



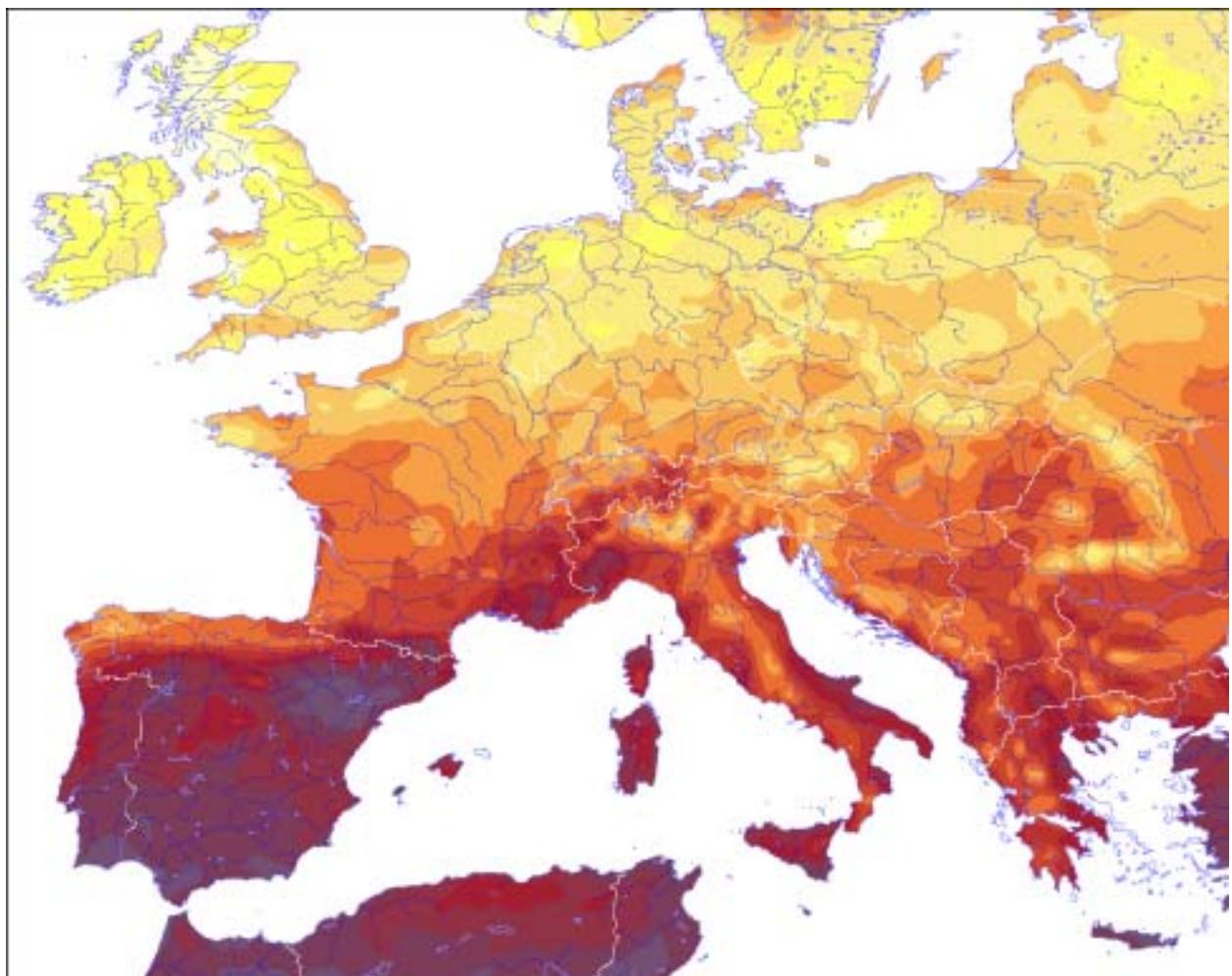
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DES PROBLÈMES DE L'ÉNERGIE

**SHC**  
SOLAR HEATING & COOLING PROGRAMME  
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## Meteonorm validation on measurements from Geneva

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Yearly means of global radiation based on ground  
measurements and satellite images (MN 5.1)

## 1. Introduction

In the field of architecture, solar engineering, summer cooling, etc, it is often necessary to conduct simulations in order to predict or to assess the performance of a building, a solar system, or an installation. These processes require input data representative of the local climate, often on a hourly time step and for the 3 solar radiation components. When these input data are missing, it is necessary to evaluate or to generate them by means of software, or to derive them from satellite images.

Meteonorm ([www.meteotest.ch](http://www.meteotest.ch)) is one of these software. It makes it possible to generate hourly climatic time series for a location situated anywhere over the world, based on an internal averaged data bank, or on real monthly mean values downloaded from the Internet.

A limited study on the 3 summer months when air-conditioning can be necessary was already published, based on temperature and radiation measurements conducted in the Geneva region, and on data generated by Meteonorm (Ineichen, 2006a, 2006b).

The purpose of this study is to carry out a more thorough validation of the radiation parameters produced by Meteonorm.

## 2. Data

Two acquisition stations are used to conduct the comparison: an urban station located in the city of Geneva on the top of a 15 floors building at the Jonction, and a rural station situated in the Geneva countryside at Geneva-Cointrin (swiss meteorological service, Anetz network, Geneva airport, [www.meteoswiss.ch](http://www.meteoswiss.ch)).

For both stations, the global horizontal radiation is available from 1998 to 2005

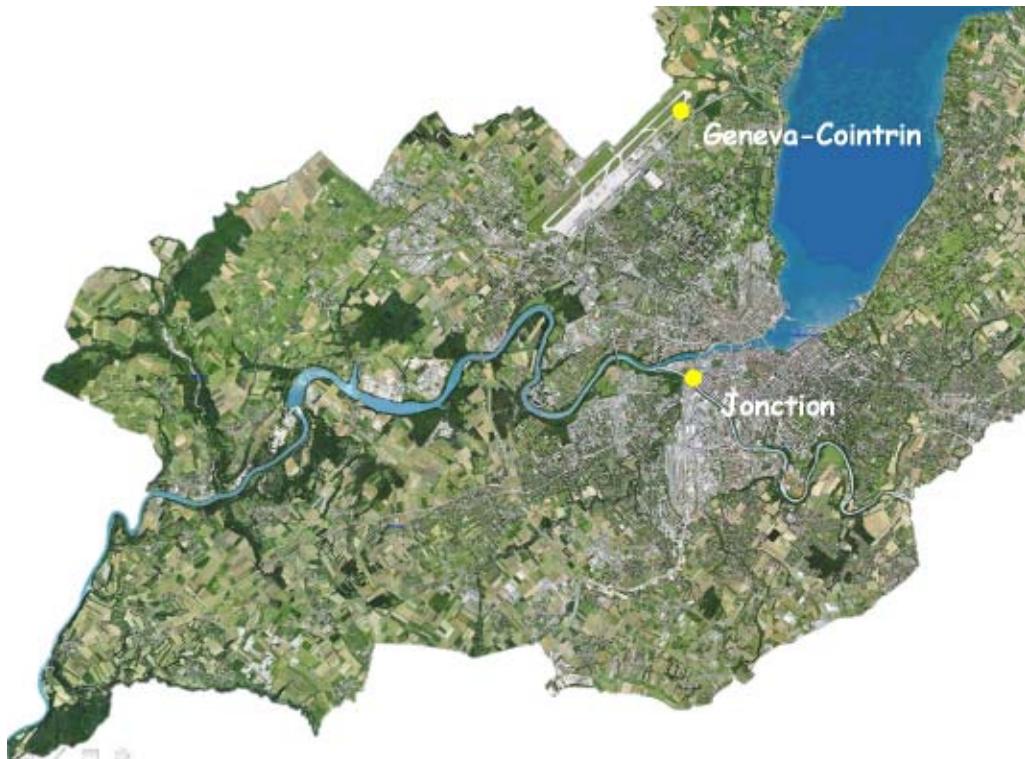


Figure 1 Localisation of the two stations used in the study in the Geneva region.

(except 2000 and 2001 at Jonction for technical reasons), on an hourly basis. At the Geneva-Jonction station, normal beam radiation is also acquired, and the diffuse is then retrieved from these two parameters.

### 3. Meteonorm 5.1

Meteonorm is a software making it possible to generate climatic data where measurements are not available. It was developed for the particular case of Switzerland and takes rather well into account the geographical characteristics of the country. It is based on well validated models and many data banks of several tens of years. It was thereafter extended to the whole world.

To generate the various climatic parameters, the software uses as input internal radiation values or real monthly mean values downloaded from the Internet. It also offers the possibility to import personal hourly or monthly data. In addition, it is also possible to specify the environment, such as for example, "open site", "urban conditions", etc.

The present analysis is carried out by means of the internal values for Geneva-Cointrin, and of real values for the years 1998 to 2005 retrieved from the Internet for comparison with the measurements acquired at Geneva-Jonction. It is done on the following 3 parameters: the global and diffuse horizontal, and the normal beam radiation, for solar altitudes higher than 5°.

### 4. Analysis method

In term of validation, when assessing satellite derived or modelled values based on measurements with the same time step, the comparison can be done hour by hour, by means of scatter plots, mean biases and root mean square differences. Indeed, to each model produced value corresponds a measured value. In the case of generated values, the time series are produced on the basis of average values (lower time step), with a random generation process, and therefore this kind of comparison is not possible.

In the field of solar radiation and natural light, the comparison is often done in term of frequency and cumulated frequency of occurrence. In the first case, the obtained graph is a bar chart (or a line) representative of the relative frequency of occurrence

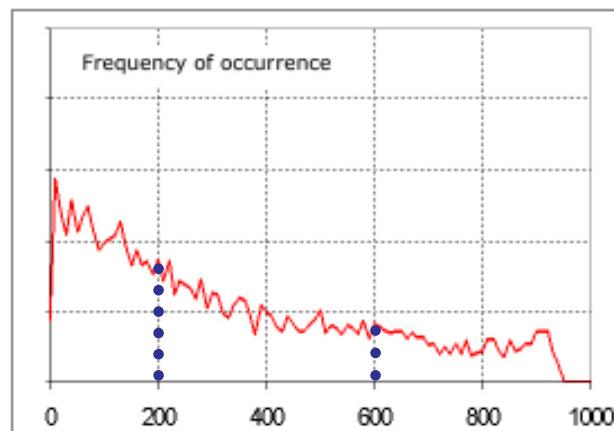


Figure 2 Frequency of occurrence of a parameter.

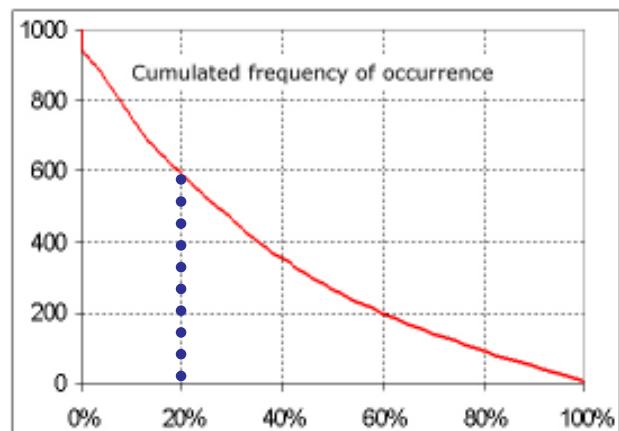


Figure 3 Cumulated frequency of occurrence of the same parameter..

of a given radiation (or any other analyzed parameter). This is illustrated on Figure 2 where for example a 200 value frequency of occurrence is two time higher than for a 600 value. In the second case, the frequencies of occurrence are cumulated, the result is a curve as illustrated on Figure 3. Here for example, one can read on the graph that a value of 600 occurs 20% of the time.

In the present comparison, 2 parameters are analyzed: the absolute irradiance value and the clearness index. The first is representative of the average value of radiation, and the second gives an estimation of the temporal distribution of the radiation over the day.

## 5. Site dependence

The cumulated frequencies of occurrence for the global radiation data from the two measurements sites are first compared. The comparison of the years 1999 and 2003 shows that no important rural-urban effect can be pointed out from the graphs (Figure 4). If specific differences occur between the two sites, the cumulated frequencies of occurrence are very similar. As only the global irradiance is available for the site of Geneva-Cointrin, the comparison with Meteonorm is done with the Geneva-Jonction measurements.

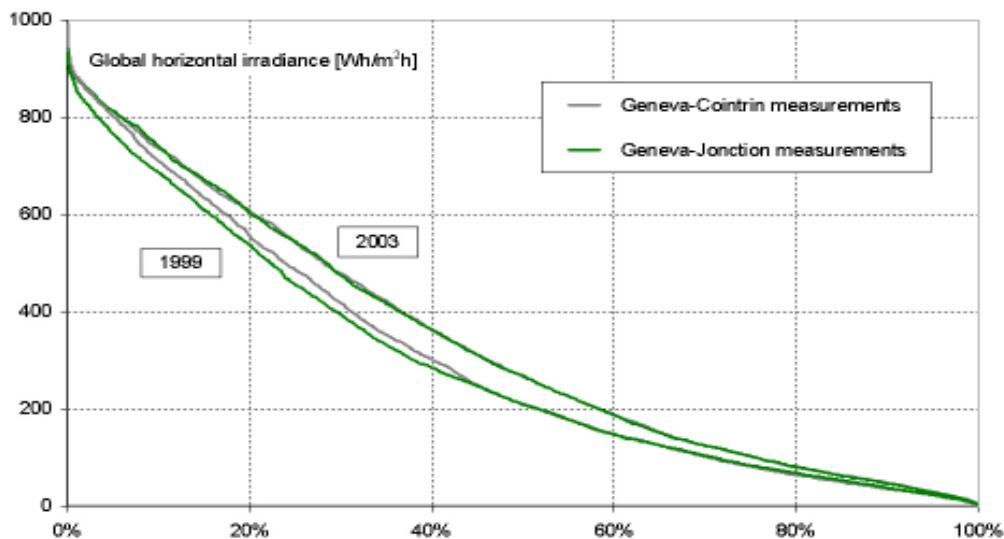


Figure 4 1999 and 2003 cumulated frequencies of occurrence for the global horizontal irradiance, for the 2 sites in the Geneva region

## 6. Interannual variations

From Figure 4, it can be seen that if the curves are very similar for the 2 sites, but they can be different from one year to the other. It is then interesting to analyze the interannual variation (from one year to the other). Figure 5 illustrates these variations for the 1998-2005 period and for the station of Geneva-Cointrin. It shows that the behaviour of the global cumulated frequencies for the different years are relatively similar, except for the year 2003. This confirms the results obtained in a preceding study over the limited summer period (Ineichen 2006a).

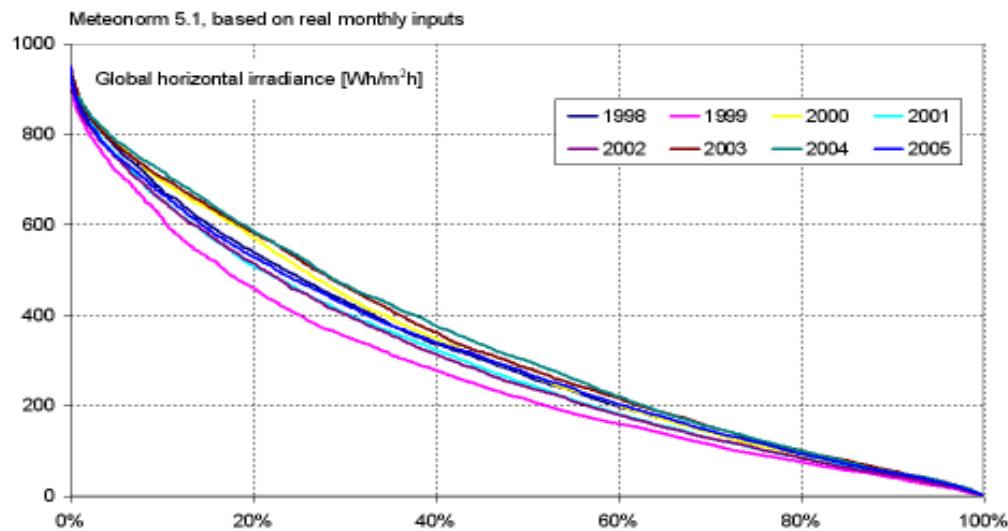


Figure 6 Global horizontal cumulated frequencies of occurrence for the 8 years generated by Meteonorm.

measurements exceed 600 [Wh/m<sup>2</sup>h] 16% of the time and Meteonorm generated data exceed the same value only 10% of the time. In contrary, for the year 2004, measurements exceed 200 [Wh/m<sup>2</sup>h] 55% of the time and Meteonorm generated data exceed the same value 63% of the time. Here it is the year 1999 that stands out negatively from the average.

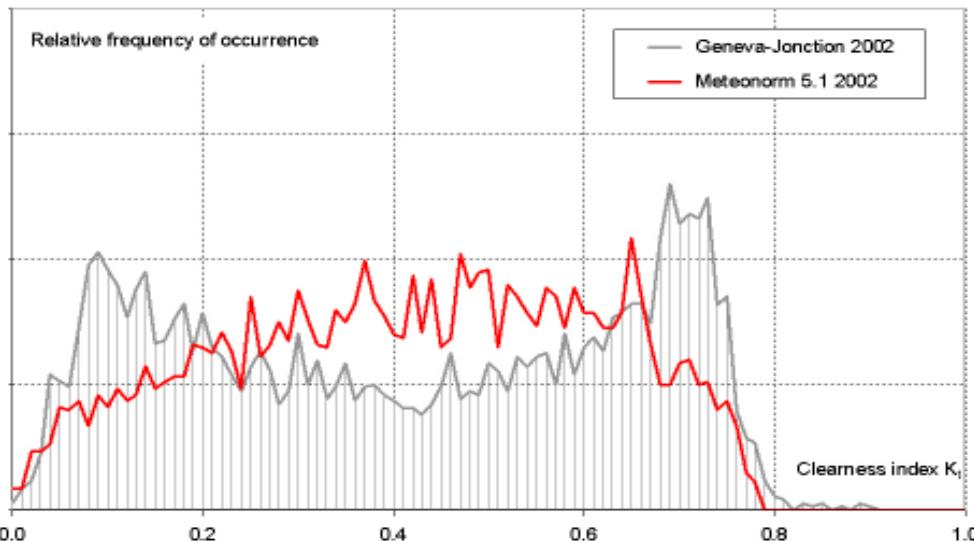


Figure 7 Clearness index  $K_t$  relative frequency of occurrence for the year 2002. Comparison between measurements and Meteonorm generated data.

The relative frequencies of occurrence for the global clearness index are compared on Figure 7. The grey bar chart corresponds to the measurements taken in the city of Geneva, and the red curve to the data generated with Meteonorm for the same year: 2002. Here it can clearly be pointed out that even if the average value of the global horizontal radiation has no bias (see Table I), the distribution of  $K_t$  is not representative of the measurements. Average clearness index values are overestimated, and the high and low  $K_t$  values are underestimated. This is an important result, because the global irradiance is a key parameter in data generation processes. The other parameters like the beam and the diffuse components are generated by splitting the global with the use of the clearness index (or a similar parameter).

Therefore, the differences underlined here will be enhanced when considering the normal beam and the diffuse components.

## 7.2 Beam irradiance

Table II gives the annual hourly mean bias difference between generated data and measurements for the normal beam component. As stated above, the fact to cumulate several models enhances the differences. Furthermore the normal beam component is considered here (and not the horizontal component) and this enhances also the

Normal beam irradiance [Wh/m <sup>2</sup> h]	1998	1999	2000	2001	2002	2003	2004	2005	1998-2005 average	internal data
Geneva-Jonction	332	278	-	-	292	337	310	318	311	-
Meteonorm	278	203	297	252	238	318	327	269	246	273
Bias (meas.-MN)	16%	27%	-	-	19%	6%	-5%	15%	21%	12%

Table II Year by year and average normal beam irradiance comparison between measurements and generated data.

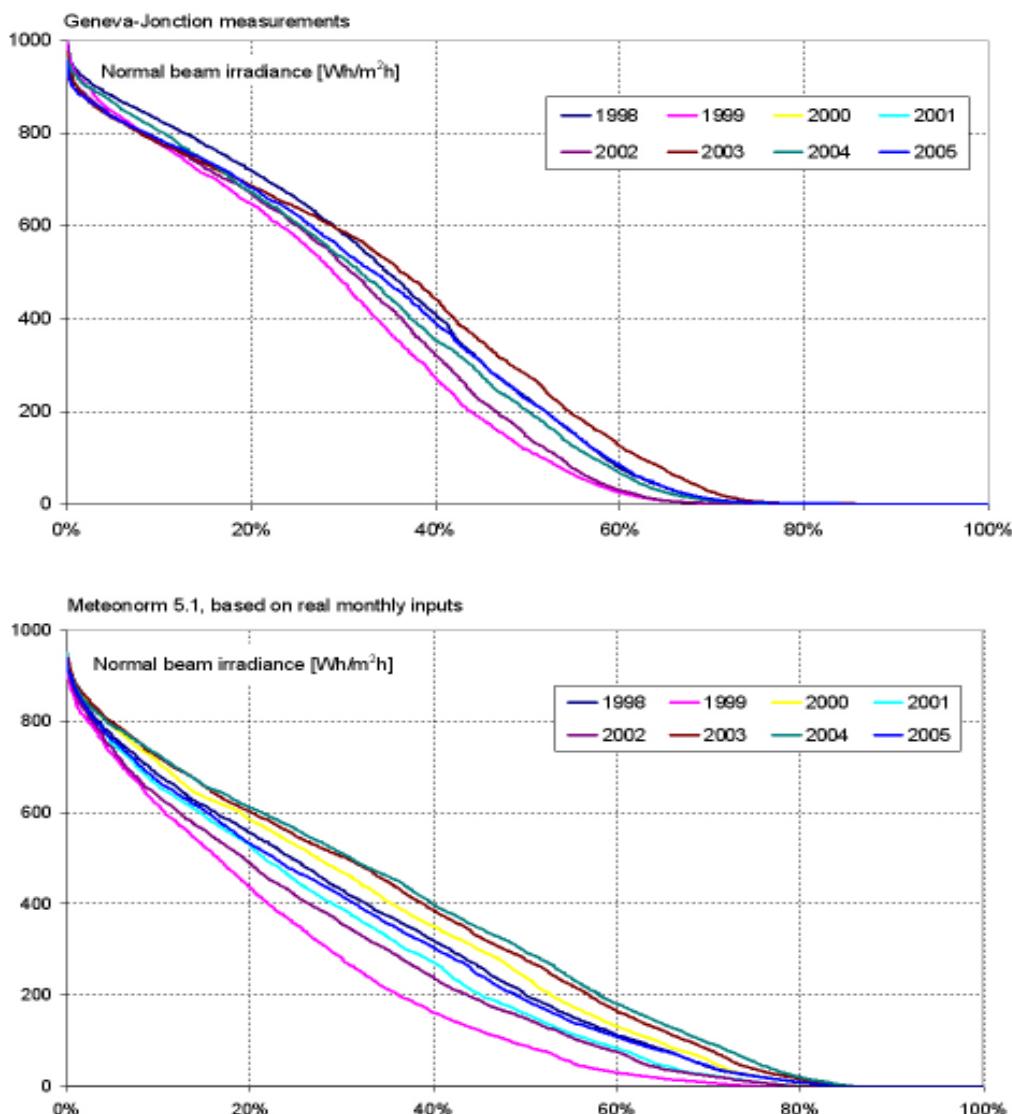


Figure 8 Normal beam cumulated frequencies of occurrence for the 8 years.  
Upper graph: measurements, lower graph: generated by Meteonorm.

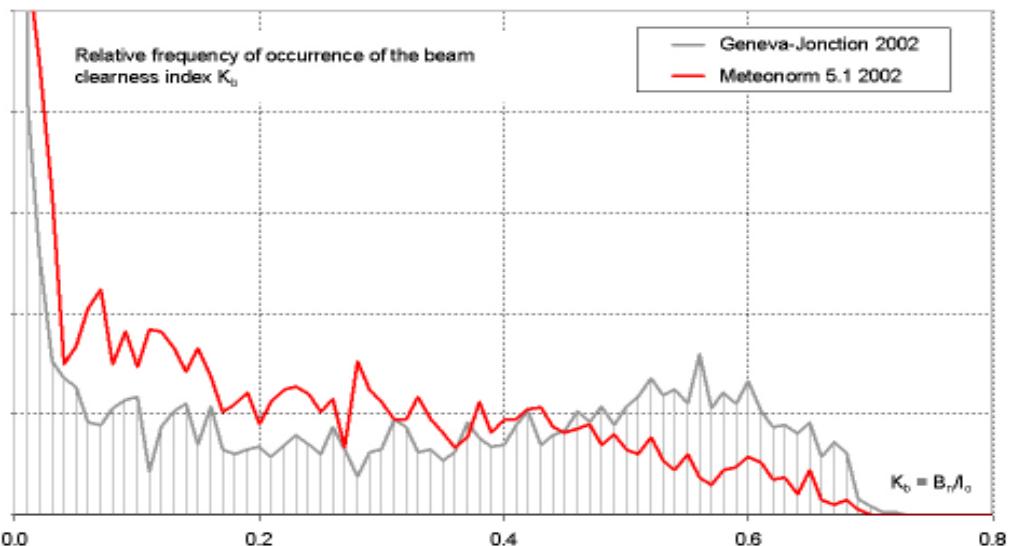


Figure 9 Clearness index  $K_b$  relative frequency of occurrence for the year 2002. Comparison between measurements and Meteonorm generated data.

differences at the beginning and the end of the day. The bias reaches here 21% over the considered period.

In the same way than for the global component, the cumulated frequencies of occurrence are plotted on Figure 8. It can be pointed out that not only the average difference is relatively high, but the shape of the curves is also very different (see Figure 11). Frequencies of occurrence of high normal beam irradiance values are always underestimated by Meteonorm.

The comparison of the relative frequency of occurrence shows an underestimation by Meteonorm for high beam clearness indices, and an overestimation for low beam clearness indices, as represented on Figure 9.

One reason of this behaviour is probably the fact that Meteonorm uses climatic inputs for the turbidity and/or the water vapour. These inputs retrieved from large climatic data banks are often too high in absolute values, and the seasonal variations are not always correctly taken into account (Ineichen, 2006c). The second reason is the completely different shape of the clearness index distribution. In fact, the global-beam splitting models available in the literature (Perez 1992, Skartveit 1998) and used in Meteonorm are not only based on the absolute global irradiance value to generate the beam and diffuses components, but also on the global clearness index which is representative of the irradiance distribution during the day.

### 7.3 Diffuse irradiance

The diffuse irradiance is obtained by difference of the global and beam components.

Diffuse irradiance [Wh/m <sup>2</sup> h]	1998	1999	2000	2001	2002	2003	2004	2005	1998-2005 average	internal data
Geneva-Jonction	125	127	-	-	131	135	134	136	131	-
Meteonorm	161	160	156	161	164	157	156	165	160	160
Bias (meas.-MN)	-29%	-26%	-	-	-25%	-16%	-17%	-22%	-22%	-22%

Table III Year by year and average diffuse irradiance comparison between measurements and generated data.

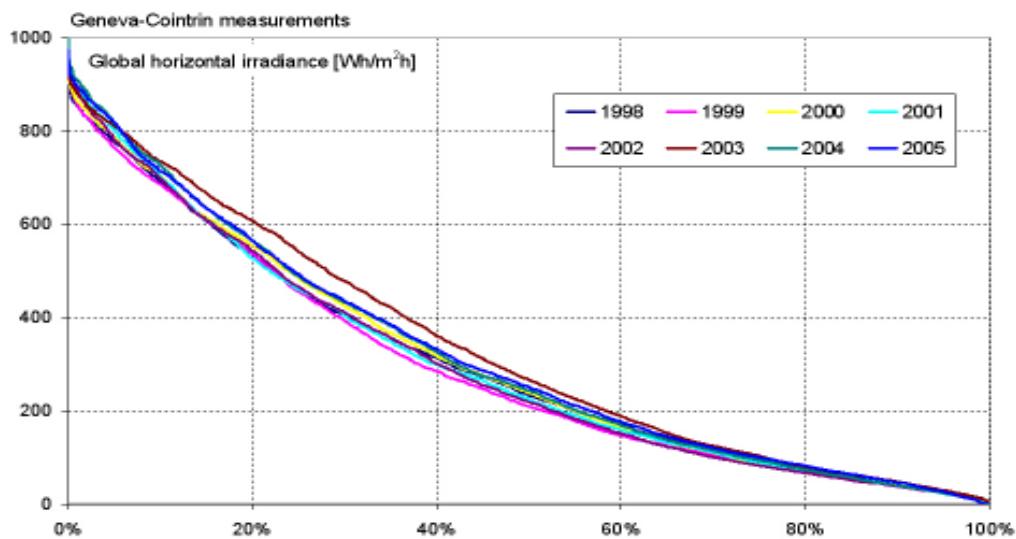


Figure 5 Global horizontal cumulated frequencies of occurrence for the rural site Geneva-Cointrin and the 8 years under analysis

## 7. Comparison with Meteonorm

For the comparison, the radiation components are generated with Meteonorm 5.1 on the basis of 12 average values per year retrieved from the Internet (global irradiance and dry bulb temperature). Meteonorm then splits the global into the beam and diffuse components by the means of well validated models. A comparison is also done with the radiation components generated by Meteonorm on the basis of its internal data bank (average over 10 years of global and temperature measurements from 1983 to 1992).

### 7.1 Global irradiance

The first comparison is done on the annual hourly mean values and the average over the considered period. Table I gives the global horizontal irradiance annual hourly mean for sun elevations higher than 5° (in order to avoid biases due to the horizon). The Table shows that even if based on real monthly values, Meteonorm over- and underestimates the global irradiance up to 7-9%. On the other hand, there is quite no bias if one considers the average over the 8 years period.

Global irradiance [Wh/m <sup>2</sup> h]	1998	1999	2000	2001	2002	2003	2004	2005	1998-2005 average	internal data
Geneva-Cointrin	301	289	305	298	296	333	313	317	306	-
Geneva-Jonction	319	299	-	-	303	333	316	319	315	-
Meteonorm	318	273	326	302	299	336	342	316	314	299
Bias (meas.-MN)	-3%	7%	-7%	-1%	0%	-1%	-9%	0%	-1%	4%

Table I Year by year and average global irradiance comparison between measurements and generated data.

The second step consists of the comparison of the cumulated frequencies of occurrence. Figure 6 represents the same curves than Figure 5, but for global irradiances generated with Meteonorm and based on measured monthly averages. Here also the biases shown on Table I are present: for example, for the year 1999,

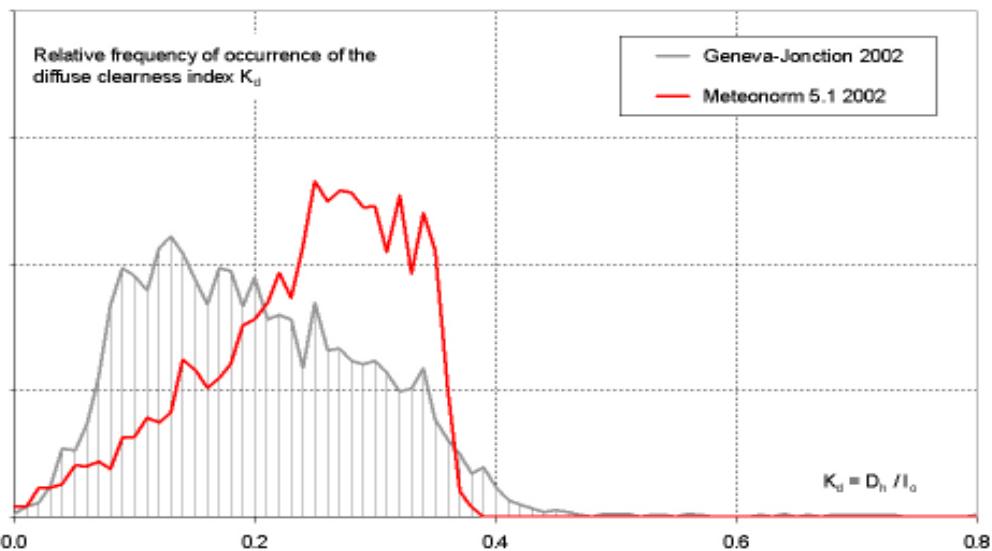


Figure 10 Diffuse clearness index  $K_d$  relative frequency of occurrence for the year 2002. Comparison between measurements and Meteonorm generated data.

The consequence of the slight Meteonorm global overestimation and beam underestimation conducts to an important overestimation of the diffuse component. The annual hourly averages are given in Table III.

Figure 10 illustrates the diffuse clearness index relative frequency of occurrence distribution. It clearly shows that these distributions are completely different. This means that the behaviour of the irradiance during the day is not correctly taken into account.

Due to the low diffuse average hourly values, the relative mean bias differences are high. These biases are intrinsically not very important, but the fact that the distribution does not correspond to the measurements can be a not negligible source of error depending of the use of the generated data.

Figures 7, 9 and 10 represent the year 2002. The same graphs can be made year by year and for the average over the period; the relative frequencies show then exactly the same tendency (see. Figure 13).

## 8. Conclusions

Meteonorm is widely used to generate data were no measurements are available. Two kind of climatic time series can be generated: on the basis of average internal data, and of global irradiance monthly mean measured values.

The produced time series are compared in term of annual hourly means, cumulated frequency and relative frequency of occurrence, and in term of absolute irradiance values and clearness indices.

The following conclusions come out from this study:

- no significative **site dependence** could be pointed between the two measurement sites situated in the city of Geneva and in the countryside, the global irradiance and the clearness index behaviour are very similar. This means that the observed differences between measurements and Meteonorm data cannot be attributed to the localisation of the measurements (Figure 11).
- Except for the year 2003, **the variation from one year to the other** in term

of global irradiance and frequency of occurrence is very tight. For the beam irradiance, the interannual variation is more significative, but the shape of the curves is preserved. It is therefore possible to use average curves over the considered period to express the model-measurements differences.

- If **the global** average value and frequency of occurrence are in relatively good accordance (Figure 12, upper graph), the clearness index distribution is very different between Meteonorm generated time series and measurements. This means that the variation during the day is not correctly taken into account by Meteonorm (Figure 13, upper graph).
- **The beam component** time series is modelled on the basis of the global clearness index (or a similar parameter). The distribution discrepancies observed for the global clearness index are enhanced by cumulating several models, and the shape of the frequency of occurrence curves and clearness index distributions are very different between Meteonorm and measurements (Figure 12 and 13, middle graphs). Another possible source of differences is the fact that Meteonorm uses climatic data banks for the turbidity and/or the water vapour content of the atmosphere. These are often overestimated.
- **The diffuse component** is retrieved from the global and beam components and presents therefore the beam complementary abnormalities (Figures 12 and 13, lower graphs).

The use of software such as Meteonorm for the generation of data when those are missing must be made with precautions and one has to be very critical when using such data for the evaluation of specific buildings or installations.

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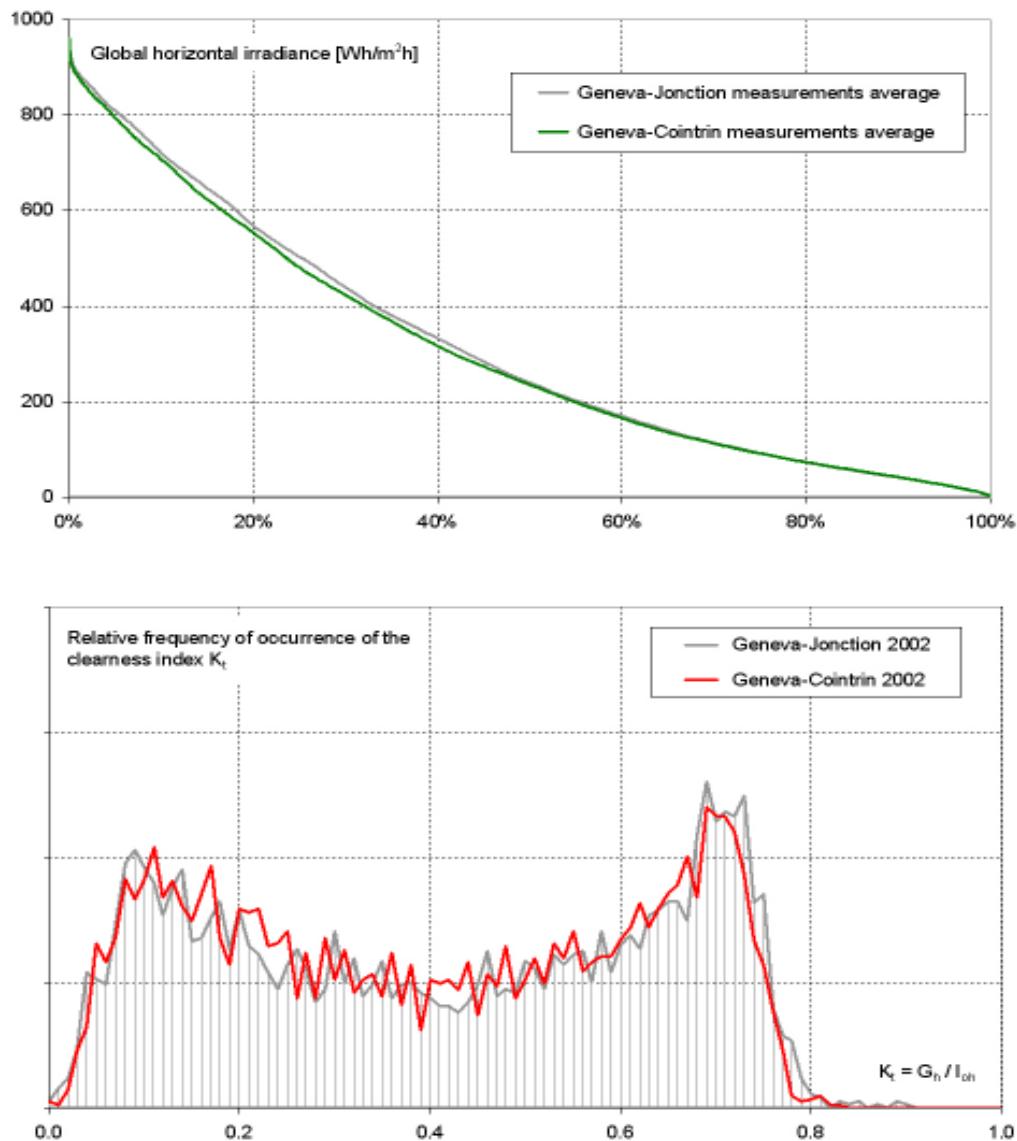


Figure 11 Comparison of the data acquired at Geneva-Jonction and Geneva-Cointrin averaged over the considered period.  
Upper graph: global irradiance cumulated frequency of occurrence.  
Lower graph: relative frequency of occurrence of the global clearness index.

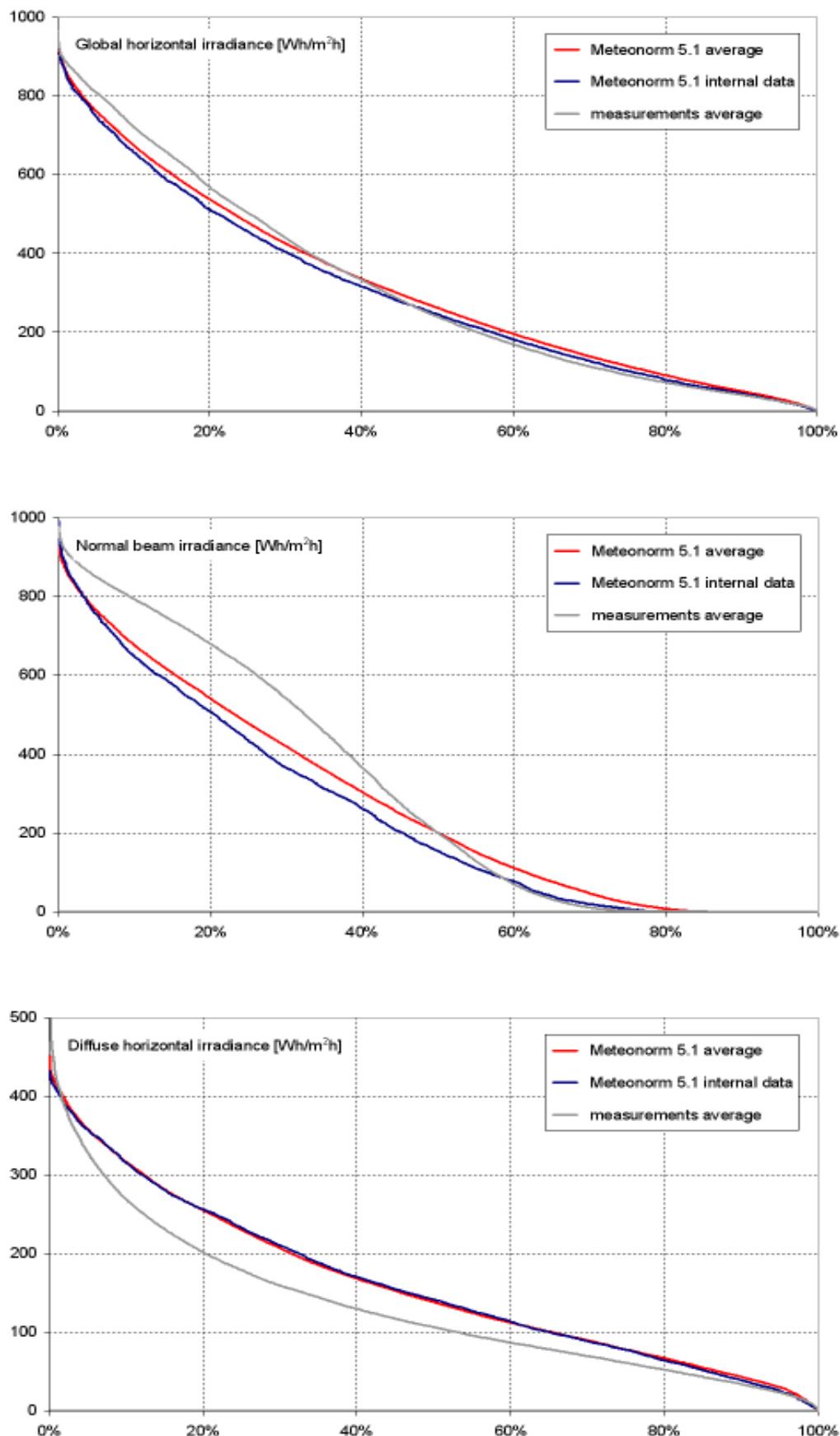


Figure 12 Average cumulated frequencies of occurrence for the 3 radiation components, comparison between Geneva-Jonction and Meteonorm.  
Upper graph: global horizontal irradiance  
Middle graph: normal beam irradiance  
Lower graph: diffuse horizontal irradiance.

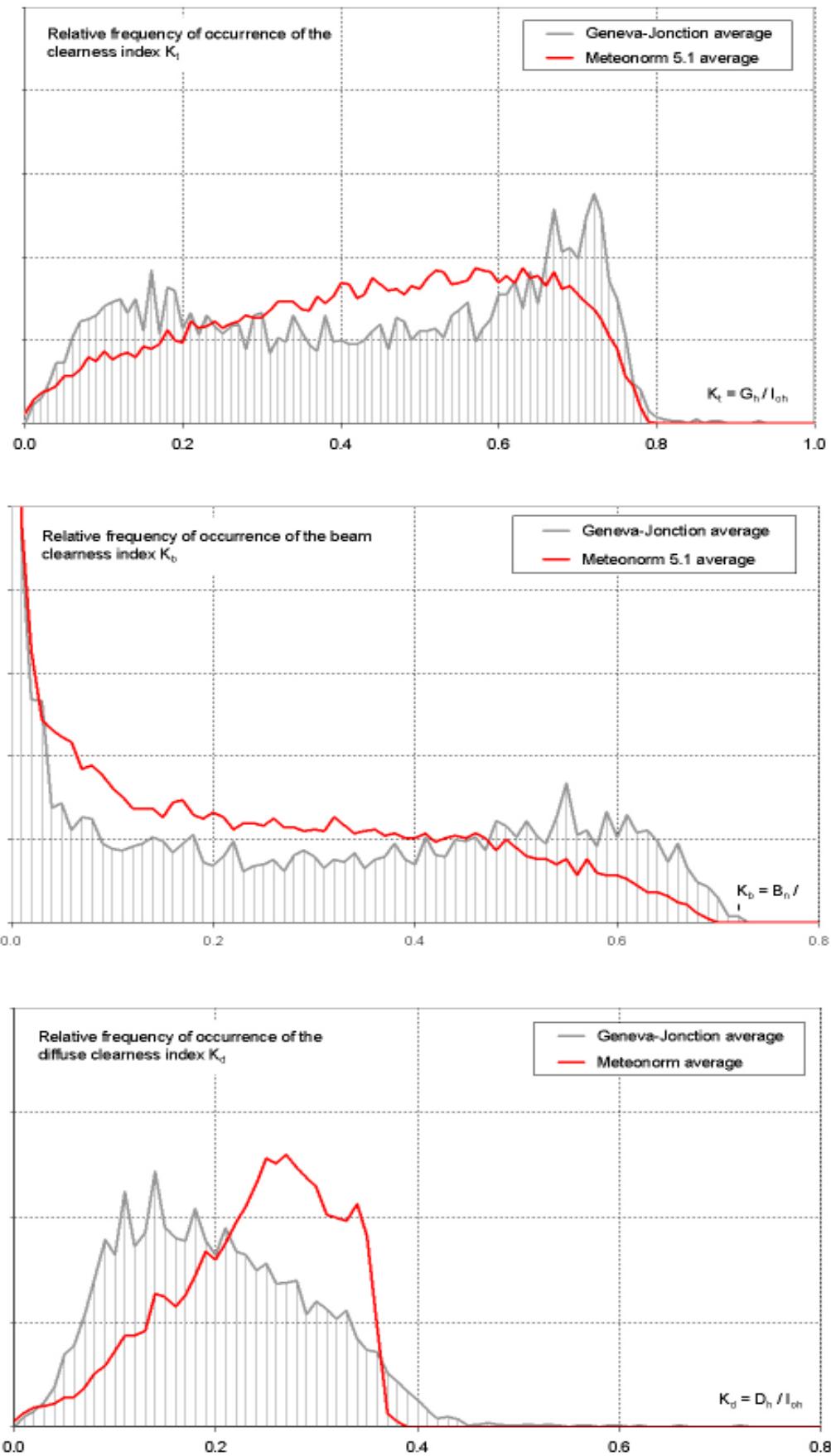


Figure 13 Clearness index relative frequency of occurrence (1998-2005 average). Comparison between measurements and Meteonorm generated data  
 Upper graph: global clearness index  
 Middle graph: beam clearness index  
 Lower graph: diffuse clearness index.