22 W/m² (-3.4 %)
RMSE: 64 W/m² (10.0 %)
CC: 0.860
x = y
(y): McClear Irradiance (W m^-2)
(x): BSRN ground Irradiance (W m^-2)
0
275
550
825
1100
0.30 %
0.25
0.20
0.15
0.10
0.05


Clear sky Global Clearness Index (KT^{glo}) (2005-2007) [N39.754, E116.962, alt. 32 m]
NDATA: 33795
MREF: 0.75
BIAS: -0.01 (-1.3 %)
RMSE: 0.04 (4.9 %)
CC: 0.628
(y): McClear KT^{glo}
(x): BSRN ground KT^{glo}
x = y
1.80 %
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00


Clear sky Beam Clearness Index (KT^beam) (2005-2007) [N39.754, E116.962, alt. 32 m]
NDATA: 33795
MREF: 0.61
BIAS: -0.02 (-3.8 %)
RMSE: 0.06 (10.6 %)
CC: 0.552
(y): McClear KT^beam
(x): BSRN ground KT^beam
x = y
0.60 %
0.50
0.40
0.30
0.20
0.10
0.00
0
0.3
0.5
0.8
1