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Global irradiance on tilted and oriented planes: model validations

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Abstract

Hourly models that predict global irradiance on tilted surfaces are validated on one year data acquired in Geneva and Denver. The reflected component is analyzed separately for the site of Geneva.

As the beam component is an input parameter for anisotropic transposition models, three ways are investigated: the transposition based on measured beam irradiance, the model chain based on the only global irradiance input data, and the transposition of synthetic hourly data generated from monthly values.

The main conclusions confirm the results published in the literature:

- if the reflected component is known, the tilted irradiance can be evaluated with a low bias of some percents, and a precision around 11% for the best model,
- the bias is not influenced by the use of a diffuse fraction model to obtain the beam component from the measured global, while the dispersion is higher and reaches 22% for the best model,
- the knowledge of the reflected irradiance has a great importance on the overall bias when dealing with high tilt angles, its error is directly reported on the model bias.

1. Introduction

In the field of photovoltaïc powerplants, thermal applications or architecture, most of the solar systems are oriented and tilted. The solar ressource data, if not acquired specifically for the considered system, are available only for the horizontal plane, and often only for the global component. It is therefore necessary to transpose the irradiance from horizontal to the tilted and oriented plane.

The present study is complementary to many other transposition from horizontal to inclined surfaces models validations already published (for example Chirarattananon 2007, Diez-Mediavilla 2005, Gueymard 2009, Ineichen 1988, Mehleri 2010, Perez 1987, Robledo 1998, Temps R.C 1977, Vartiainen E. 2000, Harrison 1989, Badescu 2002, Noorian 2008, etc.). It is based upon one year of global and reflected, tilted and oriented measurements with artificial horizon in Geneva (CH), and one year of global and reflected measurements in Denver (USA).

2. Ground data

In Geneva, the data were acquired from June 1986 to May 1987 on the four vertical planes, and 30°, 45° and 60° south oriented planes. The reflected and celestial global tilted irradiances were acquired separetely with the use of an artificial horizon, covered with a black honeycomb. The pyranometers were Kipp+Zonen CM10 for the global, the reflected, and the diffuse irradiance. The normal beam was acquired with an Eppley NIP, the diffuse component with the help of a shading disk. The acquisition time step was 6 minutes, integrated to hourly values.

The Denver data were downloaded from NREL. The global and diffuse components were acquired on a one minute time step with Eppley PSP, and the beam component with an Eppley NIP. The diffuse is obtained with a shading disk, the reflected component from an Eppley PSP situated at 1.6 m from the ground.

A first quality control is applied by the laboratory in charge of the acquisition. A second quality control is applied following Ineichen (2009 and 2011), and finally, the data are kept if the absolute difference (G_h - D_h versus B_h) doesn't exceed 10%.

Hourly values are considered here for the validation, and only the celestial part of the global irradiance is taken into account. For the data acquired in Geneva, the reflected and celestial parts are acquired separately and can directly be used as are. For the data from Denver, the hemispherical inclined irradiance are acquired, but only the horizontal reflected component; it is therefore necessary to remove the reflected part from the inclined global irradiances. To assess the istotropy assumption on the reflected irradiance, the data from Geneva are used and the corresponding measurements against evaluated reflected irradiances are given on Figure 1. The conclusion drawn from the Geneva's data is that the isotropic assumption is correct for the all south oriented planes, and that the isotropic reflected irradiance on the other orientations have to be enhanced by 15%. This correction is applied on the data from Denver.

The sky type classification is based on the modified clearness index K_t' (Perez 1990) and is done following Ineichen (2009 and 2011).

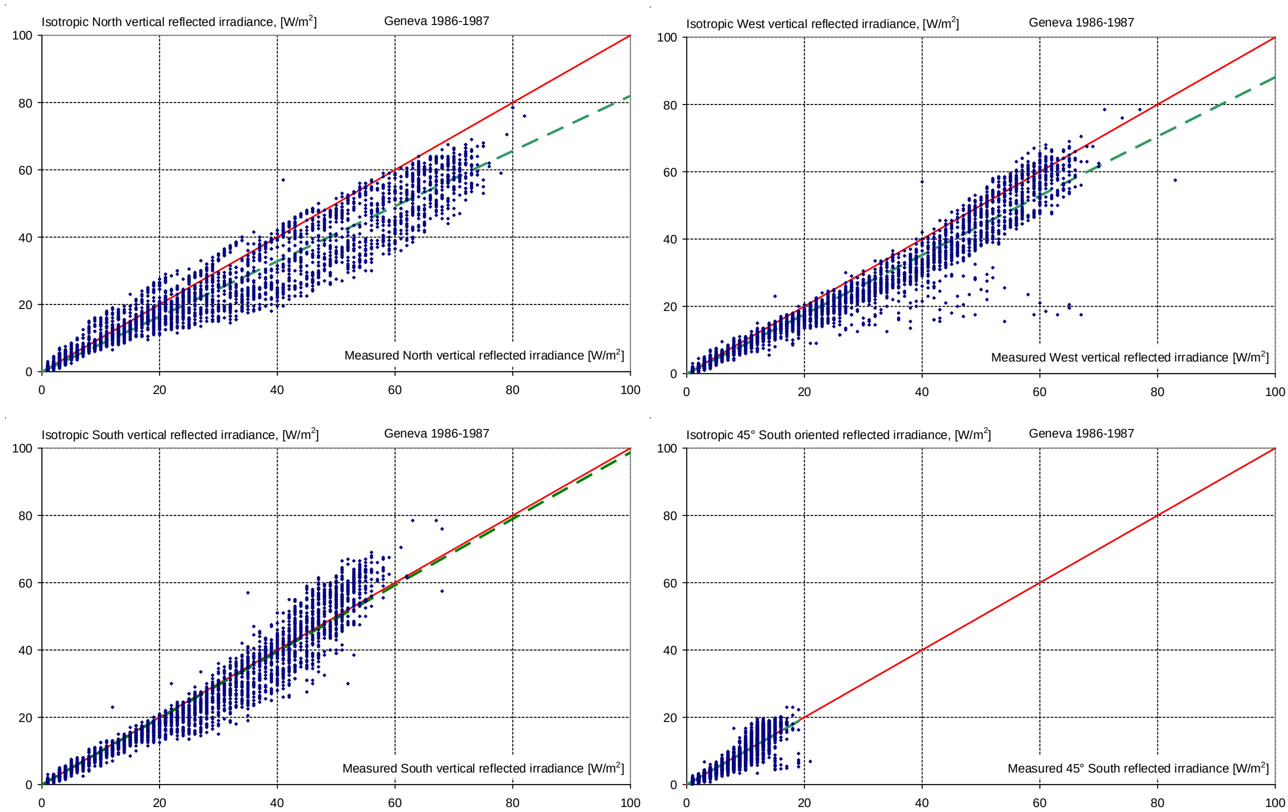

Figure 1 Modelled against measured reflected irradiance for data from Geneva. The isotropic assumption is used here to evaluate the inclined reflected irradiance.

3. Models description

In a first step, the assumption is done that the beam irradiance is available on an hourly basis in the data set and is used as input to the models. In a second step, a diffuse fraction model is applied on the global irradiance to obtain the beam component that is used as input instead of the measurements. Finally, the transposition models are applied on synthetic hourly data.

3.1 Transposition models

Seven transposition models are investigated in this study; they will be compared to the isotropic hypothesis:

- the isotropic hypothesis assumes that the diffuse radiance is the same over the complete sky vault,

- the hay model (Hay 1979) adds a circumsolar component modulated by the beam clearness index K_b defined by:

$$K_b = \frac{B_n}{I_o}$$

- the Perez model (Perez 1987) uses a brightening in the circumsolar and the horizon region. The model is based on a sky clearness index ε and a sky brightness index Δ,
- the Klucher model (Klucher 1979) has a circumsolar and a horizon brightening based on a diffuse fraction defined as:

$$F = \left(1 - \frac{D_h}{G_h} \right)^2$$

- the Reindl model (Reindl 1990) is similar to the Hay model with an added horizon brightening based on the B_h/G_h ratio,
- in the Gueymard model (Gueymard 1987) the sky diffuse component is derived from typical radiance patterns for clear and overcast conditions, taking anisotropic effects into account,
- the Temps & Coulson model (Temps 1977) is an evolution of the Robinson model (Robinson 1966); it is based on radiative transfer calculations,
- the Willmott model (Willmott 1982) takes into account diurnal assymetries and the effects of the horizon brightening.

All these models are well described in their original reference. If other parameters than the basic irradiance components are needed as input by the model, the author gives a substitution form based on the irradiance; this formulation is used in the present study.

3.2 Diffuse fraction models

Three diffuse fraction moldels are used to split the global irradiance into the diffuse and beam components:

- Erbs model (or EKD model, Erbs, Klucher and Duffie 1982): the first correlation between the hourly clearness index K_t defined as:

$$K_t = \frac{G_h}{I_o \cdot \sin(h)}$$

  and the corresponding diffuse fraction was developed in 1960 by Liu and Jordan (Liu 1960) as a linear function, it was revised as polynomial by Orgill & Hollands (Orgill 1977) and Ruth & Chant (Ruth 1976), based on 4 years data acquired in Toronto. The diffuse irradiance was measured with a shadowband pyranometer. In 1982 Erbs et al. adapted this correlation to extend it to latitudes from 31° to 42° North, and validated it on data from the United States, based on pyrheliometric measurements. The correlation is divided into 3 zones: a linear regression for

$0 < K_t \leq 0.22$, a fourth degree polynomial for $0.22 < K_t \leq 0.80$ and a constant value for $K_t > 0.80$.

- the DirInt global to direct model (Perez et al., 1992) is based on a quasi-physical model, the DISC model, developed by Maxwell (Maxwell 1987), which has the form of a clear sky irradiance based on a Linke turbidity factor T_L equal to 2.2, attenuated by a function of the clearness index K_t. This beam component is then corrected by a function of the modified clearness index K'_t as defined in Perez et al. (Perez 1990):

$$K_t' = \frac{K_t}{\left(1.031 \cdot \exp\left(-1.4 / \left(0.9 + 9.4 / AM\right)\right) + 0.1\right)}$$

  where AM is the optical air mass, the solar zenith angle, the atmospheric water vapor column *w* and a stability index ΔK_t that accounts for the dynamics of the time series. The corresponding coefficients are obtained from a four-dimensional lookup table consisting of a 6x6x5x7 matrix.

- Skartveit and Olseth model: following the idea of Perez et al. (Perez 1992), Skartveit and Olseth modified their diffuse fraction model and introduced an hour-to-hour variability index (Skartveit et al., 1998). If the basic concept of the model is similar to the DirInt model and needs the same input parameters, the main difference is that its driving functions are analytical and continuous rather than based upon lookup tables as in the DirInt model.

3.3 Synthetic hourly irradiance

The transposition models are applied on synthetic hourly data generated from 12 monthly values. Data generated by PvSyst and Meteonorm are used for the validation. Both softwares use the same algorithms as a basis: Aguiar model (Aguiar 1988) to generate daily values from the monthly total, and, in a second step, Aguiar's autoregressive gaussian model to generate the hourly values (Aguiar 1992). In Meteonorm, the Markov matrices are adapted to take into account local conditions such as the altitude and the turbidity; they are based on the clear sky index K_c:

$$K_c = \frac{G_h}{G_{hc}}$$

where G_{hc} is the clear sky global irradiance, instead of the original matrices based on the clearness index K_t (see Meteonorm user manuals).

The next step is the derivation of the beam component from the synthetic generated global irradiance with the help of a diffuse fraction model. The DirInt model is implemented in Meteonorm, while the Erbs, Klucher and Duffie algorithm is used in PvSyst. It is planed to replace it by the DirInt model in the next version of PvSyst (version 6).

4. Validation procedure

The hourly validation is done in terms of the usual first order statistics represented by the mean bias difference *mbd* between the model and the measurements, and the root mean square difference *rmsd* respectively defined by:

$$mbd = \frac{1}{N}\sum_{i=1}^{N}(R_{i,\mathrm{mod}} - R_{i,meas})$$

and

$$rmsd = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(R_{i,\mathrm{mod}} - R_{i,meas})^2}$$

where $R_{i,mod}$ and $R_{i,meas}$ are the modelled and measured irradiances, N the number of considered points.

The first validation is conducted with ground global and beam irradiance measurements as input data for the transposition models; the results reflects the bias and precisions of the different models.

In a second step, the beam irradiance is retrieved from the global measurements with the help of the three diffuse fraction models described in section 3. These models are extensively validated in (Ineichen 2008, Perez 1989). The obtained results for Geneva and Denver are illustrated on Figure 2. The general conclusion was that the models perform with a mean bias difference of -3% to -5% and a root mean square difference of 25%.

Finally, the hourly data are cumulated into monthly values in order to evaluate the chain represented by the Aguiar synthetic generation process and the transposition models. In this case, the hour by hour comparison is not applicable, only the bias of the models can be avaluated.

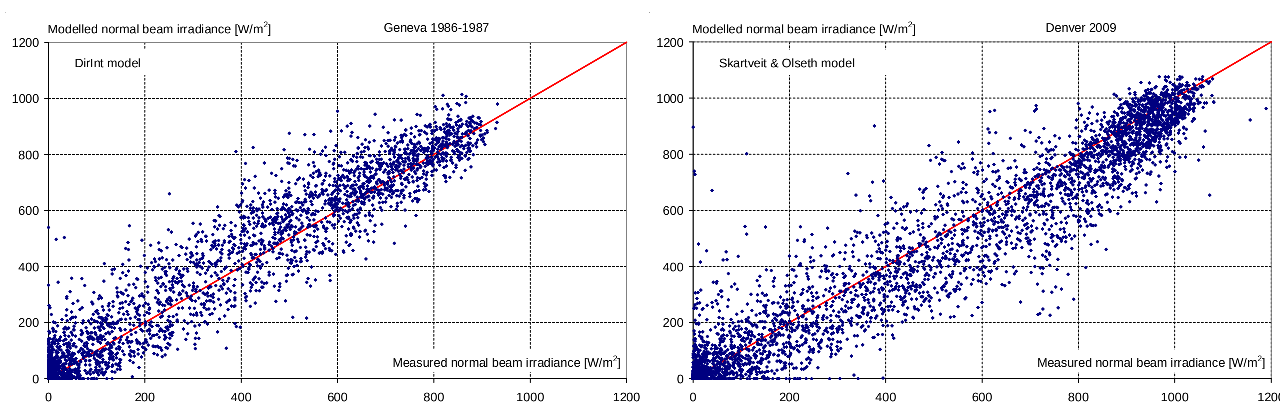

Figure 2 Modelled against measured normal beam irradiance for the DirInt model in Geneva and the Skartveit & Olseth model in Denver.

5. Irradiance transposition validation

A visual validation is illustrated on Figure 3 for two different models applied on data from the site of Geneva and the south oriented vertical plane. The graphs for both sites, all the orientations and models are given in the Annex. Even if the north oriented vertical plane has not much sigification, it is nevertheles also given.

5.1 Transposition

The results for the two sites in term of mean bias difference and root mean square difference are given on Table I and Figure 4. The correlation coefficients R^2 are not given in the Table, they are all higher than 0.96 (they can be found on the graphs in the Annex. Except for the north oriented vertical plane, the results are very similar for the two sites. The biases are less than 5% for the best models, and the slight variations can be attributed to the fact that in Denver, the reflected irradiance is not measured, but evaluated from the horizontal outgoing global component.

The root mean square difference is higher for the north oriented vertical plane due to the low level of irradiance (the table is in relative values). In term of absolute values, they have the same order of magnitude than for the other planes. The same behavior can be seen for the east and west oriented plane in a less manner.

Differentiating the sky types gives significantly similar results in term of ranking: the bias remain slightly negative for clear and intermediate conditions, the root mean square difference is around 10% for clear, 15% for intermediate and 25% for overcast sky types. The values are higher for the overcast conditions due to the low level of irradiance. The Tables and Figures for the three sky conditions are given in the Annex in absolute and relative values.

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	53	4027	28%	52%	2%	40%	4%	29%	51%	80%	2%	40%	18%	41%	-10%	55%	-22%	86%
	East	134	4027	-4%	30%	-5%	22%	-2%	20%	5%	31%	-5%	22%	-6%	28%	-12%	36%	-12%	35%
	South	187	4027	-10%	22%	-7%	15%	-3%	12%	-3%	18%	-7%	15%	-10%	21%	-14%	32%	-11%	22%
	West	139	4027	-3%	29%	-4%	21%	-2%	19%	5%	30%	-4%	21%	-5%	26%	-12%	35%	-12%	36%
	S45°	319	4027	-8%	14%	-5%	9%	-3%	6%	-3%	9%	-5%	9%	-7%	13%	-15%	29%	-10%	17%
Denver (2009) Measurements	North	70	4098	-6%	39%	-28%	51%	-18%	33%	12%	48%	-28%	51%	-11%	33%	-36%	59%	-56%	99%
	East	224	4098	-8%	18%	-7%	14%	-3%	10%	-2%	17%	-7%	14%	-7%	15%	-14%	22%	-13%	24%
	South	291	4098	-8%	15%	-5%	10%	-2%	8%	-4%	13%	-5%	10%	-7%	13%	-12%	20%	-9%	15%
	West	181	4098	-9%	22%	-10%	19%	-5%	13%	-2%	21%	-10%	19%	-9%	19%	-16%	28%	-19%	34%
	S40°	435	4098	0%	9%	2%	8%	4%	9%	4%	10%	2%	8%	1%	9%	-7%	19%	-2%	12%
Geneva (86-87) Measurements	all	195	16108	-7%	22%	-5%	15%	-3%	12%	0%	19%	-5%	15%	-7%	20%	-14%	33%	-11%	25%
Denver (2009) Measurements	all	283	16392	-5%	14%	-4%	12%	0%	10%	0%	14%	-4%	12%	-4%	13%	-11%	22%	-9%	19%
all	all	239	32500	-6%	17%	-4%	13%	-1%	11%	0%	16%	-4%	13%	-5%	15%	-13%	26%	-10%	21%

Table I Global irradiance Model-Measurements *mbd* and *rmsd*. The transposition is based on measurements of the global and the beam irradiances . (The north orientation is not taken into account in the «all» statistic).

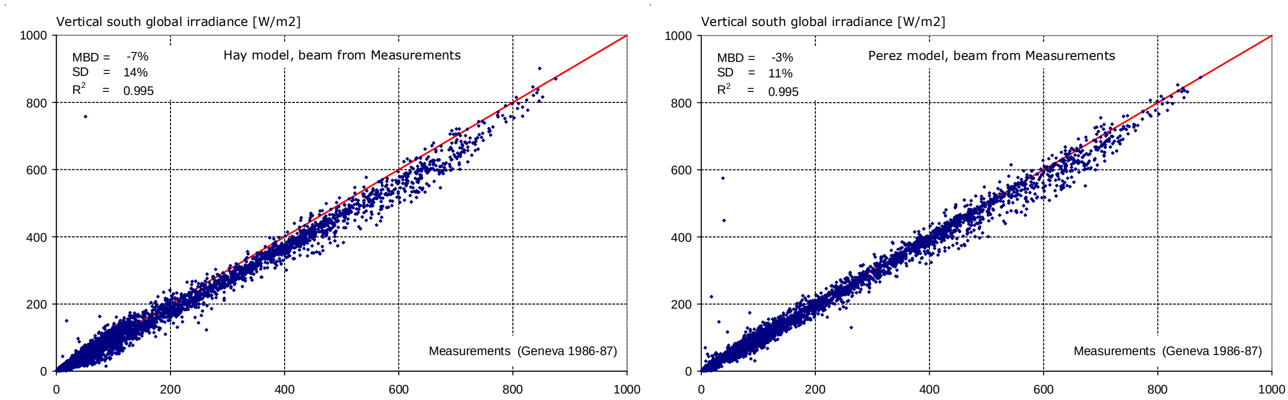

Figure 3 Scatter plots for the site of Geneva and two transposition models: Hay and Perez The mean bias difference, the standard deviation and the correlation coefficient are given on the graph.

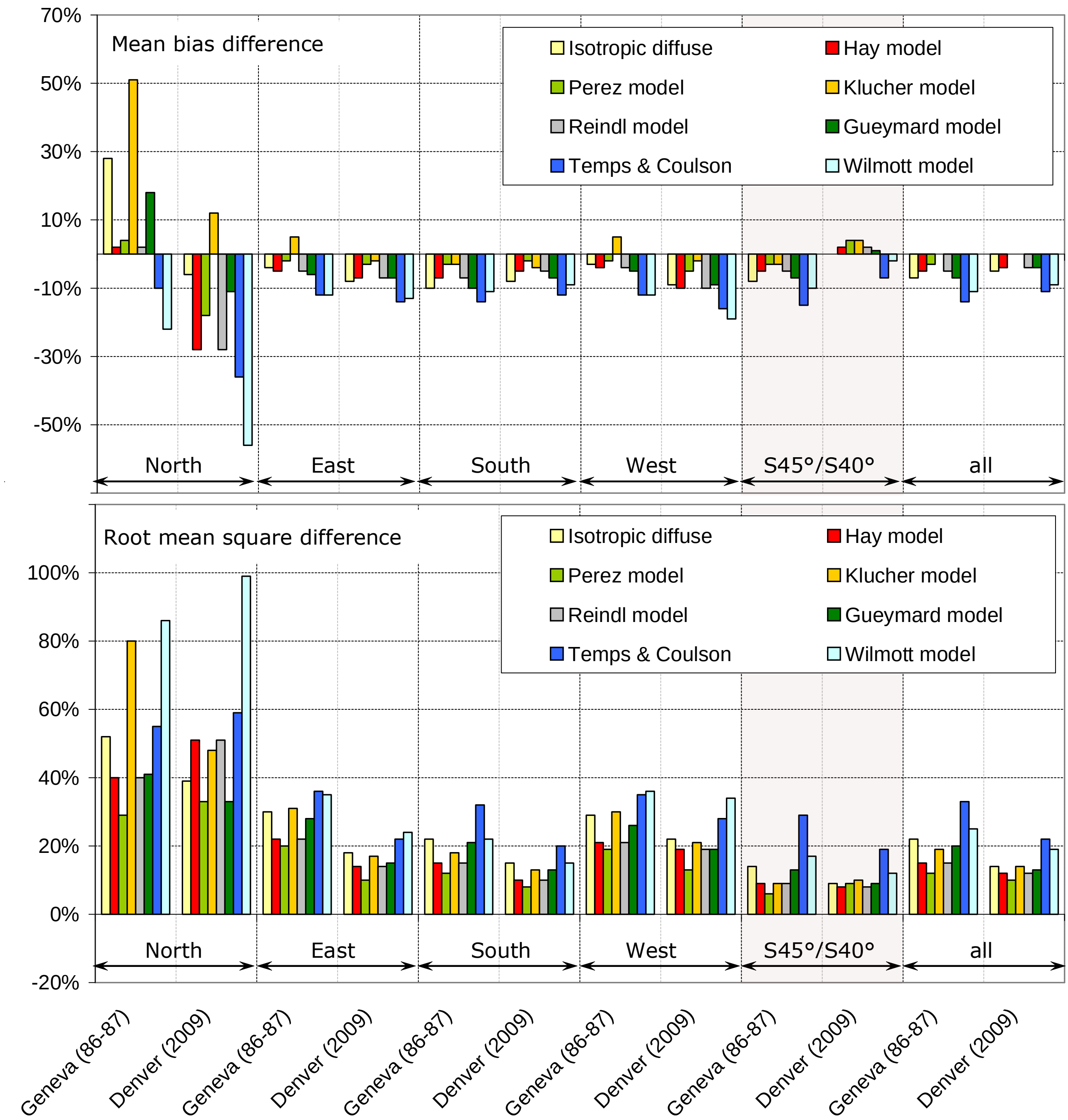

Figure 4 Mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes.

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Erbs model	North	53	4027	27%	54%	0%	55%	5%	43%	49%	75%	0%	55%	16%	46%	-8%	63%	-12%	67%
	East	134	4027	-1%	41%	-2%	40%	3%	37%	7%	42%	-2%	40%	-3%	41%	-8%	44%	-7%	44%
	South	187	4027	-7%	23%	-3%	19%	1%	16%	0%	21%	-3%	19%	-6%	23%	-10%	30%	-7%	23%
	West	139	4027	-4%	44%	-4%	43%	0%	39%	4%	44%	-4%	43%	-6%	45%	-10%	46%	-9%	47%
	S45°	319	4027	-5%	12%	-1%	9%	1%	8%	0%	10%	-1%	9%	-4%	11%	-11%	23%	-7%	14%
Denver (2009) Erbs model	North	70	4098	2%	40%	-26%	55%	-13%	36%	22%	50%	-26%	55%	-4%	37%	-29%	60%	-37%	67%
	East	224	4098	-11%	36%	-9%	31%	-4%	28%	-5%	36%	-9%	31%	-10%	35%	-16%	35%	-14%	34%
	South	291	4098	-11%	25%	-7%	19%	-3%	17%	-7%	24%	-7%	19%	-9%	22%	-15%	26%	-11%	22%
	West	181	4098	-13%	42%	-15%	37%	-8%	33%	-5%	41%	-15%	37%	-13%	41%	-20%	41%	-20%	41%
	S40°	435	4098	-1%	14%	2%	12%	4%	13%	4%	14%	2%	12%	0%	13%	-8%	19%	-3%	14%
Geneva (86-87) Erbs model	all	195	16108	-5%	26%	-3%	24%	1%	22%	2%	25%	-3%	24%	-5%	26%	-10%	33%	-8%	28%
Denver (2009) Erbs model	all	283	16392	-8%	26%	-5%	22%	-1%	20%	-2%	25%	-5%	22%	-6%	24%	-13%	28%	-10%	24%
all	all	239	32500	-6%	26%	-4%	23%	0%	21%	0%	26%	-4%	23%	-5%	25%	-12%	30%	-9%	26%

Table II Global irradiance Model-Measurements *mbd* and *rmsd*. The transposition is based on beam irradiance evaluated from the global with the Erbs diffuse fraction model. (The north orientation is not taken into account in the «all» statistic).

5.2 Diffuse fraction and transposition

The second validation step is to chain the diffuse fraction model with the transpositions model. This is usual when only the global component is available; it is the case for the majority of the satellite irradiance data banks (Ineichen 2011).

To illustrate the effect on the bias and the root mean square difference, Table II and Figures 5 & 6 give the results for the Erbs diffuse fraction model. The choice of the Erbs model to illustrate the performance degradation is based on the diffuse fraction model validation conducted in 2008 by Ineichen: the Erbs model shows the highest bias and the highest root mean square difference; therefore, it should induce the highest difference.

The most interesting result is that the use of a diffuse fraction split model to obtain the beam component has no effect on the resulting transposition bias. Concerning the dispersion, the degradation depends on the orientation and inclination: similar results for the 40°/45° south oriented, slightly higher for the vertical south orientation and around twice higher for the east and west planes. These results are not site dependent (cf Annex).

5.3 Synthetic data and transposition

The last step of the validation is based on synthetic generated hourly data. The transposition of the irradiance is chained with Aguiar's method applied on 12 monthly global irradiance values obtained from cumulated hourly measurements, and a diffuse fraction model for the beam irradiance derivation. As described above, the hour by hour comparison is not applicable, only the mean bias difference is considered. Also, due to the synthetic generation, a dependence analysis, function of the sky conditions, is not possible.

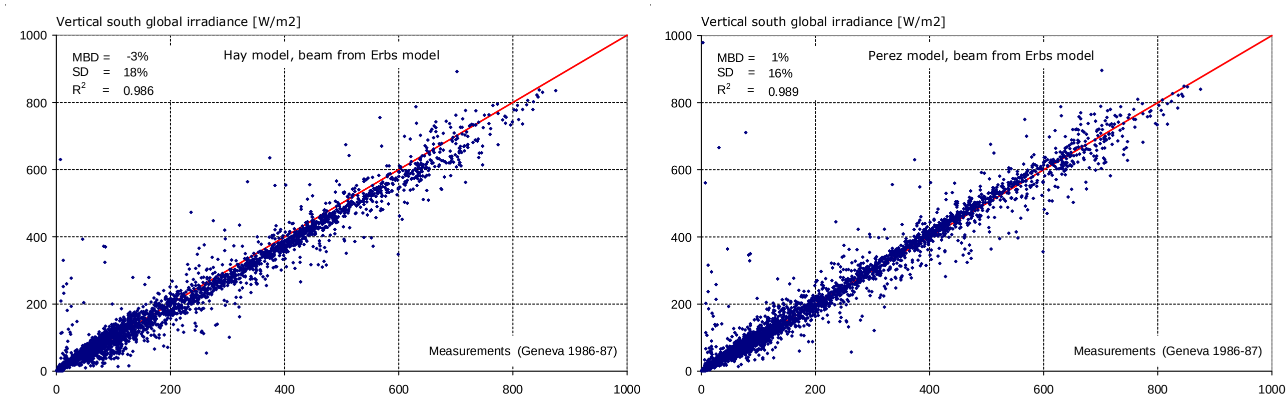

Figure 5 Scatter plots for the site ofGeneva and two transposition models: Hay and Perez The beam component used as input to the model is derived from the global with the Erbs model.

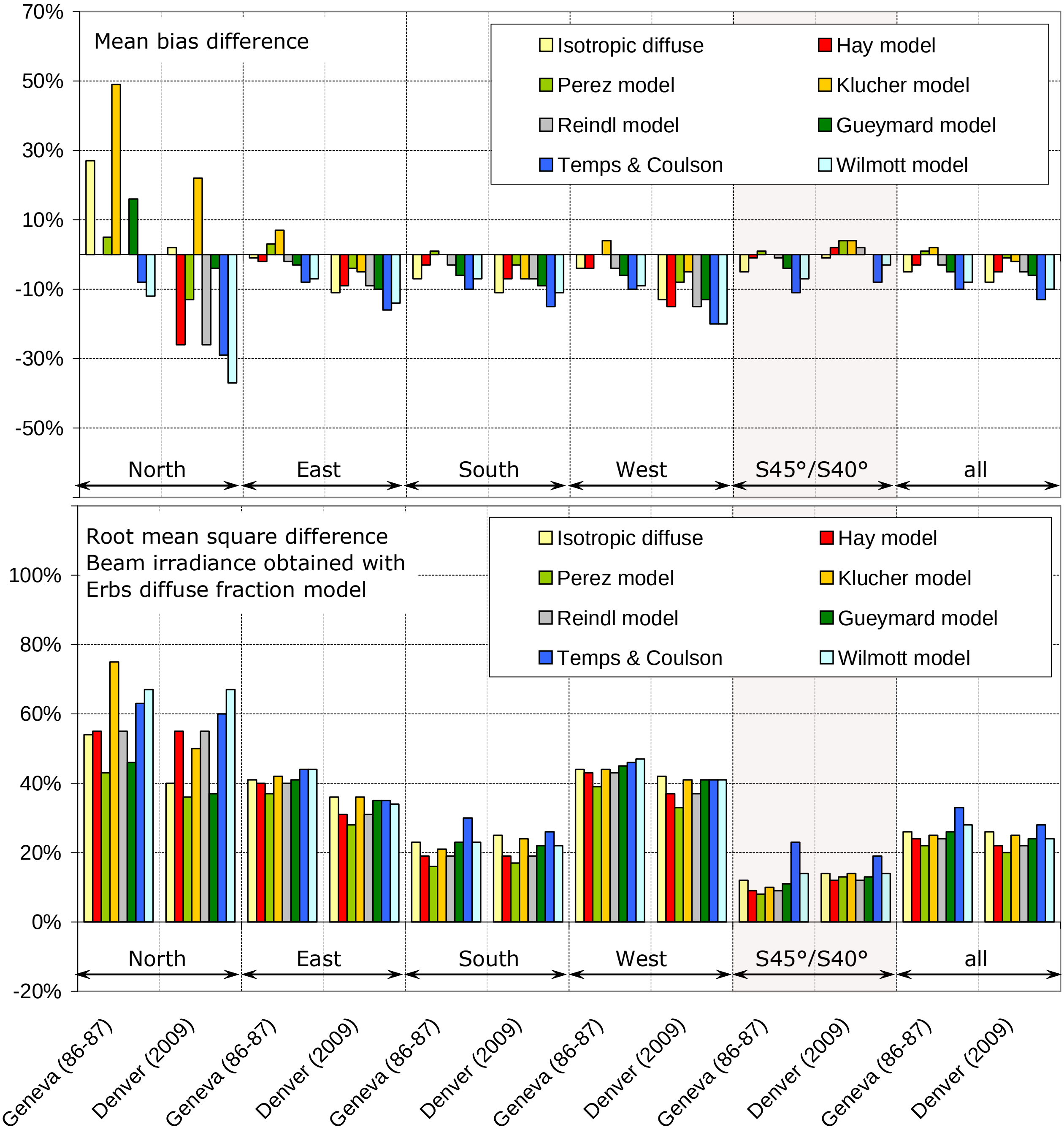

Figure 6 Mean bias difference and root mean square difference between model and measurements for all the oriented/inclined planes. The beam irradiance is retrieved from the global with the Erbs model

					Isotropic diffuse	Hay model	Perez model	Klucher model	Reindl model	Gueymard model	Temps & Coulson	Wilmott model
Horizontal global 295 [W/m2]			Global [W/m^2]	nb	mbd	mbd	mbd	mbd	mbd	mbd	mbd	mbd
Geneva (86-87)	based on measurements for reference	West	139	4027	-3%	-4%	-2%	5%	-4%	-5%	-12%	-12%
		South	187	4027	-10%	-7%	-3%	-3%	-7%	-10%	-14%	-11%
		S30°	329	4027	-6%	-4%	-2%	0%	-4%	-5%	-16%	-9%
		S45°	319	4027	-8%	-5%	-3%	-3%	-5%	-7%	-15%	-10%
		S60°	294	4027	-10%	-7%	-4%	-6%	-7%	-9%	-16%	-12%
Geneva (86-87)	synthetic global (PvSyst) and Erbs diffuse fraction model	West	139	4027	0%	0%	3%	9%	0%	-4%	-9%	-5%
		South	187	4027	-12%	-9%	-4%	-5%	-9%	-13%	-17%	-13%
		S30°	329	4027	-8%	-6%	-4%	-1%	-6%	-8%	-19%	-11%
		S45°	319	4027	-10%	-7%	-4%	-5%	-7%	-10%	-19%	-13%
		S60°	294	4027	-12%	-9%	-6%	-8%	-9%	-12%	-19%	-14%
Geneva (86-87)	synthetic global (MN6) and Perez diffuse fraction model	West	139	4027	2%	3%	5%	10%	3%	0%	-8%	-2%
		South	187	4027	-11%	-8%	-4%	-5%	-8%	-12%	-17%	-12%
		S30°	329	4027	-8%	-6%	-4%	-1%	-6%	-7%	-19%	-11%
		S45°	319	4027	-10%	-7%	-5%	-5%	-7%	-9%	-19%	-12%
		S60°	294	4027	-11%	-9%	-6%	-8%	-9%	-12%	-19%	-13%
Geneva (86-87)	Measurements	all	254	20135	-7%	-5%	-3%	-2%	-5%	-7%	-15%	-11%
Geneva (86-87)	Synthetic PvSyst	all	254	20135	-9%	-7%	-4%	-3%	-7%	-10%	-18%	-12%
Geneva (86-87)	Synthetic MN6	all	254	20135	-8%	-6%	-4%	-3%	-6%	-9%	-17%	-11%

Table III Model-Measurements *mbd* and *rmsd* for tilted irradiances evaluated from synthetic data (the results based on measurements are given as reference).

The results are given in Table III for the site of Geneva and the two considered synthetic data generators. The main conclusion is that the use of 12 monthly values and a synthetic hourly data generator has a negligible impact on the overall bias of the transposition models for south oriented surfaces. Here again, the Perez model gives better results than the Hay model. In term of bias, the Klucher model is slightly better, but as mentioned above, its dispersion is much higher.

The corresponding graph is given on Figure 7 for the data generated by PvSyst. The results for the site of Denver are given in the Annex; an average albedo coefficient of 20% is used for the reflected component.

6. Conclusions

The results of the present analysis confirm the conclusions of most of the validation publications concerning the transposition of the global irradiance to tilted surfaces: on the average, the Perez model gives the best results, followed by the Hay model and the Reindl model.

On one year data acquired in Geneva (CH) and in Denver (USA), the overall bias on oriented and inclined surfaces is around several percents(-1% to -4%), and the dispersion (or root mean square difference) is 11% to 13% (26 to 31 [W/m^2]) for the best models. These results are based on horizontal global and normal beam measurements. When

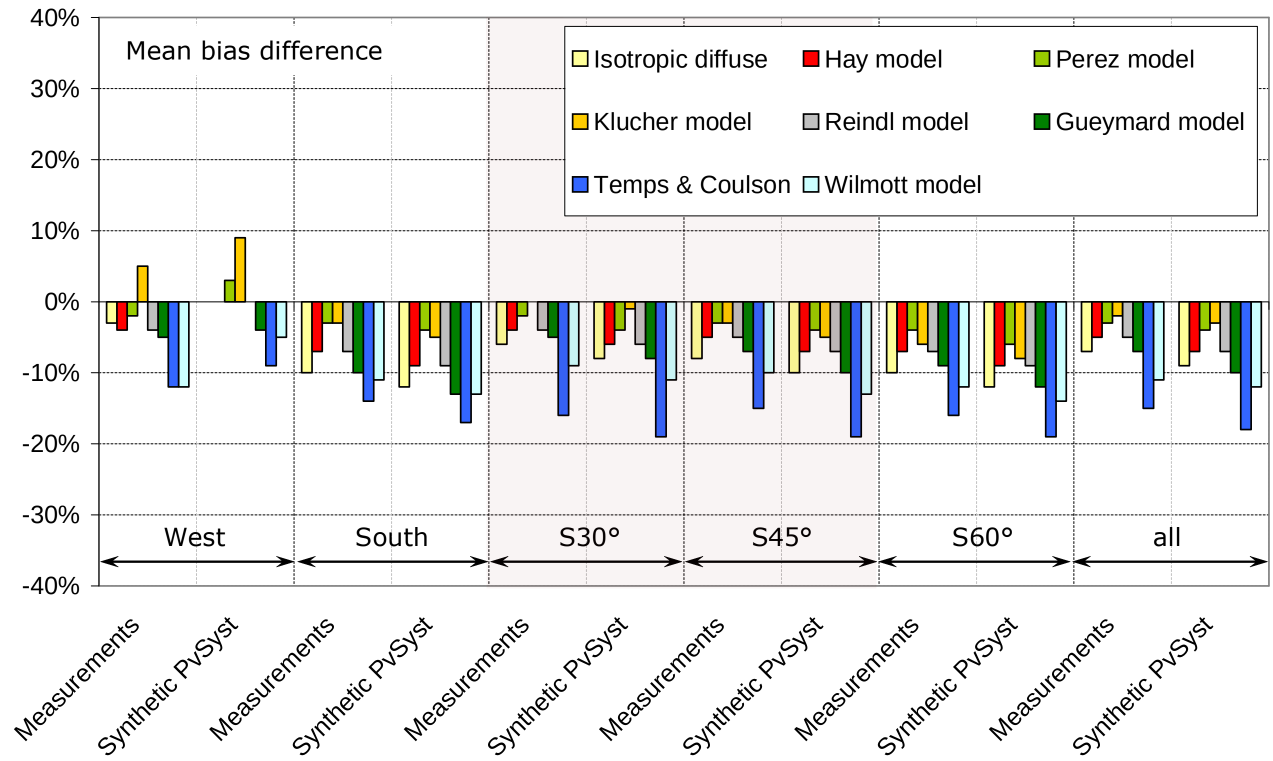

Figure 7 Mean bias difference between model and measurements for tilted irradiance evaluated from ground measurements and from synthetic data (here generated with PvSyst)

modelled beam is used as input, the bias remain in the same order of magnitude (-3% to 1%), and the dispersion becomes 22% to 24%. This result shows that if the data are used for photovoltaïc applications where the system outpout is more or less a percentage of the input, the choice of the model is not the only criterion, the accuracy of the reflected component is also to be taken into account when dealing with high tilt angles. For thermal applications, where the irradiance threshold (and therefore the dispersion) plays a role in the performance, it is important to use the better ranked model.

Looking more into details, particularly on the scatter plots given in the Annex, it can be seen that the Hay and the Perez models have a very similar behavior; the main difference between the two models is the dispersion (or the root mean square difference), much lower for the Perez model. On data from Geneva, Klucher and Reindl models have slightly higher biases and dispersion, but remain satisfactory. The ranking is not so clear on data from Denver. This is certainly due to the assumption done for the estimation of the reflected component.

If the results slightly differ from other validations published in the literature, it is probably also due to the reflected component. In Gueymard's validation (Gueymard 2010), when a 20% albedo coefficient is assumed, a degradation can be seen on the performance of all the models, in term of bias and root mean square difference. Nevertheless, if not exactly the same, the ranking is similar.

7. References

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Annex: figures in the following pages:

For the clear, intermediate and overcast sky conditions:

- Absolute mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [W/m^2].

- Relative mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [%].

- Mean bias difference between model and measurements for the two sites and all the oriented/inclined planes.

- Root mean square difference between model and measurements for the two sites and all the oriented/inclined planes.

Global tilted irradiance based on beam measurements Clear sky conditions: $0.65 < K'_t \leq 1.00$

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		rmsd	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	62	1582	17	33	-13	25	2	19	40	55	-13	25	13	28	-14	34	-43	69
	East	229	1582	-16	52	-21	38	-3	30	6	54	-21	38	-13	47	-38	62	-45	69
	South	344	1582	-40	57	-30	38	-11	24	-18	44	-30	38	-32	51	-62	81	-48	59
	West	232	1582	-13	49	-18	36	-1	30	9	52	-18	36	-10	43	-36	63	-43	73
	S45°	587	1582	-50	63	-30	38	-15	27	-21	41	-30	38	-39	55	-92	122	-63	81
Denver (2009) Measurements	North	74	2383	-15	27	-37	43	-19	25	0	32	-37	43	-16	25	-33	42	-67	87
	East	318	2383	-28	45	-23	36	-6	25	-13	42	-23	36	-18	35	-39	50	-43	67
	South	417	2383	-35	50	-22	33	-7	25	-20	42	-22	33	-22	39	-45	60	-36	52
	West	225	2383	-26	42	-30	39	-13	25	-11	40	-30	39	-20	33	-39	51	-54	75
	S40°	613	2383	-4	41	14	41	24	45	20	46	14	41	8	42	-29	74	-11	60
Geneva (86-87) Measurements	all	348	6328	-30	56	-25	38	-8	28	-6	48	-25	38	-24	49	-57	86	-50	71
Denver (2009) Measurements	all	393	9532	-23	45	-15	37	-1	31	-6	43	-15	37	-13	37	-38	60	-36	64
all	all	375	15860	-26	49	-19	37	-3	30	-6	45	-19	37	-17	43	-46	71	-41	67

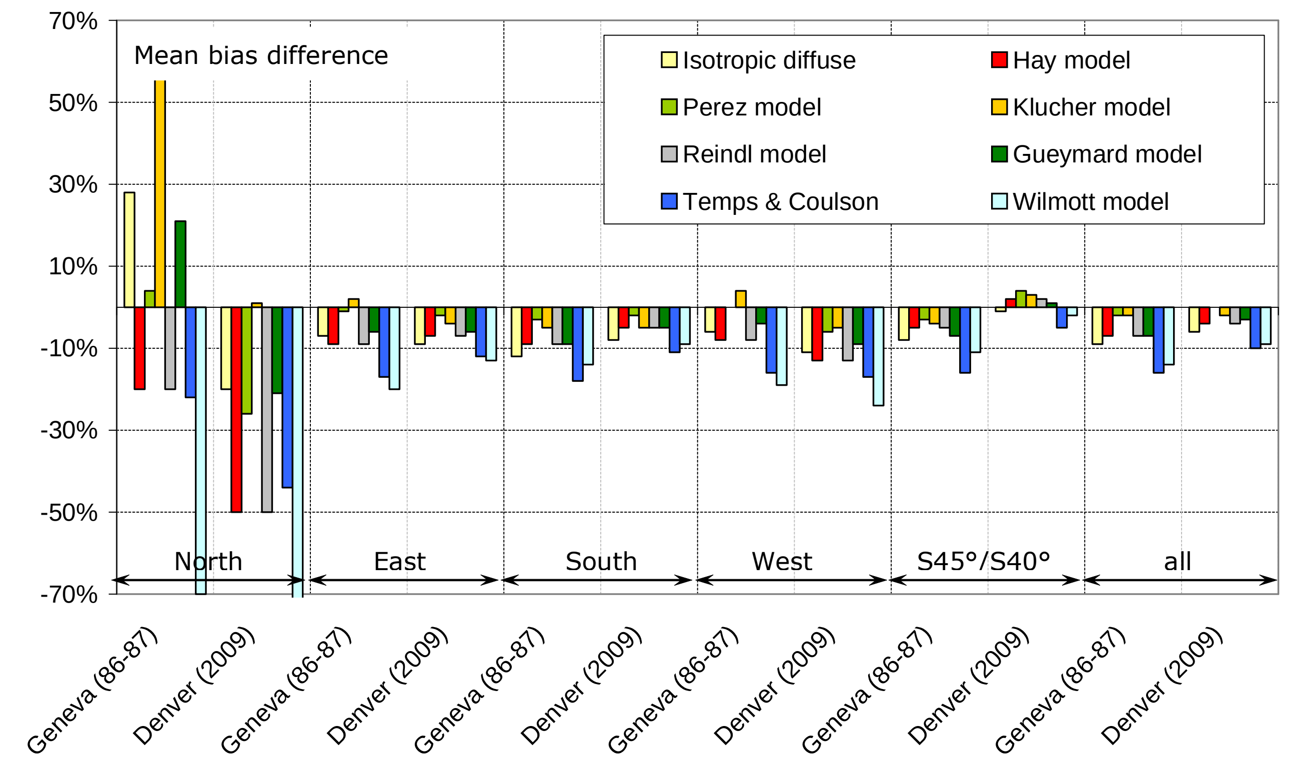
Absolute mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [W/m²].

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	62	1582	28%	54%	-20%	40%	4%	31%	63%	89%	-20%	40%	21%	45%	-22%	54%	-70%	112%
	East	229	1582	-7%	23%	-9%	17%	-1%	13%	2%	24%	-9%	17%	-6%	20%	-17%	27%	-20%	30%
	South	344	1582	-12%	17%	-9%	11%	-3%	7%	-5%	13%	-9%	11%	-9%	15%	-18%	23%	-14%	17%
	West	232	1582	-6%	21%	-8%	16%	0%	13%	4%	22%	-8%	16%	-4%	18%	-16%	27%	-19%	31%
	S45°	587	1582	-8%	11%	-5%	7%	-3%	5%	-4%	7%	-5%	7%	-7%	9%	-16%	21%	-11%	14%
Denver (2009) Measurements	North	74	2383	-20%	37%	-50%	58%	-26%	34%	1%	43%	-50%	58%	-21%	33%	-44%	56%	-90%	118%
	East	318	2383	-9%	14%	-7%	11%	-2%	8%	-4%	13%	-7%	11%	-6%	11%	-12%	16%	-13%	21%
	South	417	2383	-8%	12%	-5%	8%	-2%	6%	-5%	10%	-5%	8%	-5%	9%	-11%	14%	-9%	12%
	West	225	2383	-11%	19%	-13%	17%	-6%	11%	-5%	18%	-13%	17%	-9%	15%	-17%	23%	-24%	33%
	S40°	613	2383	-1%	7%	2%	7%	4%	7%	3%	8%	2%	7%	1%	7%	-5%	12%	-2%	10%
Geneva (86-87) Measurements	all	348	6328	-9%	16%	-7%	11%	-2%	8%	-2%	14%	-7%	11%	-7%	14%	-16%	25%	-14%	20%
Denver (2009) Measurements	all	393	9532	-6%	11%	-4%	9%	0%	8%	-2%	11%	-4%	9%	-3%	9%	-10%	15%	-9%	16%
all	all	375	15860	-7%	13%	-5%	10%	-1%	8%	-2%	12%	-5%	10%	-5%	11%	-12%	19%	-11%	18%

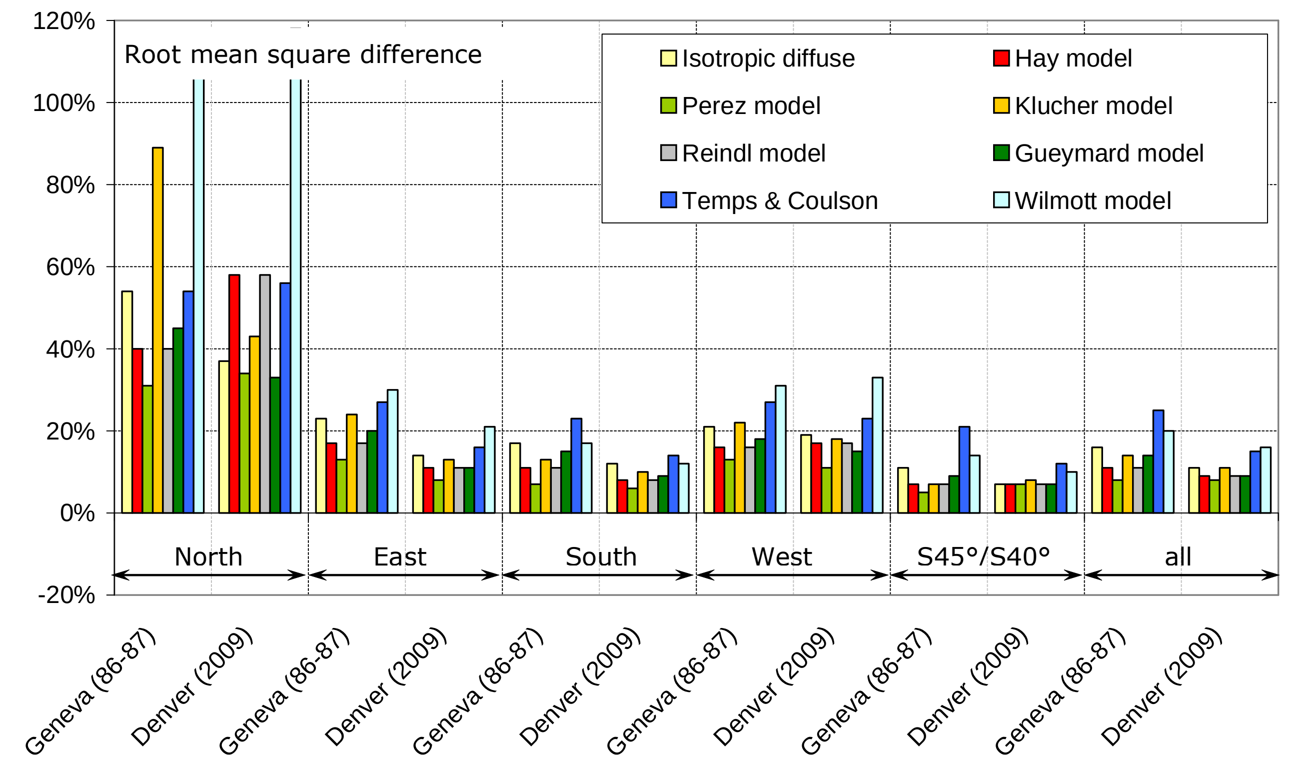
Relative mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [%].

Global tilted irradiance based on beam measurements

Clear sky conditions: $0.65 < K'_t \leq 1.00$



Mean bias difference between model and measurements for the two sites and all the oriented/inclined planes.



Root mean square difference between model and measurements for the two sites and all the oriented/inclined planes.

Global tilted irradiance based on beam measurements Intermediate sky conditions: $0.30 < K'_t \leq 0.65$

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		rmsd	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	63	1150	19	31	12	23	3	12	30	44	12	23	11	23	2	29	8	23
	East	116	1150	-3	42	-2	29	-1	22	7	44	-2	29	-12	43	-6	45	-5	30
	South	140	1150	-16	39	-11	27	-5	21	-5	33	-11	27	-24	44	-15	53	-14	31
	West	127	1150	-4	46	-1	33	-1	26	7	48	-1	33	-12	45	-7	48	-5	34
	S45°	228	1150	-21	40	-15	29	-7	20	-4	28	-15	29	-26	44	-37	82	-27	42
Denver (2009) Measurements	North	79	1007	13	26	3	20	-5	13	27	41	3	19	4	18	-15	42	-5	30
	East	125	1007	-6	37	-9	26	-9	21	8	42	-9	25	-15	37	-23	53	-16	35
	South	162	1007	-16	37	-13	27	-6	21	-2	35	-13	27	-25	42	-30	63	-20	35
	West	167	1007	-10	41	-6	28	-3	21	4	44	-6	28	-18	42	-23	55	-13	35
	S40°	263	1007	-4	38	2	33	10	35	16	40	2	33	-8	39	-44	103	-17	47
Geneva (86-87) Measurements	all	153	4600	-11	42	-7	30	-4	22	1	39	-7	30	-19	44	-16	59	-13	35
Denver (2009) Measurements	all	179	4028	-9	38	-7	29	-2	25	7	40	-7	28	-17	40	-30	71	-17	38
all	all	165	8628	-10	40	-7	29	-3	24	4	40	-7	29	-18	42	-23	65	-15	36

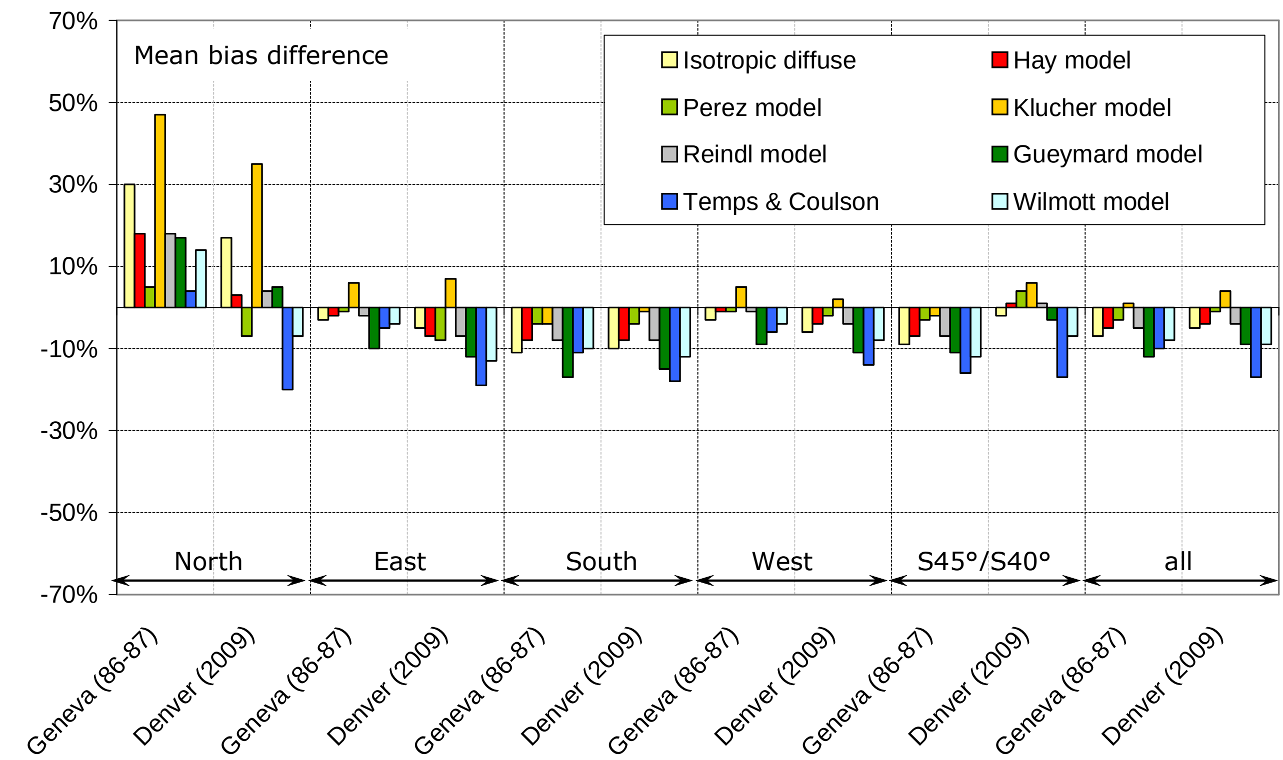
Absolute mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [W/m²].

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	63	1150	30%	50%	18%	37%	5%	20%	47%	71%	18%	37%	17%	36%	4%	46%	14%	36%
	East	116	1150	-3%	36%	-2%	25%	-1%	19%	6%	38%	-2%	25%	-10%	37%	-5%	39%	-4%	26%
	South	140	1150	-11%	28%	-8%	20%	-4%	15%	-4%	24%	-8%	20%	-17%	31%	-11%	38%	-10%	22%
	West	127	1150	-3%	36%	-1%	26%	-1%	20%	5%	38%	-1%	26%	-9%	35%	-6%	37%	-4%	27%
	S45°	228	1150	-9%	18%	-7%	13%	-3%	9%	-2%	12%	-7%	13%	-11%	19%	-16%	36%	-12%	19%
Denver (2009) Measurements	North	79	1007	17%	33%	3%	25%	-7%	17%	35%	53%	4%	24%	5%	22%	-20%	53%	-7%	38%
	East	125	1007	-5%	29%	-7%	21%	-8%	17%	7%	33%	-7%	20%	-12%	30%	-19%	43%	-13%	28%
	South	162	1007	-10%	23%	-8%	17%	-4%	13%	-1%	22%	-8%	17%	-15%	26%	-18%	39%	-12%	22%
	West	167	1007	-6%	25%	-4%	17%	-2%	13%	2%	26%	-4%	17%	-11%	25%	-14%	33%	-8%	21%
	S40°	263	1007	-2%	15%	1%	13%	4%	13%	6%	15%	1%	13%	-3%	15%	-17%	39%	-7%	18%
Geneva (86-87) Measurements	all	153	4600	-7%	27%	-5%	20%	-3%	14%	1%	25%	-5%	20%	-12%	29%	-10%	39%	-8%	23%
Denver (2009) Measurements	all	179	4028	-5%	21%	-4%	16%	-1%	14%	4%	22%	-4%	16%	-9%	22%	-17%	40%	-9%	21%
all	all	165	8628	-6%	24%	-4%	18%	-2%	15%	2%	24%	-4%	18%	-11%	25%	-14%	39%	-9%	22%

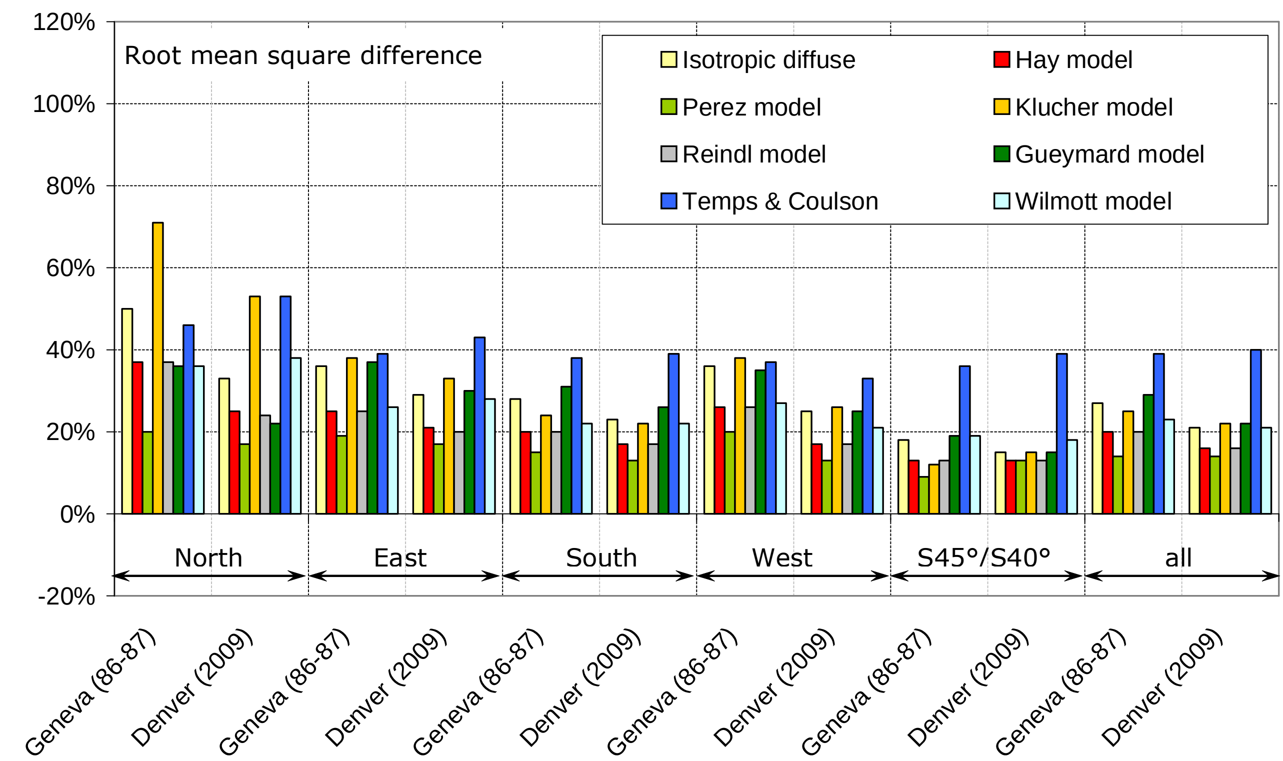
Relative mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [%].

Global tilted irradiance based on beam measurements

Intermediate sky conditions: 0.30 < $K'_t \leq$ 0.65



Mean bias difference between model and measurements for the two sites and all the oriented/inclined planes.



Root mean square difference between model and measurements for the two sites and all the oriented/inclined planes.

Global tilted irradiance based on beam measurements Overcast sky conditions: $0 < K'_t \leq 0.30$

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		rmsd	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	34	1295	8	14	8	14	0	12	9	14	9	13	4	8	-2	23	9	13
	East	35	1295	8	14	8	13	-4	25	8	14	8	13	3	9	3	28	8	13
	South	38	1295	6	12	6	12	-2	19	6	12	6	11	1	9	6	32	6	11
	West	37	1295	6	13	6	13	-4	23	6	13	6	13	1	10	1	27	6	13
	S45°	72	1295	2	8	2	8	-1	8	3	8	2	8	-1	8	-7	48	-2	8
Denver (2009) Measurements	North	42	708	8	27	8	26	-1	25	10	26	8	25	2	24	-13	38	7	26
	East	49	708	2	14	2	14	-8	20	4	13	2	12	-4	14	-15	39	1	14
	South	49	708	3	14	3	14	-4	14	4	12	3	11	-3	13	-13	38	2	13
	West	50	708	3	21	3	22	-6	25	5	20	4	20	-2	20	-9	38	3	22
	S40°	84	708	8	26	8	26	5	25	10	25	9	25	6	24	-25	65	3	24
Geneva (86-87) Measurements	all	46	5180	6	12	6	12	-3	20	6	12	6	11	1	9	1	35	5	11
Denver (2009) Measurements	all	58	2832	4	19	4	20	-3	21	6	18	5	18	-1	18	-16	46	2	19
all	all	50	8012	5	15	5	15	-3	20	6	15	5	14	0	13	-5	39	4	15

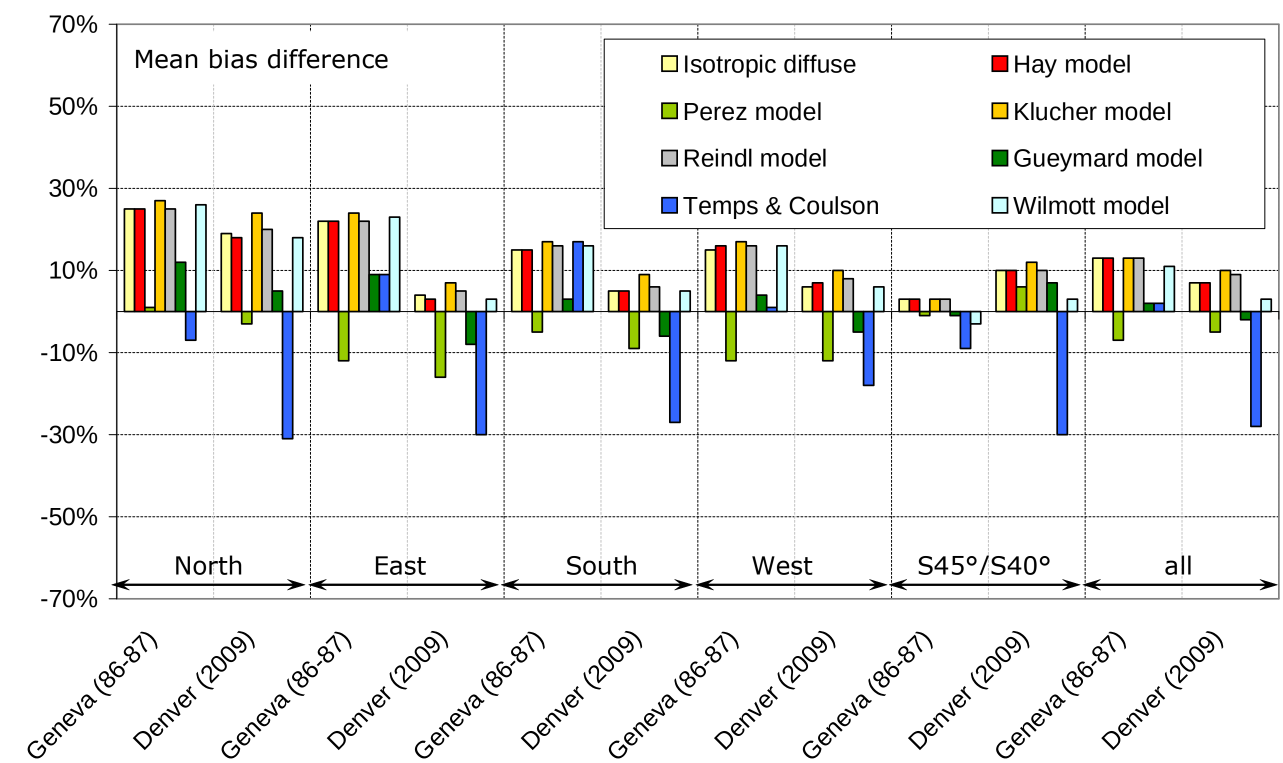
Absolute mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [W/m²].

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	34	1295	25%	41%	25%	40%	1%	34%	27%	42%	25%	40%	12%	25%	-7%	68%	26%	40%
	East	35	1295	22%	38%	22%	38%	-12%	71%	24%	39%	22%	37%	9%	25%	9%	78%	23%	37%
	South	38	1295	15%	31%	15%	31%	-5%	51%	17%	31%	16%	30%	3%	23%	17%	85%	16%	30%
	West	37	1295	15%	36%	16%	36%	-12%	61%	17%	36%	16%	35%	4%	27%	1%	73%	16%	35%
	S45°	72	1295	3%	11%	3%	11%	-1%	11%	3%	11%	3%	11%	-1%	11%	-9%	66%	-3%	12%
Denver (2009) Measurements	North	42	708	19%	63%	18%	63%	-3%	60%	24%	61%	20%	59%	5%	58%	-31%	92%	18%	63%
	East	49	708	4%	29%	3%	28%	-16%	41%	7%	27%	5%	24%	-8%	29%	-30%	80%	3%	28%
	South	49	708	5%	28%	5%	28%	-9%	30%	9%	24%	6%	23%	-6%	27%	-27%	78%	5%	28%
	West	50	708	6%	42%	7%	44%	-12%	49%	10%	40%	8%	40%	-5%	40%	-18%	76%	6%	44%
	S40°	84	708	10%	31%	10%	31%	6%	30%	12%	30%	10%	30%	7%	29%	-30%	78%	3%	28%
Geneva (86-87) Measurements	all	46	5180	13%	26%	13%	26%	-7%	43%	13%	26%	13%	24%	2%	20%	2%	76%	11%	24%
Denver (2009) Measurements	all	58	2832	7%	33%	7%	34%	-5%	36%	10%	31%	9%	31%	-2%	31%	-28%	79%	3%	33%
all	all	50	8012	10%	30%	10%	30%	-6%	40%	12%	30%	10%	28%	0%	26%	-10%	78%	8%	30%

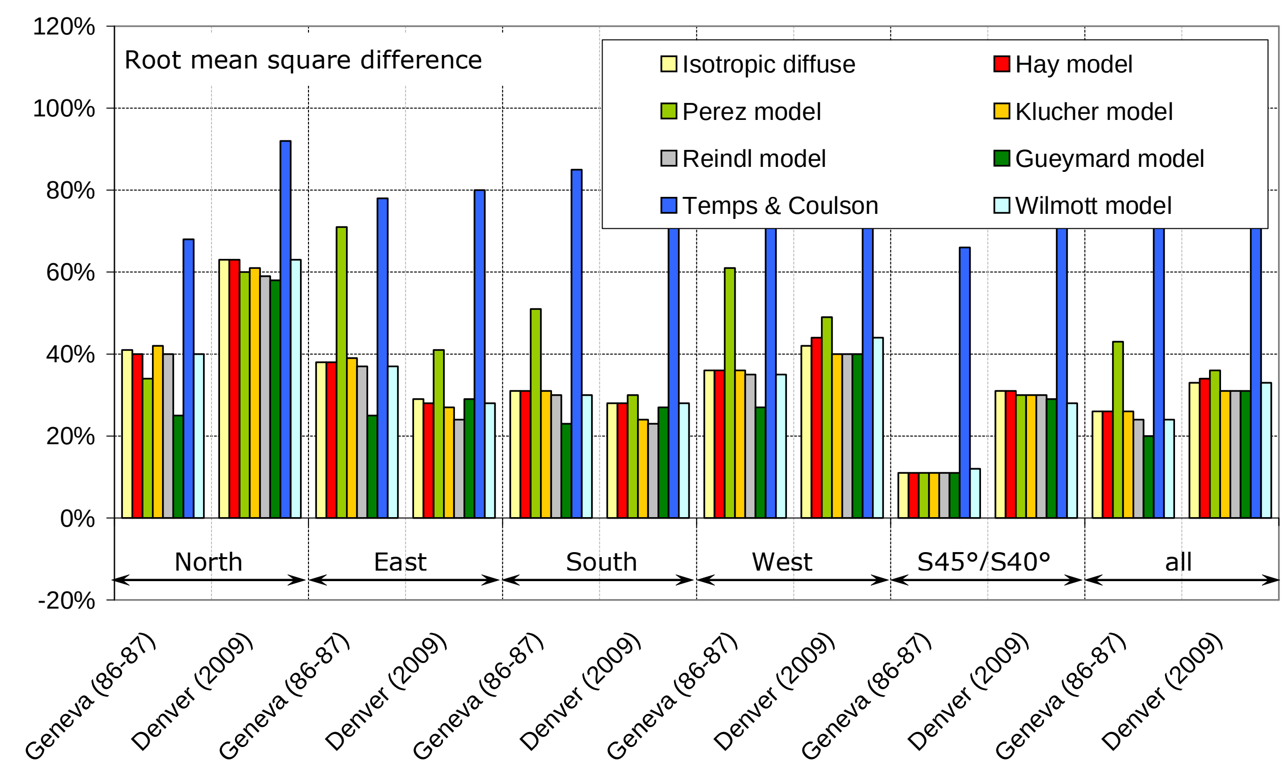
Relative mean bias difference and root mean square difference between model and measurements for the two sites and all the oriented/inclined planes expressed in [%].

Global tilted irradiance based on beam measurements

Overcast sky conditions: $0 < K'_t \leq 0.30$



Mean bias difference between model and measurements for the two sites and all the oriented/inclined planes.



Root mean square difference between model and measurements for the two sites and all the oriented/inclined planes.

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Geneva (86-87) Measurements	North	53	4027	28%	52%	2%	40%	4%	29%	51%	80%	2%	40%	18%	41%	-10%	55%	-22%	86%
	East	134	4027	-4%	30%	-5%	22%	-2%	20%	5%	31%	-5%	22%	-6%	28%	-12%	36%	-12%	35%
	South	187	4027	-10%	22%	-7%	15%	-3%	12%	-3%	18%	-7%	15%	-10%	21%	-14%	32%	-11%	22%
	West	139	4027	-3%	29%	-4%	21%	-2%	19%	5%	30%	-4%	21%	-5%	26%	-12%	35%	-12%	36%
	S45°	319	4027	-8%	14%	-5%	9%	-3%	6%	-3%	9%	-5%	9%	-7%	13%	-15%	29%	-10%	17%
Geneva (86-87) DirInt model	North	53	4027	28%	55%	1%	50%	6%	38%	49%	79%	1%	50%	17%	45%	-10%	58%	-12%	63%
	East	134	4027	2%	31%	1%	33%	6%	32%	11%	34%	1%	33%	1%	30%	-6%	39%	-4%	38%
	South	187	4027	-6%	19%	-3%	16%	2%	15%	1%	17%	-3%	16%	-5%	18%	-10%	30%	-7%	22%
	West	139	4027	-1%	33%	-1%	33%	3%	30%	7%	34%	-1%	33%	-2%	33%	-9%	40%	-7%	38%
	S45°	319	4027	-4%	10%	-1%	7%	1%	7%	1%	8%	-1%	7%	-4%	10%	-12%	25%	-7%	14%
Geneva (86-87) Measurements	all	195	16108	-7%	22%	-5%	15%	-3%	12%	0%	19%	-5%	15%	-7%	20%	-14%	33%	-11%	25%
Geneva (86-87) DirInt model	all	195	16108	-3%	21%	-1%	19%	3%	18%	4%	20%	-1%	19%	-3%	19%	-10%	32%	-7%	25%

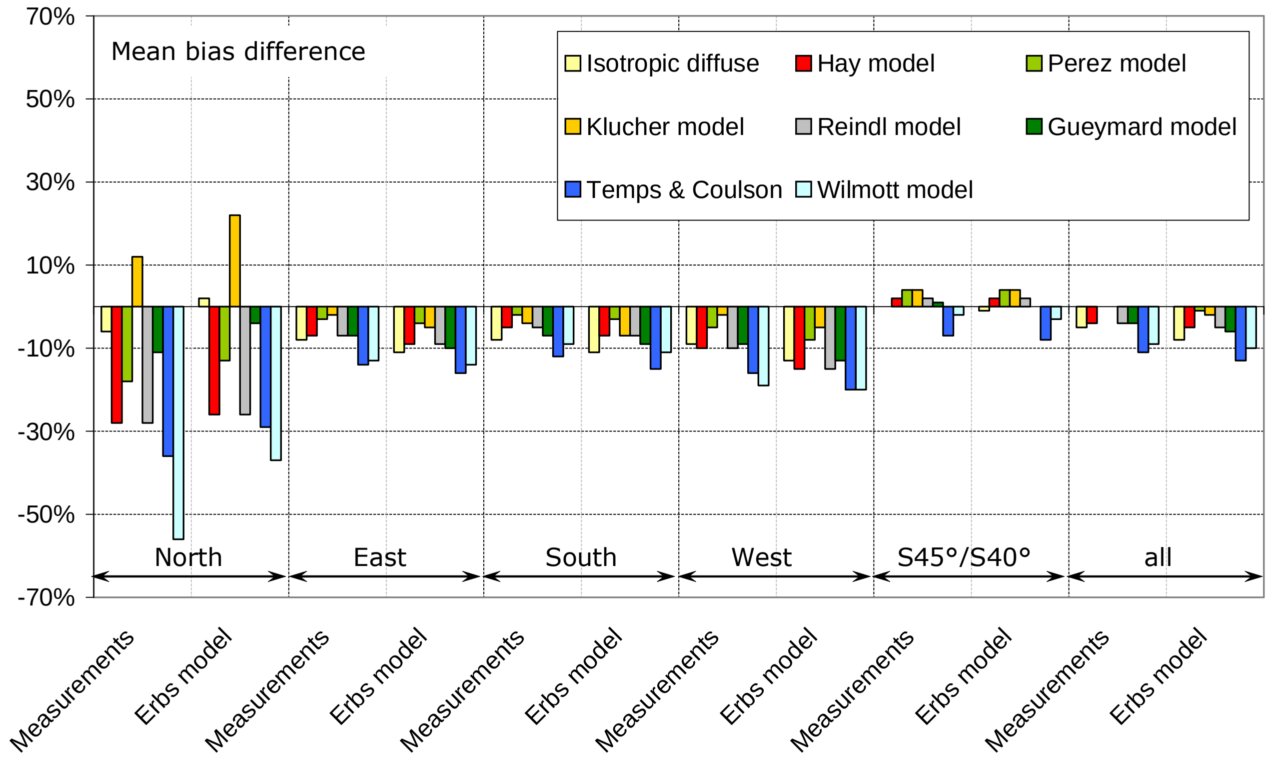
Relative mean bias difference and root mean square difference between model and measurements for the site of Geneva based on measured and modelled beam irradiance. The diffuse fraction model is the DirInt model.

		Global [W/m²]	nb	Isotropic diffuse		Hay model		Perez model		Klucher model		Reindl model		Gueymard model		Temps & Coulson		Wilmott model	
				mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd	mbd	rmsd
Denver (2009) Measurements	North	70	4098	-6%	39%	-28%	51%	-18%	33%	12%	48%	-28%	51%	-11%	33%	-36%	59%	-56%	99%
	East	224	4098	-8%	18%	-7%	14%	-3%	10%	-2%	17%	-7%	14%	-7%	15%	-14%	22%	-13%	24%
	South	291	4098	-8%	15%	-5%	10%	-2%	8%	-4%	13%	-5%	10%	-7%	13%	-12%	20%	-9%	15%
	West	181	4098	-9%	22%	-10%	19%	-5%	13%	-2%	21%	-10%	19%	-9%	19%	-16%	28%	-19%	34%
	S40°	435	4098	0%	9%	2%	8%	4%	9%	4%	10%	2%	8%	1%	9%	-7%	19%	-2%	12%
Denver (2009) DirInt model	North	70	4098	-1%	41%	-26%	54%	-14%	34%	19%	53%	-26%	54%	-7%	36%	-33%	59%	-37%	65%
	East	224	4098	-8%	25%	-6%	20%	-2%	17%	-2%	25%	-6%	20%	-6%	22%	-14%	26%	-11%	24%
	South	291	4098	-10%	21%	-6%	15%	-2%	14%	-5%	19%	-6%	15%	-8%	17%	-14%	24%	-10%	19%
	West	181	4098	-12%	33%	-13%	29%	-7%	24%	-5%	32%	-13%	29%	-12%	31%	-19%	35%	-18%	33%
	S40°	435	4098	-1%	12%	3%	11%	5%	12%	4%	13%	3%	11%	1%	11%	-8%	19%	-3%	13%
Denver (2009) Measurements	all	283	16392	-5%	14%	-4%	12%	0%	10%	0%	14%	-4%	12%	-4%	13%	-11%	22%	-9%	19%
Denver (2009) DirInt model	all	283	16392	-6%	20%	-4%	17%	0%	16%	-1%	20%	-4%	17%	-5%	18%	-12%	24%	-8%	19%

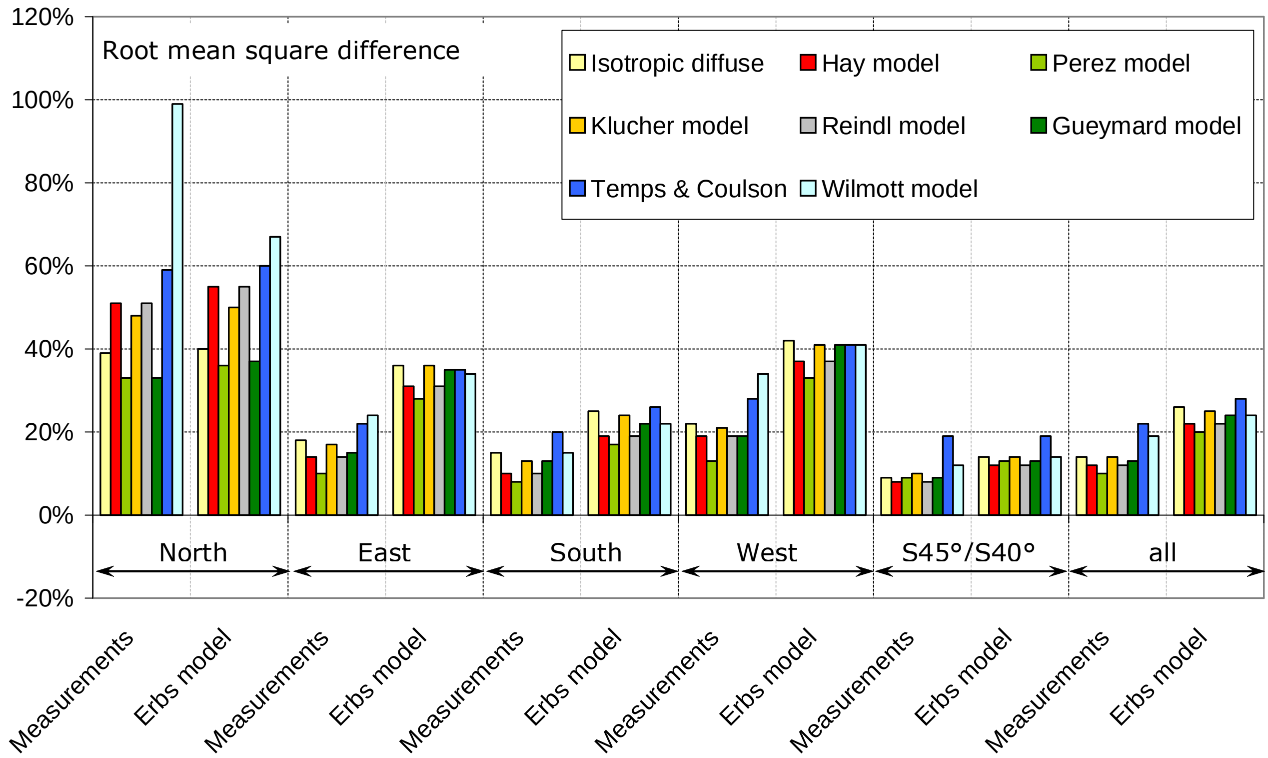
Relative mean bias difference and root mean square difference between model and measurements for the site of Denver based on measured and modelled beam irradiance. The diffuse fraction model is the DirInt model.

Transposition based on measured and modelled beam component

Beam component derived with the Erbs model for the site of Denver



Mean bias difference between model and measurements for the site of Denver and Erbs model.



Root mean square difference between model and measurements for the site of Denver and Erbs model.

					Isotropic diffuse	Hay model	Perez model	Klucher model	Reindl model	Gueymard model	Temps & Coulson	Wilmott model
Horizontal global 383 [W/m2]			Global [W/m^2]	nb	mbd	mbd	mbd	mbd	mbd	mbd	mbd	mbd
Denver (2009)	based on measurements for reference	West	181	4098	-9%	-10%	-5%	-2%	-10%	-9%	-16%	-19%
		South	291	4098	-8%	-5%	-2%	-4%	-5%	-7%	-12%	-9%
		S40°	435	4098	0%	2%	4%	4%	2%	1%	-7%	-2%
Denver (2009)	synthetic global (PvSyst) and Erbs diffuse fraction model	West	181	4098	5%	6%	12%	15%	6%	5%	-3%	0%
		South	291	4098	-13%	-8%	-4%	-7%	-8%	-11%	-18%	-12%
		S40°	435	4098	-4%	0%	3%	2%	0%	-2%	-12%	-6%
Denver (2009)	synthetic global (MN6) and Perez diffuse fraction model	West	181	4098	4%	5%	10%	12%	5%	4%	-5%	0%
		South	291	4098	-12%	-8%	-4%	-7%	-8%	-10%	-17%	-11%
		S40°	435	4098	-3%	0%	2%	2%	0%	-2%	-12%	-5%
Denver (2009)	Measurements	all	302	12294	-5%	-3%	0%	0%	-3%	-4%	-11%	-8%
Denver (2009)	Synthetic PvSyst	all	302	12294	-5%	-2%	3%	2%	-2%	-4%	-12%	-7%
Denver (2009)	Synthetic MN6	all	302	12294	-5%	-1%	2%	1%	-1%	-4%	-12%	-6%

Table Mean bias difference between model and measurements. The tilted irradiances are evaluated from ground measurements (for reference) and from synthetic data.

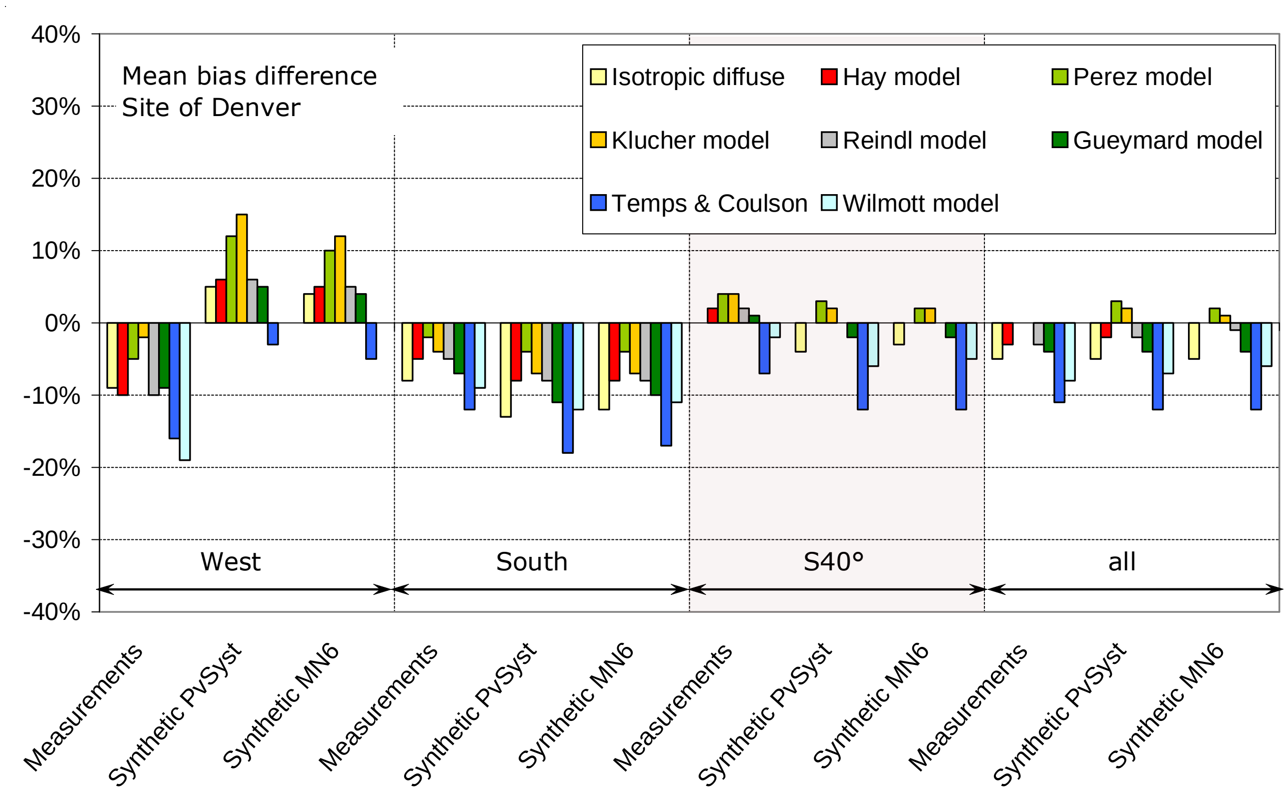


Figure Mean bias difference between model and measurements for tilted irradiance evaluated from ground measurements and from synthetic data (here generated with PvSyst)

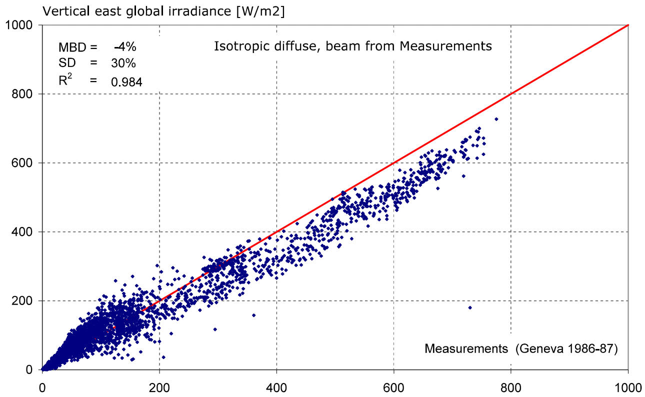
Geneva (Switzerland)

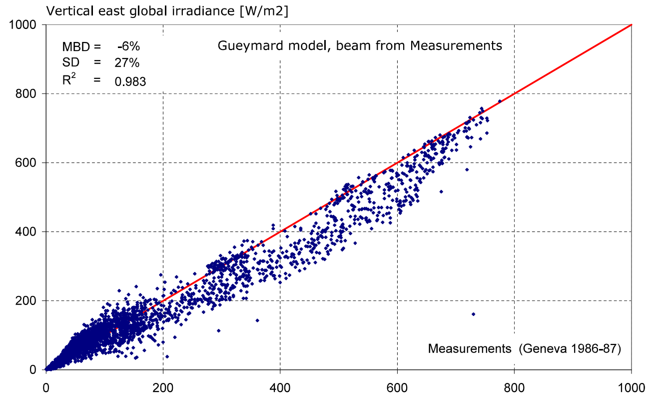
Latitude:	46.20°
Longitude:	6.13°
Altitude over sea level:	420m

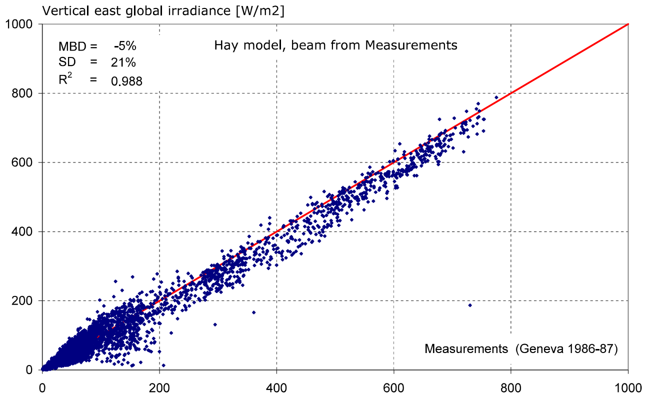
Beam irradiance from measurements

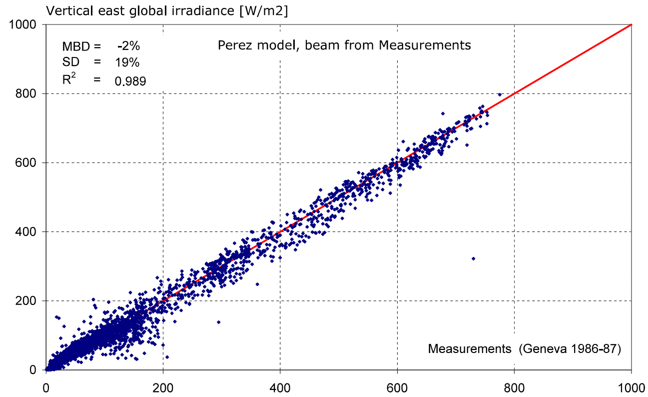
Figures in the following pages:

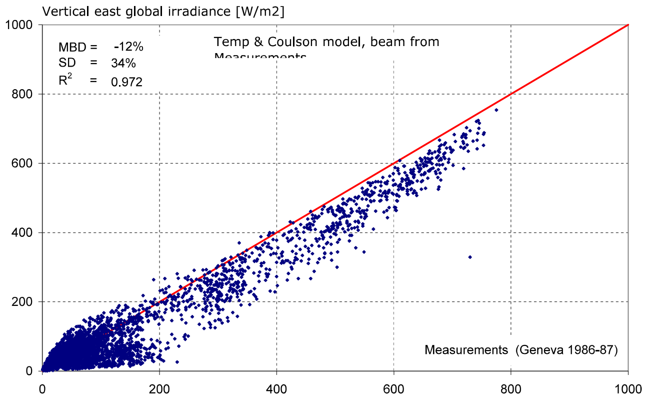
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

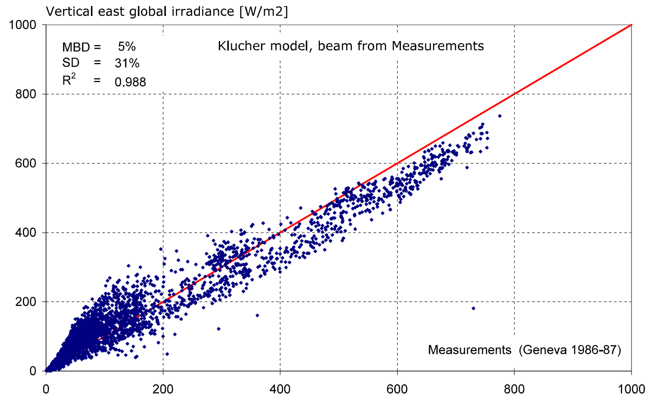

Vertical east global irradiance [W/m2]
MBD = -4%
SD = 30%
R2 = 0.984
Isotropic diffuse, beam from Measurements
Measurements (Geneva 1986-87)

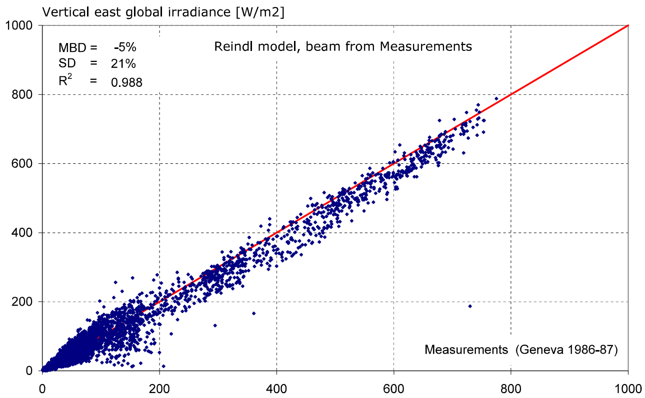

Vertical east global irradiance [W/m2]
MBD = -6%
SD = 27%
R2 = 0.983
Gueymard model, beam from Measurements
Measurements (Geneva 1986-87)

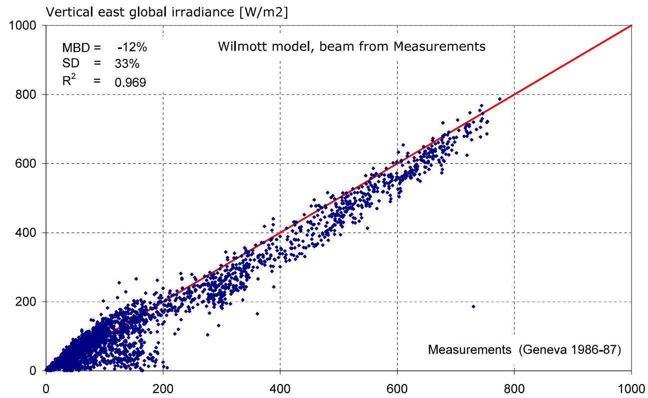

Vertical east global irradiance [W/m2]
MBD = -5%
SD = 21%
R2 = 0.988
Hay model, beam from Measurements
Measurements (Geneva 1986-87)

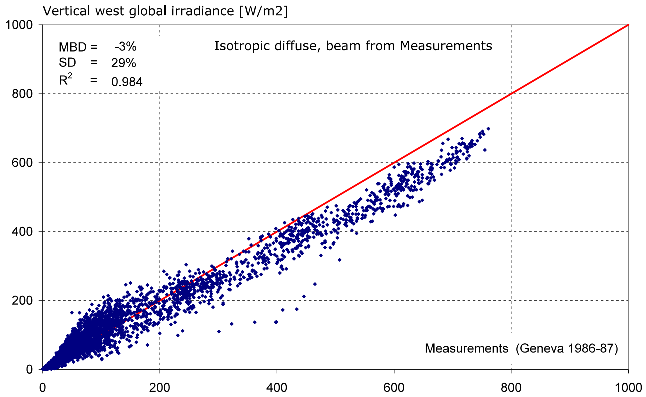

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 19%
R2 = 0.989
Perez model, beam from Measurements
Measurements (Geneva 1986-87)

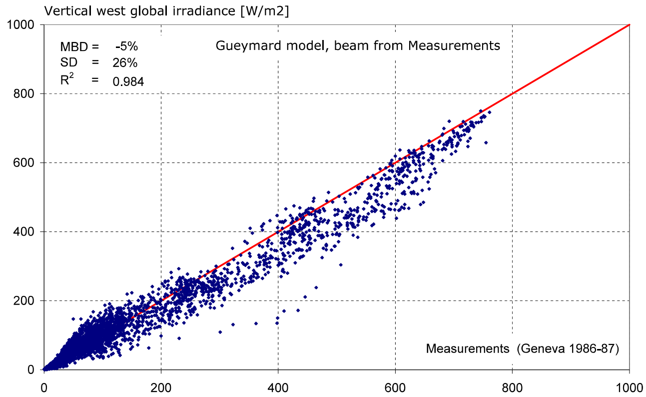

Vertical east global irradiance [W/m2]
MBD = -12%
SD = 34%
R2 = 0.972
Temp & Coulson model, beam from
Measurements (Geneva 1986-87)

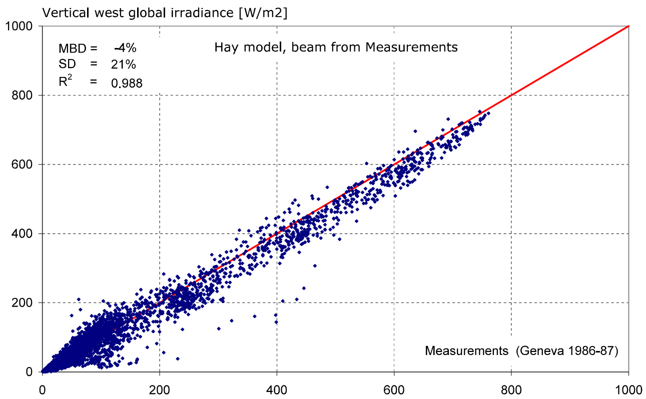

Vertical east global irradiance [W/m2]
MBD = 5%
SD = 31%
R2 = 0.988
Klucher model, beam from Measurements
Measurements (Geneva 1986-87)

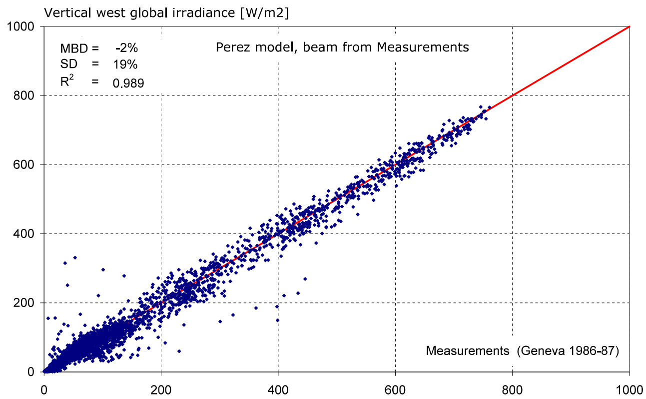

Vertical east global irradiance [W/m2]
MBD = -5%
SD = 21%
R2 = 0.988
Reindl model, beam from Measurements
Measurements (Geneva 1986-87)

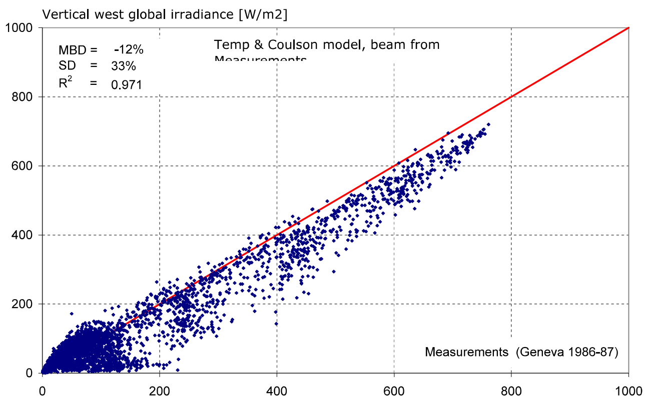

Vertical east global irradiance [W/m2]
MBD = -12%
SD = 33%
R2 = 0.969
Wilmott model, beam from Measurements
Measurements (Geneva 1986-87)

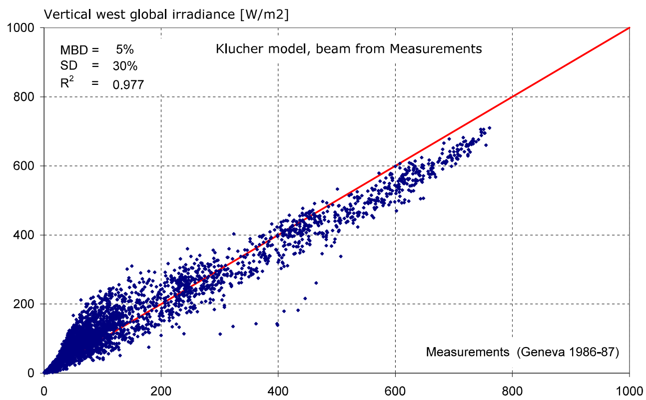

Vertical west global irradiance [W/m2]
MBD = -3%
SD = 29%
R^2 = 0.984
Isotropic diffuse, beam from Measurements
Measurements (Geneva 1986-87)

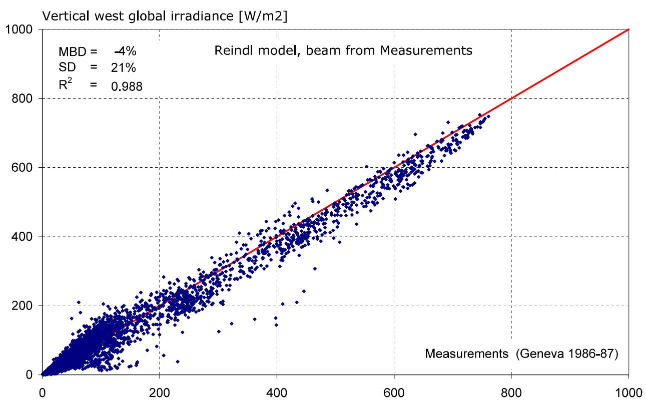

Vertical west global irradiance [W/m2]
MBD = -5%
SD = 26%
R^2 = 0.984
Gueymard model, beam from Measurements
Measurements (Geneva 1986-87)

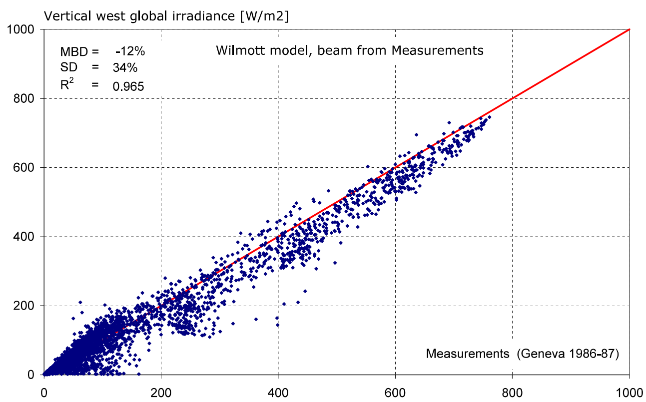

Vertical west global irradiance [W/m2]
MBD = -4%
SD = 21%
R^2 = 0.988
Hay model, beam from Measurements
Measurements (Geneva 1986-87)

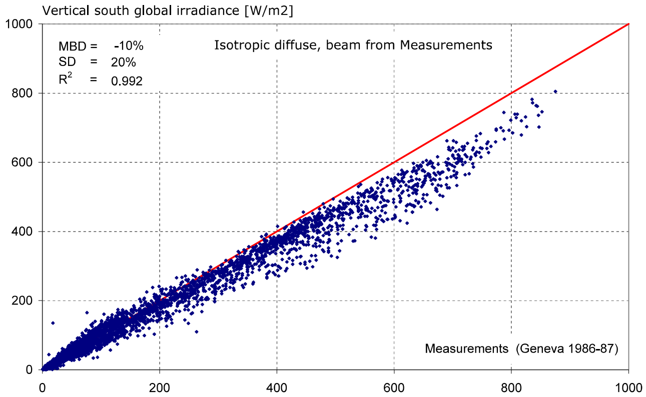

Vertical west global irradiance [W/m2]
MBD = -2%
SD = 19%
R^2 = 0.989
Perez model, beam from Measurements
Measurements (Geneva 1986-87)

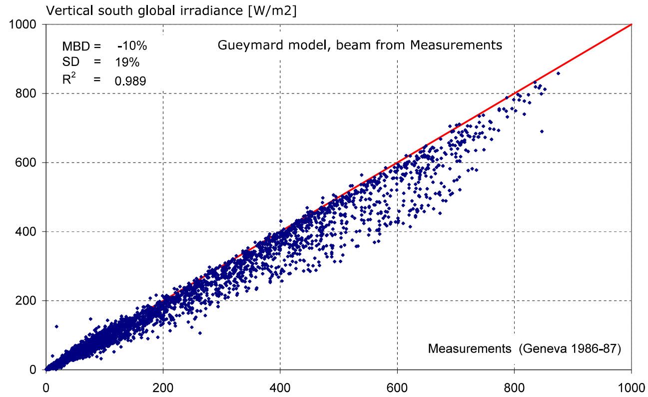

Vertical west global irradiance [W/m2]
MBD = -12%
SD = 33%
R^2 = 0.971
Temp & Coulson model, beam from
Measurements (Geneva 1986-87)

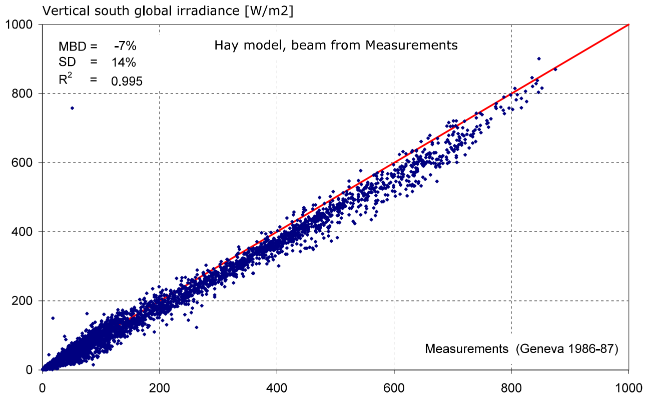

Vertical west global irradiance [W/m2]
MBD = 5%
SD = 30%
R^2 = 0.977
Klucher model, beam from Measurements
Measurements (Geneva 1986-87)

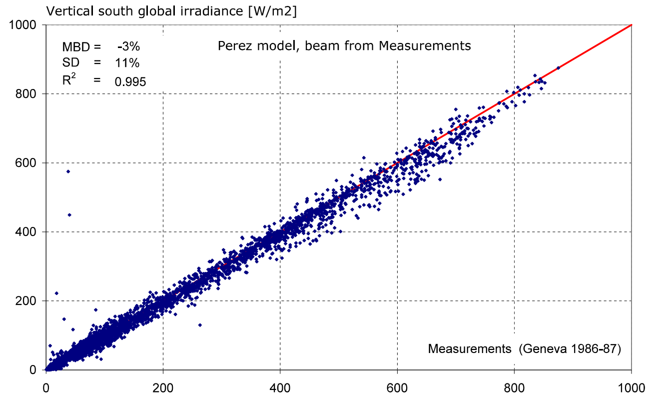

Vertical west global irradiance [W/m2]
MBD = -4%
SD = 21%
R^2 = 0.988
Reindl model, beam from Measurements
Measurements (Geneva 1986-87)

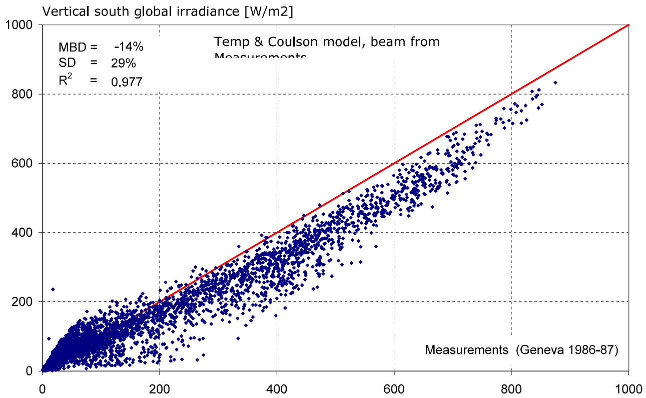

Vertical west global irradiance [W/m2]
MBD = -12%
SD = 34%
R^2 = 0.965
Wilmott model, beam from Measurements
Measurements (Geneva 1986-87)

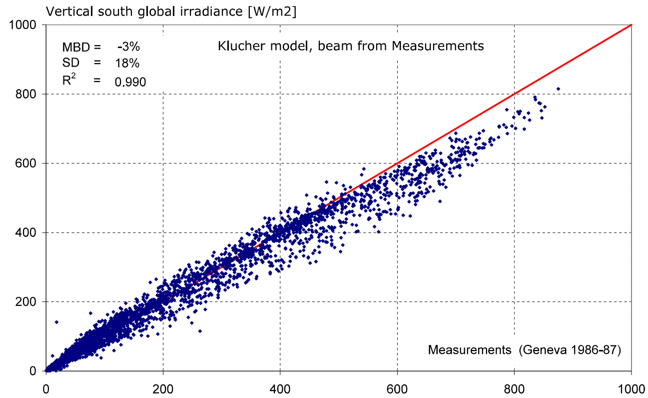

Vertical south global irradiance [W/m2]
MBD = -10%
SD = 20%
R^2 = 0.992
Isotropic diffuse, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

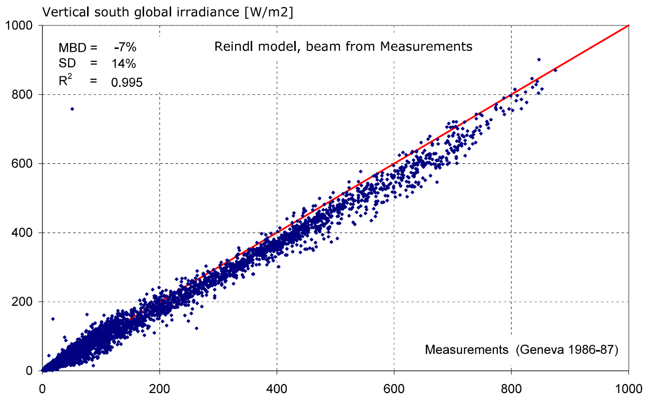

Vertical south global irradiance [W/m2]
MBD = -10%
SD = 19%
R^2 = 0.989
Gueymard model, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

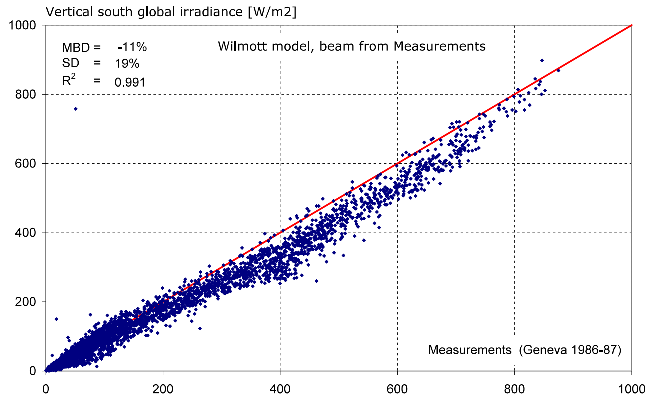

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 14%
R^2 = 0.995
Hay model, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

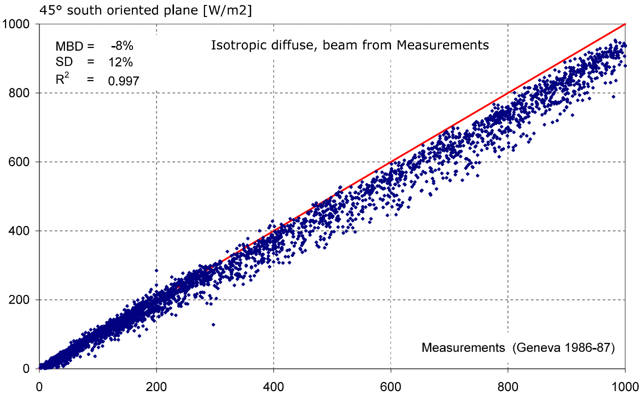

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 11%
R^2 = 0.995
Perez model, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

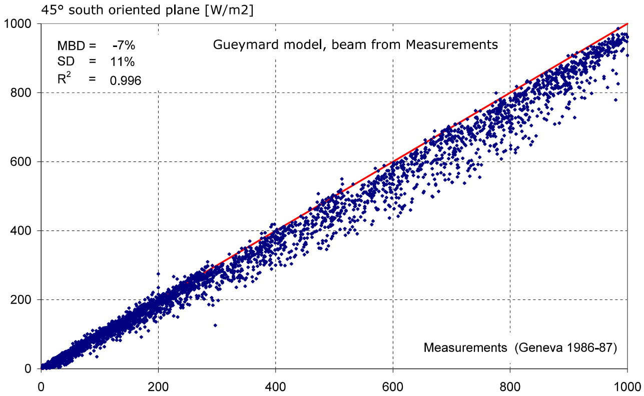

Vertical south global irradiance [W/m2]
MBD = -14%
SD = 29%
R^2 = 0.977
Temp & Coulson model, beam from
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

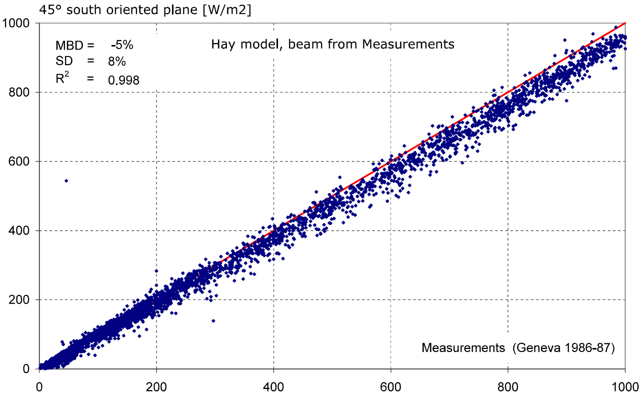

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 18%
R^2 = 0.990
Klucher model, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

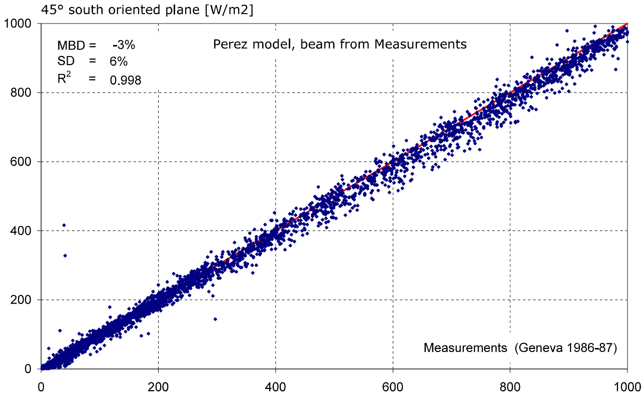

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 14%
R^2 = 0.995
Reindl model, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

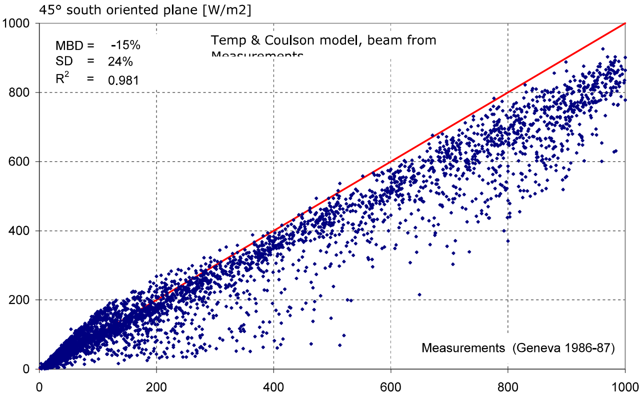

Vertical south global irradiance [W/m2]
MBD = -11%
SD = 19%
R^2 = 0.991
Wilmott model, beam from Measurements
Measurements (Geneva 1986-87)
0 200 400 600 800 1000

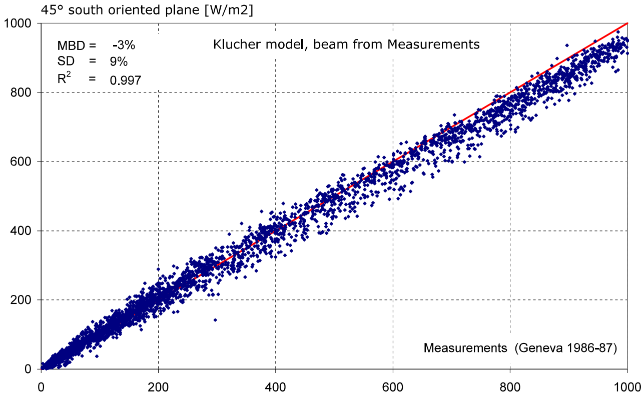

45° south oriented plane [W/m2]
MBD = -8%
SD = 12%
R^2 = 0.997
Isotropic diffuse, beam from Measurements
Measurements (Geneva 1986-87)

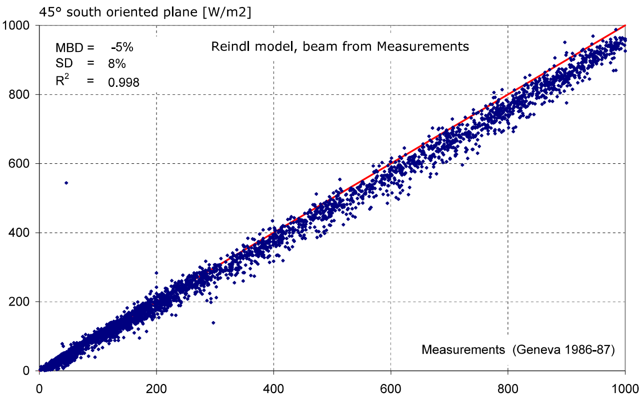

45° south oriented plane [W/m2]
MBD = -7%
SD = 11%
R^2 = 0.996
Gueymard model, beam from Measurements
Measurements (Geneva 1986-87)

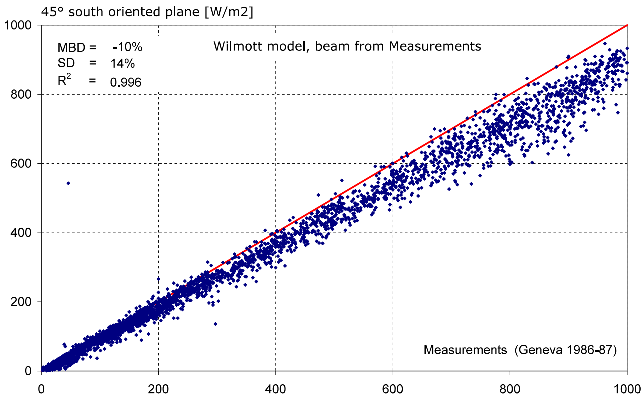

45° south oriented plane [W/m2]
MBD = -5%
SD = 8%
R^2 = 0.998
Hay model, beam from Measurements
Measurements (Geneva 1986-87)

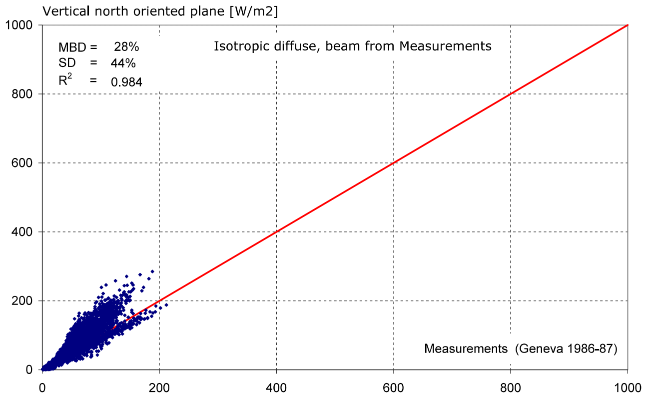

45° south oriented plane [W/m2]
MBD = -3%
SD = 6%
R^2 = 0.998
Perez model, beam from Measurements
Measurements (Geneva 1986-87)

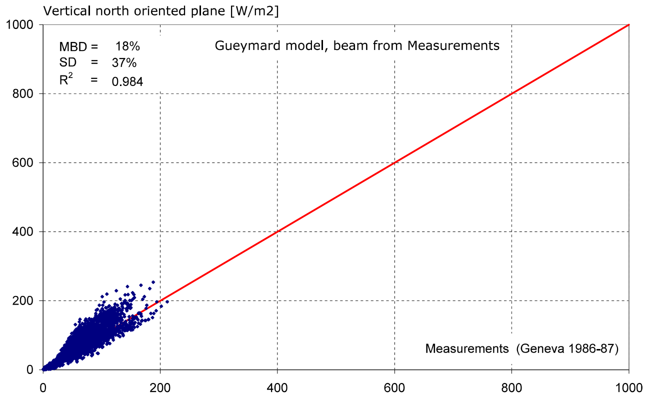

45° south oriented plane [W/m2]
MBD = -15%
SD = 24%
R^2 = 0.981
Temp & Coulson model, beam from
Measurements (Geneva 1986-87)

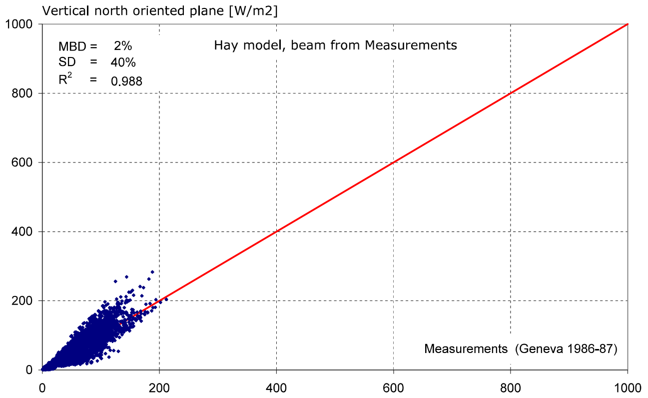

45° south oriented plane [W/m2]
MBD = -3%
SD = 9%
R^2 = 0.997
Klucher model, beam from Measurements
Measurements (Geneva 1986-87)

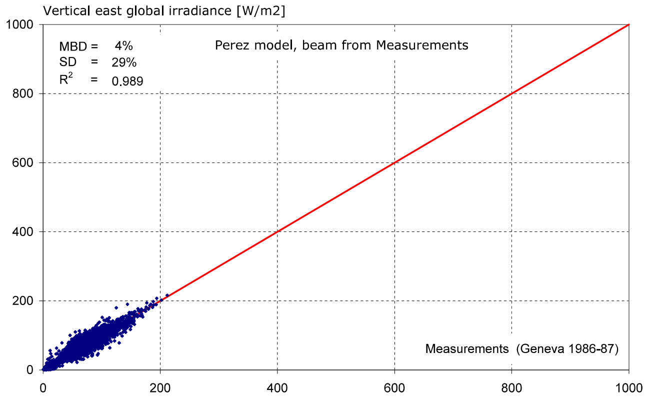

45° south oriented plane [W/m2]
MBD = -5%
SD = 8%
R^2 = 0.998
Reindl model, beam from Measurements
Measurements (Geneva 1986-87)

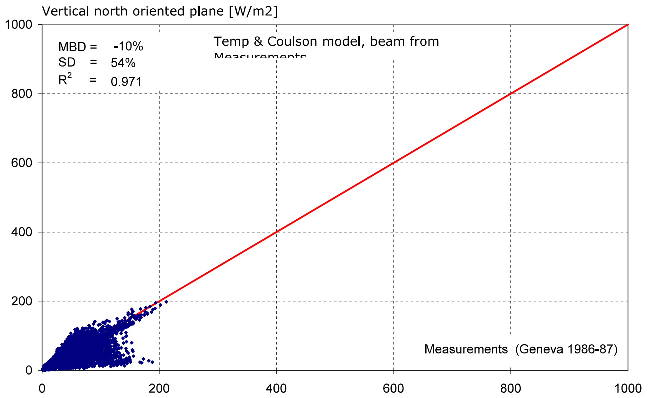

45° south oriented plane [W/m2]
MBD = -10%
SD = 14%
R^2 = 0.996
Wilmott model, beam from Measurements
Measurements (Geneva 1986-87)

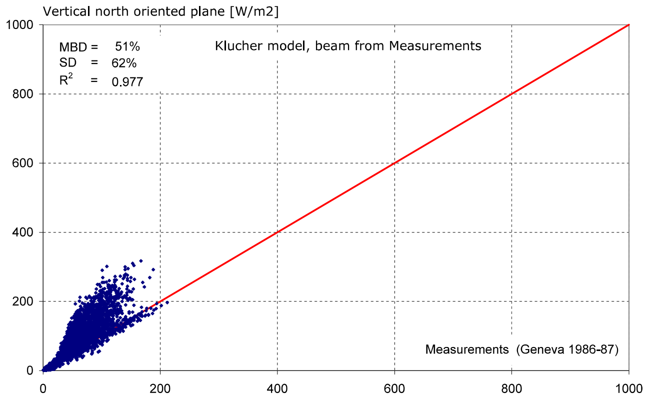

Vertical north oriented plane [W/m2]
MBD = 28%
SD = 44%
R^2 = 0.984
Isotropic diffuse, beam from Measurements
Measurements (Geneva 1986-87)

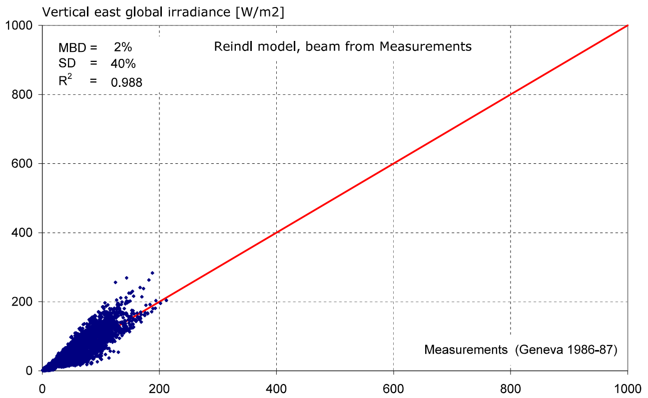

Vertical north oriented plane [W/m2]
MBD = 18%
SD = 37%
R^2 = 0.984
Gueymard model, beam from Measurements
Measurements (Geneva 1986-87)

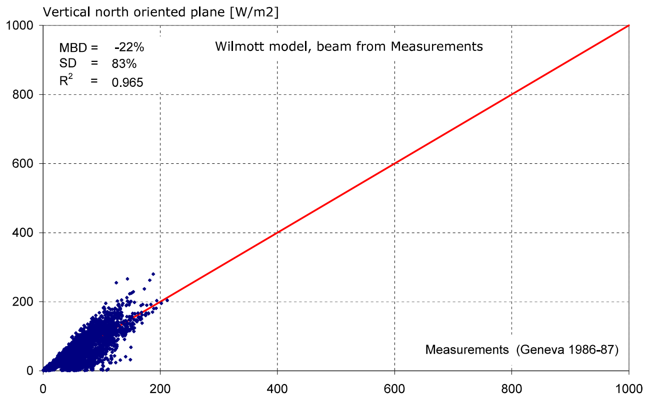

Vertical north oriented plane [W/m2]
MBD = 2%
SD = 40%
R^2 = 0.988
Hay model, beam from Measurements
Measurements (Geneva 1986-87)


Vertical east global irradiance [W/m2]
MBD = 4%
SD = 29%
R^2 = 0.989
Perez model, beam from Measurements
Measurements (Geneva 1986-87)


Vertical north oriented plane [W/m2]
MBD = -10%
SD = 54%
R^2 = 0.971
Temp & Coulson model, beam from
Measurements (Geneva 1986-87)


Vertical north oriented plane [W/m2]
MBD = 51%
SD = 62%
R^2 = 0.977
Klucher model, beam from Measurements
Measurements (Geneva 1986-87)


Vertical east global irradiance [W/m2]
MBD = 2%
SD = 40%
R^2 = 0.988
Reindl model, beam from Measurements
Measurements (Geneva 1986-87)


Vertical north oriented plane [W/m2]
MBD = -22%
SD = 83%
R^2 = 0.965
Wilmott model, beam from Measurements
Measurements (Geneva 1986-87)

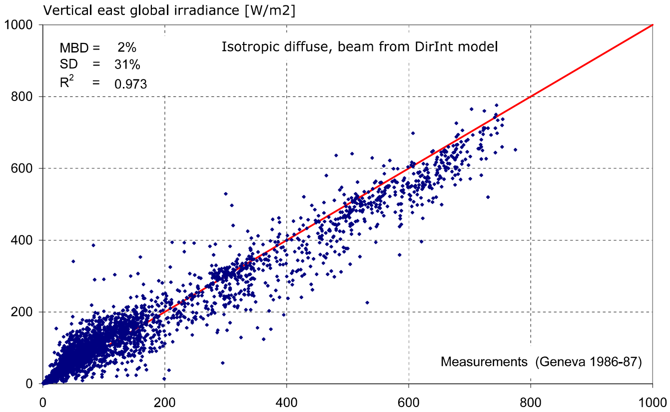
Geneva (Switzerland)

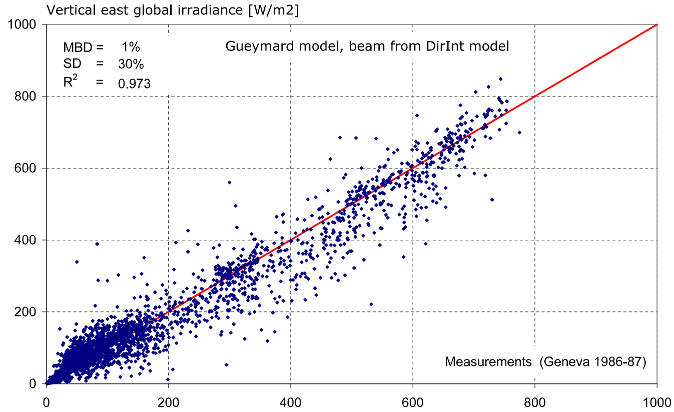
Latitude:	46.20°
Longitude:	6.13°
Altitude over sea level:	420m

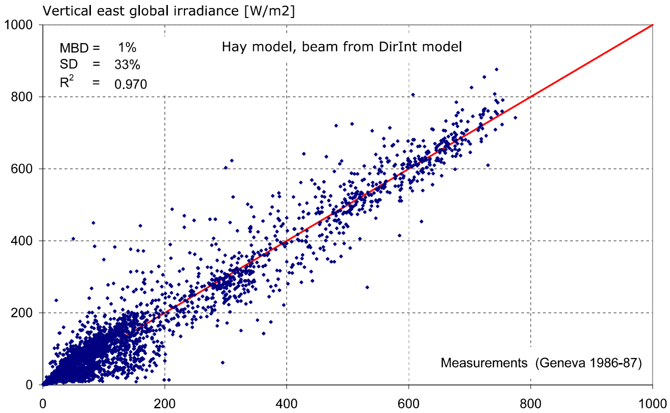
Beam irradiance from DirInt model

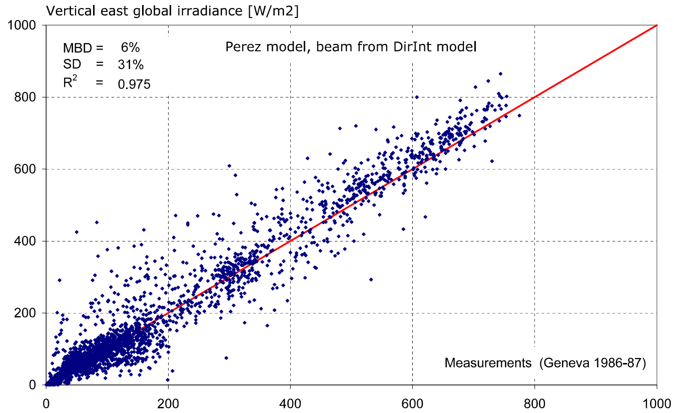
Figures in the following pages:

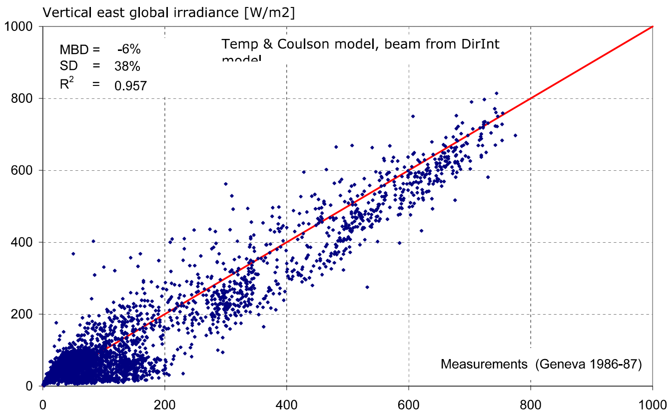
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

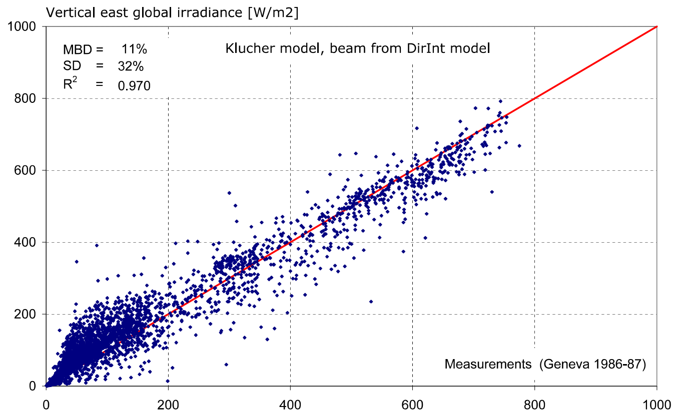

Vertical east global irradiance [W/m2]
MBD = 2%
SD = 31%
R^2 = 0.973
Isotropic diffuse, beam from DirInt model
Measurements (Geneva 1986-87)

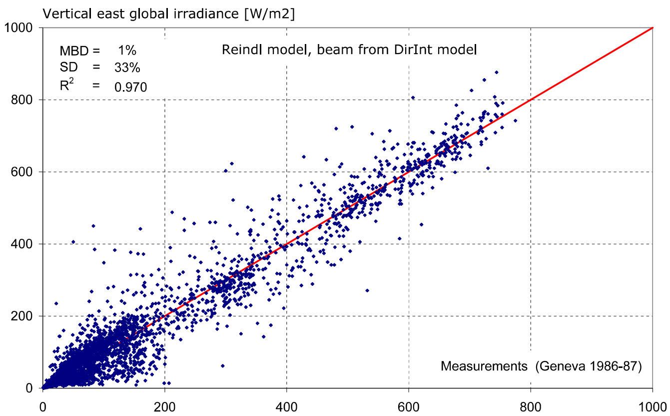

Vertical east global irradiance [W/m2]
MBD = 1%
SD = 30%
R^2 = 0.973
Gueymard model, beam from DirInt model
Measurements (Geneva 1986-87)

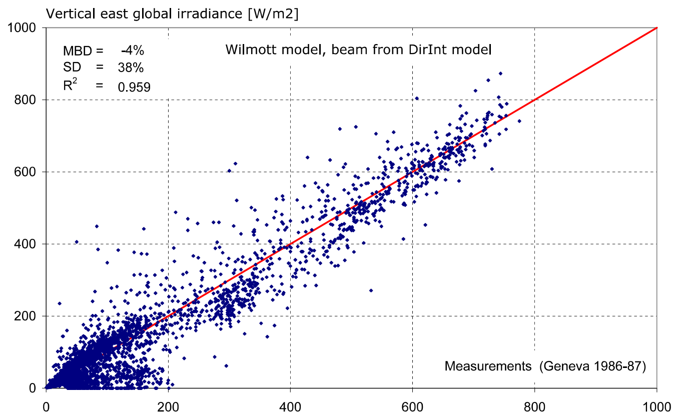

Vertical east global irradiance [W/m2]
MBD = 1%
SD = 33%
R^2 = 0.970
Hay model, beam from DirInt model
Measurements (Geneva 1986-87)

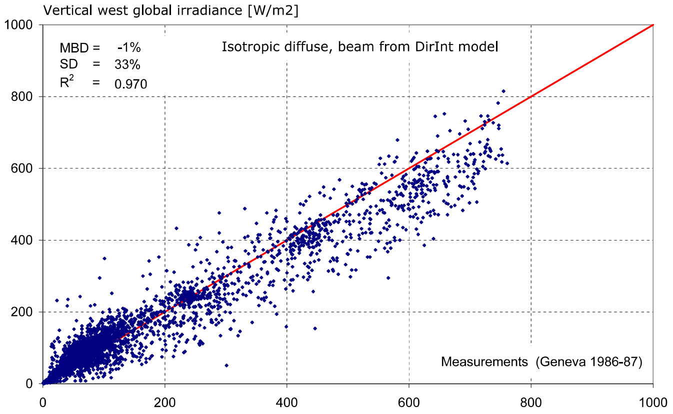

Vertical east global irradiance [W/m2]
MBD = 6%
SD = 31%
R^2 = 0.975
Perez model, beam from DirInt model
Measurements (Geneva 1986-87)

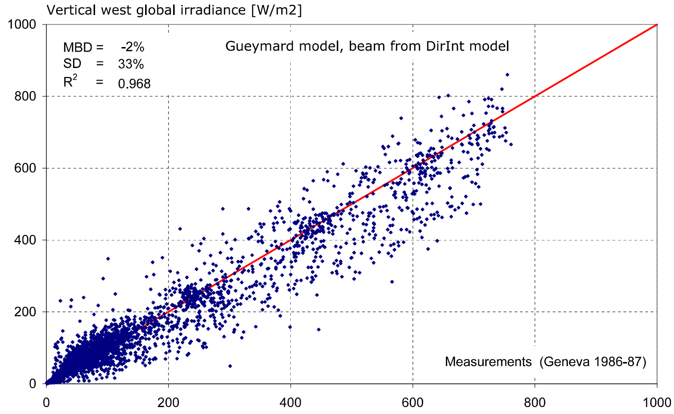

Vertical east global irradiance [W/m2]
MBD = -6%
SD = 38%
R^2 = 0.957
Temp & Coulson model, beam from DirInt
Measurements (Geneva 1986-87)

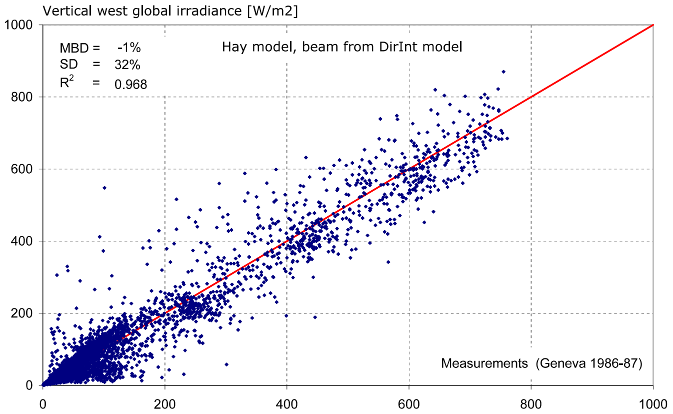

Vertical east global irradiance [W/m2]
MBD = 11%
SD = 32%
R^2 = 0.970
Klucher model, beam from DirInt model
Measurements (Geneva 1986-87)

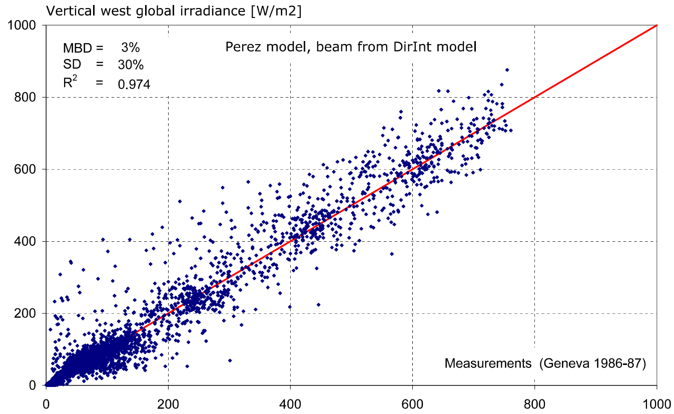

Vertical east global irradiance [W/m2]
MBD = 1%
SD = 33%
R^2 = 0.970
Reindl model, beam from DirInt model
Measurements (Geneva 1986-87)

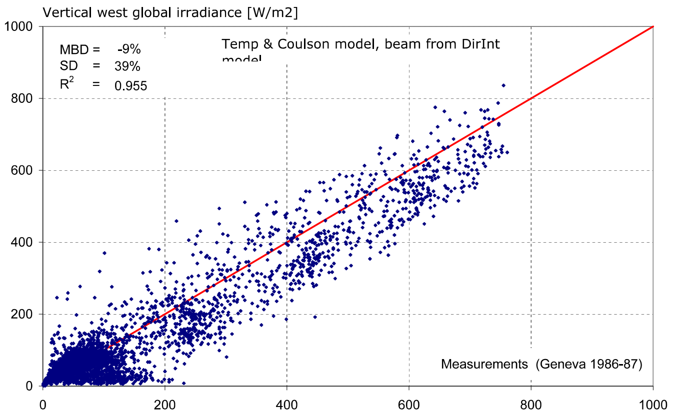

Vertical east global irradiance [W/m2]
MBD = -4%
SD = 38%
R^2 = 0.959
Wilmott model, beam from DirInt model
Measurements (Geneva 1986-87)

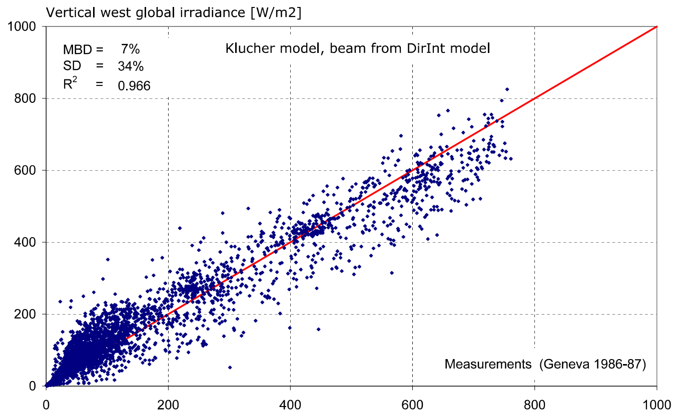

Vertical west global irradiance [W/m2]
MBD = -1%
SD = 33%
R^2 = 0.970
Isotropic diffuse, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

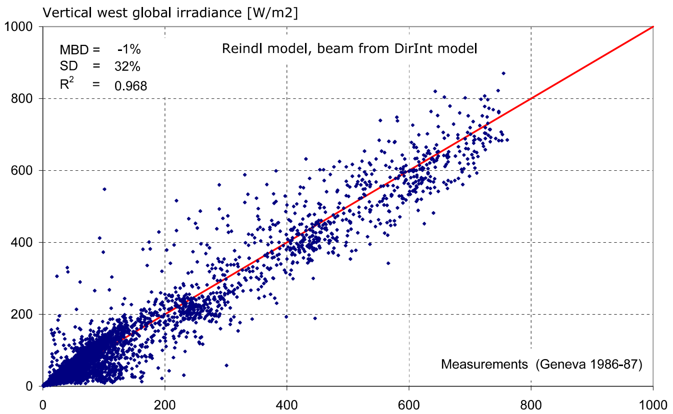

Vertical west global irradiance [W/m2]
MBD = -2%
SD = 33%
R^2 = 0.968
Gueymard model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

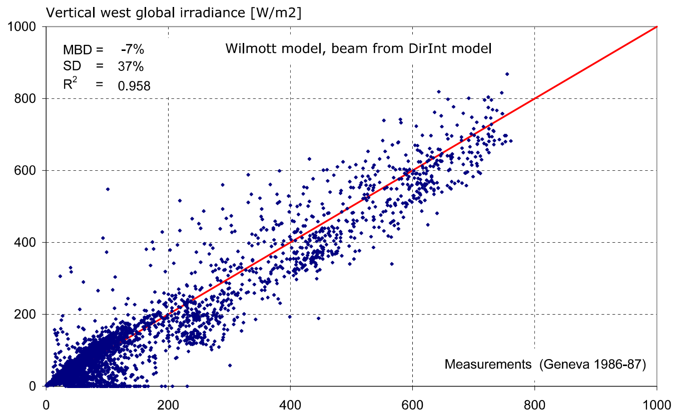

Vertical west global irradiance [W/m2]
MBD = -1%
SD = 32%
R^2 = 0.968
Hay model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

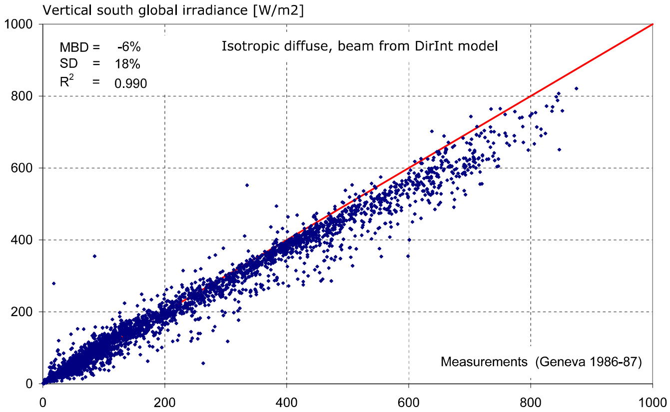

Vertical west global irradiance [W/m2]
MBD = 3%
SD = 30%
R^2 = 0.974
Perez model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

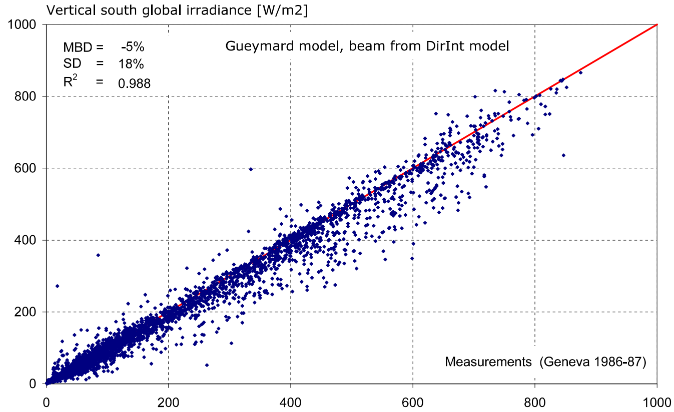

Vertical west global irradiance [W/m2]
MBD = -9%
SD = 39%
R^2 = 0.955
Temp & Coulson model, beam from DirInt
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

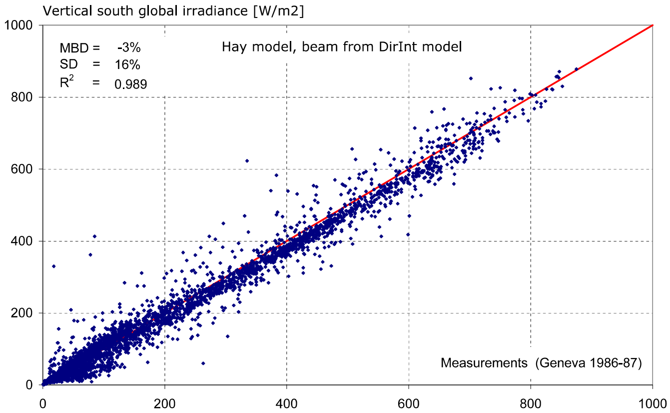

Vertical west global irradiance [W/m2]
MBD = 7%
SD = 34%
R^2 = 0.966
Klucher model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

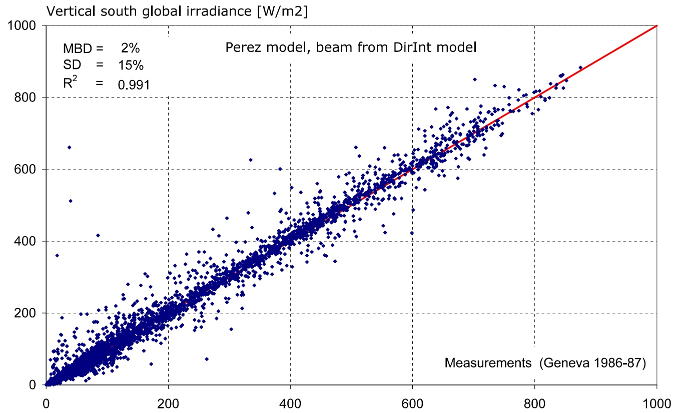

Vertical west global irradiance [W/m2]
MBD = -1%
SD = 32%
R^2 = 0.968
Reindl model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

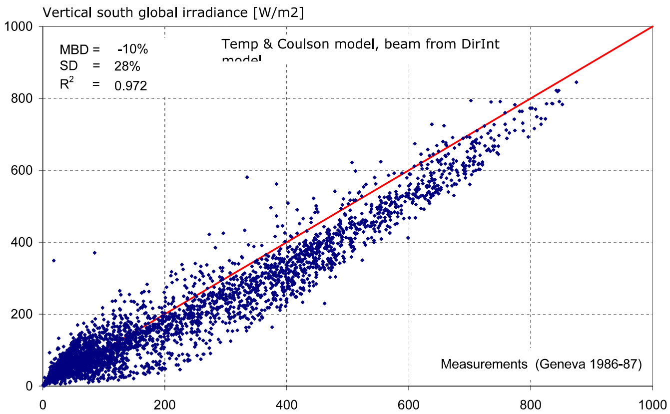

Vertical west global irradiance [W/m2]
MBD = -7%
SD = 37%
R^2 = 0.958
Wilmott model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

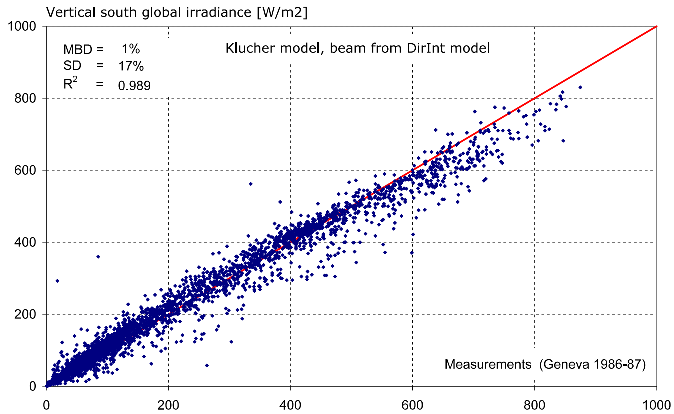

Vertical south global irradiance [W/m2]
MBD = -6%
SD = 18%
R^2 = 0.990
Isotropic diffuse, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

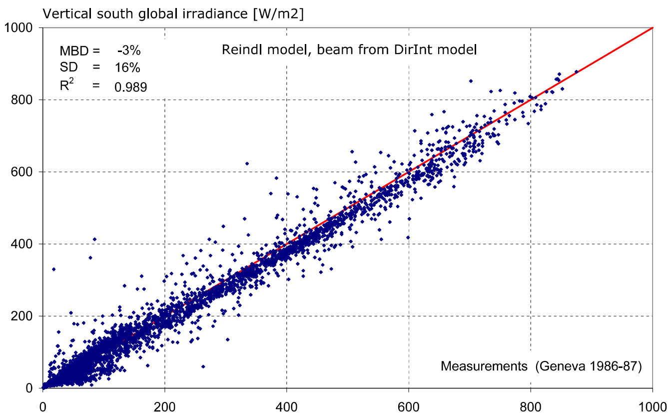

Vertical south global irradiance [W/m2]
MBD = -5%
SD = 18%
R^2 = 0.988
Gueymard model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

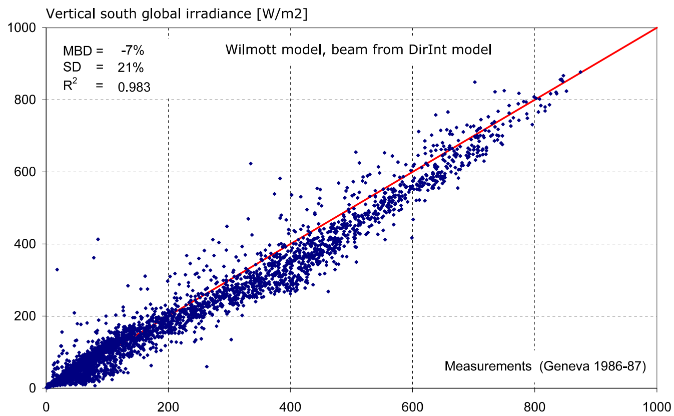

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 16%
R^2 = 0.989
Hay model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

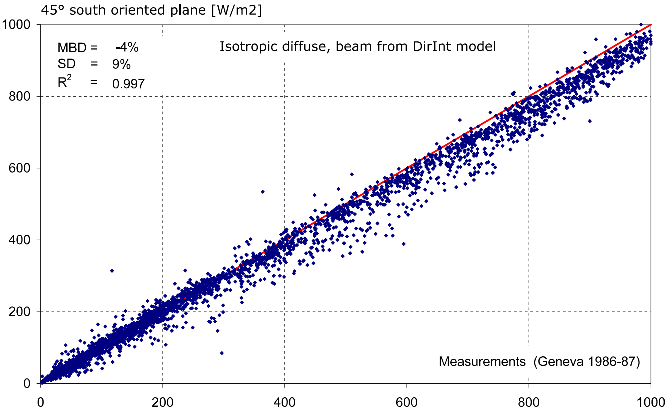

Vertical south global irradiance [W/m2]
MBD = 2%
SD = 15%
R^2 = 0.991
Perez model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

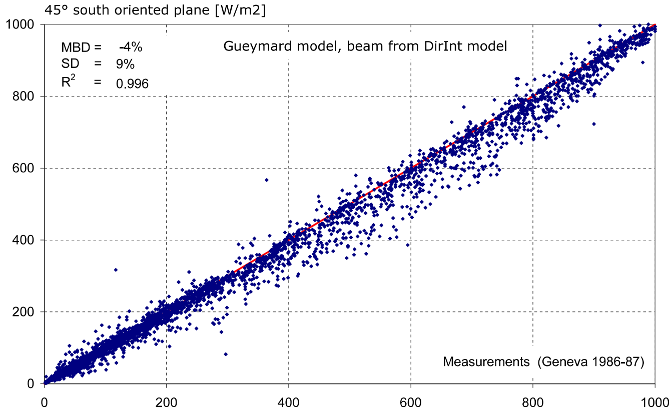

Vertical south global irradiance [W/m2]
MBD = -10%
SD = 28%
R^2 = 0.972
Temp & Coulson model, beam from DirInt
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

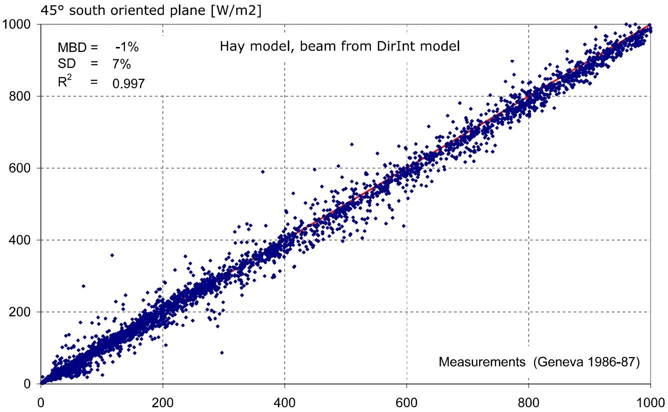

Vertical south global irradiance [W/m2]
MBD = 1%
SD = 17%
R^2 = 0.989
Klucher model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

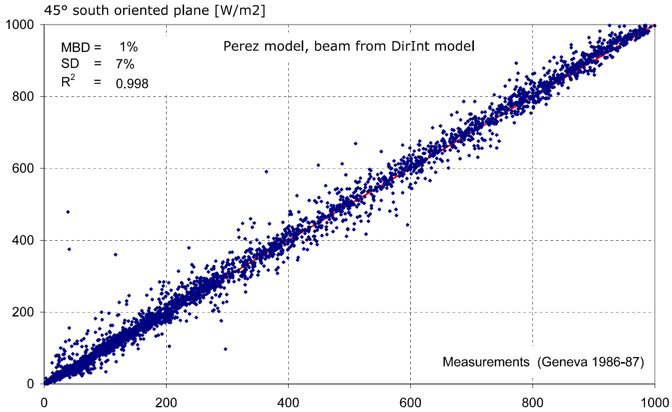

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 16%
R^2 = 0.989
Reindl model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

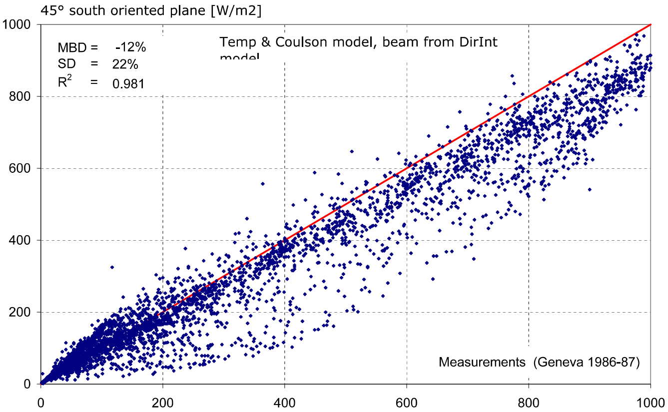

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 21%
R^2 = 0.983
Wilmott model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

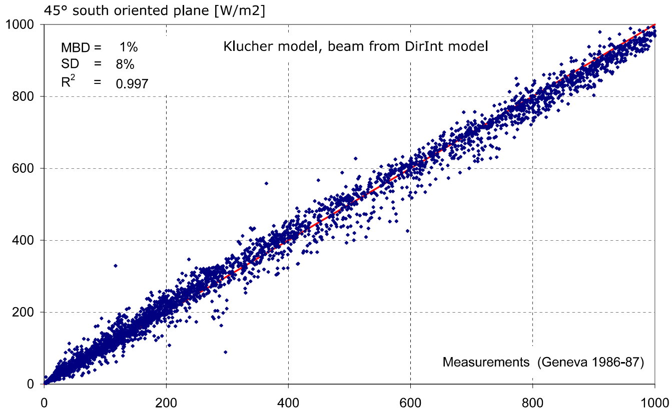

45° south oriented plane [W/m2]
MBD = -4%
SD = 9%
R^2 = 0.997
Isotropic diffuse, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

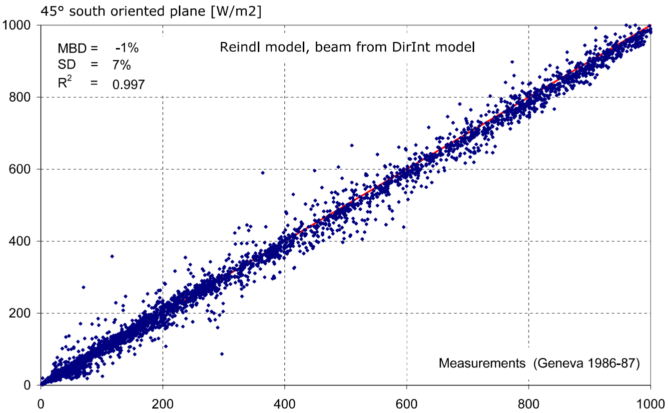

45° south oriented plane [W/m2]
MBD = -4%
SD = 9%
R^2 = 0.996
Gueymard model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

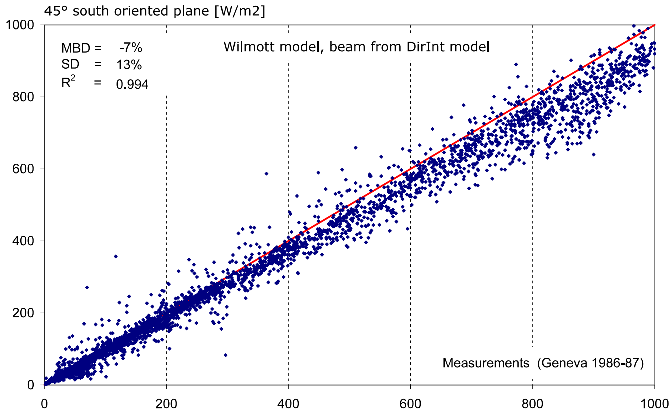

45° south oriented plane [W/m2]
MBD = -1%
SD = 7%
R^2 = 0.997
Hay model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

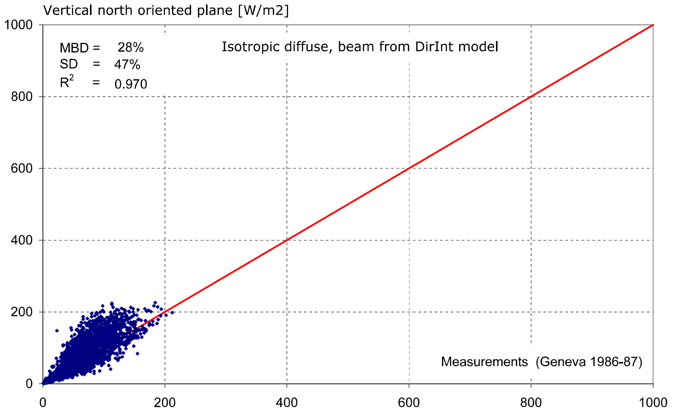

45° south oriented plane [W/m2]
MBD = 1%
SD = 7%
R^2 = 0.998
Perez model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

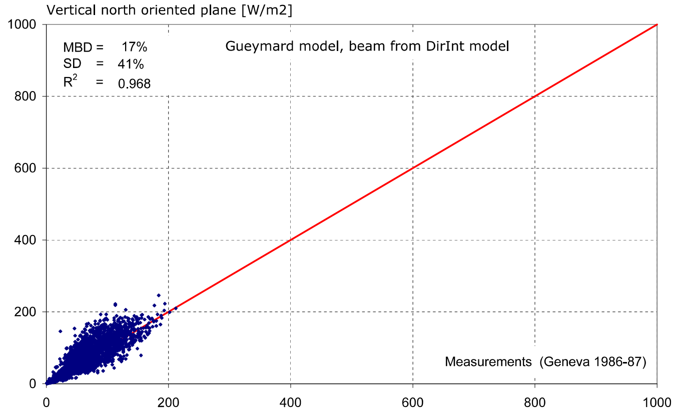

45° south oriented plane [W/m2]
MBD = -12%
SD = 22%
R^2 = 0.981
Temp & Coulson model, beam from DirInt
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

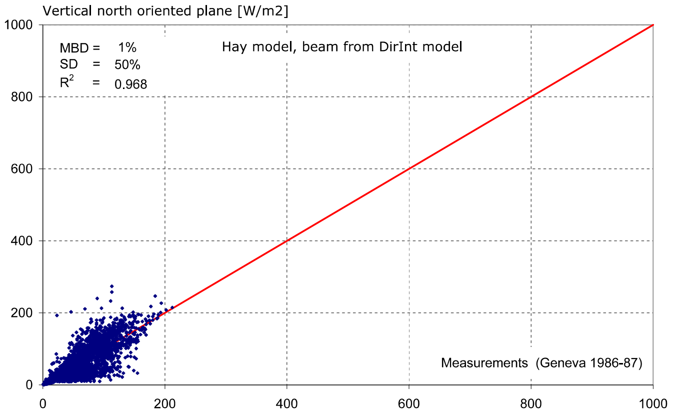

45° south oriented plane [W/m2]
MBD = 1%
SD = 8%
R^2 = 0.997
Klucher model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

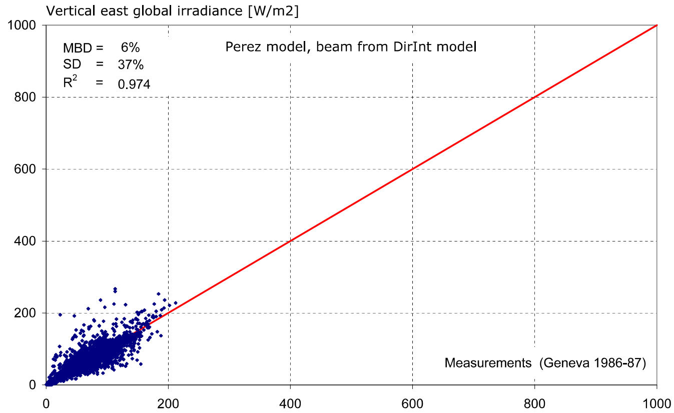

45° south oriented plane [W/m2]
MBD = -1%
SD = 7%
R^2 = 0.997
Reindl model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

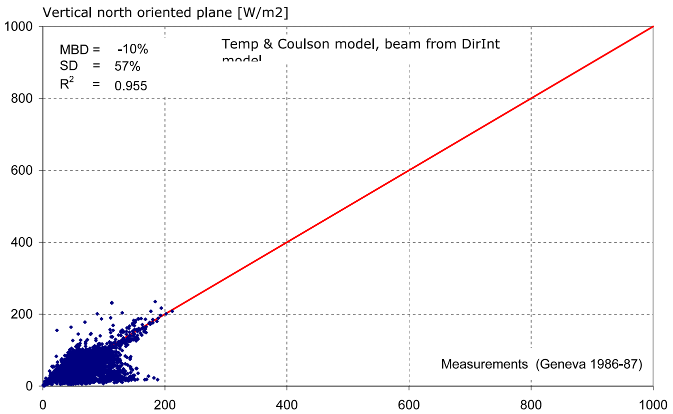

45° south oriented plane [W/m2]
MBD = -7%
SD = 13%
R^2 = 0.994
Wilmott model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

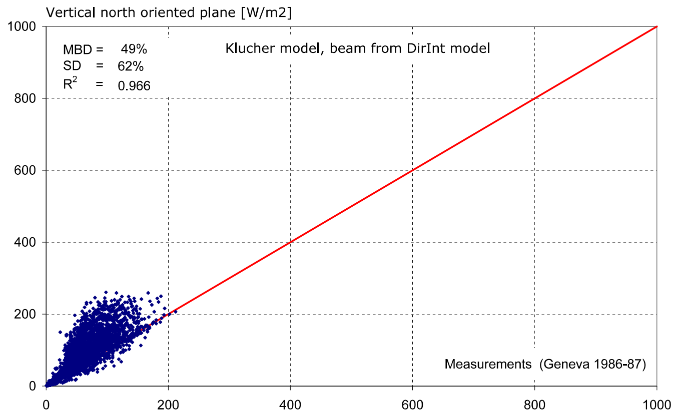

Vertical north oriented plane [W/m2]
MBD = 28%
SD = 47%
R^2 = 0.970
Isotropic diffuse, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

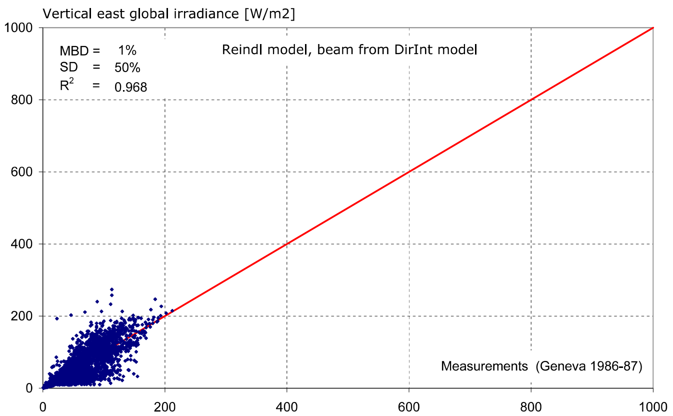

Vertical north oriented plane [W/m2]
MBD = 17%
SD = 41%
R^2 = 0.968
Gueymard model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

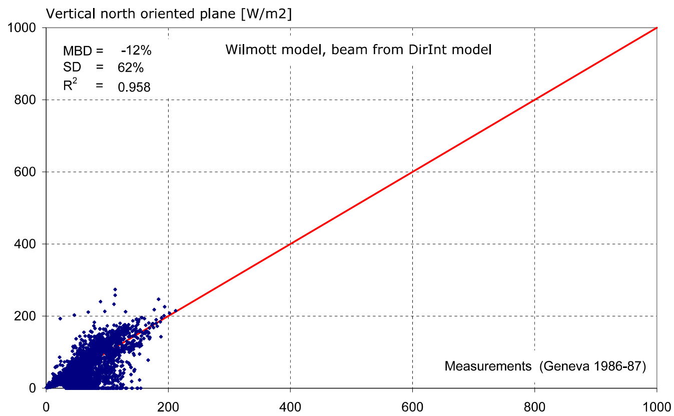

Vertical north oriented plane [W/m2]
MBD = 1%
SD = 50%
R^2 = 0.968
Hay model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = 6%
SD = 37%
R^2 = 0.974
Perez model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -10%
SD = 57%
R^2 = 0.955
Temp & Coulson model, beam from DirInt
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = 49%
SD = 62%
R^2 = 0.966
Klucher model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = 1%
SD = 50%
R^2 = 0.968
Reindl model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -12%
SD = 62%
R^2 = 0.958
Wilmott model, beam from DirInt model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

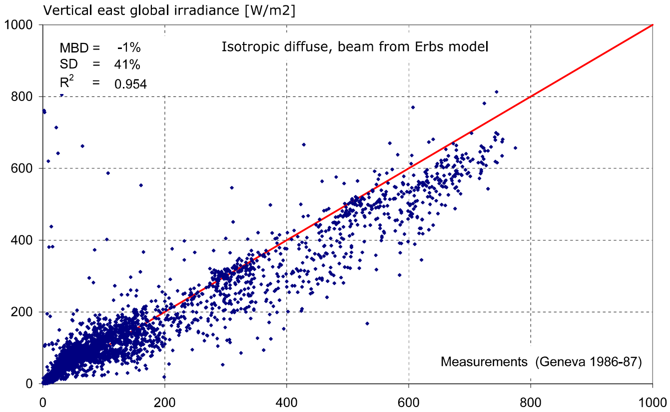
Geneva (Switzerland)

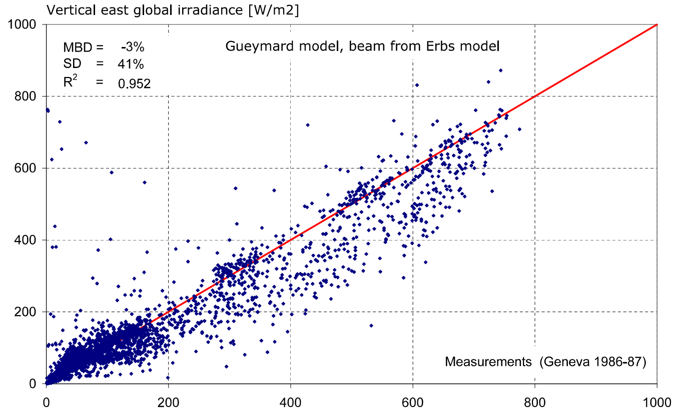
Latitude:	46.20°
Longitude:	6.13°
Altitude over sea level:	420m

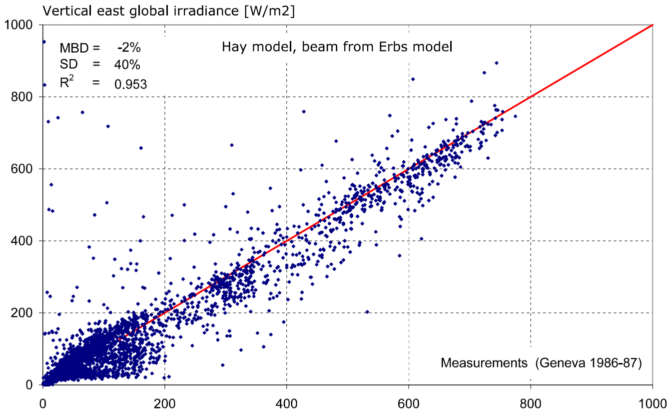
Beam irradiance from Erbs. Klucher and Duffie (EKD)

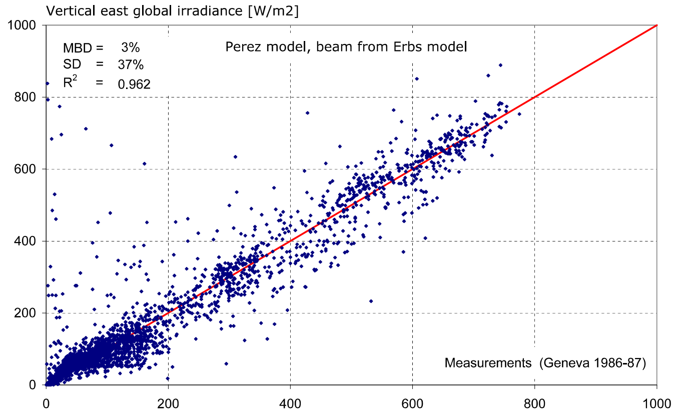
Figures in the following pages:

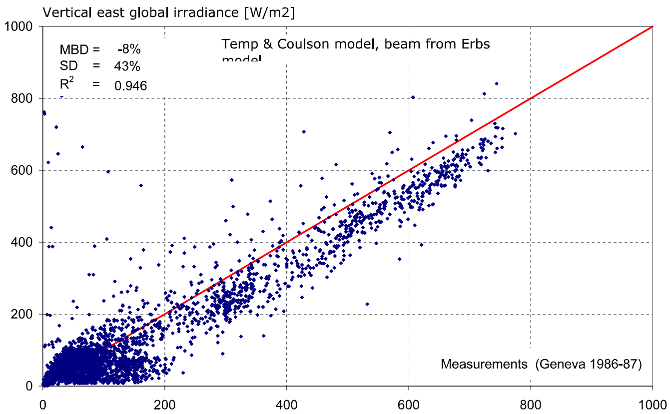
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

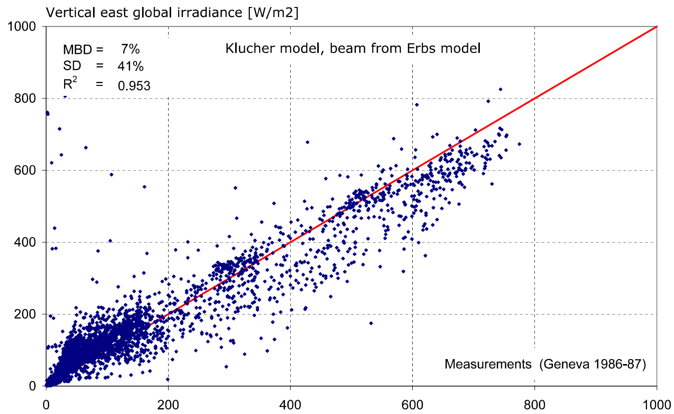

Vertical east global irradiance [W/m2]
MBD = -1%
SD = 41%
R2 = 0.954
Isotropic diffuse, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

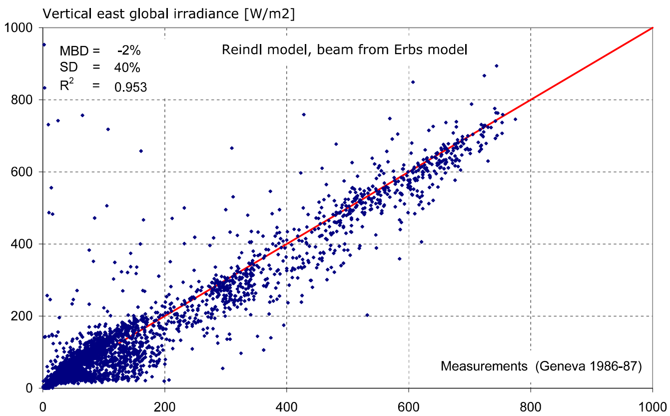

Vertical east global irradiance [W/m2]
MBD = -3%
SD = 41%
R2 = 0.952
Gueymard model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

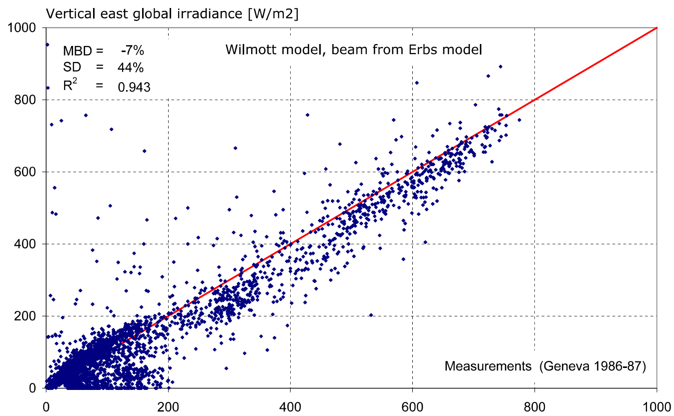

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 40%
R2 = 0.953
Hay model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

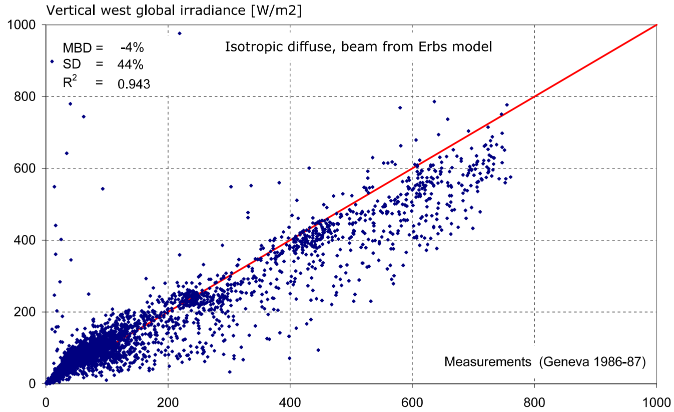

Vertical east global irradiance [W/m2]
MBD = 3%
SD = 37%
R2 = 0.962
Perez model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

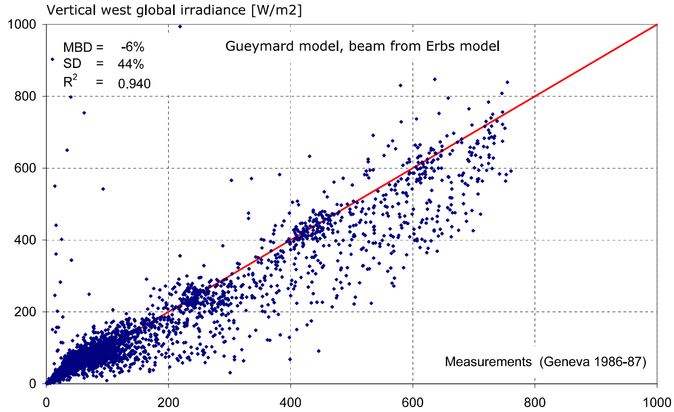

Vertical east global irradiance [W/m2]
MBD = -8%
SD = 43%
R2 = 0.946
Temp & Coulson model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

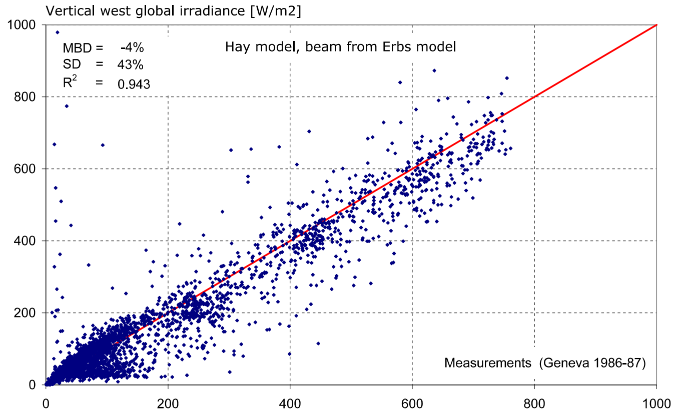

Vertical east global irradiance [W/m2]
MBD = 7%
SD = 41%
R2 = 0.953
Klucher model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

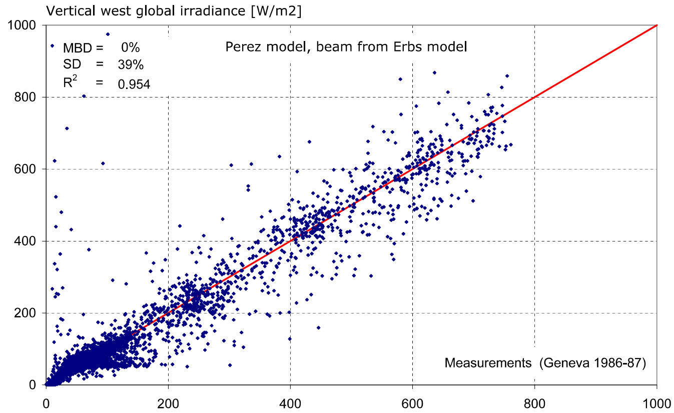

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 40%
R2 = 0.953
Reindl model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

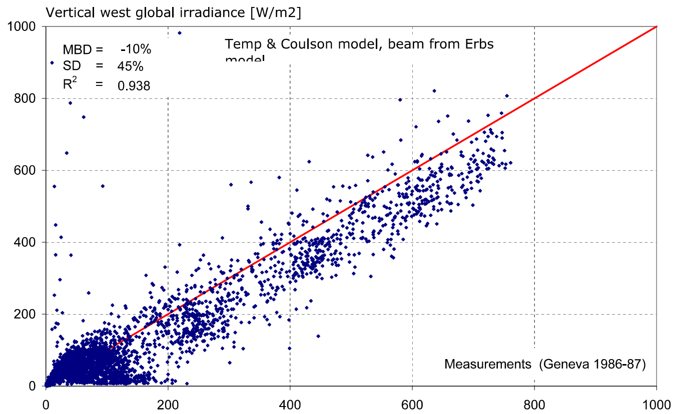

Vertical east global irradiance [W/m2]
MBD = -7%
SD = 44%
R2 = 0.943
Wilmott model, beam from Erbs model
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

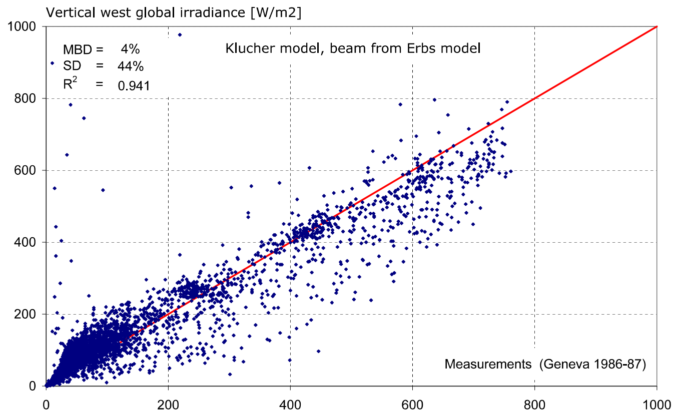

Vertical west global irradiance [W/m2]
MBD = -4%
SD = 44%
R2 = 0.943
Isotropic diffuse, beam from Erbs model
Measurements (Geneva 1986-87)

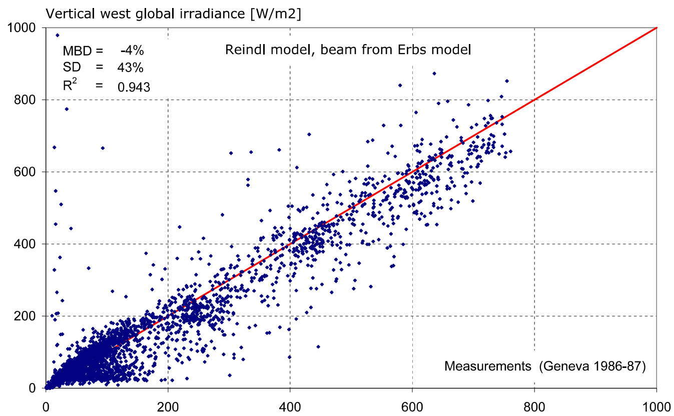

Vertical west global irradiance [W/m2]
MBD = -6%
SD = 44%
R2 = 0.940
Gueymard model, beam from Erbs model
Measurements (Geneva 1986-87)

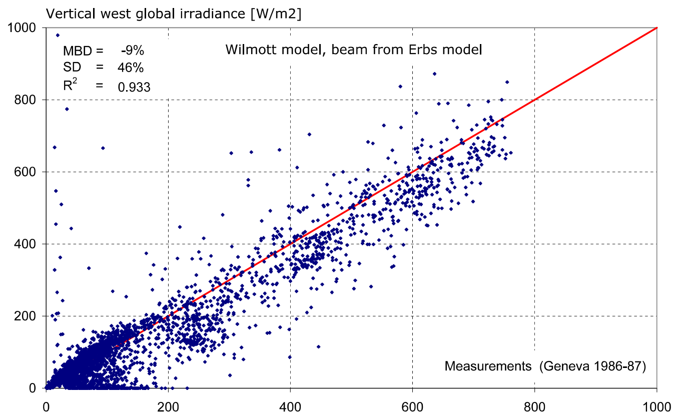

Vertical west global irradiance [W/m2]
MBD = -4%
SD = 43%
R2 = 0.943
Hay model, beam from Erbs model
Measurements (Geneva 1986-87)

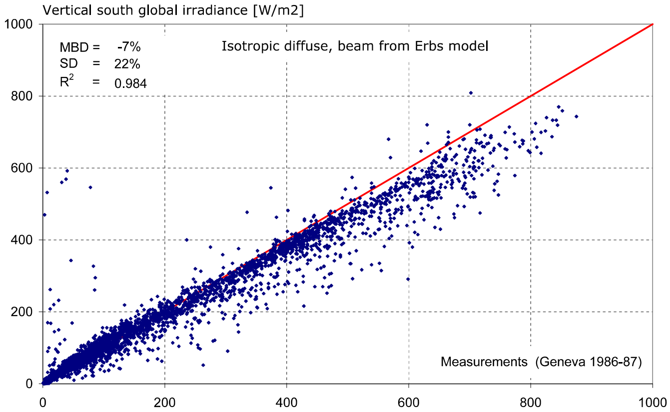

Vertical west global irradiance [W/m2]
MBD = 0%
SD = 39%
R2 = 0.954
Perez model, beam from Erbs model
Measurements (Geneva 1986-87)

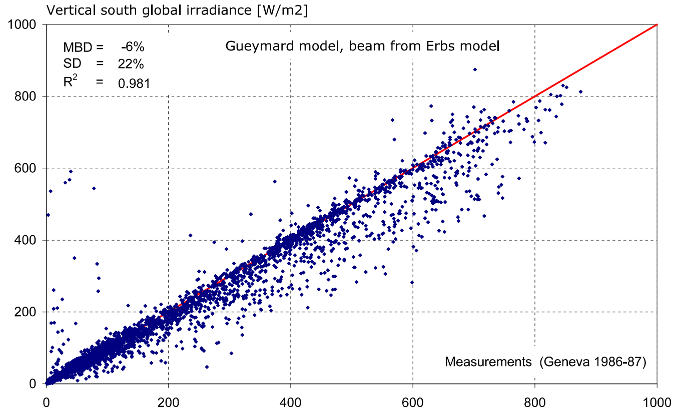

Vertical west global irradiance [W/m2]
MBD = -10%
SD = 45%
R2 = 0.938
Temp & Coulson model, beam from Erbs
Measurements (Geneva 1986-87)

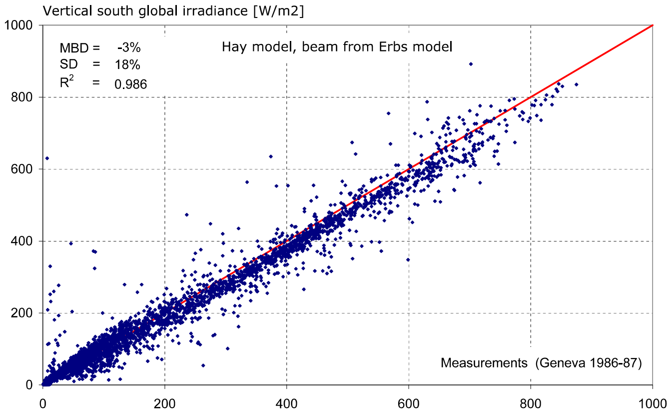

Vertical west global irradiance [W/m2]
MBD = 4%
SD = 44%
R2 = 0.941
Klucher model, beam from Erbs model
Measurements (Geneva 1986-87)

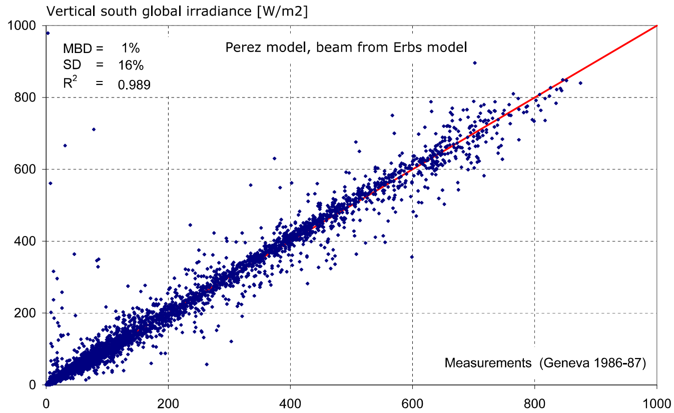

Vertical west global irradiance [W/m2]
MBD = -4%
SD = 43%
R2 = 0.943
Reindl model, beam from Erbs model
Measurements (Geneva 1986-87)

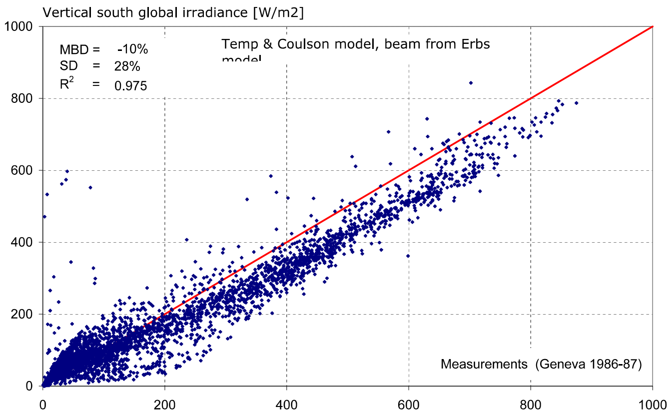

Vertical west global irradiance [W/m2]
MBD = -9%
SD = 46%
R2 = 0.933
Wilmott model, beam from Erbs model
Measurements (Geneva 1986-87)

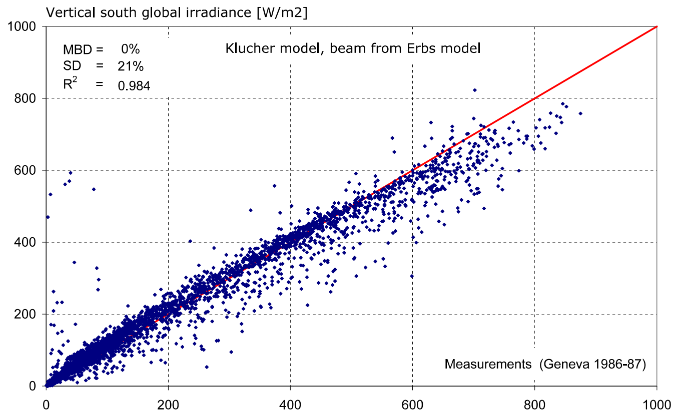

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 22%
R^2 = 0.984
Isotropic diffuse, beam from Erbs model
Measurements (Geneva 1986-87)

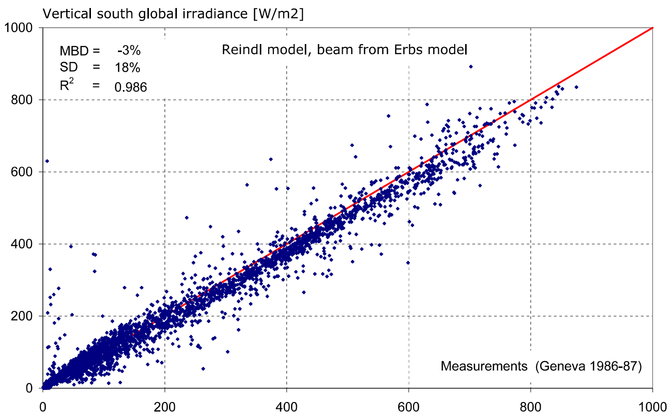

Vertical south global irradiance [W/m2]
MBD = -6%
SD = 22%
R^2 = 0.981
Gueymard model, beam from Erbs model
Measurements (Geneva 1986-87)

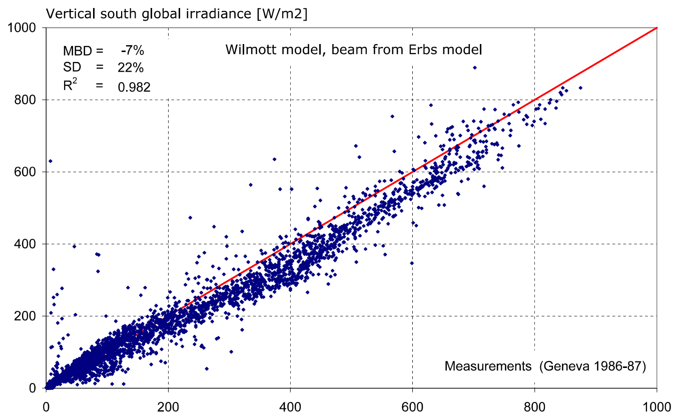

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 18%
R^2 = 0.986
Hay model, beam from Erbs model
Measurements (Geneva 1986-87)

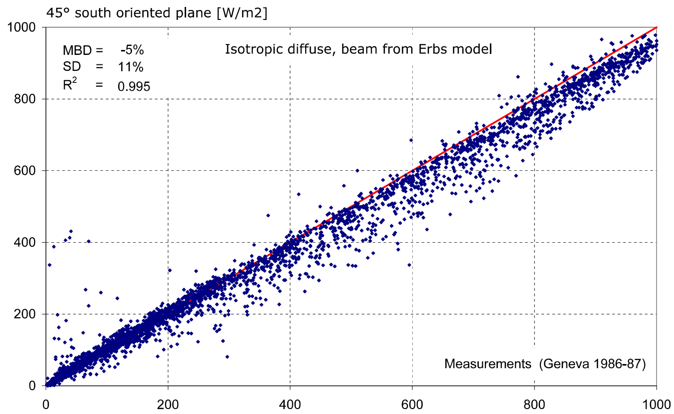

Vertical south global irradiance [W/m2]
MBD = 1%
SD = 16%
R^2 = 0.989
Perez model, beam from Erbs model
Measurements (Geneva 1986-87)

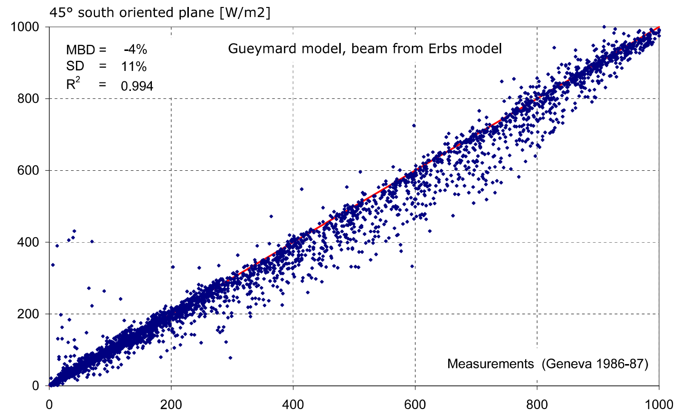

Vertical south global irradiance [W/m2]
MBD = -10%
SD = 28%
R^2 = 0.975
Temp & Coulson model, beam from Erbs
Measurements (Geneva 1986-87)

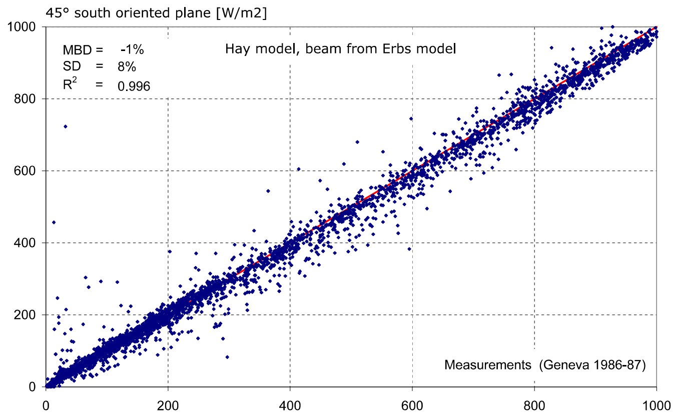

Vertical south global irradiance [W/m2]
MBD = 0%
SD = 21%
R^2 = 0.984
Klucher model, beam from Erbs model
Measurements (Geneva 1986-87)

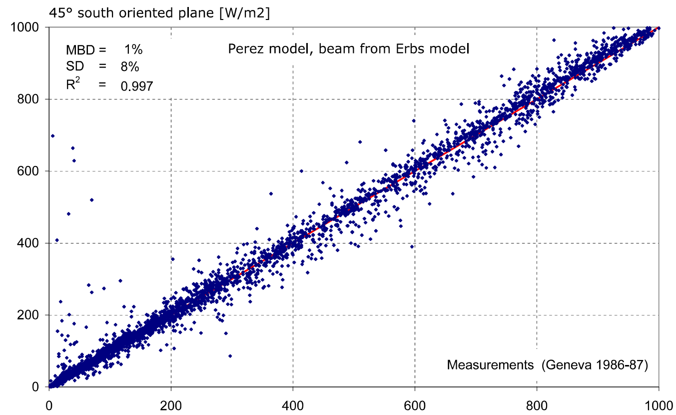

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 18%
R^2 = 0.986
Reindl model, beam from Erbs model
Measurements (Geneva 1986-87)

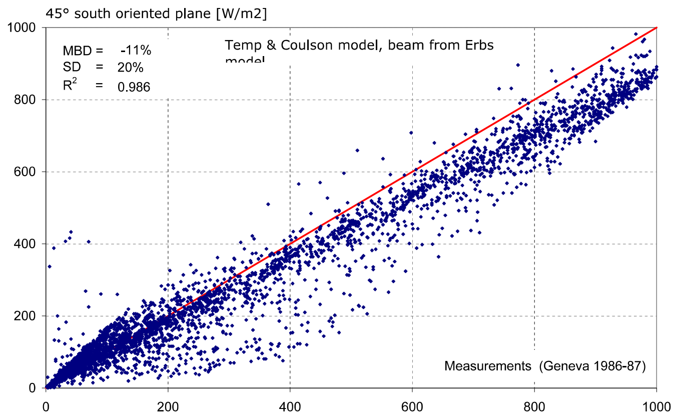

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 22%
R^2 = 0.982
Wilmott model, beam from Erbs model
Measurements (Geneva 1986-87)

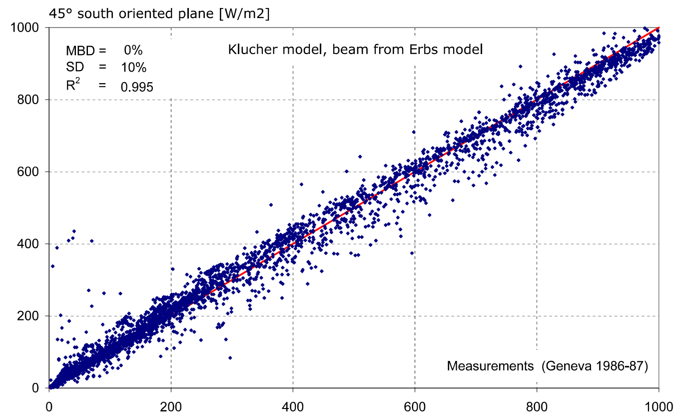

45° south oriented plane [W/m2]
MBD = -5%
SD = 11%
R2 = 0.995
Isotropic diffuse, beam from Erbs model
Measurements (Geneva 1986-87)

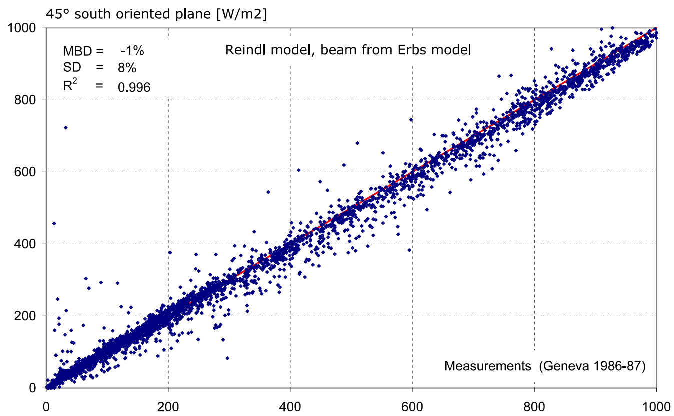

45° south oriented plane [W/m2]
MBD = -4%
SD = 11%
R2 = 0.994
Gueymard model, beam from Erbs model
Measurements (Geneva 1986-87)

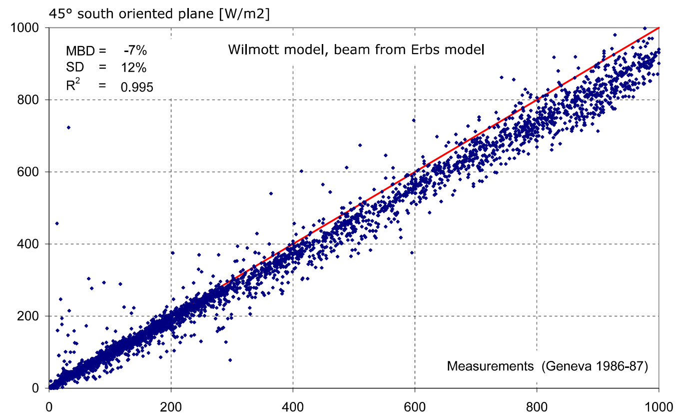

45° south oriented plane [W/m2]
MBD = -1%
SD = 8%
R2 = 0.996
Hay model, beam from Erbs model
Measurements (Geneva 1986-87)

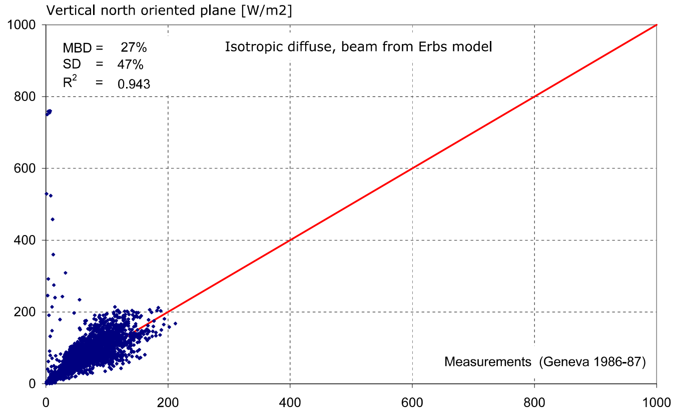

45° south oriented plane [W/m2]
MBD = 1%
SD = 8%
R2 = 0.997
Perez model, beam from Erbs model
Measurements (Geneva 1986-87)

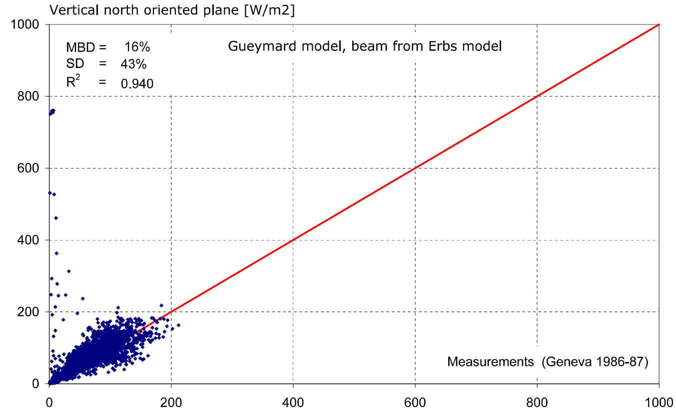

45° south oriented plane [W/m2]
MBD = -11%
SD = 20%
R2 = 0.986
Temp & Coulson model, beam from Erbs
Measurements (Geneva 1986-87)

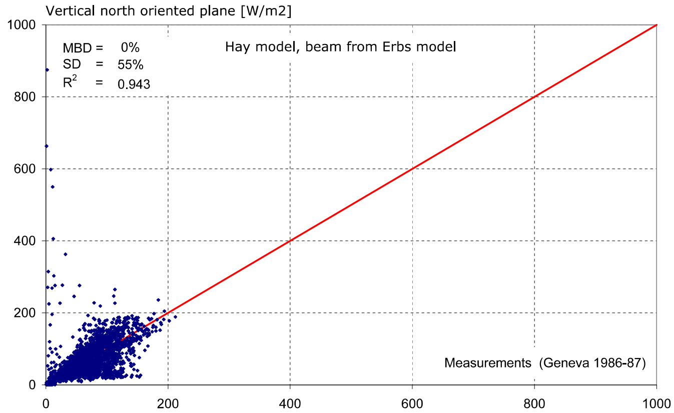

45° south oriented plane [W/m2]
MBD = 0%
SD = 10%
R2 = 0.995
Klucher model, beam from Erbs model
Measurements (Geneva 1986-87)

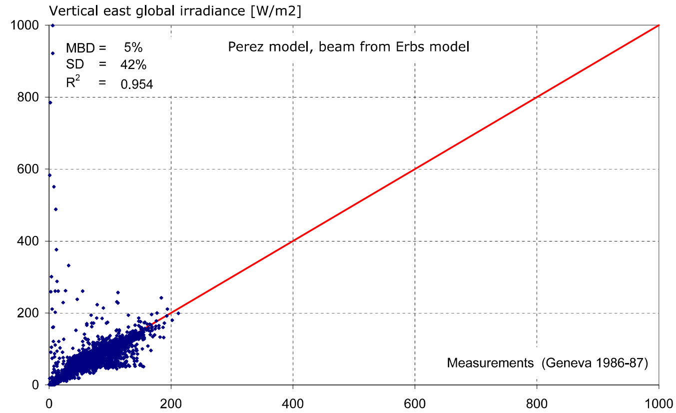

45° south oriented plane [W/m2]
MBD = -1%
SD = 8%
R2 = 0.996
Reindl model, beam from Erbs model
Measurements (Geneva 1986-87)

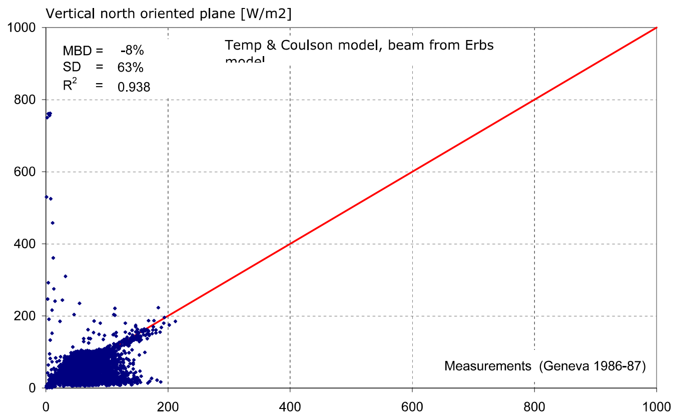

45° south oriented plane [W/m2]
MBD = -7%
SD = 12%
R2 = 0.995
Wilmott model, beam from Erbs model
Measurements (Geneva 1986-87)

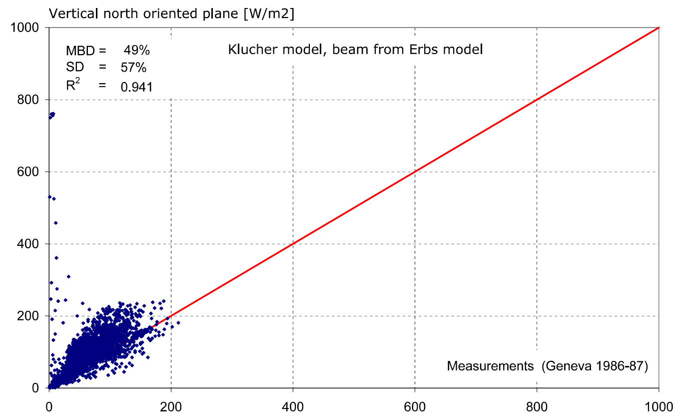

Vertical north oriented plane [W/m2]
MBD = 27%
SD = 47%
R^2 = 0.943
Isotropic diffuse, beam from Erbs model
Measurements (Geneva 1986-87)

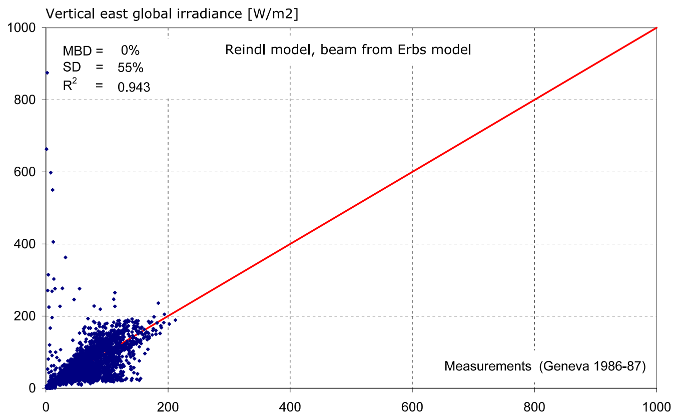

Vertical north oriented plane [W/m2]
MBD = 16%
SD = 43%
R^2 = 0.940
Gueymard model, beam from Erbs model
Measurements (Geneva 1986-87)

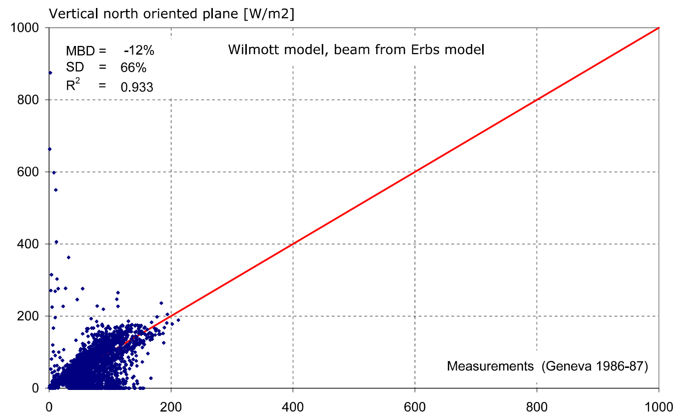

Vertical north oriented plane [W/m2]
MBD = 0%
SD = 55%
R^2 = 0.943
Hay model, beam from Erbs model
Measurements (Geneva 1986-87)


Vertical east global irradiance [W/m2]
MBD = 5%
SD = 42%
R^2 = 0.954
Perez model, beam from Erbs model
Measurements (Geneva 1986-87)


Vertical north oriented plane [W/m2]
MBD = -8%
SD = 63%
R^2 = 0.938
Temp & Coulson model, beam from Erbs
Measurements (Geneva 1986-87)


Vertical north oriented plane [W/m2]
MBD = 49%
SD = 57%
R^2 = 0.941
Klucher model, beam from Erbs model
Measurements (Geneva 1986-87)


Vertical east global irradiance [W/m2]
MBD = 0%
SD = 55%
R^2 = 0.943
Reindl model, beam from Erbs model
Measurements (Geneva 1986-87)


Vertical north oriented plane [W/m2]
MBD = -12%
SD = 66%
R^2 = 0.933
Wilmott model, beam from Erbs model
Measurements (Geneva 1986-87)

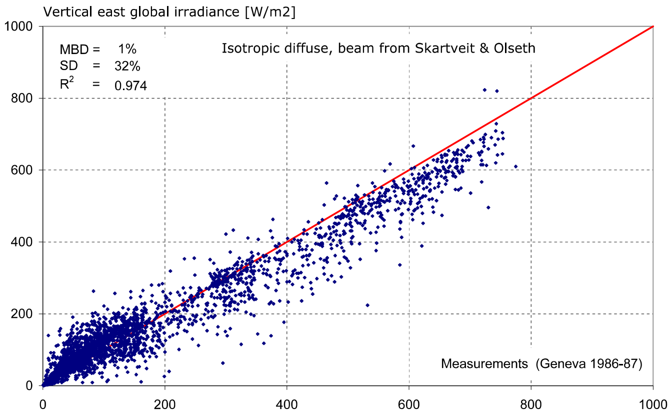
Geneva (Switzerland)

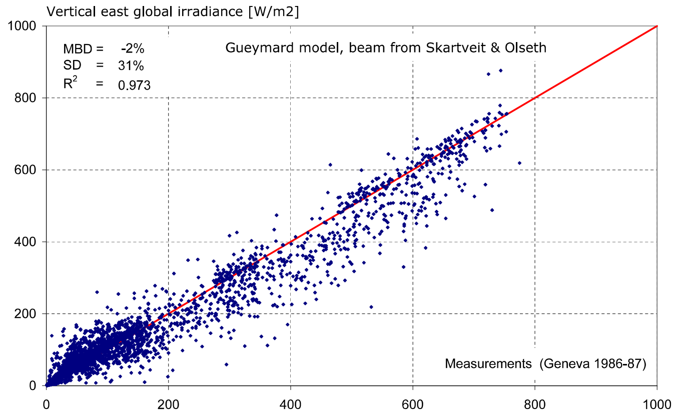
Latitude:	46.20°
Longitude:	6.13°
Altitude over sea level:	420m

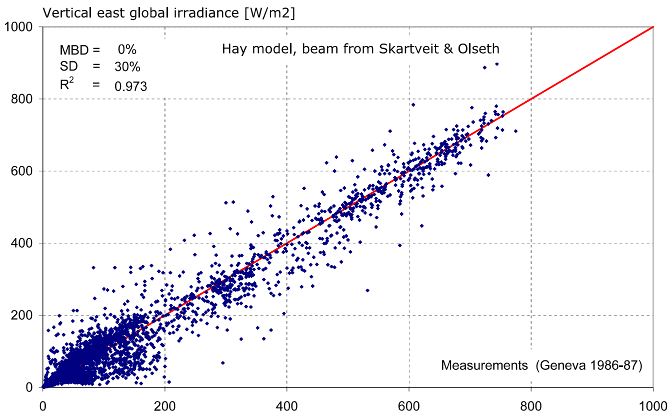
Beam irradiance from Skartveit & Olseth

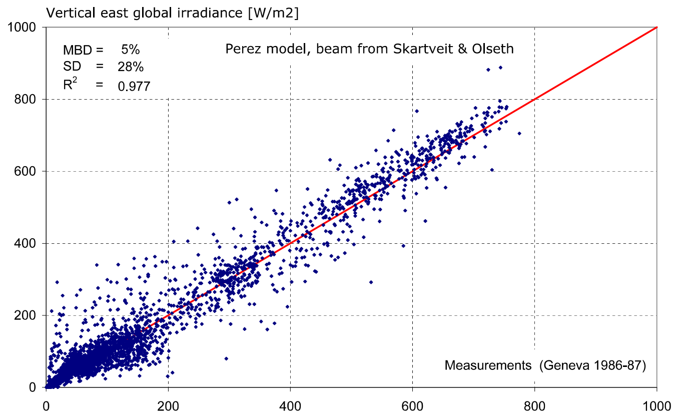
Figures in the following pages:

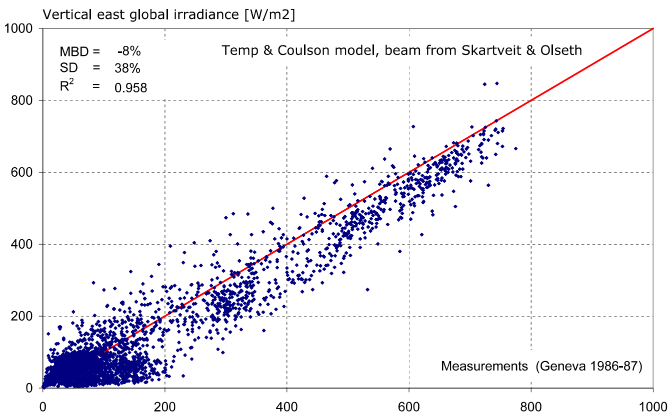
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

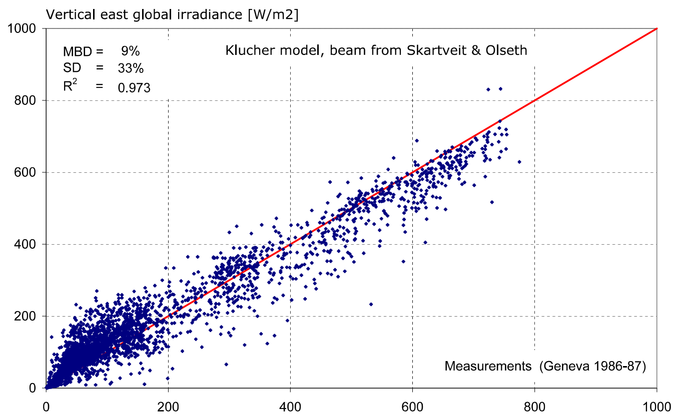

Vertical east global irradiance [W/m2]
MBD = 1%
SD = 32%
R^2 = 0.974
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

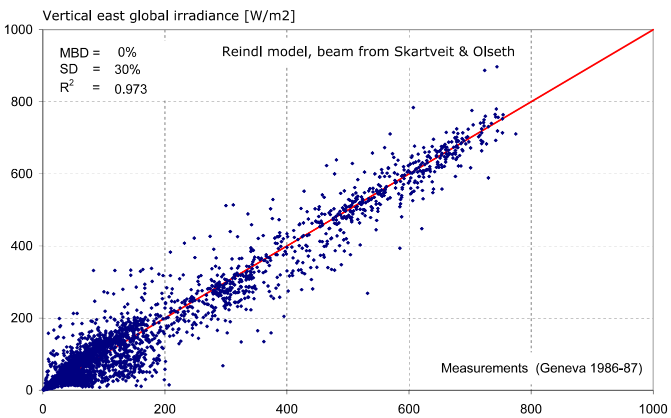

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 31%
R^2 = 0.973
Gueymard model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

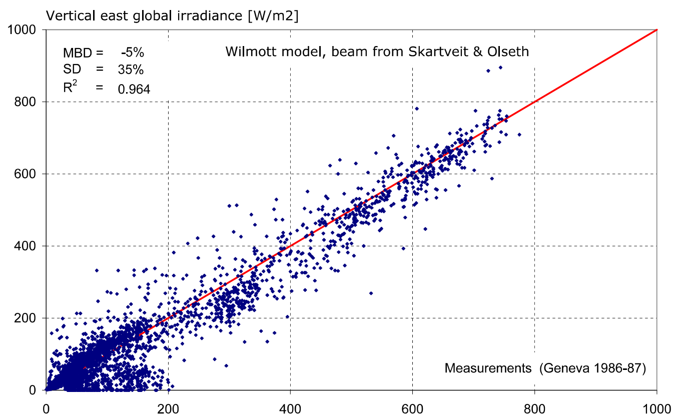

Vertical east global irradiance [W/m2]
MBD = 0%
SD = 30%
R^2 = 0.973
Hay model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

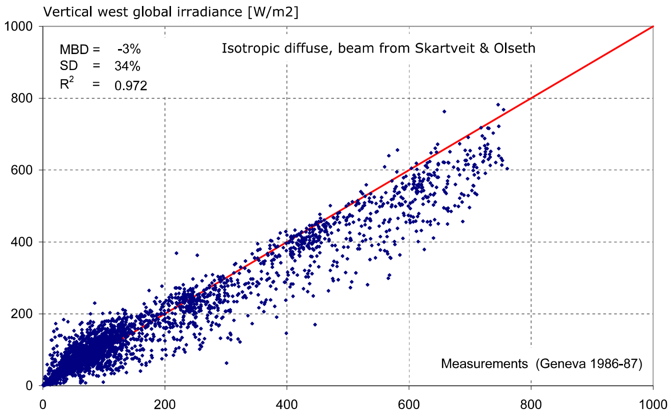

Vertical east global irradiance [W/m2]
MBD = 5%
SD = 28%
R^2 = 0.977
Perez model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

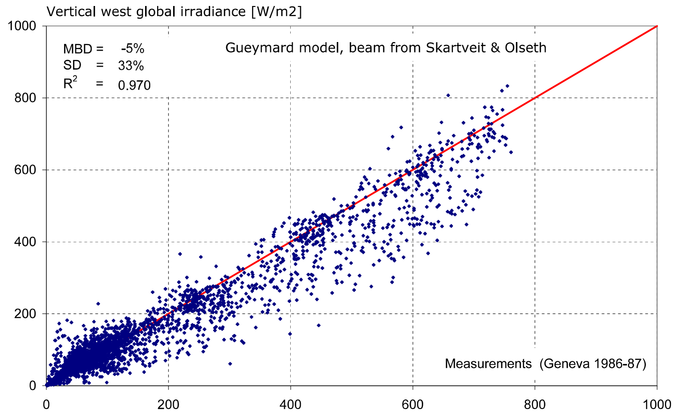

Vertical east global irradiance [W/m2]
MBD = -8%
SD = 38%
R^2 = 0.958
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

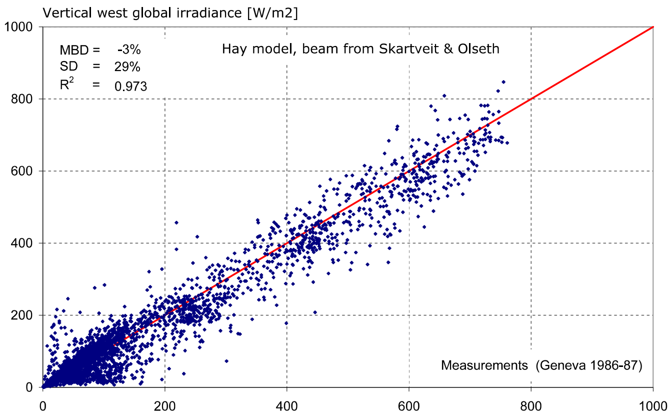

Vertical east global irradiance [W/m2]
MBD = 9%
SD = 33%
R^2 = 0.973
Klucher model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

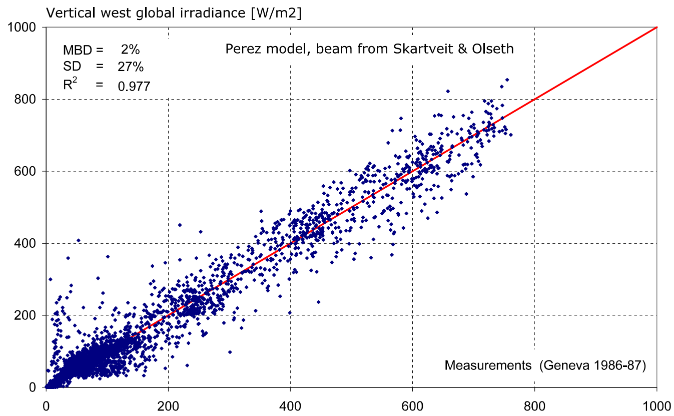

Vertical east global irradiance [W/m2]
MBD = 0%
SD = 30%
R^2 = 0.973
Reindl model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

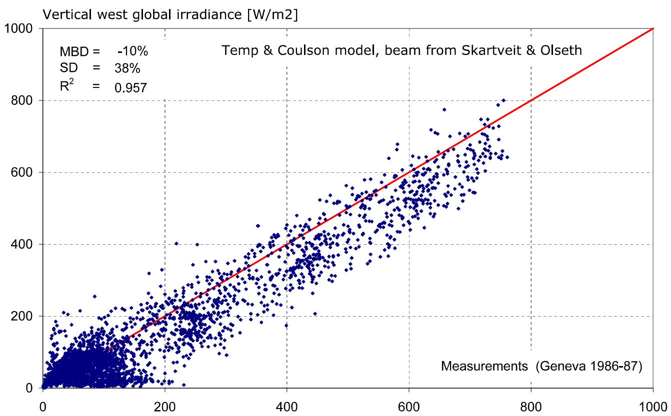

Vertical east global irradiance [W/m2]
MBD = -5%
SD = 35%
R^2 = 0.964
Wilmott model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

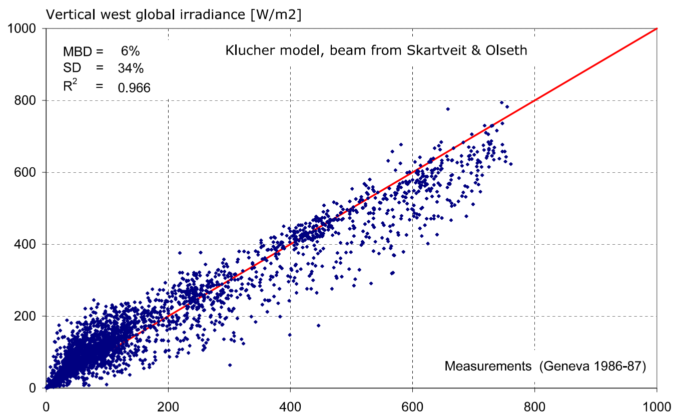

Vertical west global irradiance [W/m2]
MBD = -3%
SD = 34%
R2 = 0.972
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

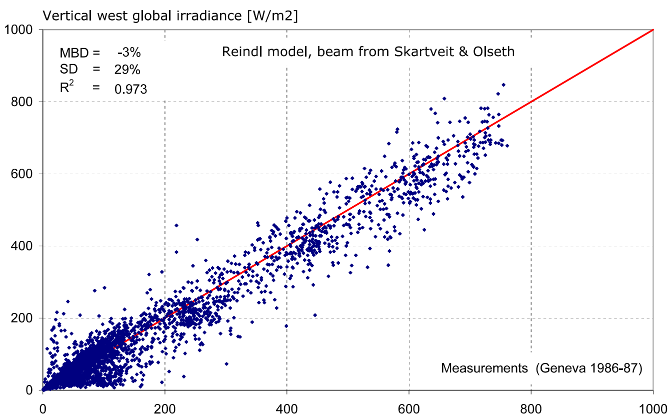

Vertical west global irradiance [W/m2]
MBD = -5%
SD = 33%
R2 = 0.970
Gueymard model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

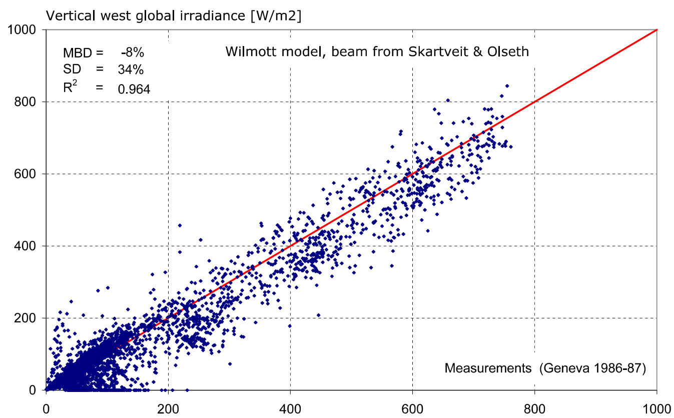

Vertical west global irradiance [W/m2]
MBD = -3%
SD = 29%
R2 = 0.973
Hay model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

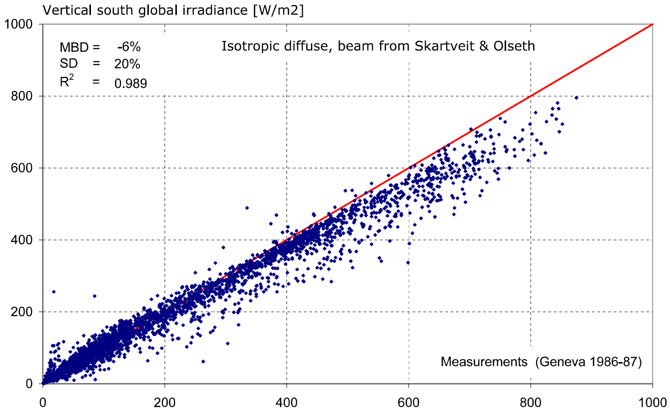

Vertical west global irradiance [W/m2]
MBD = 2%
SD = 27%
R2 = 0.977
Perez model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

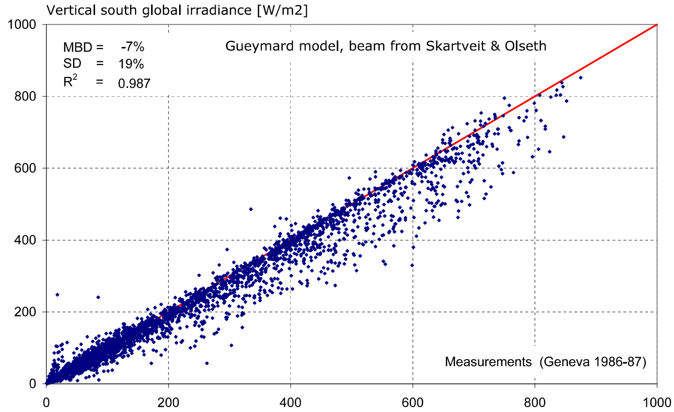

Vertical west global irradiance [W/m2]
MBD = -10%
SD = 38%
R2 = 0.957
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

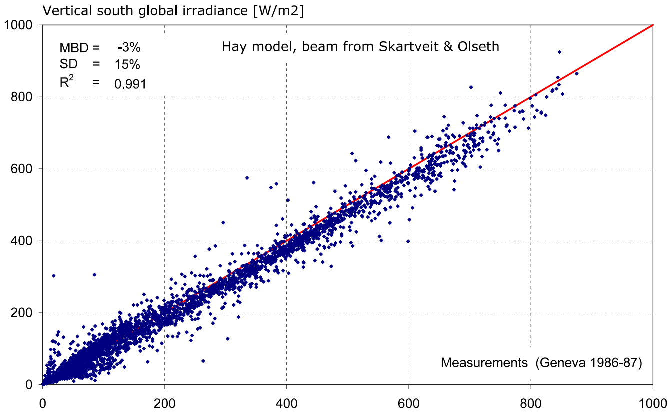

Vertical west global irradiance [W/m2]
MBD = 6%
SD = 34%
R2 = 0.966
Klucher model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

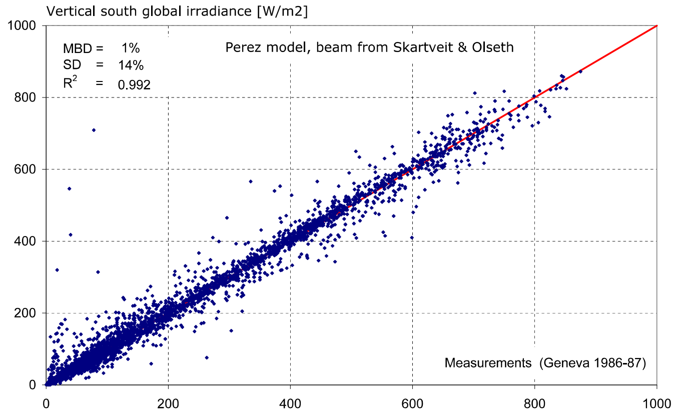

Vertical west global irradiance [W/m2]
MBD = -3%
SD = 29%
R2 = 0.973
Reindl model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

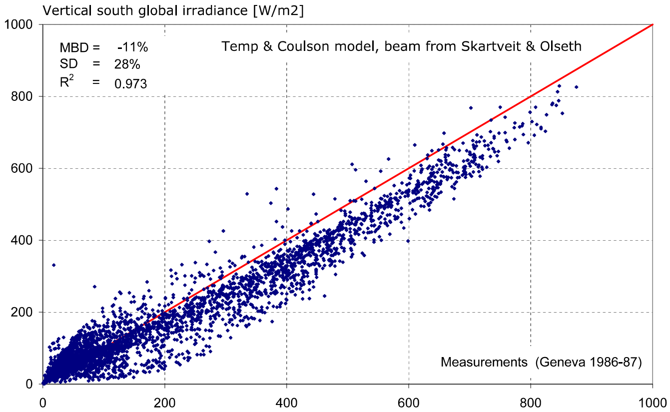

Vertical west global irradiance [W/m2]
MBD = -8%
SD = 34%
R2 = 0.964
Wilmott model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

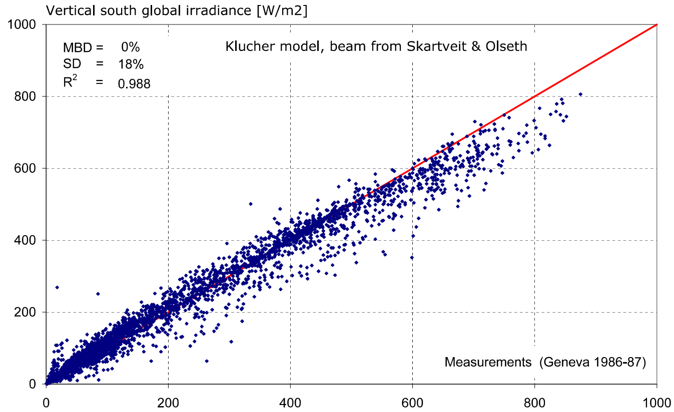

Vertical south global irradiance [W/m2]
MBD = -6%
SD = 20%
R^2 = 0.989
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

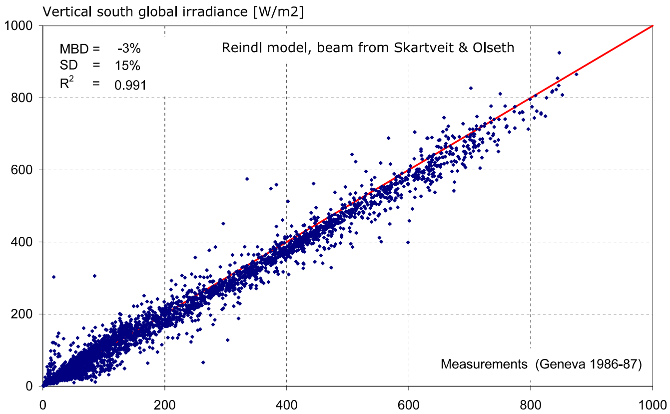

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 19%
R^2 = 0.987
Gueymard model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

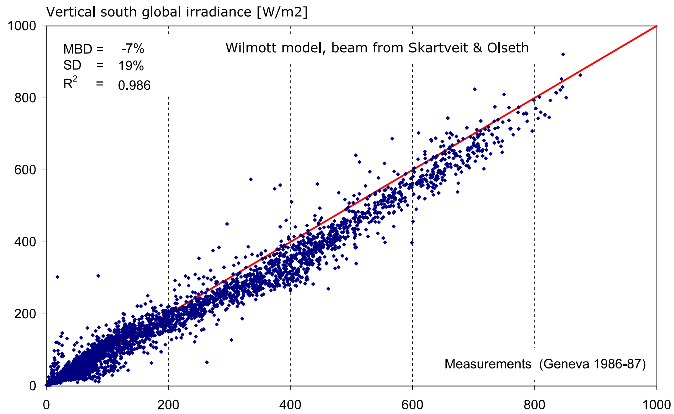

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 15%
R^2 = 0.991
Hay model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

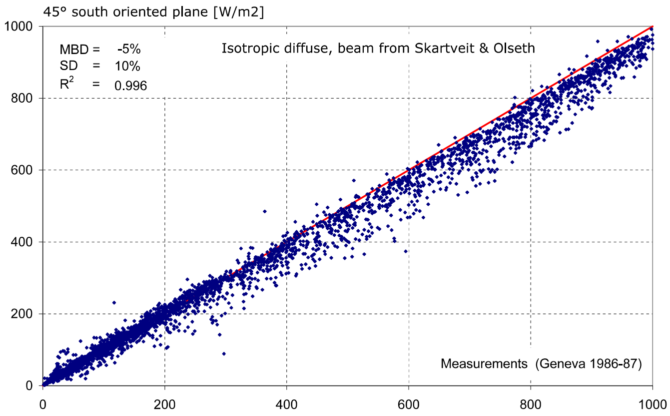

Vertical south global irradiance [W/m2]
MBD = 1%
SD = 14%
R^2 = 0.992
Perez model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

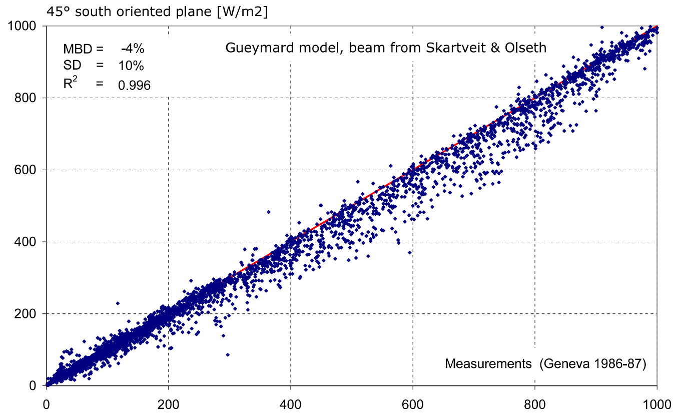

Vertical south global irradiance [W/m2]
MBD = -11%
SD = 28%
R^2 = 0.973
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

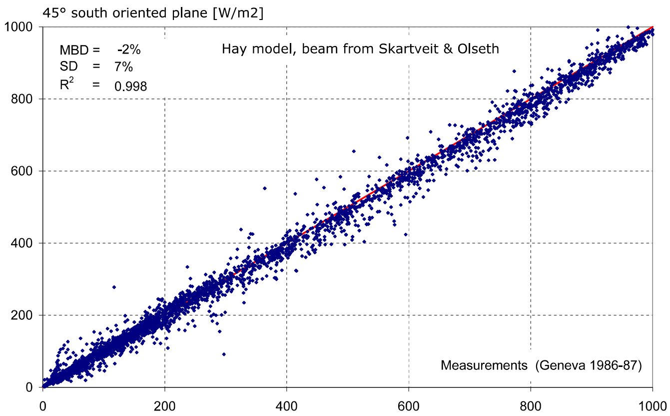

Vertical south global irradiance [W/m2]
MBD = 0%
SD = 18%
R^2 = 0.988
Klucher model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

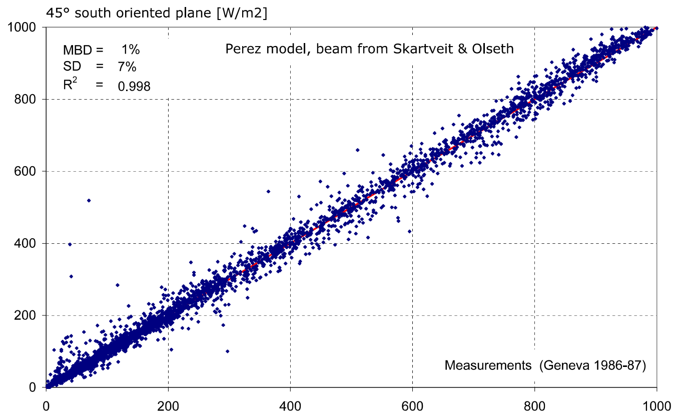

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 15%
R^2 = 0.991
Reindl model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

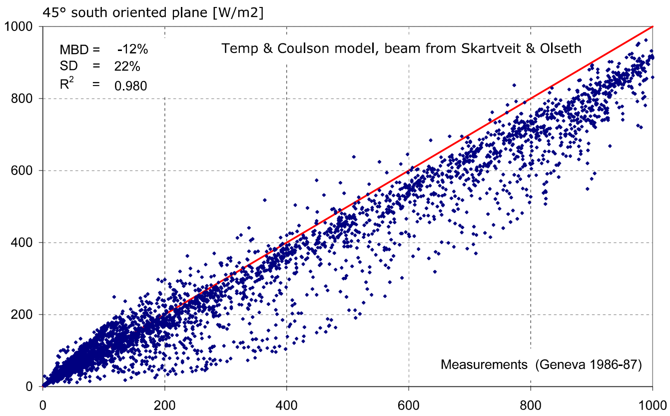

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 19%
R^2 = 0.986
Wilmott model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

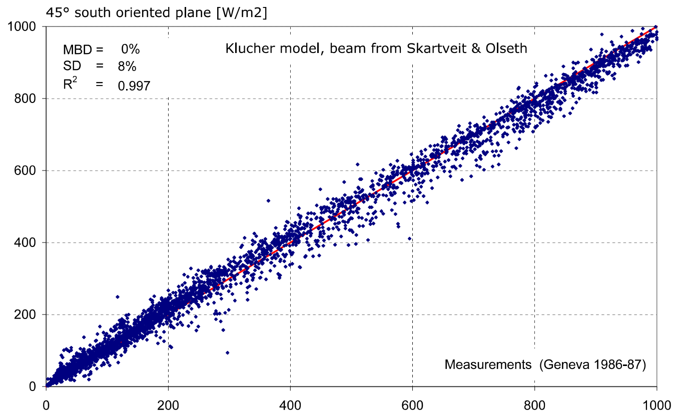

45° south oriented plane [W/m2]
MBD = -5%
SD = 10%
R^2 = 0.996
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

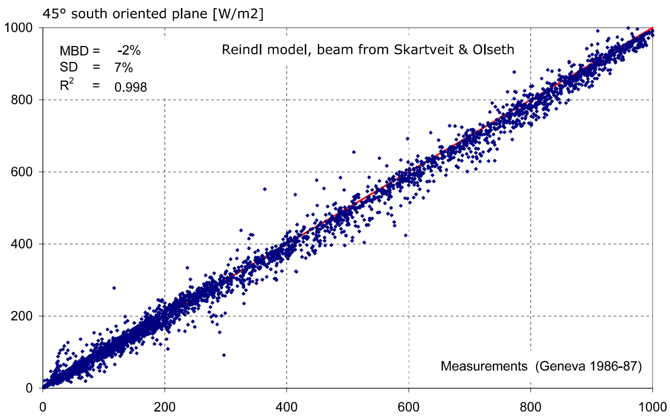

45° south oriented plane [W/m2]
MBD = -4%
SD = 10%
R^2 = 0.996
Gueymard model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

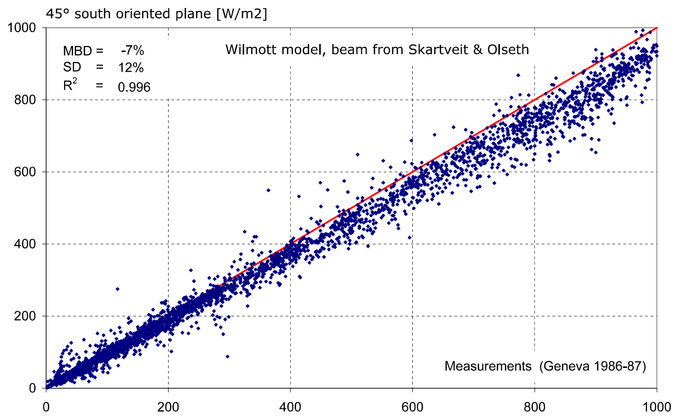

45° south oriented plane [W/m2]
MBD = -2%
SD = 7%
R^2 = 0.998
Hay model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

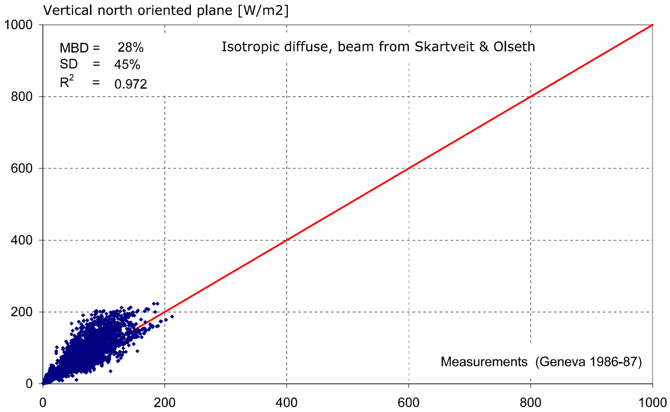

45° south oriented plane [W/m2]
MBD = 1%
SD = 7%
R^2 = 0.998
Perez model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

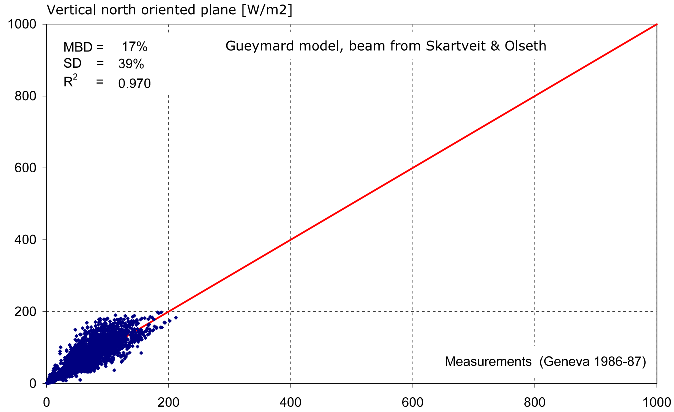

45° south oriented plane [W/m2]
MBD = -12%
SD = 22%
R^2 = 0.980
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

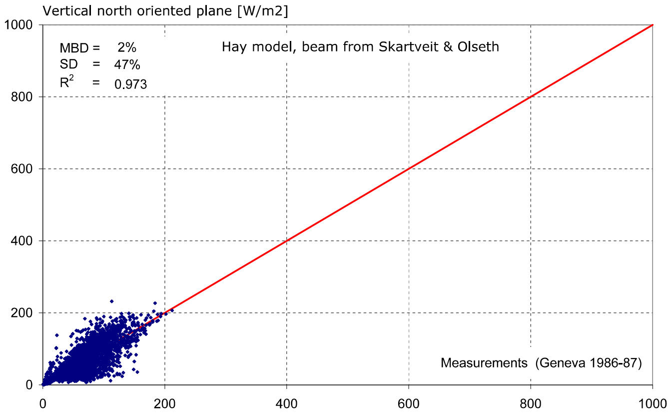

45° south oriented plane [W/m2]
MBD = 0%
SD = 8%
R^2 = 0.997
Klucher model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

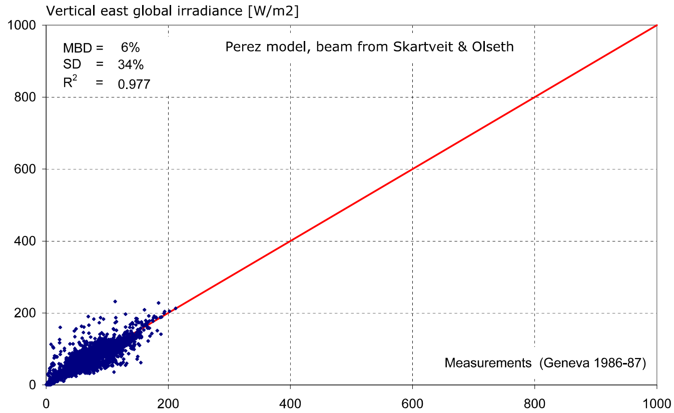

45° south oriented plane [W/m2]
MBD = -2%
SD = 7%
R^2 = 0.998
Reindl model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

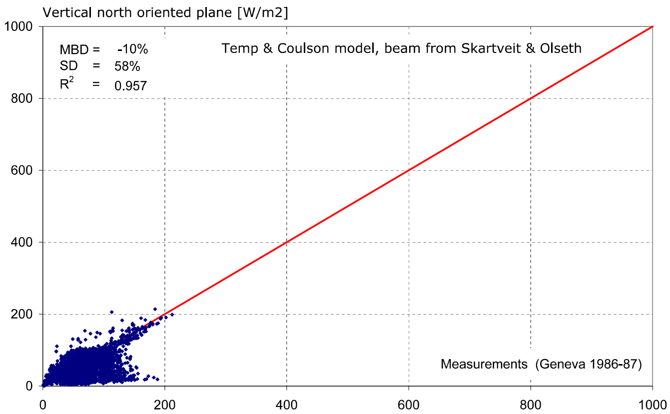

45° south oriented plane [W/m2]
MBD = -7%
SD = 12%
R^2 = 0.996
Wilmott model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)

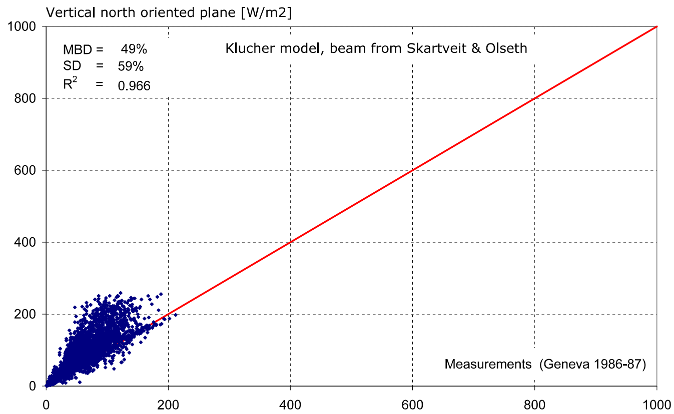

Vertical north oriented plane [W/m2]
MBD = 28%
SD = 45%
R2 = 0.972
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

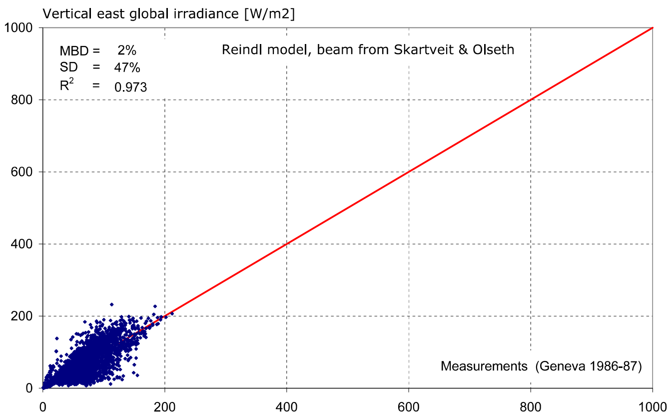

Vertical north oriented plane [W/m2]
MBD = 17%
SD = 39%
R2 = 0.970
Gueymard model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

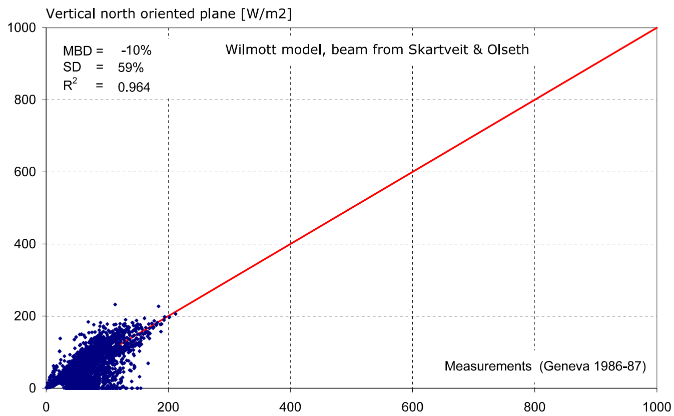

Vertical north oriented plane [W/m2]
MBD = 2%
SD = 47%
R2 = 0.973
Hay model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = 6%
SD = 34%
R2 = 0.977
Perez model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -10%
SD = 58%
R2 = 0.957
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = 49%
SD = 59%
R2 = 0.966
Klucher model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = 2%
SD = 47%
R2 = 0.973
Reindl model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -10%
SD = 59%
R2 = 0.964
Wilmott model, beam from Skartveit & Olseth
Measurements (Geneva 1986-87)
0
200
400
600
800
1000

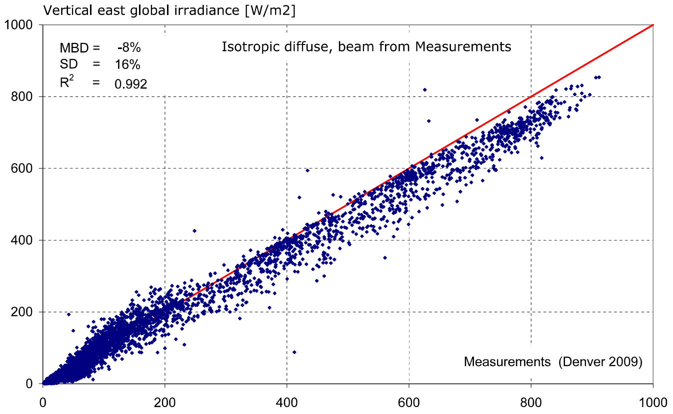
Denver (United States)

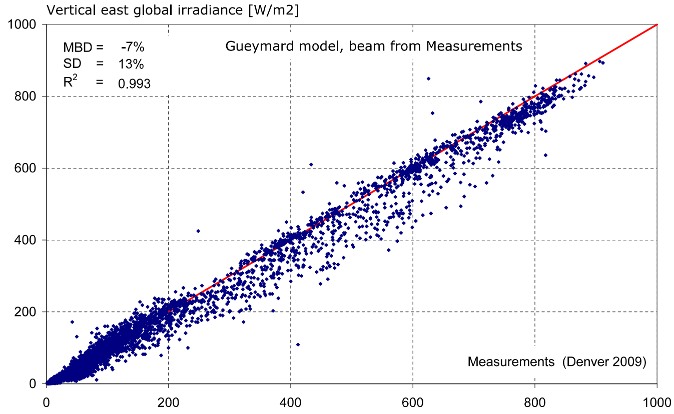
Latitude:	51.97°
Longitude:	4.93°
Altitude over sea level:	2m

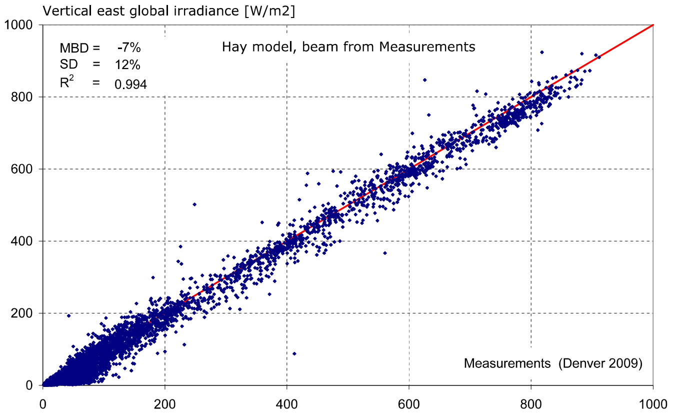
Beam irradiance from measurements

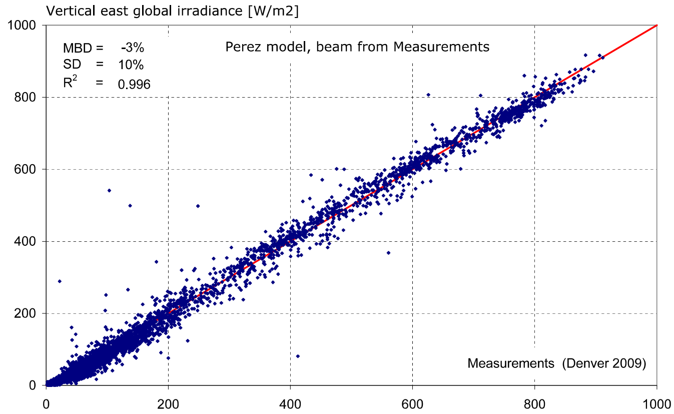
Figures in the following pages:

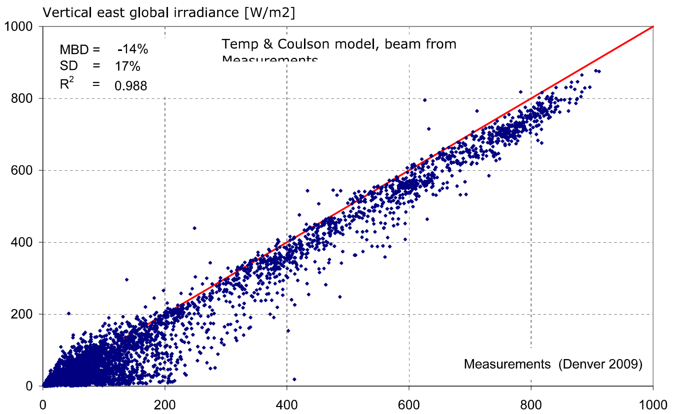
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

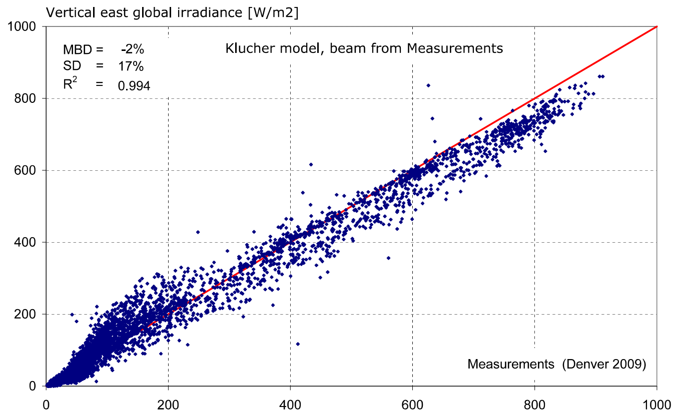

Vertical east global irradiance [W/m2]
MBD = -8%
SD = 16%
R^2 = 0.992
Isotropic diffuse, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

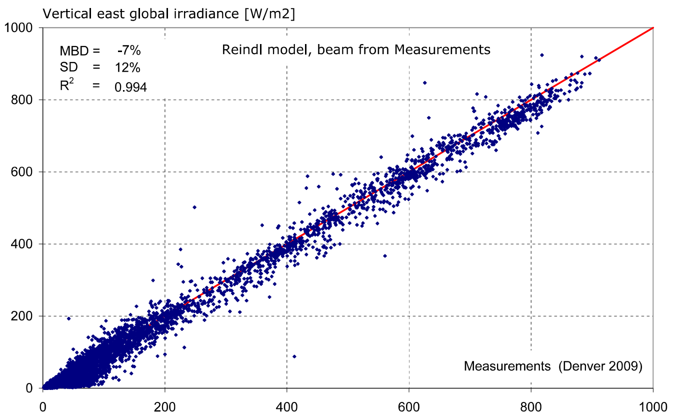

Vertical east global irradiance [W/m2]
MBD = -7%
SD = 13%
R^2 = 0.993
Gueymard model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

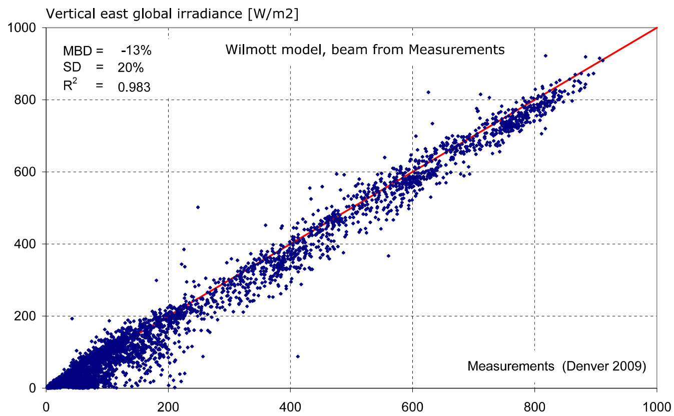

Vertical east global irradiance [W/m2]
MBD = -7%
SD = 12%
R^2 = 0.994
Hay model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

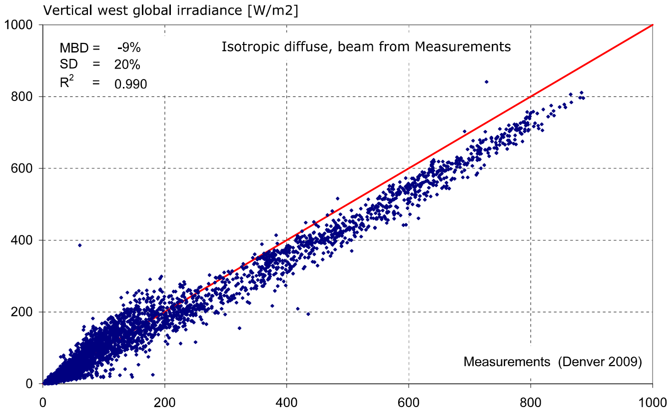

Vertical east global irradiance [W/m2]
MBD = -3%
SD = 10%
R^2 = 0.996
Perez model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

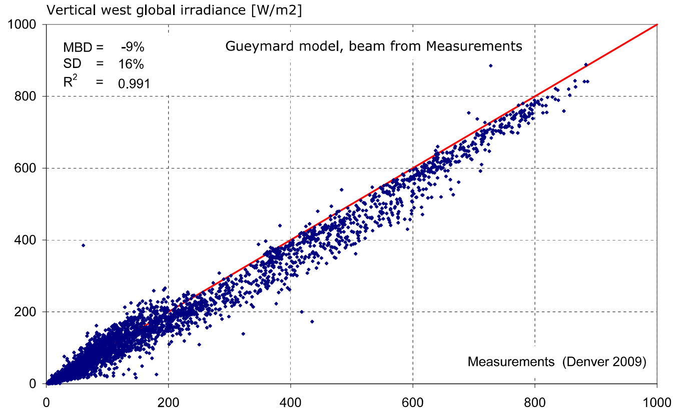

Vertical east global irradiance [W/m2]
MBD = -14%
SD = 17%
R^2 = 0.988
Temp & Coulson model, beam from
Measurements (Denver 2009)
0
200
400
600
800
1000

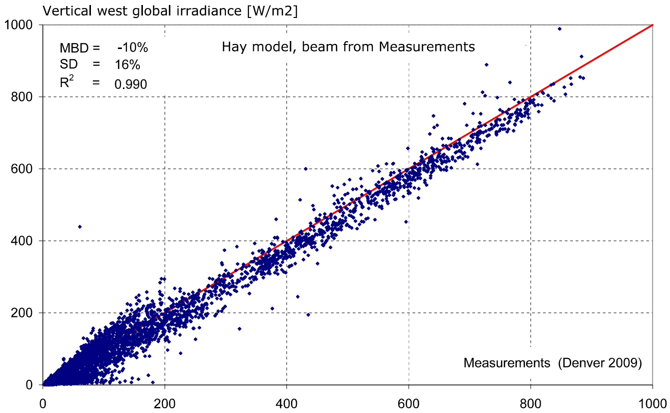

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 17%
R^2 = 0.994
Klucher model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

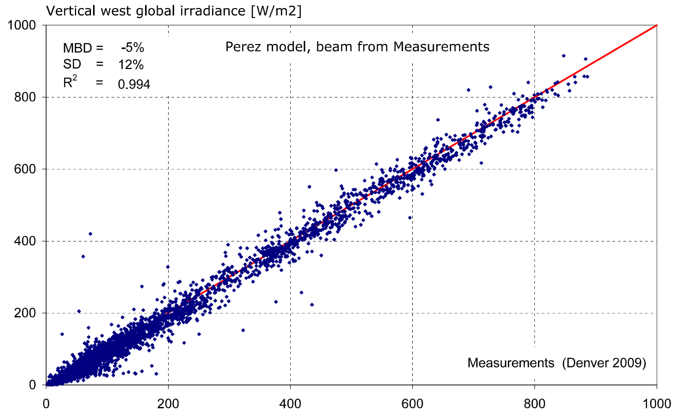

Vertical east global irradiance [W/m2]
MBD = -7%
SD = 12%
R^2 = 0.994
Reindl model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

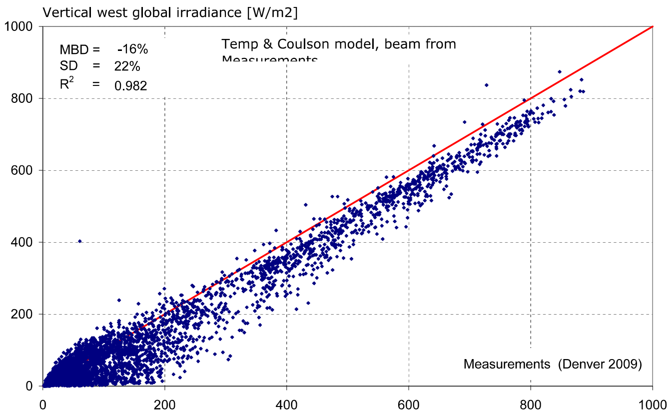

Vertical east global irradiance [W/m2]
MBD = -13%
SD = 20%
R^2 = 0.983
Wilmott model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

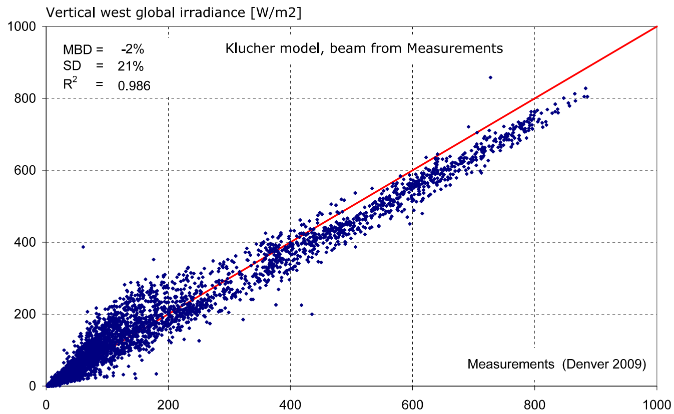

Vertical west global irradiance [W/m2]
MBD = -9%
SD = 20%
R2 = 0.990
Isotropic diffuse, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

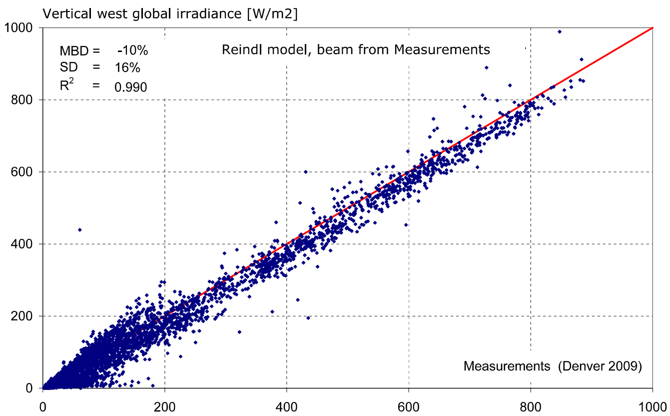

Vertical west global irradiance [W/m2]
MBD = -9%
SD = 16%
R2 = 0.991
Gueymard model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

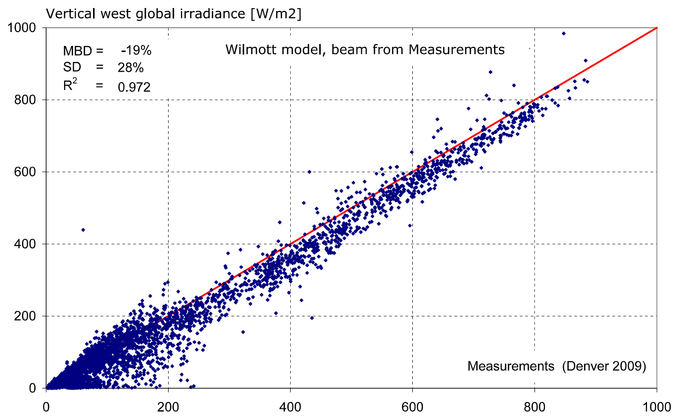

Vertical west global irradiance [W/m2]
MBD = -10%
SD = 16%
R2 = 0.990
Hay model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

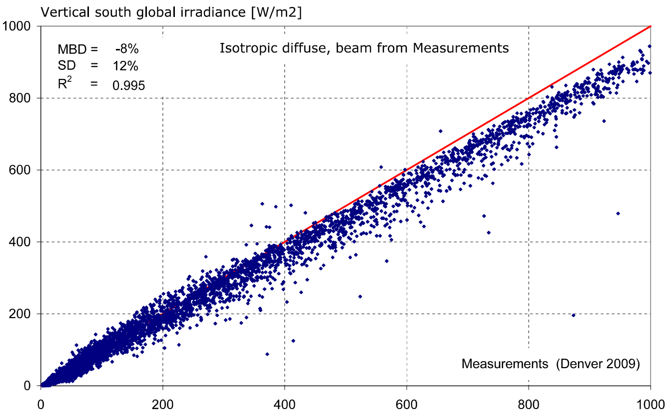

Vertical west global irradiance [W/m2]
MBD = -5%
SD = 12%
R2 = 0.994
Perez model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

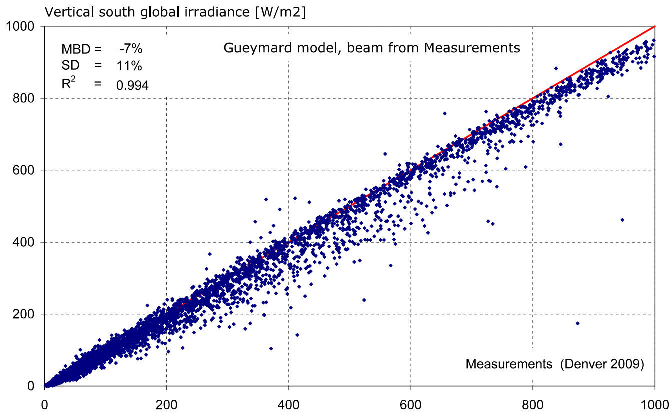

Vertical west global irradiance [W/m2]
MBD = -16%
SD = 22%
R2 = 0.982
Temp & Coulson model, beam from
Measurements (Denver 2009)
0
200
400
600
800
1000

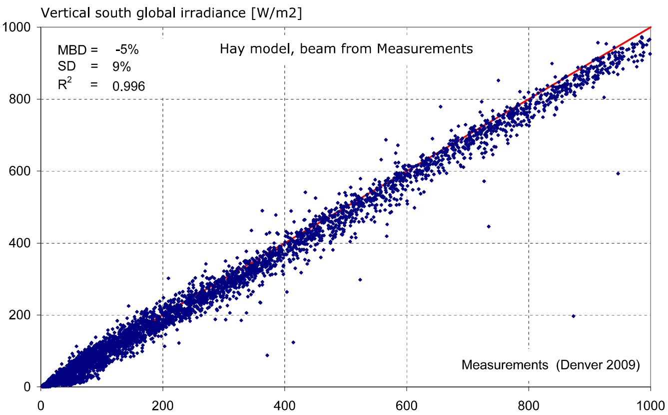

Vertical west global irradiance [W/m2]
MBD = -2%
SD = 21%
R2 = 0.986
Klucher model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

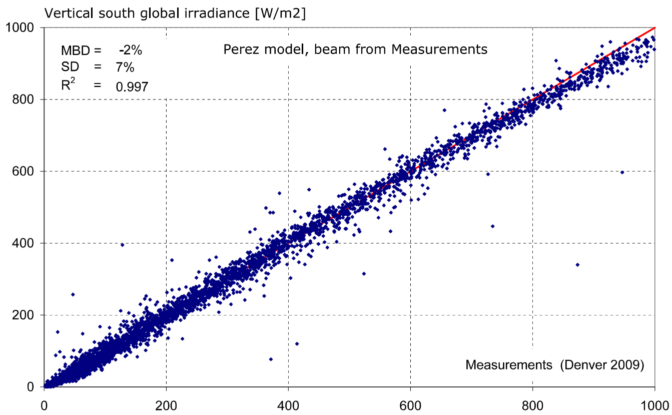

Vertical west global irradiance [W/m2]
MBD = -10%
SD = 16%
R2 = 0.990
Reindl model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

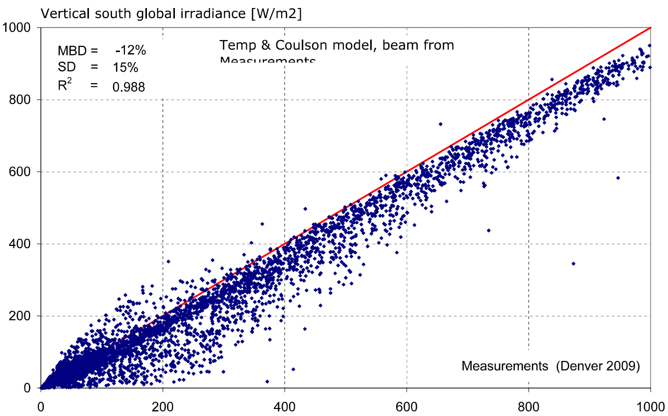

Vertical west global irradiance [W/m2]
MBD = -19%
SD = 28%
R2 = 0.972
Wilmott model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

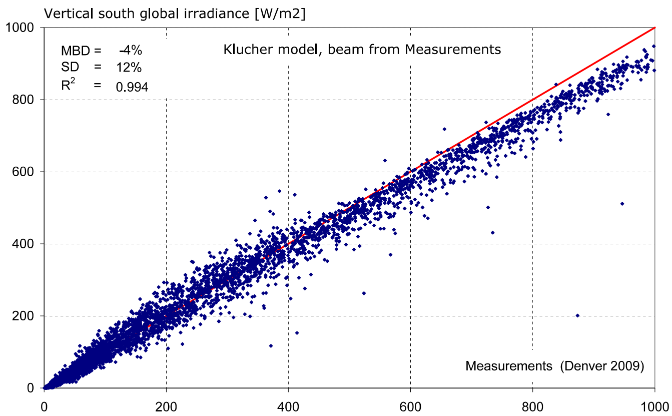

Vertical south global irradiance [W/m2]
MBD = -8%
SD = 12%
R^2 = 0.995
Isotropic diffuse, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

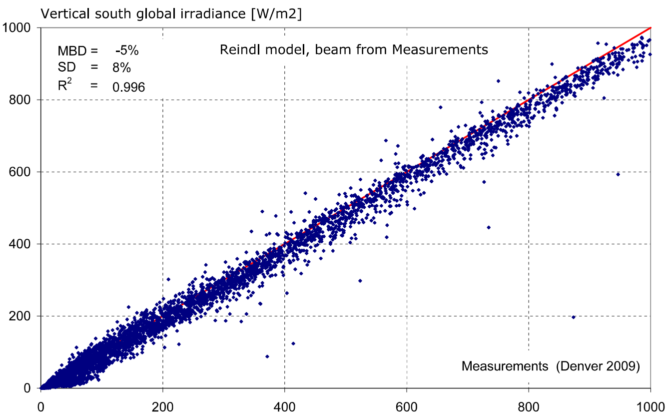

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 11%
R^2 = 0.994
Gueymard model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

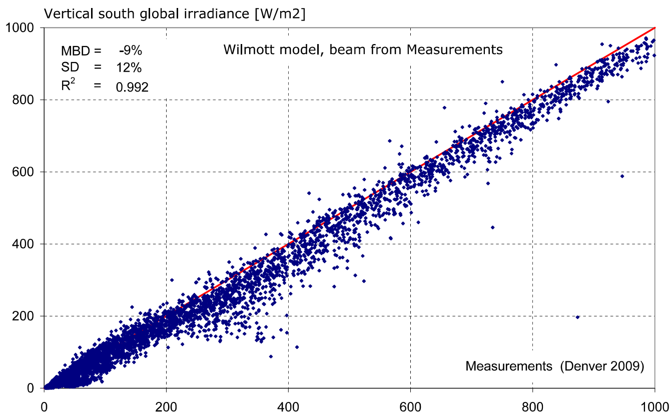

Vertical south global irradiance [W/m2]
MBD = -5%
SD = 9%
R^2 = 0.996
Hay model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

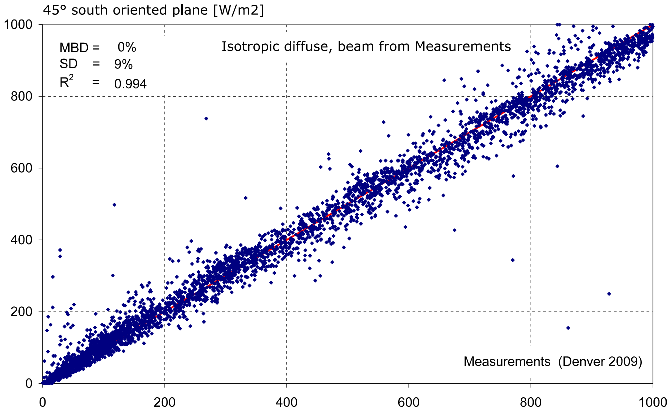

Vertical south global irradiance [W/m2]
MBD = -2%
SD = 7%
R^2 = 0.997
Perez model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

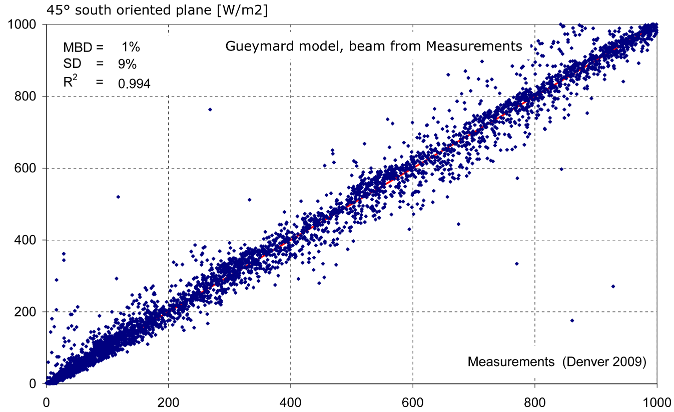

Vertical south global irradiance [W/m2]
MBD = -12%
SD = 15%
R^2 = 0.988
Temp & Coulson model, beam from
Measurements (Denver 2009)
0
200
400
600
800
1000

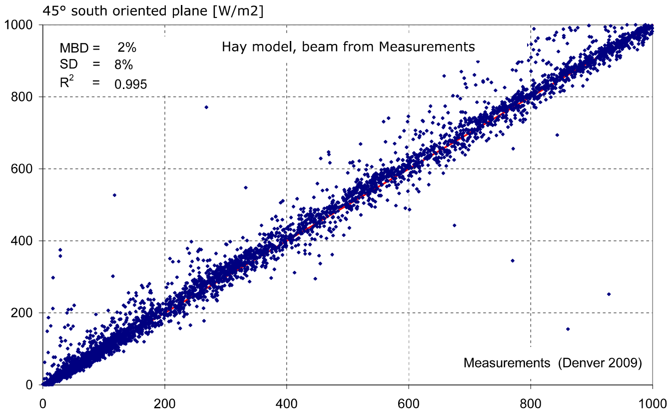

Vertical south global irradiance [W/m2]
MBD = -4%
SD = 12%
R^2 = 0.994
Klucher model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

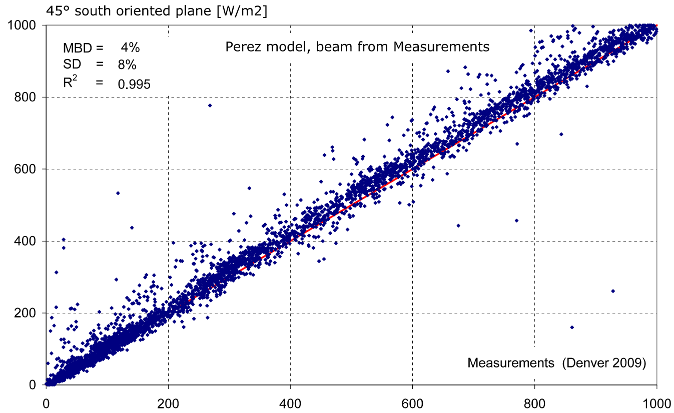

Vertical south global irradiance [W/m2]
MBD = -5%
SD = 8%
R^2 = 0.996
Reindl model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

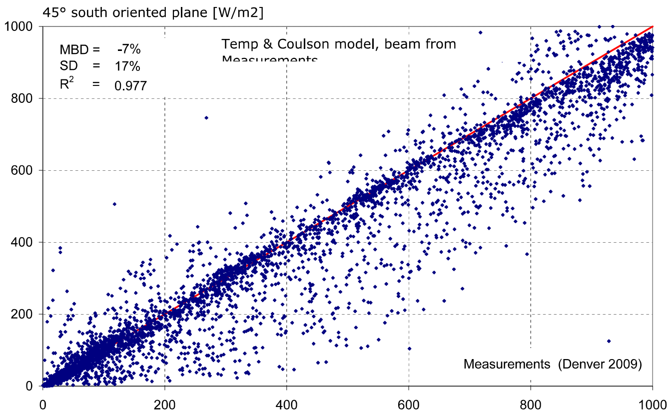

Vertical south global irradiance [W/m2]
MBD = -9%
SD = 12%
R^2 = 0.992
Wilmott model, beam from Measurements
Measurements (Denver 2009)
0
200
400
600
800
1000

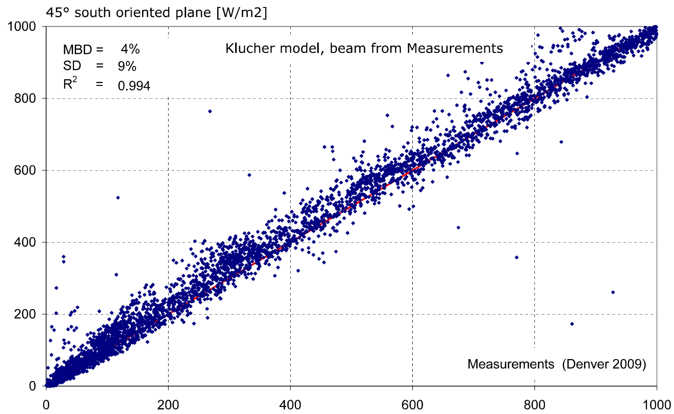

45° south oriented plane [W/m2]
MBD = 0%
SD = 9%
R^2 = 0.994
Isotropic diffuse, beam from Measurements
Measurements (Denver 2009)

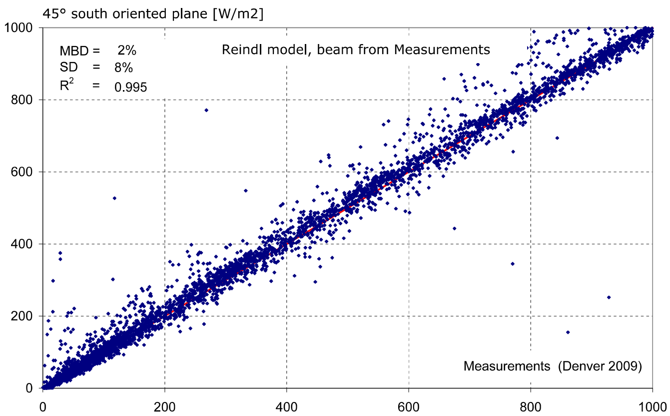

45° south oriented plane [W/m2]
MBD = 1%
SD = 9%
R^2 = 0.994
Gueymard model, beam from Measurements
Measurements (Denver 2009)

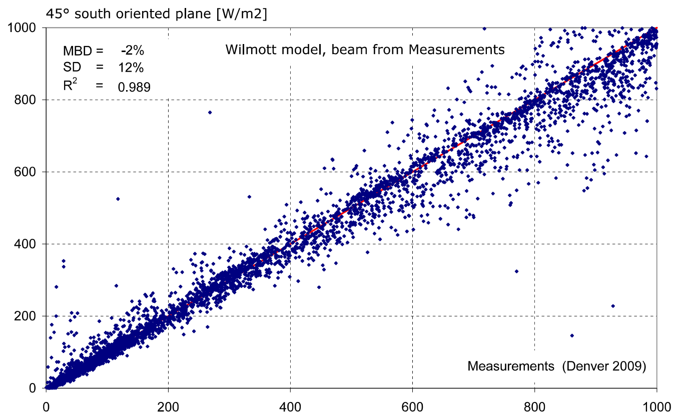

45° south oriented plane [W/m2]
MBD = 2%
SD = 8%
R^2 = 0.995
Hay model, beam from Measurements
Measurements (Denver 2009)

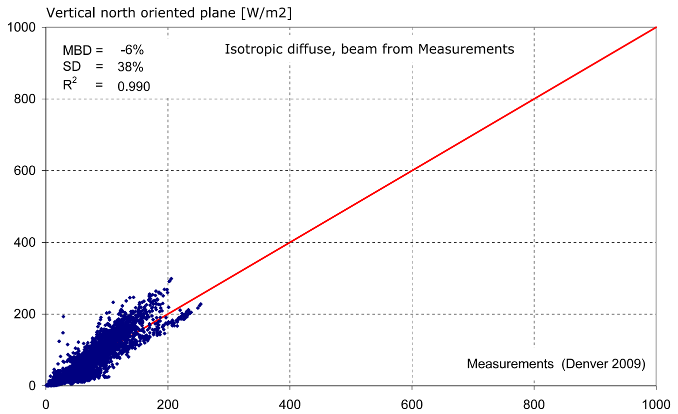

45° south oriented plane [W/m2]
MBD = 4%
SD = 8%
R^2 = 0.995
Perez model, beam from Measurements
Measurements (Denver 2009)

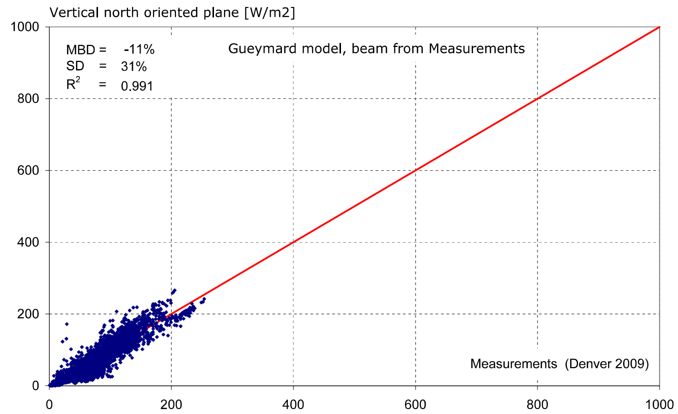

45° south oriented plane [W/m2]
MBD = -7%
SD = 17%
R^2 = 0.977
Temp & Coulson model, beam from
Measurements (Denver 2009)

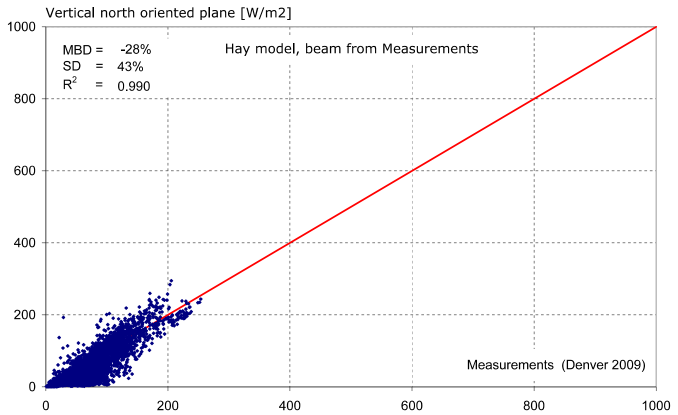

45° south oriented plane [W/m2]
MBD = 4%
SD = 9%
R^2 = 0.994
Klucher model, beam from Measurements
Measurements (Denver 2009)

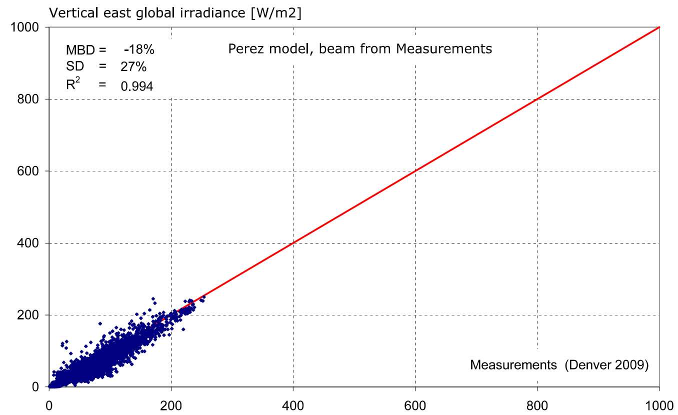

45° south oriented plane [W/m2]
MBD = 2%
SD = 8%
R^2 = 0.995
Reindl model, beam from Measurements
Measurements (Denver 2009)

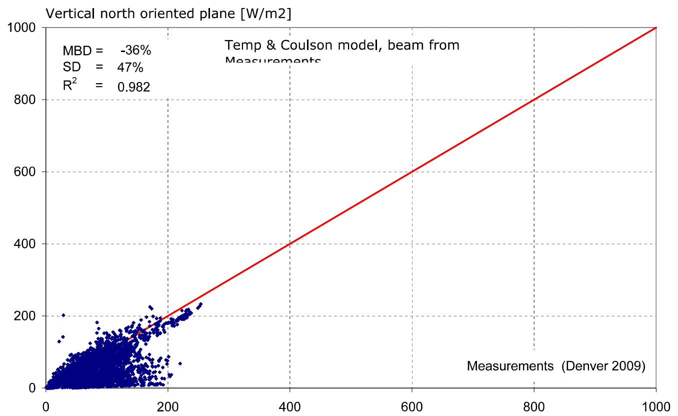

45° south oriented plane [W/m2]
MBD = -2%
SD = 12%
R^2 = 0.989
Wilmott model, beam from Measurements
Measurements (Denver 2009)

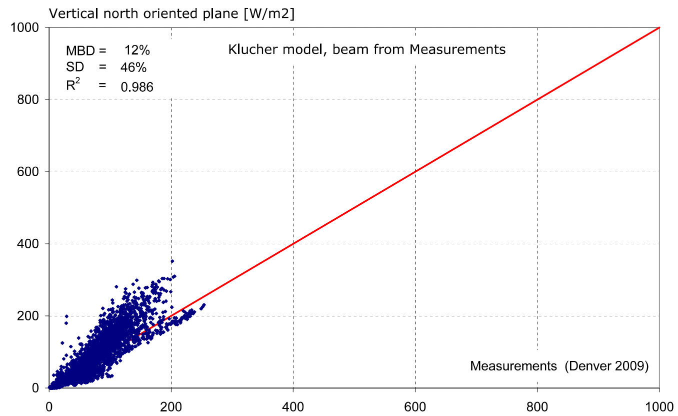

Vertical north oriented plane [W/m2]
MBD = -6%
SD = 38%
R2 = 0.990
Isotropic diffuse, beam from Measurements
Measurements (Denver 2009)

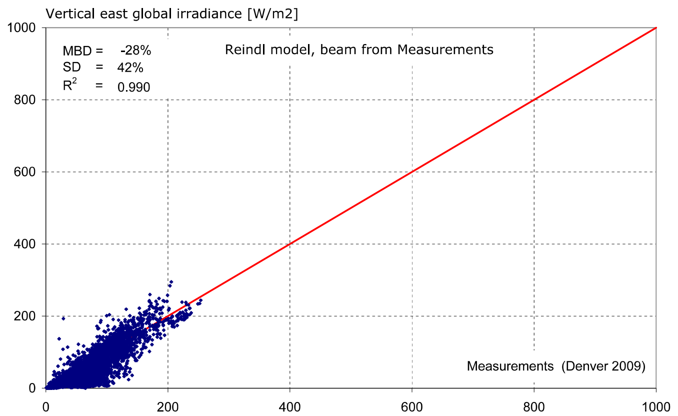

Vertical north oriented plane [W/m2]
MBD = -11%
SD = 31%
R2 = 0.991
Gueymard model, beam from Measurements
Measurements (Denver 2009)

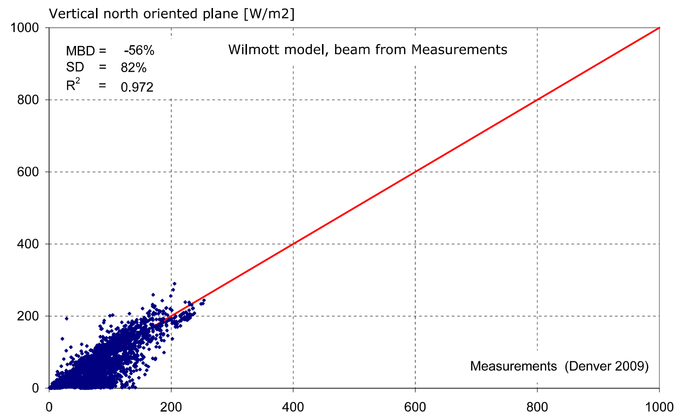

Vertical north oriented plane [W/m2]
MBD = -28%
SD = 43%
R2 = 0.990
Hay model, beam from Measurements
Measurements (Denver 2009)


Vertical east global irradiance [W/m2]
MBD = -18%
SD = 27%
R2 = 0.994
Perez model, beam from Measurements
Measurements (Denver 2009)


Vertical north oriented plane [W/m2]
MBD = -36%
SD = 47%
R2 = 0.982
Temp & Coulson model, beam from
Measurements (Denver 2009)


Vertical north oriented plane [W/m2]
MBD = 12%
SD = 46%
R2 = 0.986
Klucher model, beam from Measurements
Measurements (Denver 2009)


Vertical east global irradiance [W/m2]
MBD = -28%
SD = 42%
R2 = 0.990
Reindl model, beam from Measurements
Measurements (Denver 2009)


Vertical north oriented plane [W/m2]
MBD = -56%
SD = 82%
R2 = 0.972
Wilmott model, beam from Measurements
Measurements (Denver 2009)

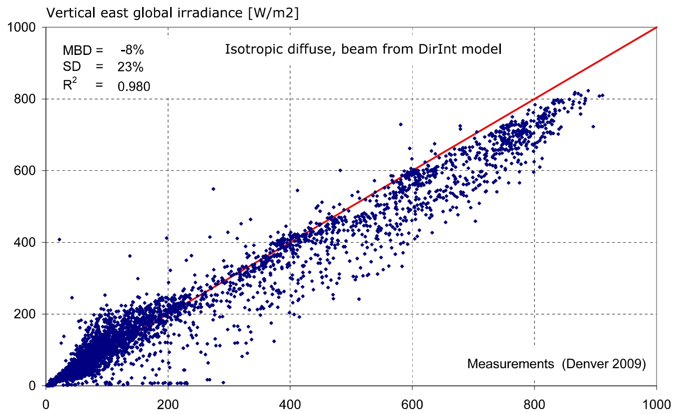
Denver (United States)

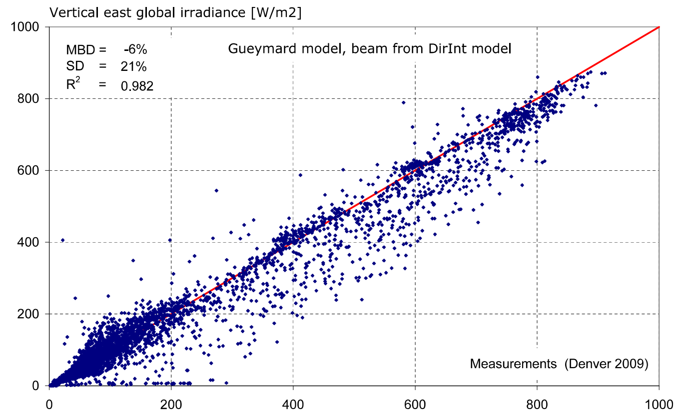
Latitude:	39.74°
Longitude:	-105.18°
Altitude over sea level:	1829m

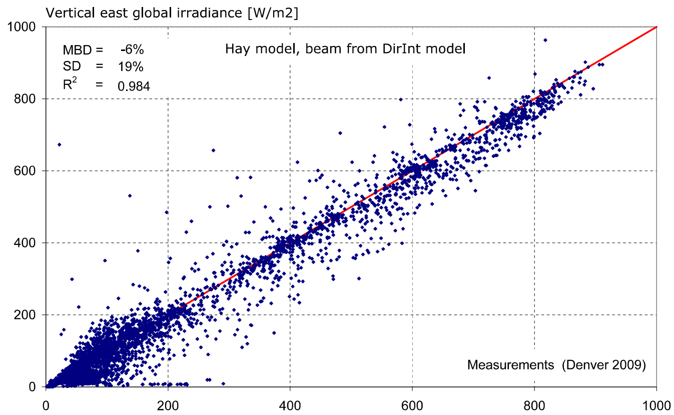
Beam irradiance from DirInt model

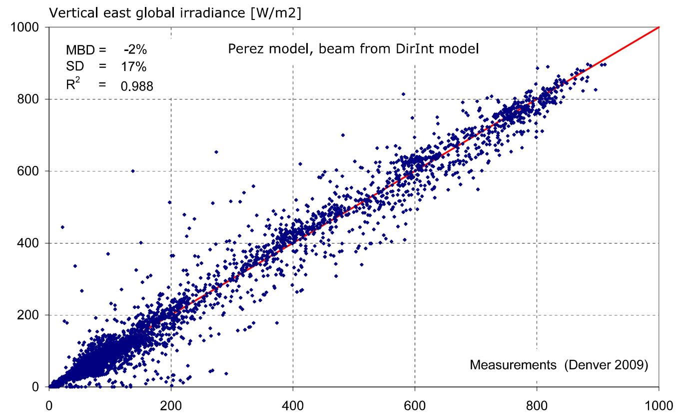
Figures in the following pages:

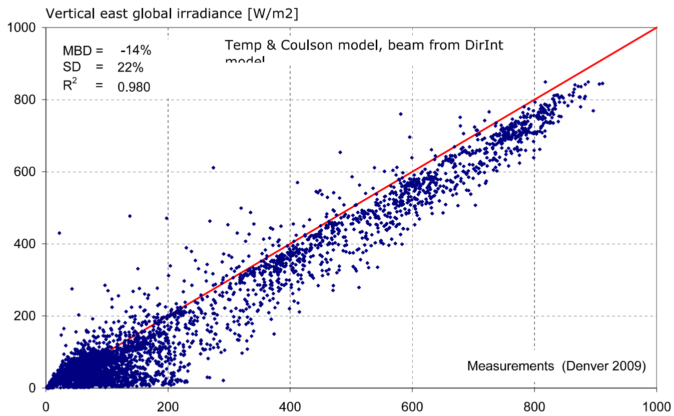
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

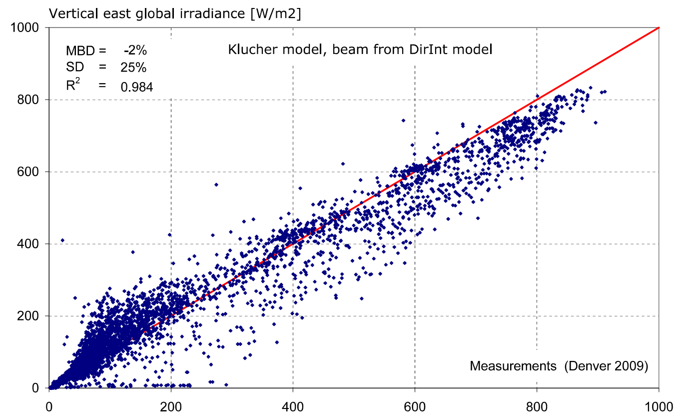

Vertical east global irradiance [W/m2]
MBD = -8%
SD = 23%
R^2 = 0.980
Isotropic diffuse, beam from DirInt model
Measurements (Denver 2009)

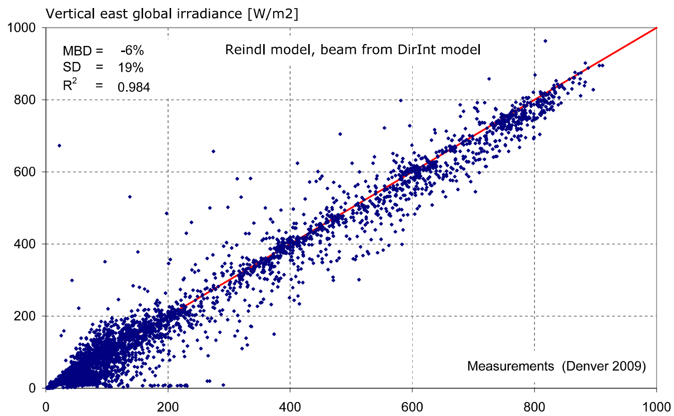

Vertical east global irradiance [W/m2]
MBD = -6%
SD = 21%
R^2 = 0.982
Gueymard model, beam from DirInt model
Measurements (Denver 2009)

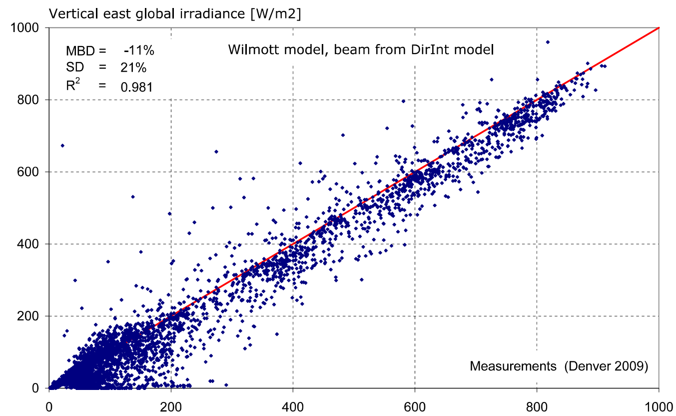

Vertical east global irradiance [W/m2]
MBD = -6%
SD = 19%
R^2 = 0.984
Hay model, beam from DirInt model
Measurements (Denver 2009)

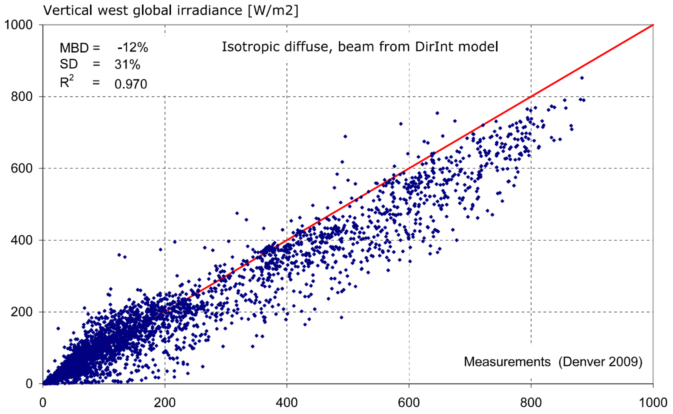

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 17%
R^2 = 0.988
Perez model, beam from DirInt model
Measurements (Denver 2009)

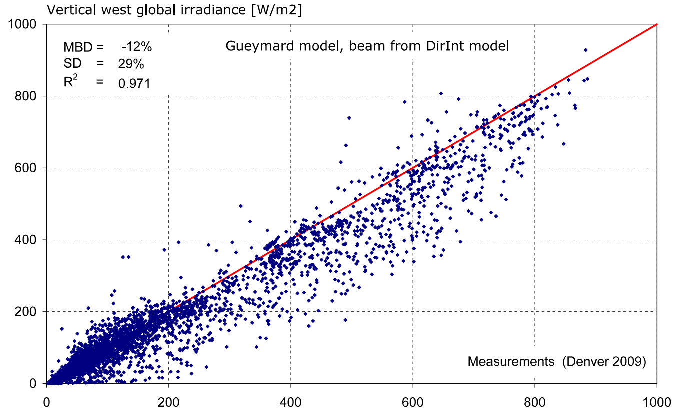

Vertical east global irradiance [W/m2]
MBD = -14%
SD = 22%
R^2 = 0.980
Temp & Coulson model, beam from DirInt
Measurements (Denver 2009)

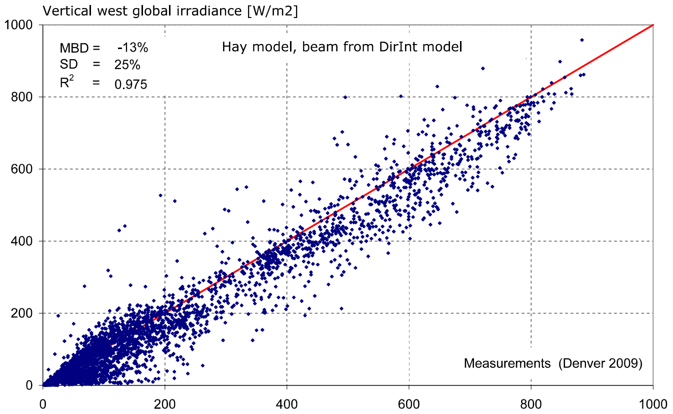

Vertical east global irradiance [W/m2]
MBD = -2%
SD = 25%
R^2 = 0.984
Klucher model, beam from DirInt model
Measurements (Denver 2009)

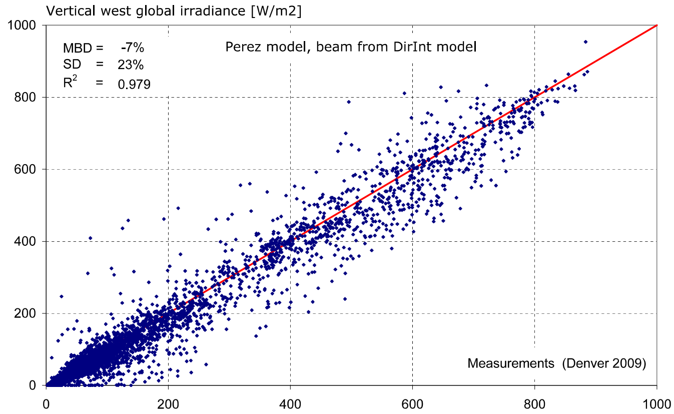

Vertical east global irradiance [W/m2]
MBD = -6%
SD = 19%
R^2 = 0.984
Reindl model, beam from DirInt model
Measurements (Denver 2009)

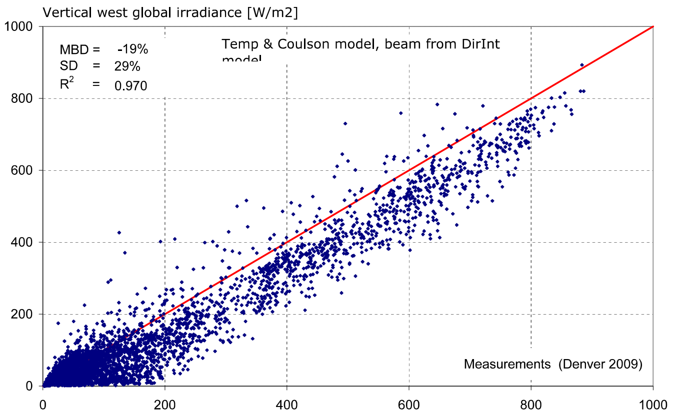

Vertical east global irradiance [W/m2]
MBD = -11%
SD = 21%
R^2 = 0.981
Wilmott model, beam from DirInt model
Measurements (Denver 2009)

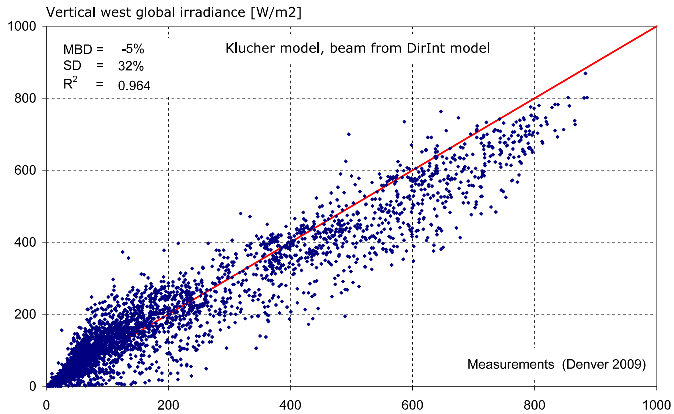

Vertical west global irradiance [W/m2]
MBD = -12%
SD = 31%
R2 = 0.970
Isotropic diffuse, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

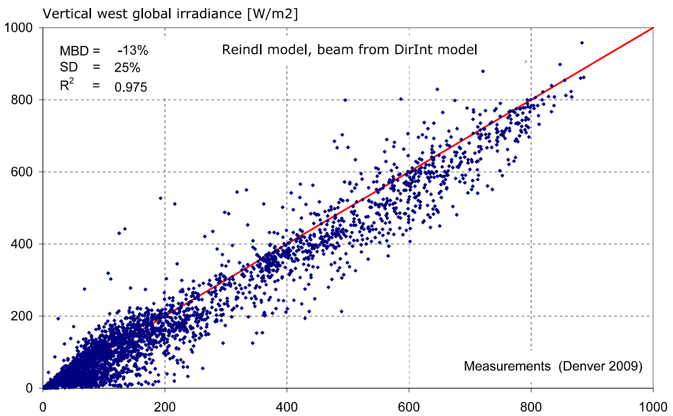

Vertical west global irradiance [W/m2]
MBD = -12%
SD = 29%
R2 = 0.971
Gueymard model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

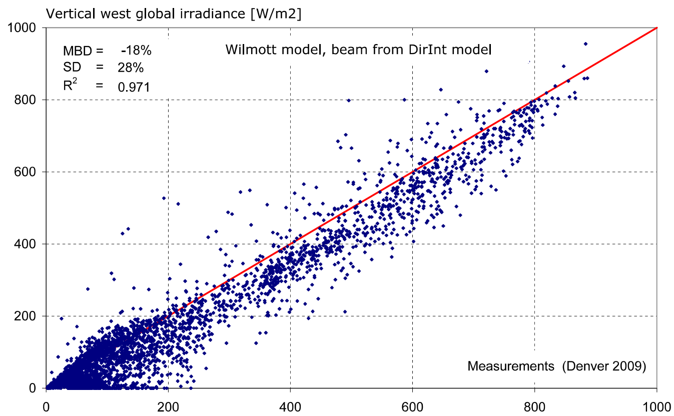

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 25%
R2 = 0.975
Hay model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

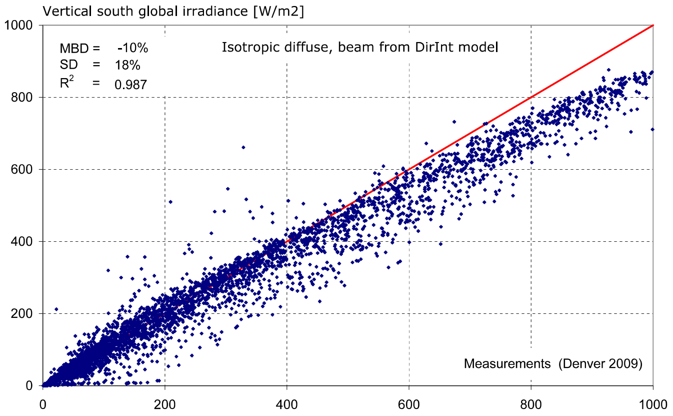

Vertical west global irradiance [W/m2]
MBD = -7%
SD = 23%
R2 = 0.979
Perez model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

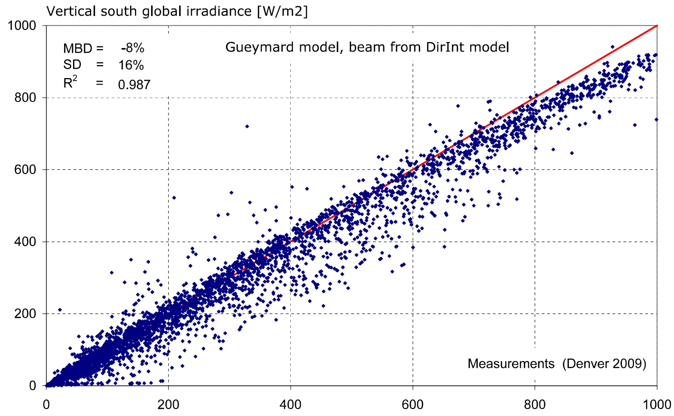

Vertical west global irradiance [W/m2]
MBD = -19%
SD = 29%
R2 = 0.970
Temp & Coulson model, beam from DirInt
Measurements (Denver 2009)
0
200
400
600
800
1000

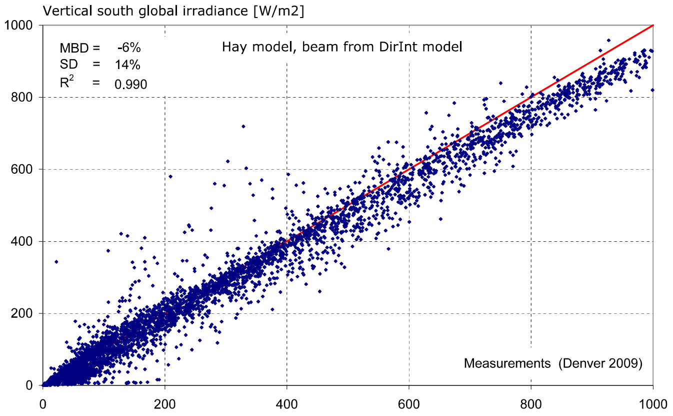

Vertical west global irradiance [W/m2]
MBD = -5%
SD = 32%
R2 = 0.964
Klucher model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

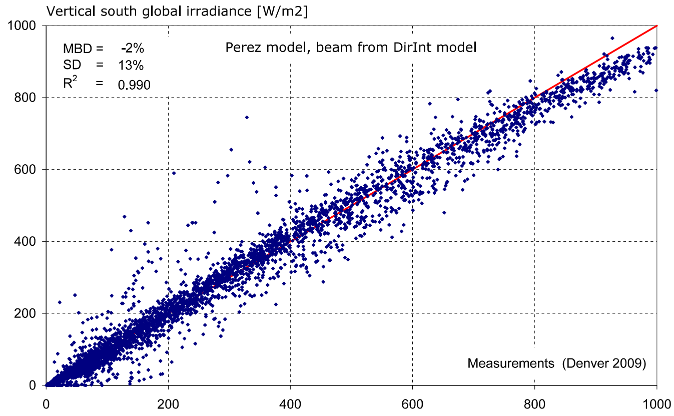

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 25%
R2 = 0.975
Reindl model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

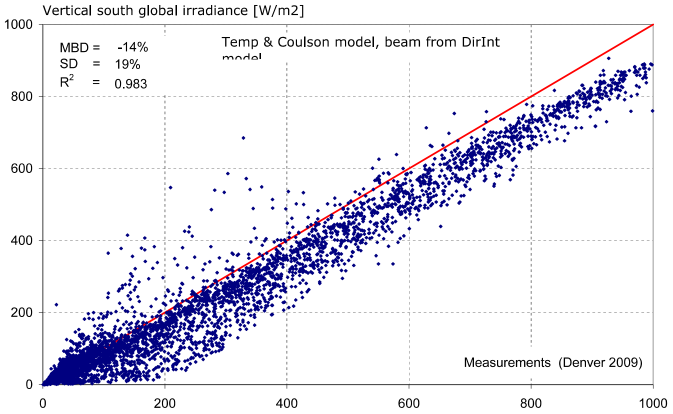

Vertical west global irradiance [W/m2]
MBD = -18%
SD = 28%
R2 = 0.971
Wilmott model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

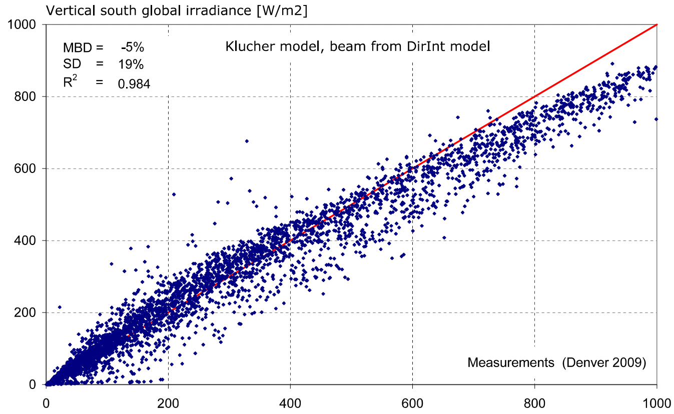

Vertical south global irradiance [W/m2]
MBD = -10%
SD = 18%
R^2 = 0.987
Isotropic diffuse, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

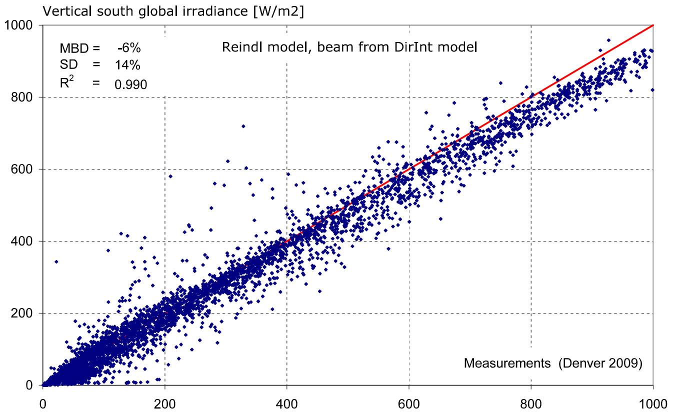

Vertical south global irradiance [W/m2]
MBD = -8%
SD = 16%
R^2 = 0.987
Gueymard model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

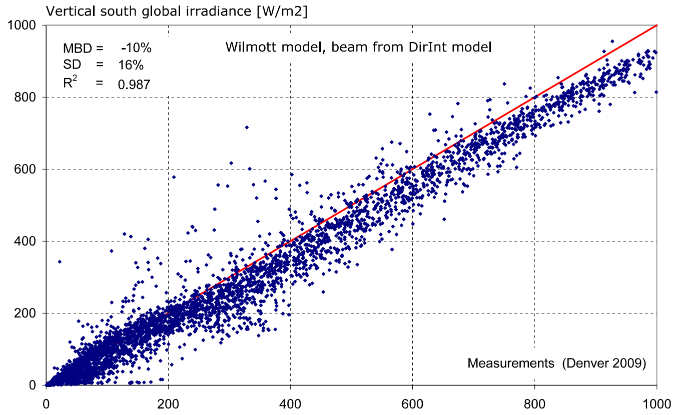

Vertical south global irradiance [W/m2]
MBD = -6%
SD = 14%
R^2 = 0.990
Hay model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

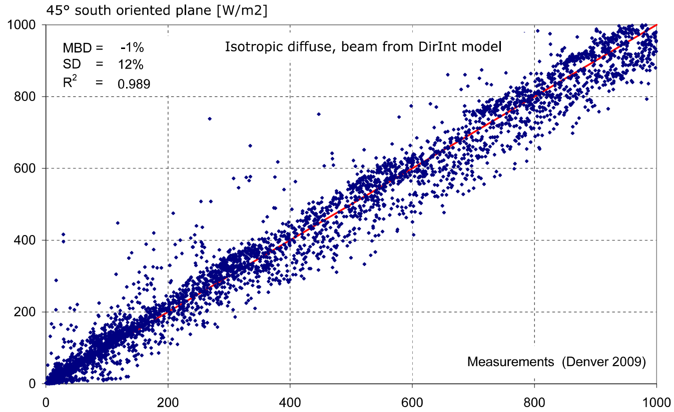

Vertical south global irradiance [W/m2]
MBD = -2%
SD = 13%
R^2 = 0.990
Perez model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

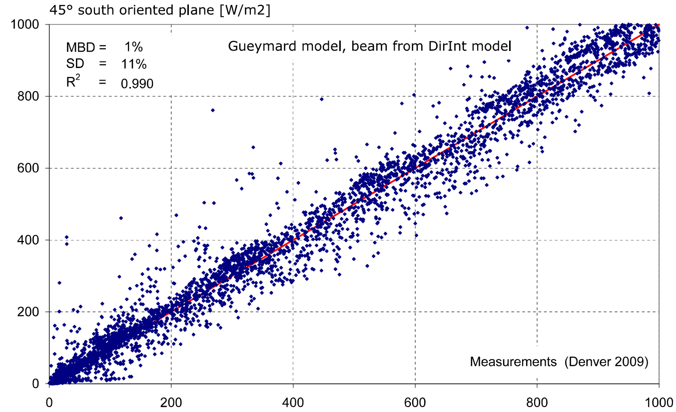

Vertical south global irradiance [W/m2]
MBD = -14%
SD = 19%
R^2 = 0.983
Temp & Coulson model, beam from DirInt
Measurements (Denver 2009)
0
200
400
600
800
1000

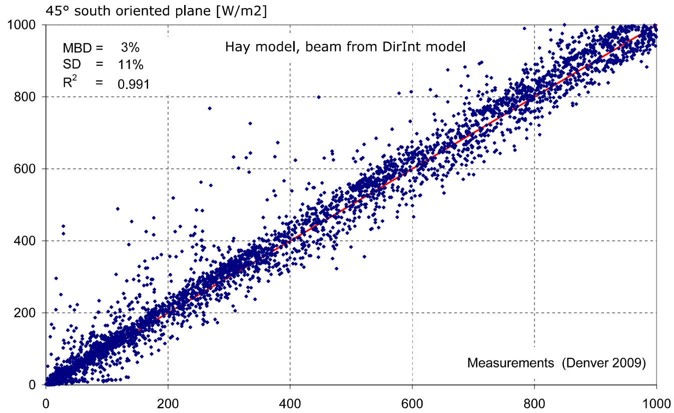

Vertical south global irradiance [W/m2]
MBD = -5%
SD = 19%
R^2 = 0.984
Klucher model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

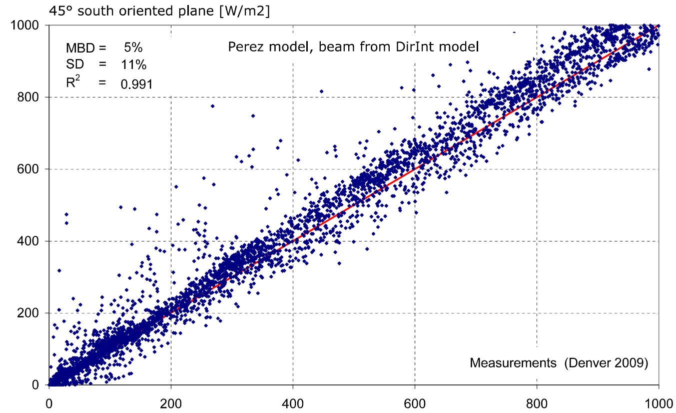

Vertical south global irradiance [W/m2]
MBD = -6%
SD = 14%
R^2 = 0.990
Reindl model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

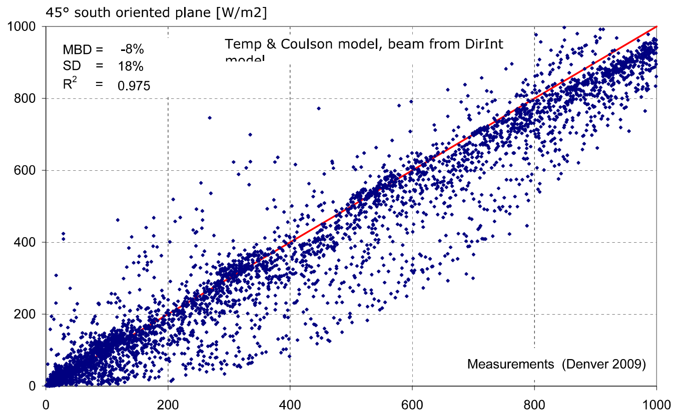

Vertical south global irradiance [W/m2]
MBD = -10%
SD = 16%
R^2 = 0.987
Wilmott model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

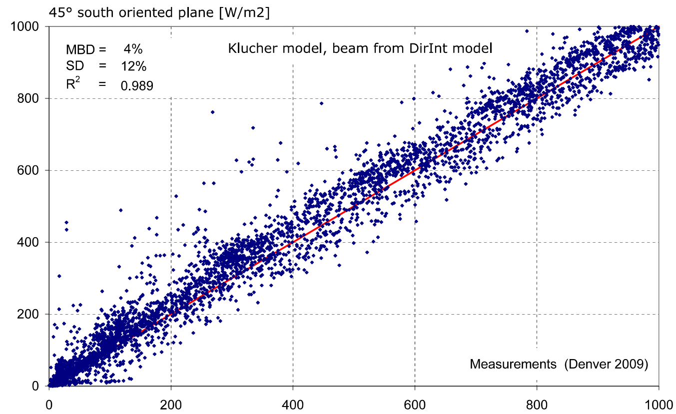

45° south oriented plane [W/m2]
MBD = -1%
SD = 12%
R2 = 0.989
Isotropic diffuse, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

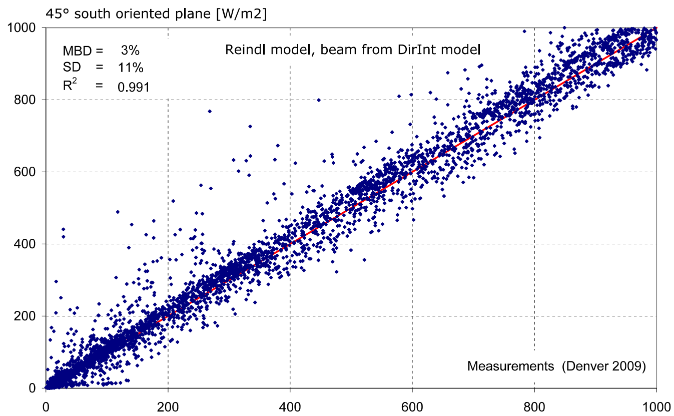

45° south oriented plane [W/m2]
MBD = 1%
SD = 11%
R2 = 0.990
Gueymard model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

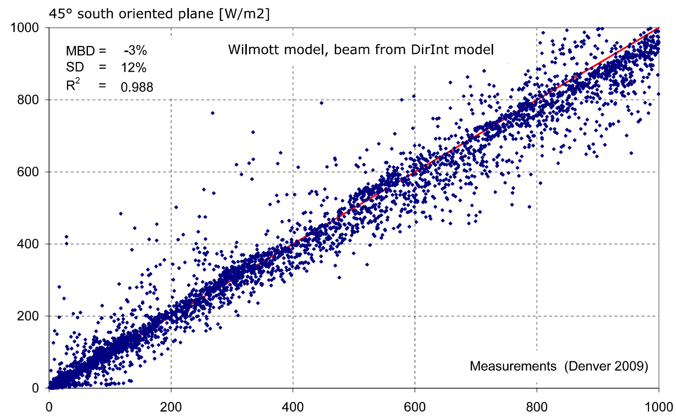

45° south oriented plane [W/m2]
MBD = 3%
SD = 11%
R2 = 0.991
Hay model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

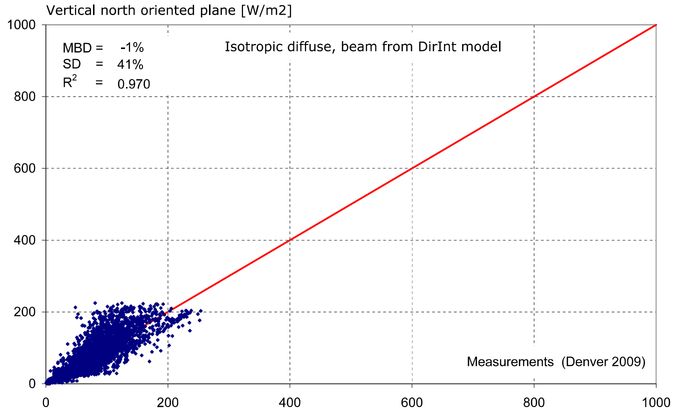

45° south oriented plane [W/m2]
MBD = 5%
SD = 11%
R2 = 0.991
Perez model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

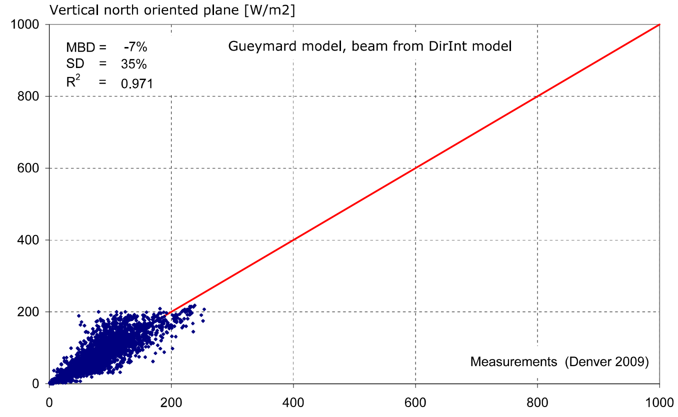

45° south oriented plane [W/m2]
MBD = -8%
SD = 18%
R2 = 0.975
Temp & Coulson model, beam from DirInt
Measurements (Denver 2009)
0
200
400
600
800
1000

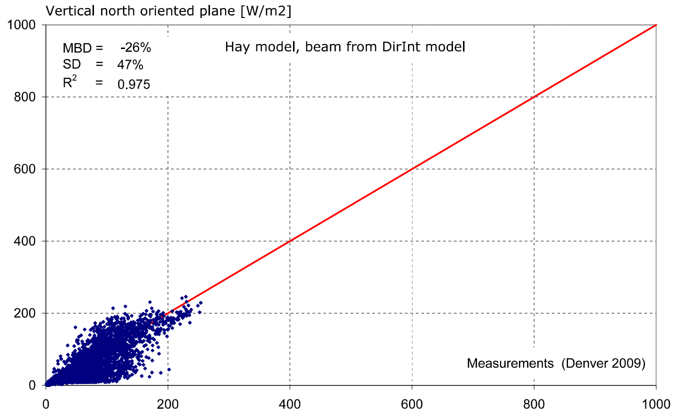

45° south oriented plane [W/m2]
MBD = 4%
SD = 12%
R2 = 0.989
Klucher model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

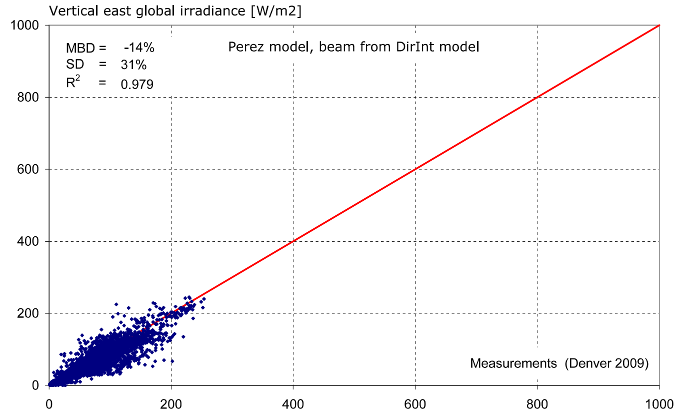

45° south oriented plane [W/m2]
MBD = 3%
SD = 11%
R2 = 0.991
Reindl model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

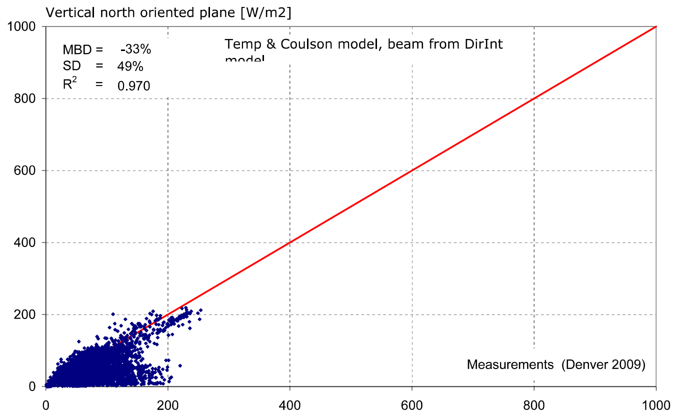

45° south oriented plane [W/m2]
MBD = -3%
SD = 12%
R2 = 0.988
Wilmott model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

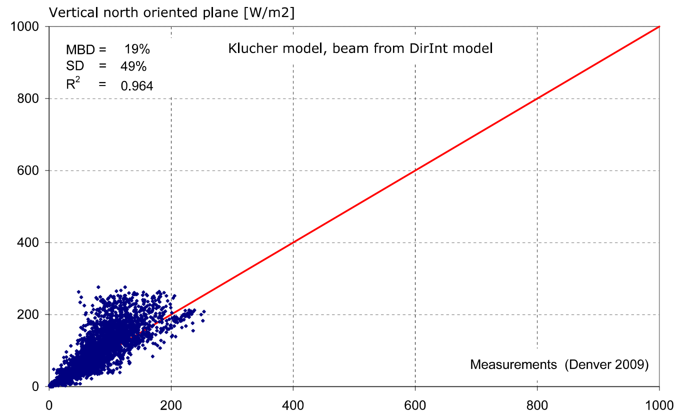

Vertical north oriented plane [W/m2]
MBD = -1%
SD = 41%
R^2 = 0.970
Isotropic diffuse, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

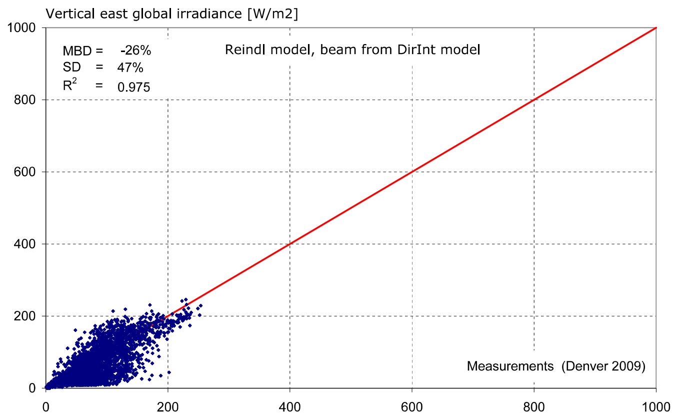

Vertical north oriented plane [W/m2]
MBD = -7%
SD = 35%
R^2 = 0.971
Gueymard model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

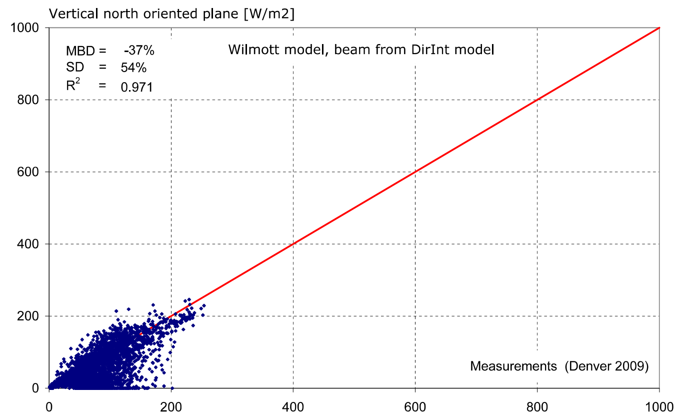

Vertical north oriented plane [W/m2]
MBD = -26%
SD = 47%
R^2 = 0.975
Hay model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = -14%
SD = 31%
R^2 = 0.979
Perez model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -33%
SD = 49%
R^2 = 0.970
Temp & Coulson model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = 19%
SD = 49%
R^2 = 0.964
Klucher model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = -26%
SD = 47%
R^2 = 0.975
Reindl model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -37%
SD = 54%
R^2 = 0.971
Wilmott model, beam from DirInt model
Measurements (Denver 2009)
0
200
400
600
800
1000

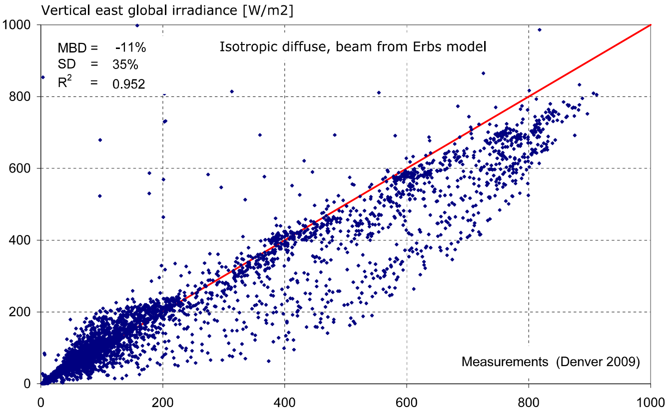
Denver (United States)

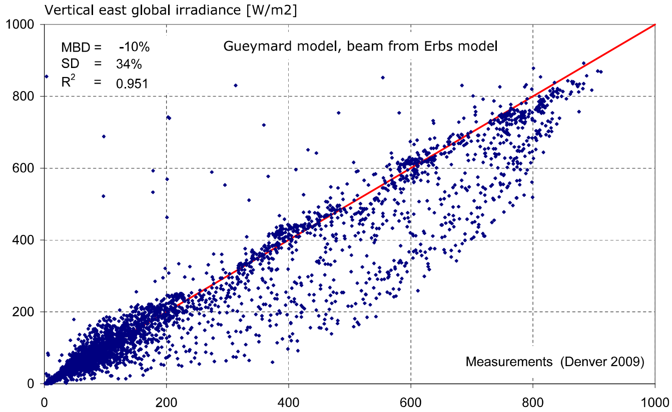
Latitude:	39.74°
Longitude:	-105.18°
Altitude over sea level:	1829m

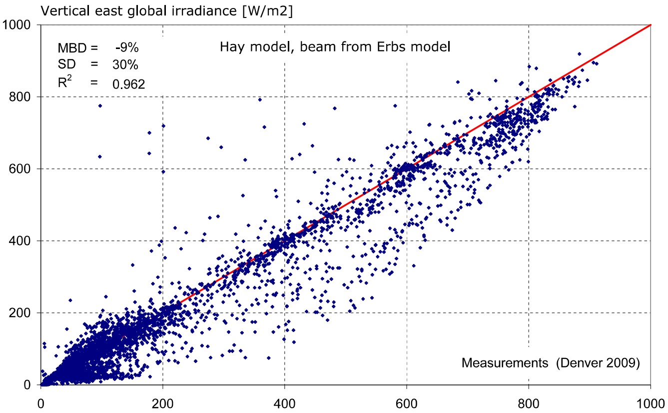
Beam irradiance from Erbs. Klucher and Duffie (EKD)

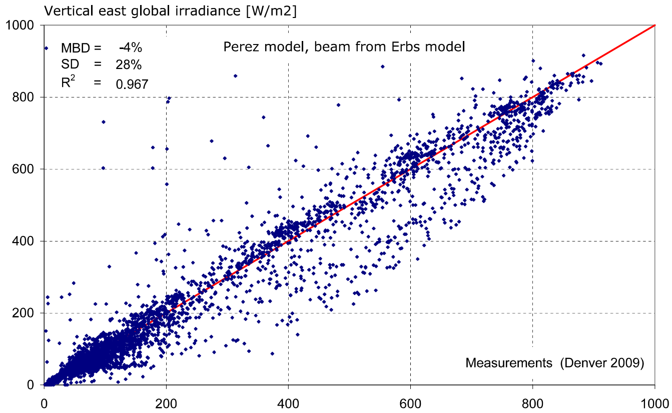
Figures in the following pages:

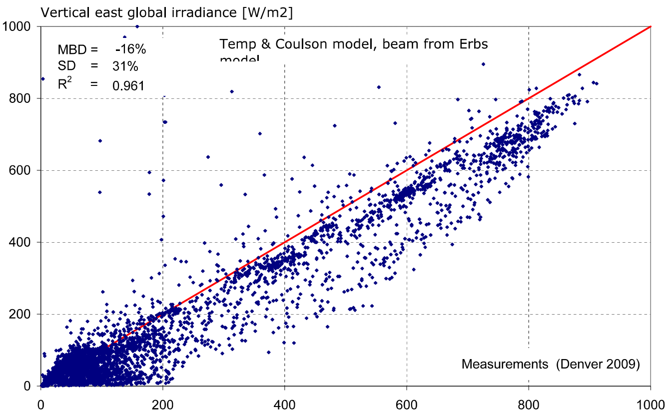
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

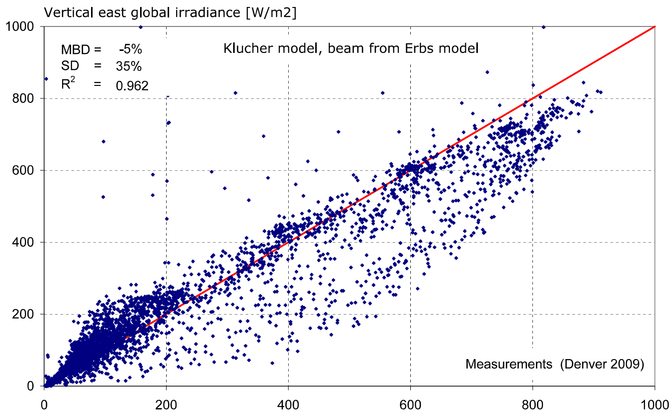

Vertical east global irradiance [W/m2]
MBD = -11%
SD = 35%
R^2 = 0.952
Isotropic diffuse, beam from Erbs model
Measurements (Denver 2009)

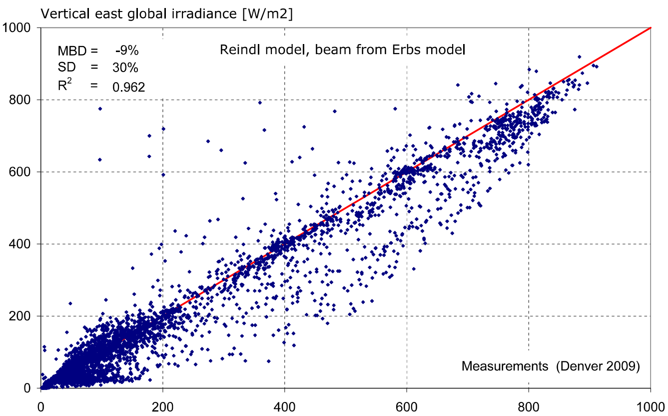

Vertical east global irradiance [W/m2]
MBD = -10%
SD = 34%
R^2 = 0.951
Gueymard model, beam from Erbs model
Measurements (Denver 2009)

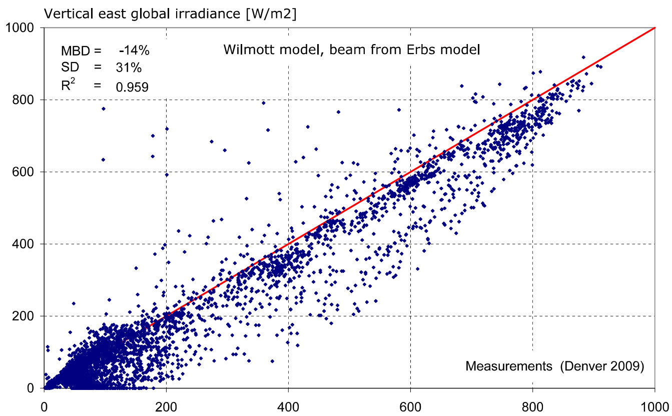

Vertical east global irradiance [W/m2]
MBD = -9%
SD = 30%
R^2 = 0.962
Hay model, beam from Erbs model
Measurements (Denver 2009)

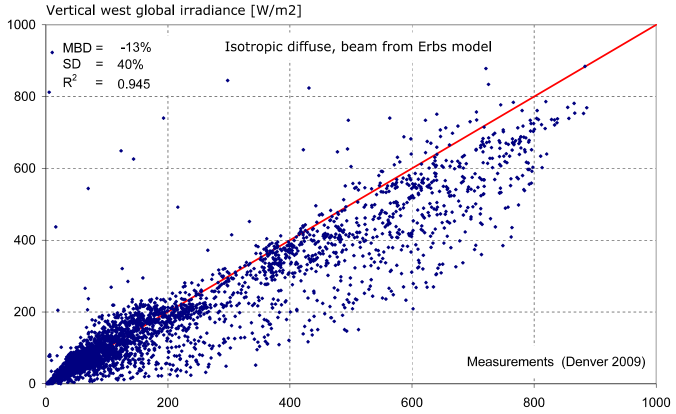

Vertical east global irradiance [W/m2]
MBD = -4%
SD = 28%
R^2 = 0.967
Perez model, beam from Erbs model
Measurements (Denver 2009)

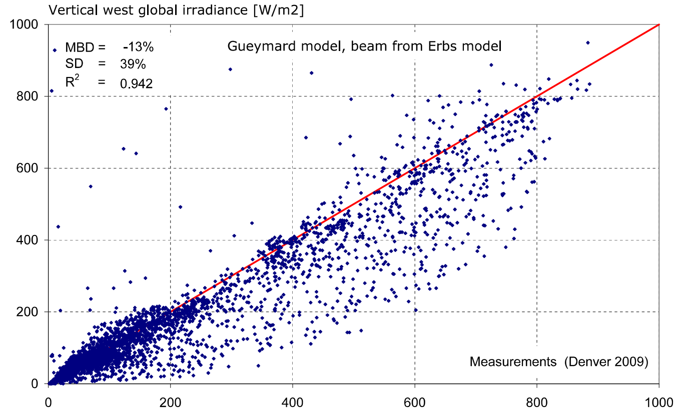

Vertical east global irradiance [W/m2]
MBD = -16%
SD = 31%
R^2 = 0.961
Temp & Coulson model, beam from Erbs
Measurements (Denver 2009)

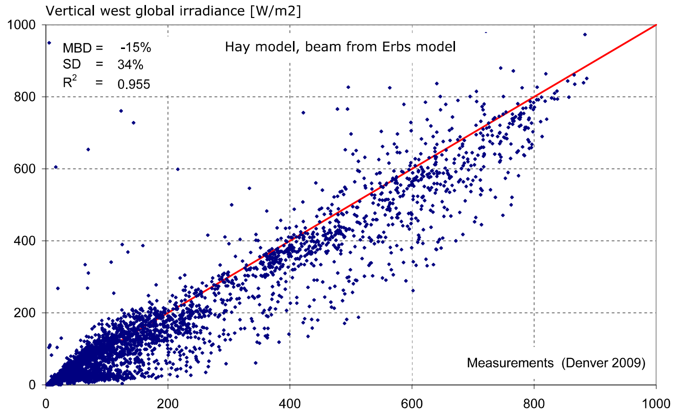

Vertical east global irradiance [W/m2]
MBD = -5%
SD = 35%
R^2 = 0.962
Klucher model, beam from Erbs model
Measurements (Denver 2009)

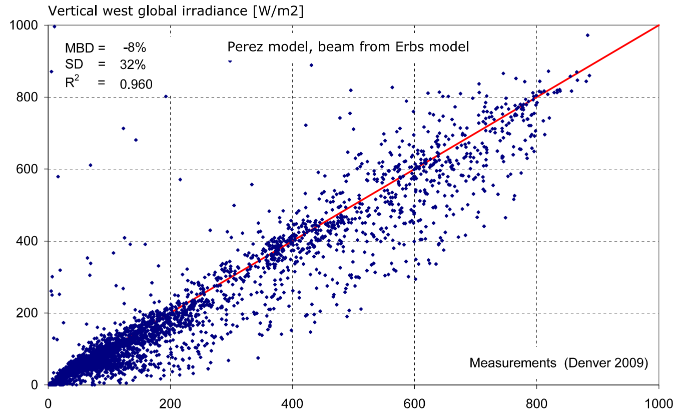

Vertical east global irradiance [W/m2]
MBD = -9%
SD = 30%
R^2 = 0.962
Reindl model, beam from Erbs model
Measurements (Denver 2009)

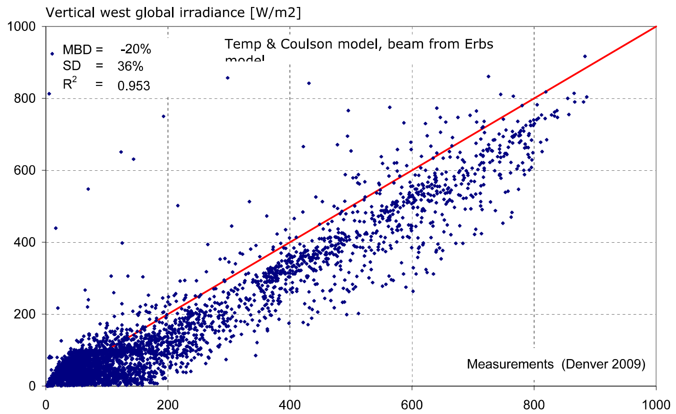

Vertical east global irradiance [W/m2]
MBD = -14%
SD = 31%
R^2 = 0.959
Wilmott model, beam from Erbs model
Measurements (Denver 2009)

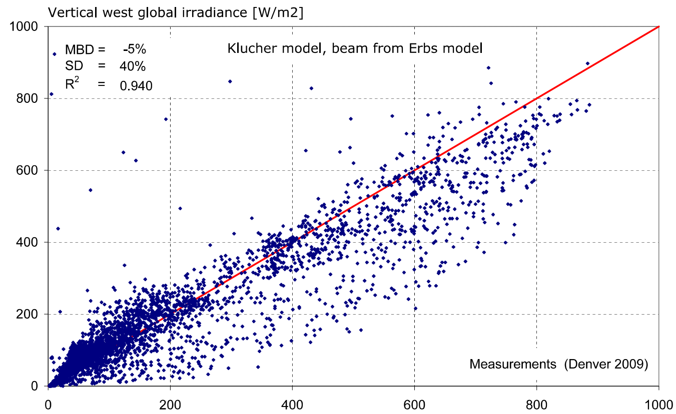

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 40%
R^2 = 0.945
Isotropic diffuse, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

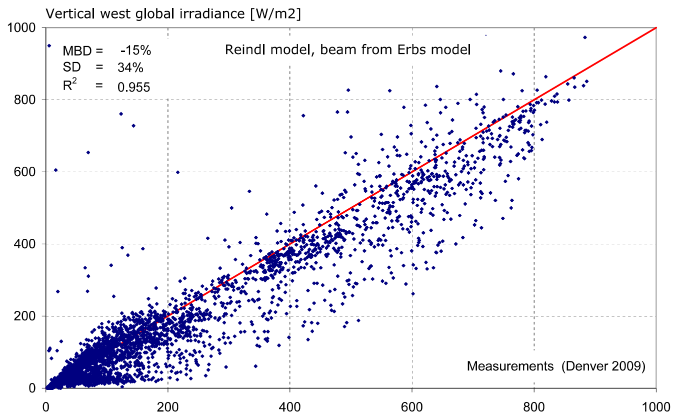

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 39%
R^2 = 0.942
Gueymard model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

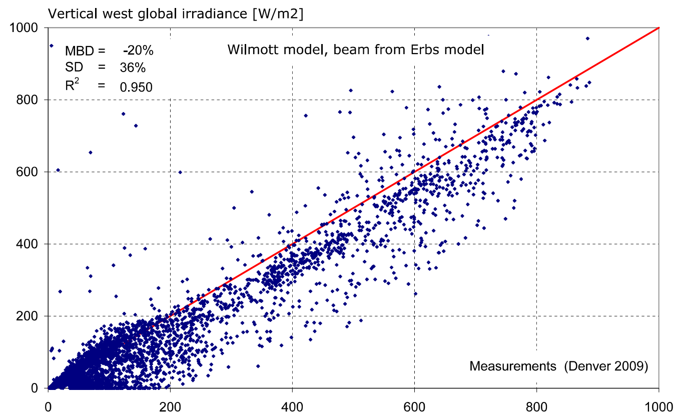

Vertical west global irradiance [W/m2]
MBD = -15%
SD = 34%
R^2 = 0.955
Hay model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

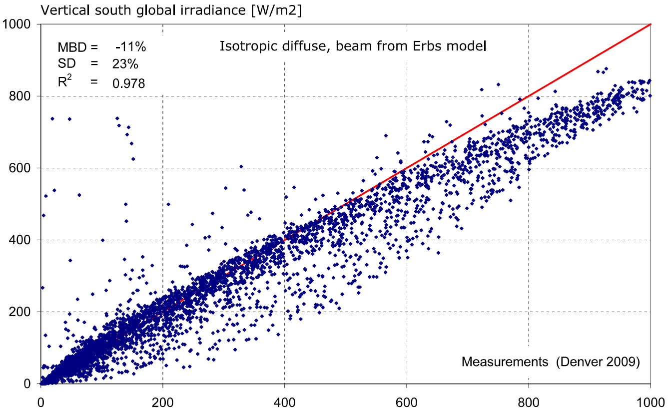

Vertical west global irradiance [W/m2]
MBD = -8%
SD = 32%
R^2 = 0.960
Perez model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

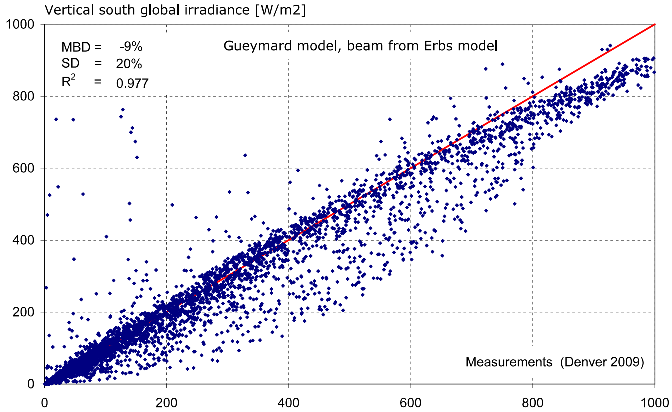

Vertical west global irradiance [W/m2]
MBD = -20%
SD = 36%
R^2 = 0.953
Temp & Coulson model, beam from Erbs
Measurements (Denver 2009)
0
200
400
600
800
1000

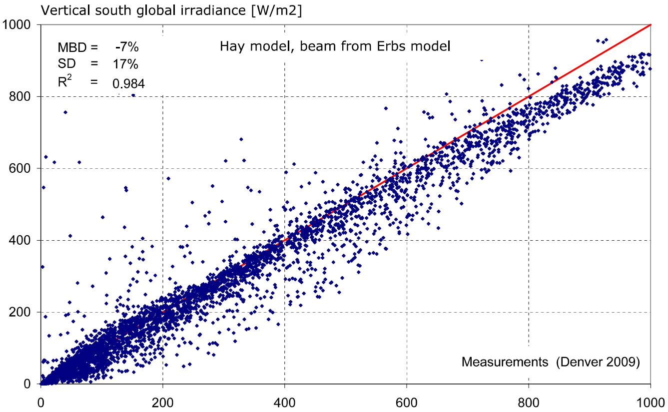

Vertical west global irradiance [W/m2]
MBD = -5%
SD = 40%
R^2 = 0.940
Klucher model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

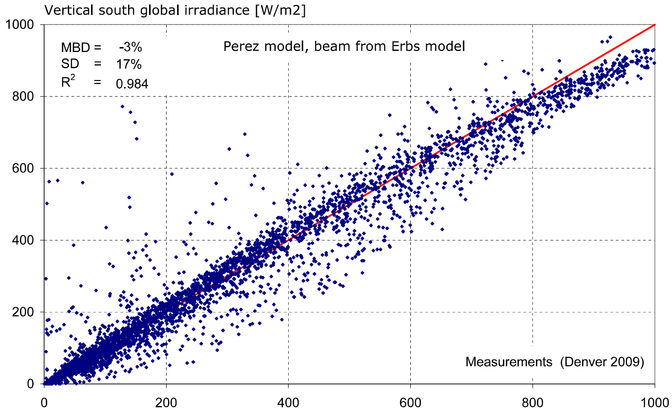

Vertical west global irradiance [W/m2]
MBD = -15%
SD = 34%
R^2 = 0.955
Reindl model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

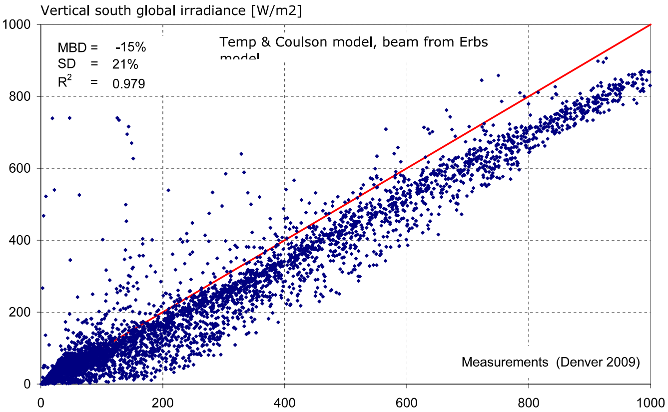

Vertical west global irradiance [W/m2]
MBD = -20%
SD = 36%
R^2 = 0.950
Wilmott model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

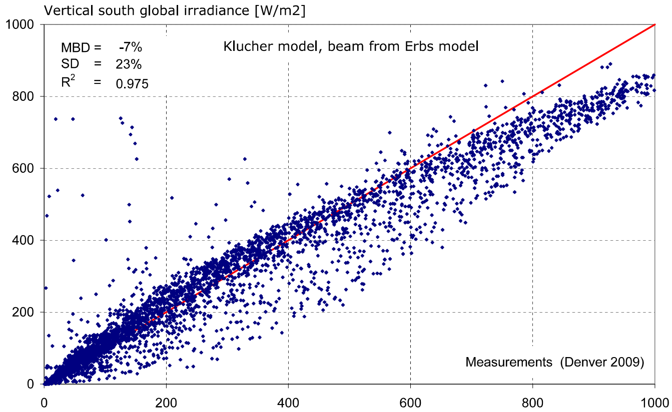

Vertical south global irradiance [W/m2]
MBD = -11%
SD = 23%
R^2 = 0.978
Isotropic diffuse, beam from Erbs model
Measurements (Denver 2009)

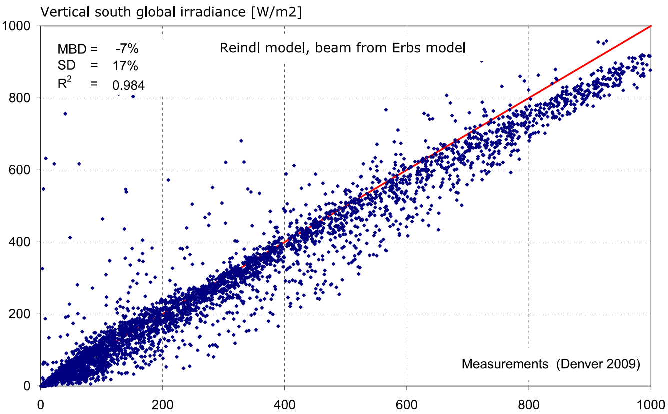

Vertical south global irradiance [W/m2]
MBD = -9%
SD = 20%
R^2 = 0.977
Gueymard model, beam from Erbs model
Measurements (Denver 2009)

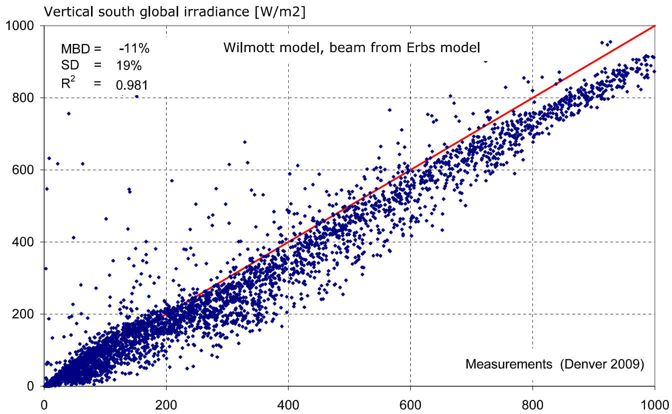

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 17%
R^2 = 0.984
Hay model, beam from Erbs model
Measurements (Denver 2009)

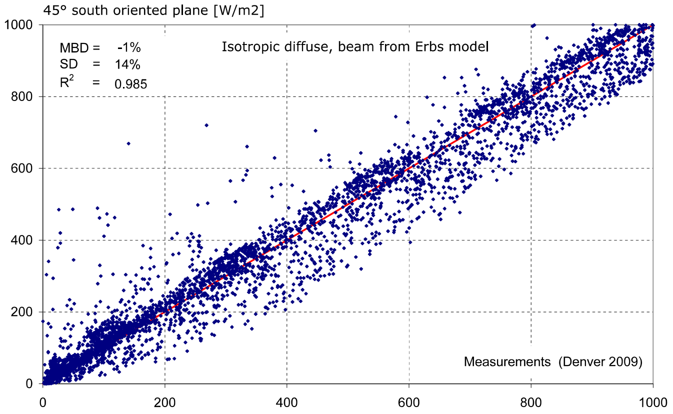

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 17%
R^2 = 0.984
Perez model, beam from Erbs model
Measurements (Denver 2009)

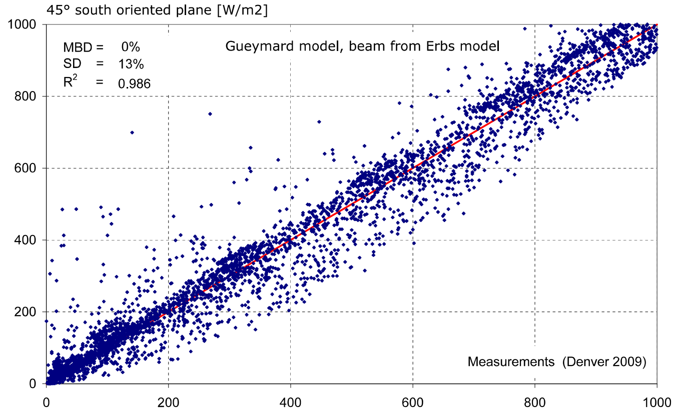

Vertical south global irradiance [W/m2]
MBD = -15%
SD = 21%
R^2 = 0.979
Temp & Coulson model, beam from Erbs
Measurements (Denver 2009)

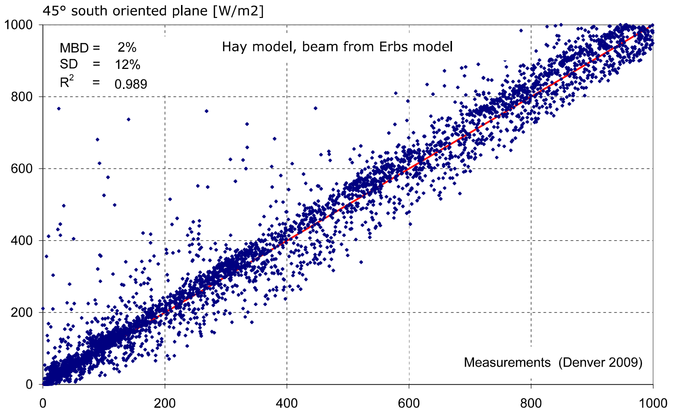

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 23%
R^2 = 0.975
Klucher model, beam from Erbs model
Measurements (Denver 2009)

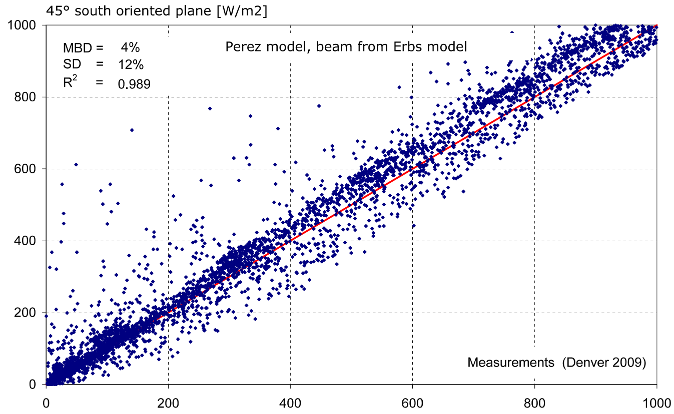

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 17%
R^2 = 0.984
Reindl model, beam from Erbs model
Measurements (Denver 2009)

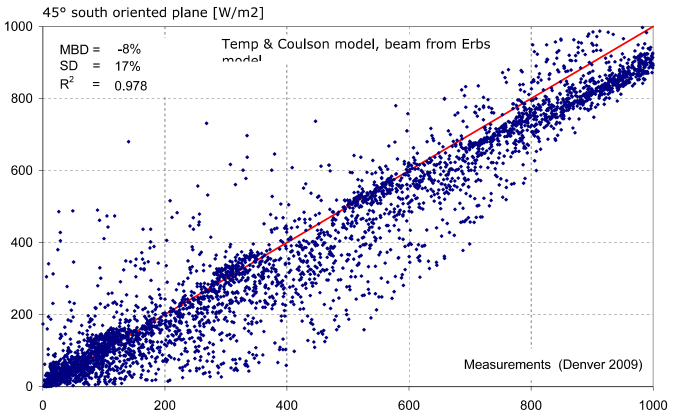

Vertical south global irradiance [W/m2]
MBD = -11%
SD = 19%
R^2 = 0.981
Wilmott model, beam from Erbs model
Measurements (Denver 2009)

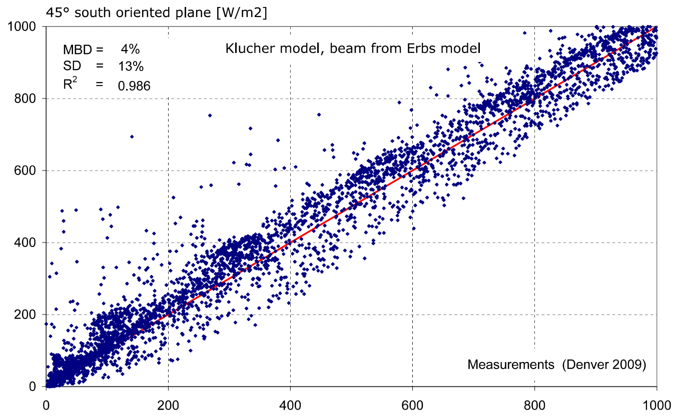

45° south oriented plane [W/m2]
MBD = -1%
SD = 14%
R^2 = 0.985
Isotropic diffuse, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

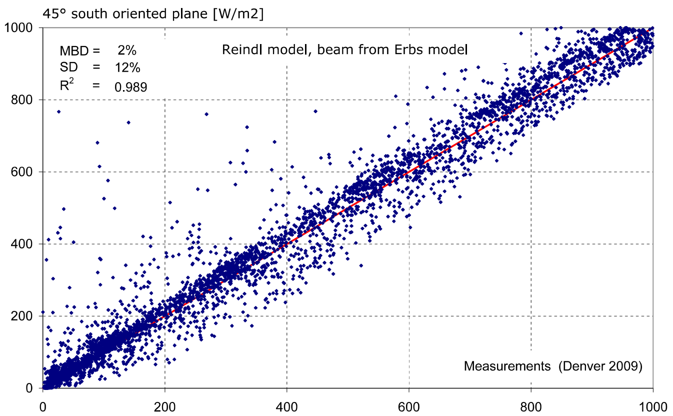

45° south oriented plane [W/m2]
MBD = 0%
SD = 13%
R^2 = 0.986
Gueymard model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

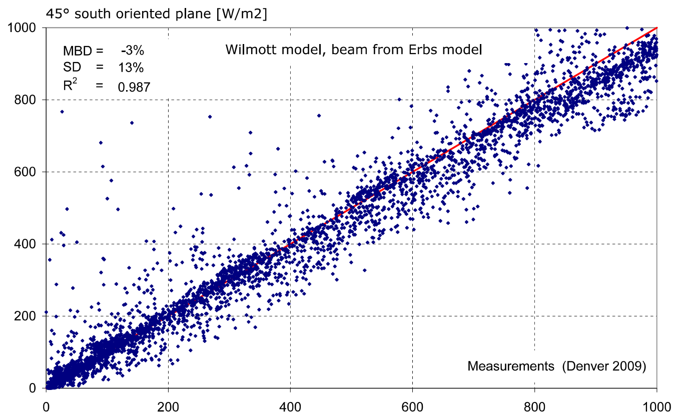

45° south oriented plane [W/m2]
MBD = 2%
SD = 12%
R^2 = 0.989
Hay model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

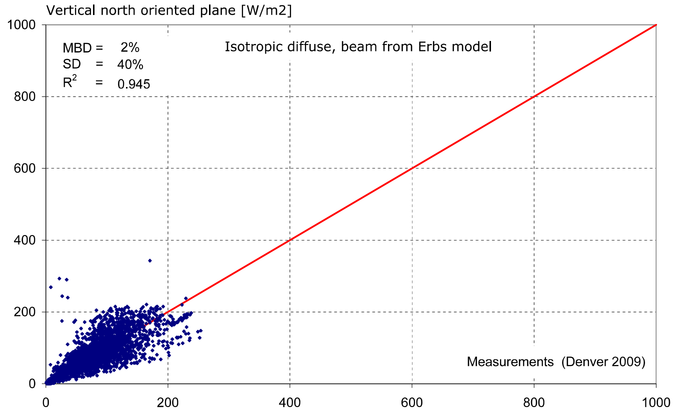

45° south oriented plane [W/m2]
MBD = 4%
SD = 12%
R^2 = 0.989
Perez model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

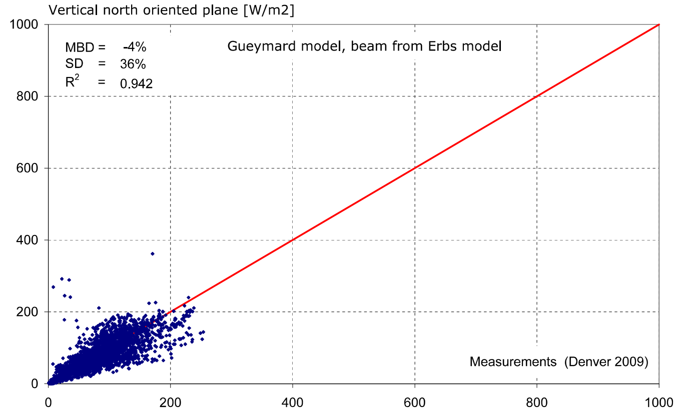

45° south oriented plane [W/m2]
MBD = -8%
SD = 17%
R^2 = 0.978
Temp & Coulson model, beam from Erbs
Measurements (Denver 2009)
0
200
400
600
800
1000

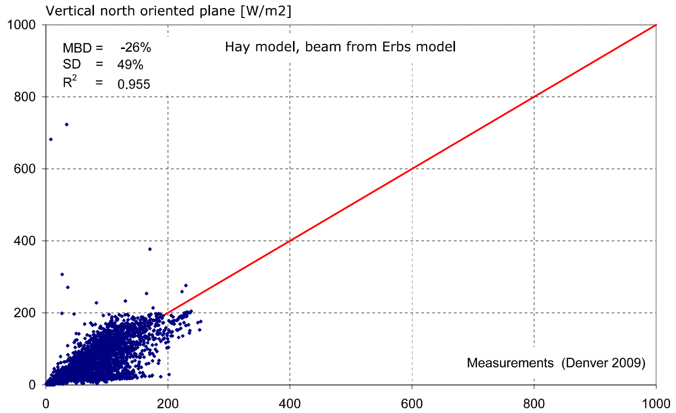

45° south oriented plane [W/m2]
MBD = 4%
SD = 13%
R^2 = 0.986
Klucher model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

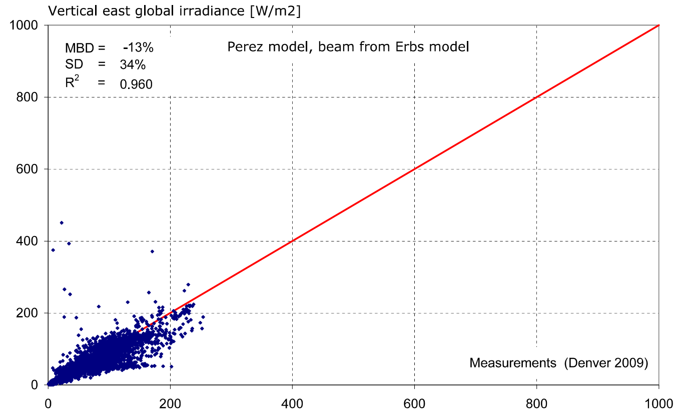

45° south oriented plane [W/m2]
MBD = 2%
SD = 12%
R^2 = 0.989
Reindl model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

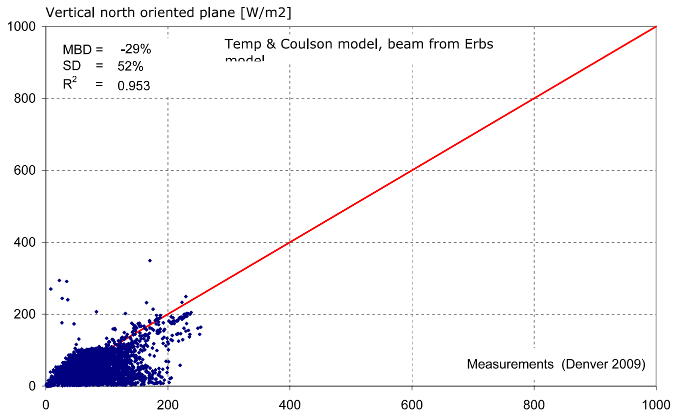

45° south oriented plane [W/m2]
MBD = -3%
SD = 13%
R^2 = 0.987
Wilmott model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

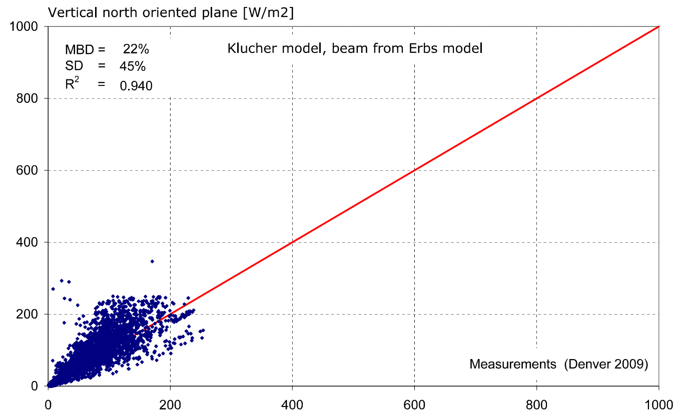

Vertical north oriented plane [W/m2]
MBD = 2%
SD = 40%
R2 = 0.945
Isotropic diffuse, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

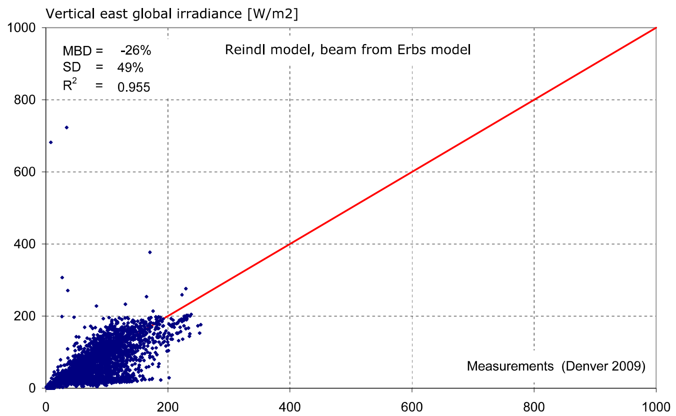

Vertical north oriented plane [W/m2]
MBD = -4%
SD = 36%
R2 = 0.942
Gueymard model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

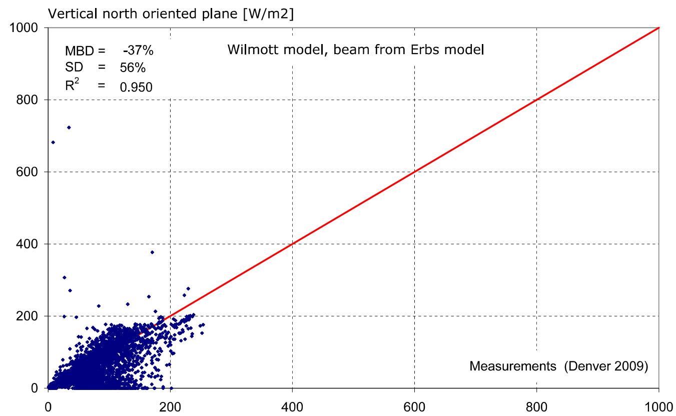

Vertical north oriented plane [W/m2]
MBD = -26%
SD = 49%
R2 = 0.955
Hay model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = -13%
SD = 34%
R2 = 0.960
Perez model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -29%
SD = 52%
R2 = 0.953
Temp & Coulson model, beam from Erbs
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = 22%
SD = 45%
R2 = 0.940
Klucher model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = -26%
SD = 49%
R2 = 0.955
Reindl model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -37%
SD = 56%
R2 = 0.950
Wilmott model, beam from Erbs model
Measurements (Denver 2009)
0
200
400
600
800
1000

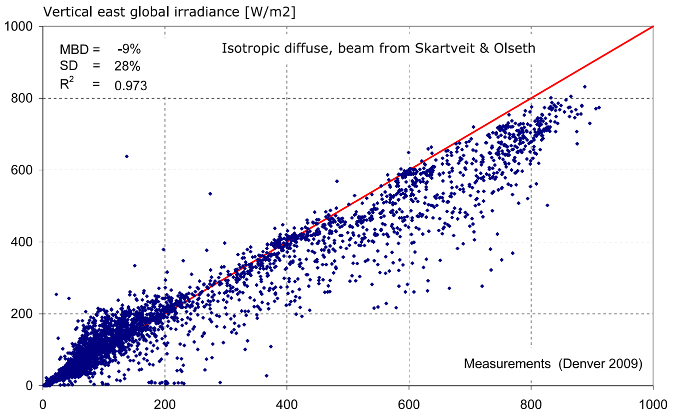
Denver (United States)

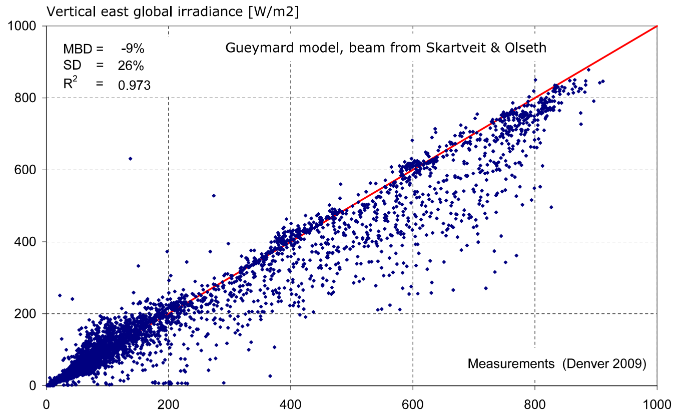
Latitude:	39.74°
Longitude:	-105.18°
Altitude over sea level:	1829m

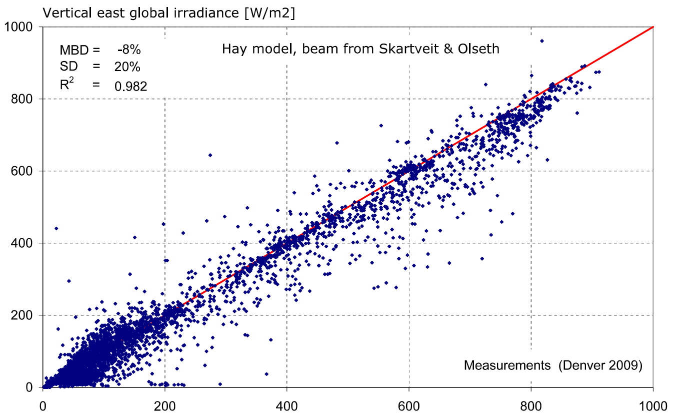
Beam irradiance from Skartveit & Olseth

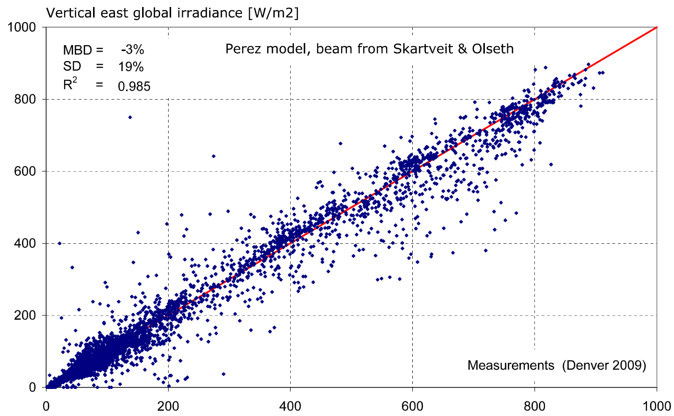
Figures in the following pages:

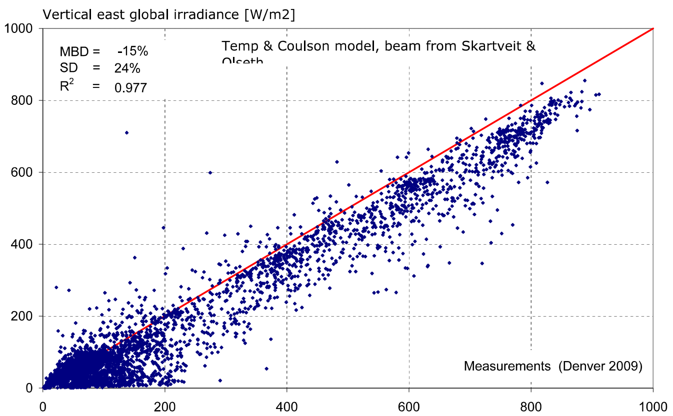
- scatter plots for the east vertical global solar irradiance, model against measurements,
- scatter plots for the west vertical global solar irradiance, model against measurements,
- scatter plots for the south vertical global solar irradiance, model against measurements,
- scatter plots for the 45° inclined south oriented global solar irradiance, model against measurements,
- scatter plots for the north vertical global solar irradiance, model against measurements.

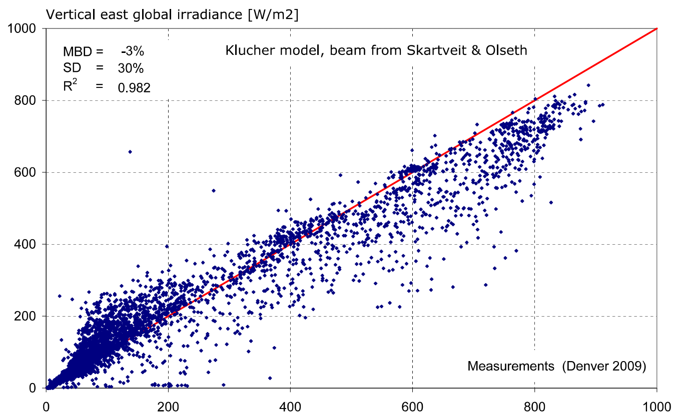

Vertical east global irradiance [W/m2]
MBD = -9%
SD = 28%
R^2 = 0.973
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

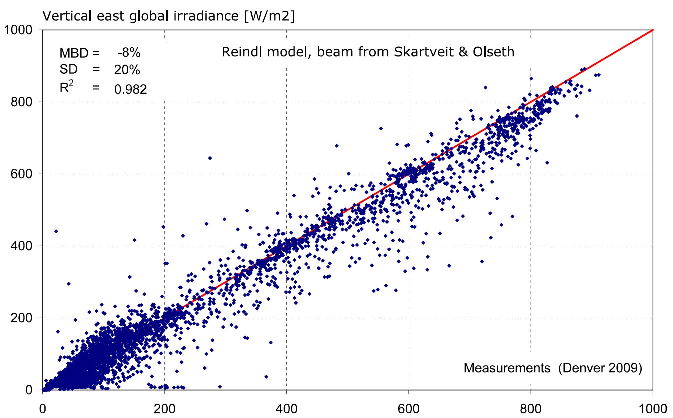

Vertical east global irradiance [W/m2]
MBD = -9%
SD = 26%
R^2 = 0.973
Gueymard model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

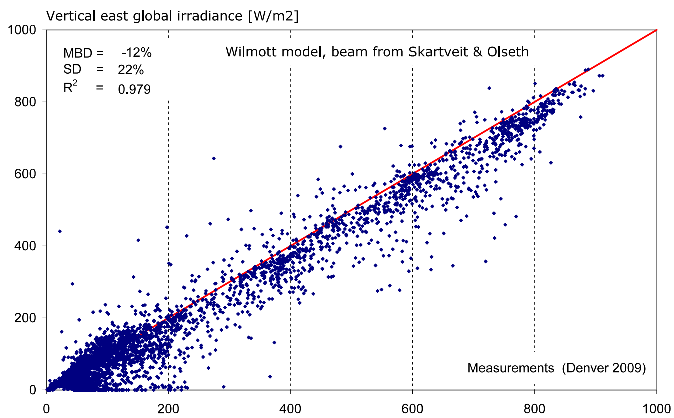

Vertical east global irradiance [W/m2]
MBD = -8%
SD = 20%
R^2 = 0.982
Hay model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

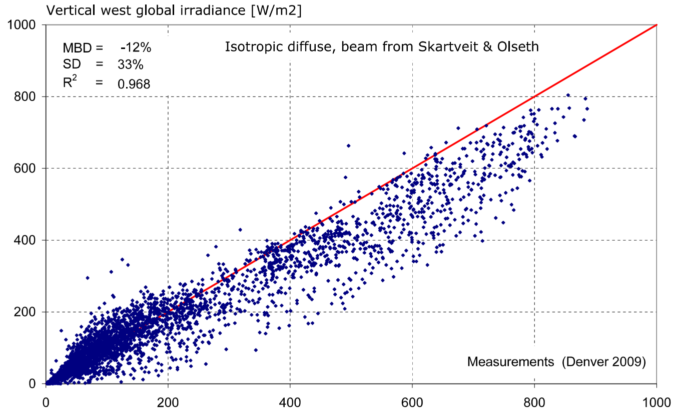

Vertical east global irradiance [W/m2]
MBD = -3%
SD = 19%
R^2 = 0.985
Perez model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

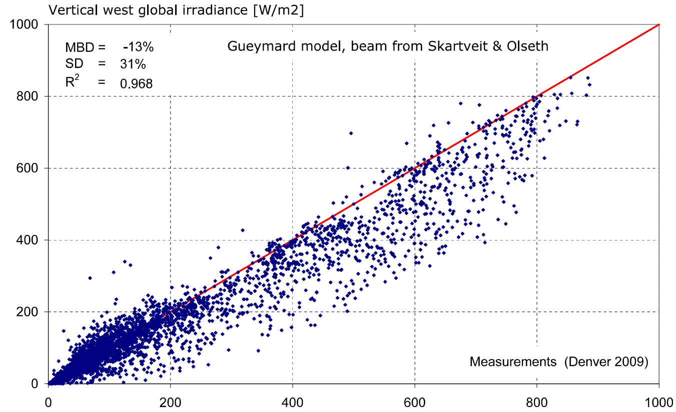

Vertical east global irradiance [W/m2]
MBD = -15%
SD = 24%
R^2 = 0.977
Temp & Coulson model, beam from Skartveit &
Measurements (Denver 2009)
0
200
400
600
800
1000

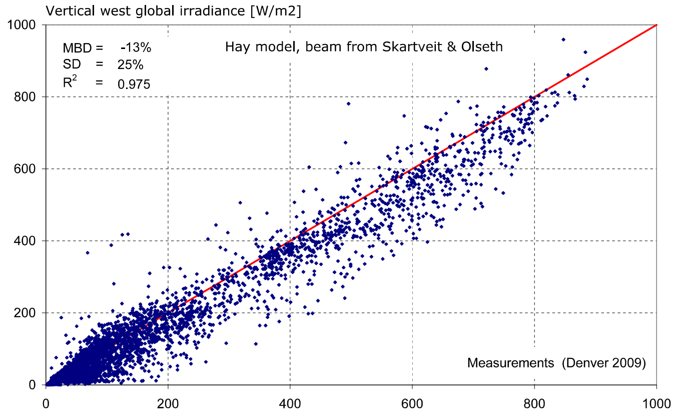

Vertical east global irradiance [W/m2]
MBD = -3%
SD = 30%
R^2 = 0.982
Klucher model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

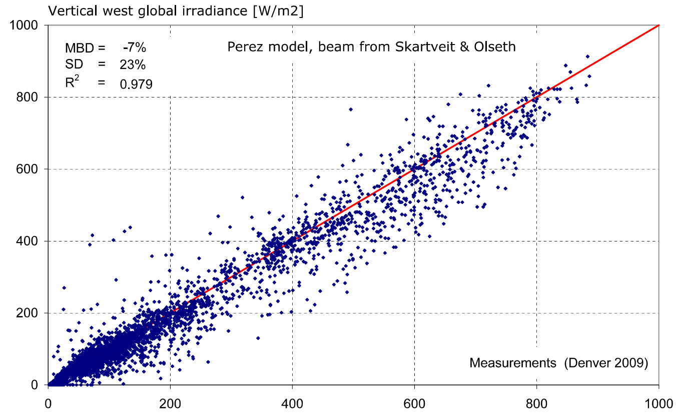

Vertical east global irradiance [W/m2]
MBD = -8%
SD = 20%
R^2 = 0.982
Reindl model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

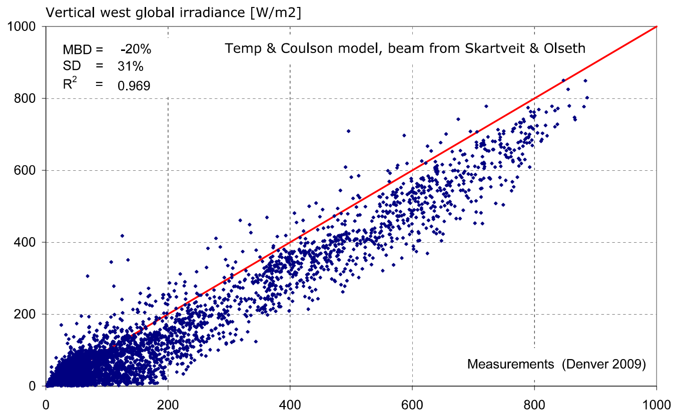

Vertical east global irradiance [W/m2]
MBD = -12%
SD = 22%
R^2 = 0.979
Wilmott model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

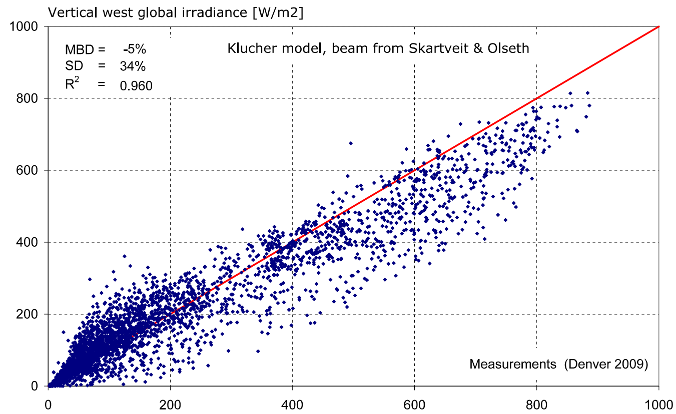

Vertical west global irradiance [W/m2]
MBD = -12%
SD = 33%
R2 = 0.968
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

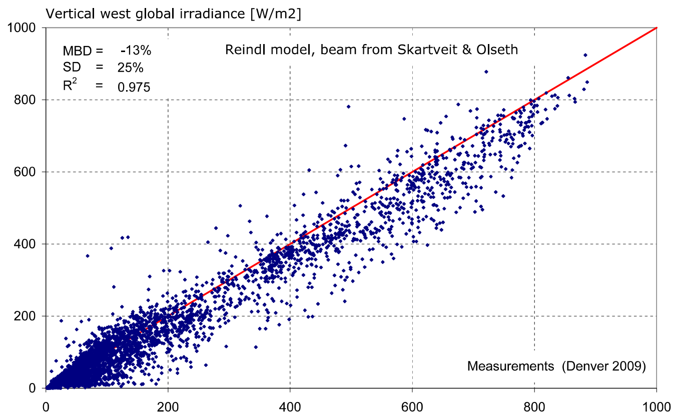

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 31%
R2 = 0.968
Gueymard model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

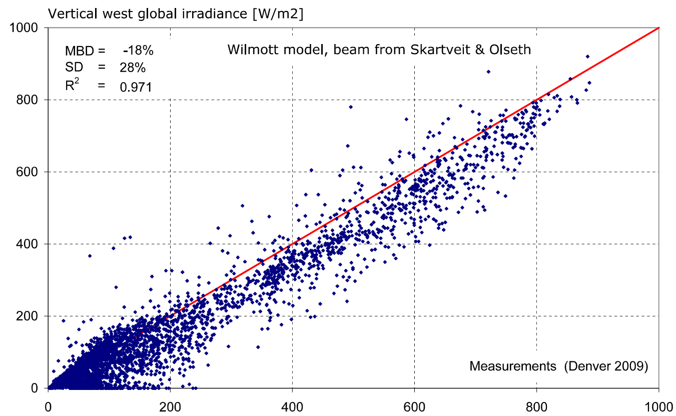

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 25%
R2 = 0.975
Hay model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

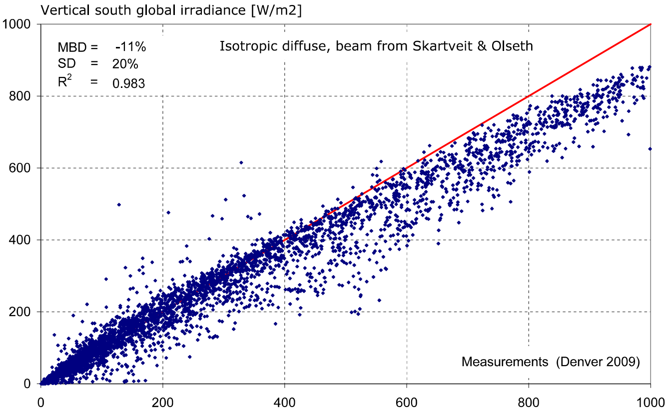

Vertical west global irradiance [W/m2]
MBD = -7%
SD = 23%
R2 = 0.979
Perez model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

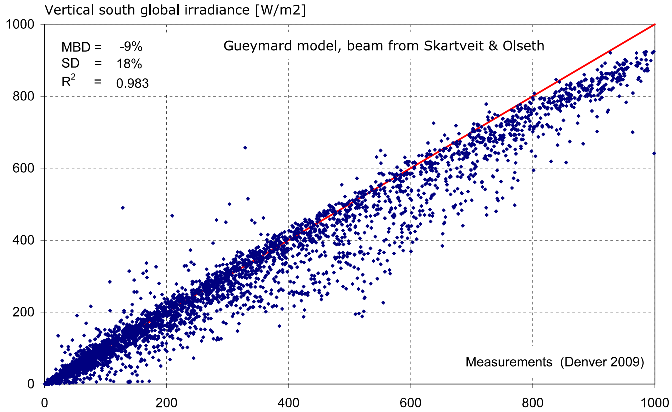

Vertical west global irradiance [W/m2]
MBD = -20%
SD = 31%
R2 = 0.969
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

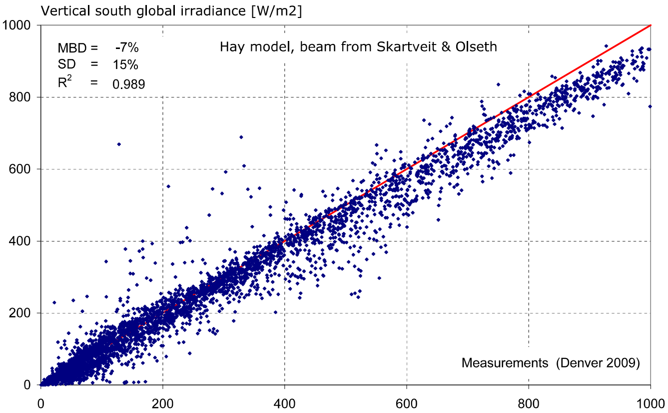

Vertical west global irradiance [W/m2]
MBD = -5%
SD = 34%
R2 = 0.960
Klucher model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

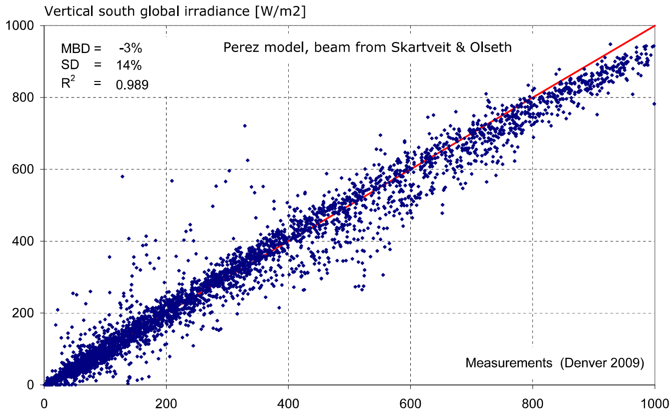

Vertical west global irradiance [W/m2]
MBD = -13%
SD = 25%
R2 = 0.975
Reindl model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

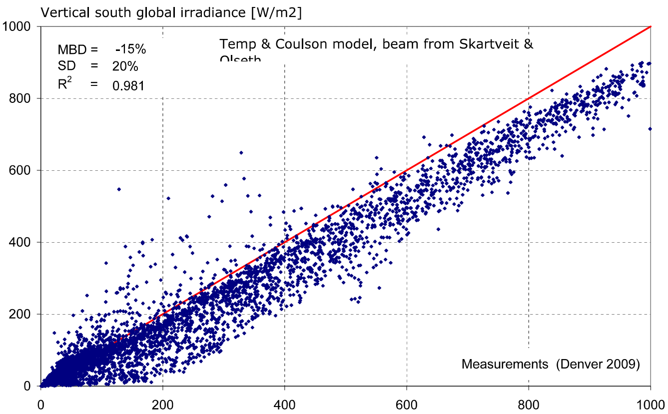

Vertical west global irradiance [W/m2]
MBD = -18%
SD = 28%
R2 = 0.971
Wilmott model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

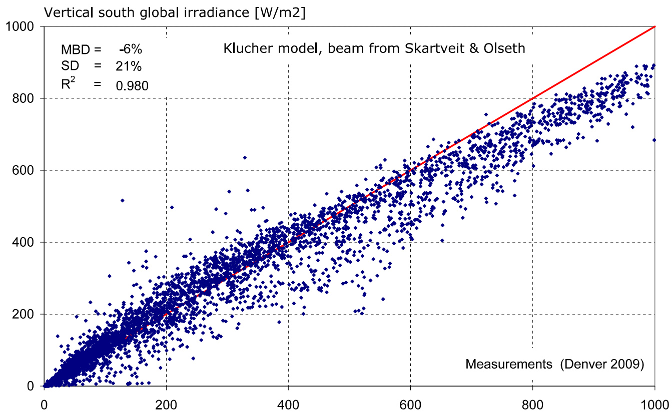

Vertical south global irradiance [W/m2]
MBD = -11%
SD = 20%
R2 = 0.983
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

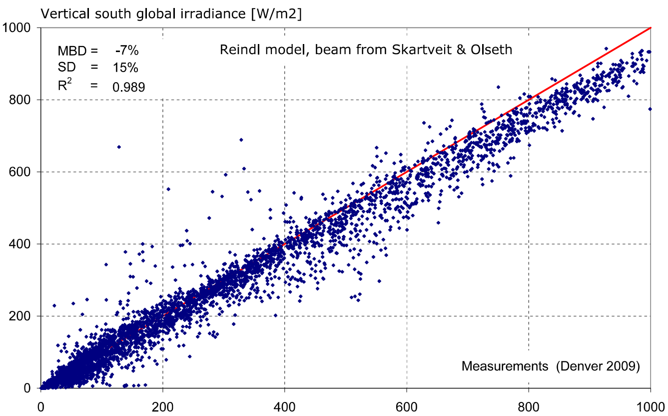

Vertical south global irradiance [W/m2]
MBD = -9%
SD = 18%
R2 = 0.983
Gueymard model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

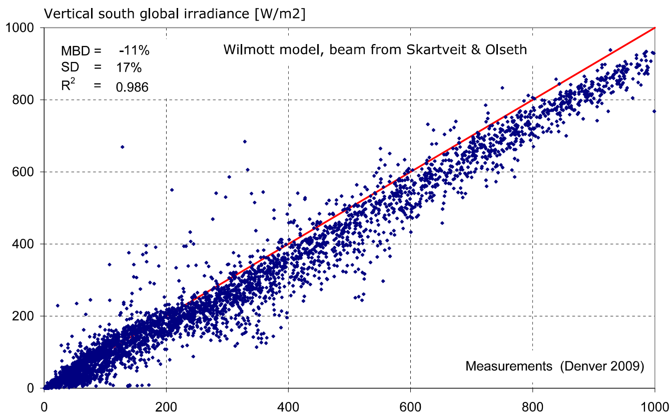

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 15%
R2 = 0.989
Hay model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

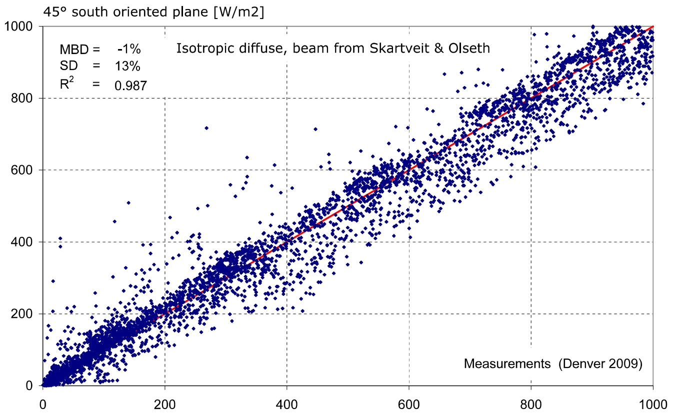

Vertical south global irradiance [W/m2]
MBD = -3%
SD = 14%
R2 = 0.989
Perez model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

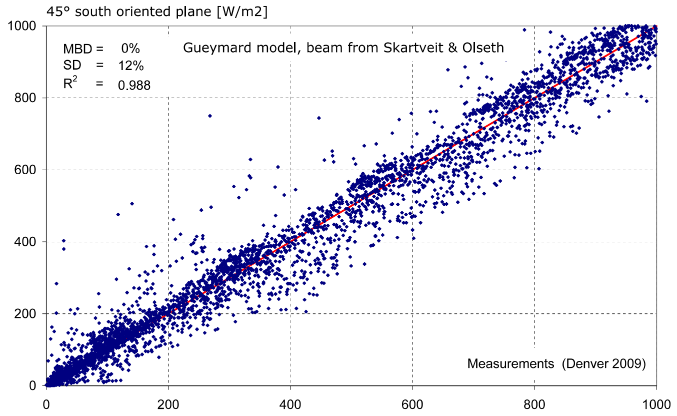

Vertical south global irradiance [W/m2]
MBD = -15%
SD = 20%
R2 = 0.981
Temp & Coulson model, beam from Skartveit &
Measurements (Denver 2009)
0 200 400 600 800 1000

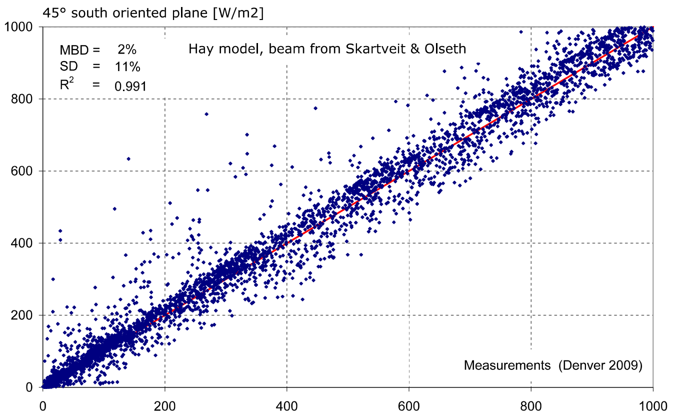

Vertical south global irradiance [W/m2]
MBD = -6%
SD = 21%
R2 = 0.980
Klucher model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

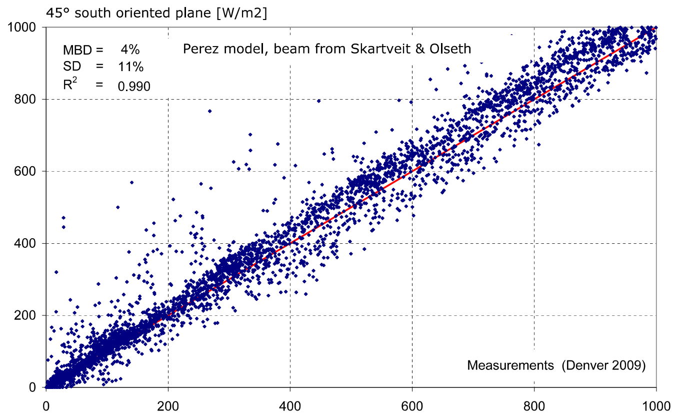

Vertical south global irradiance [W/m2]
MBD = -7%
SD = 15%
R2 = 0.989
Reindl model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

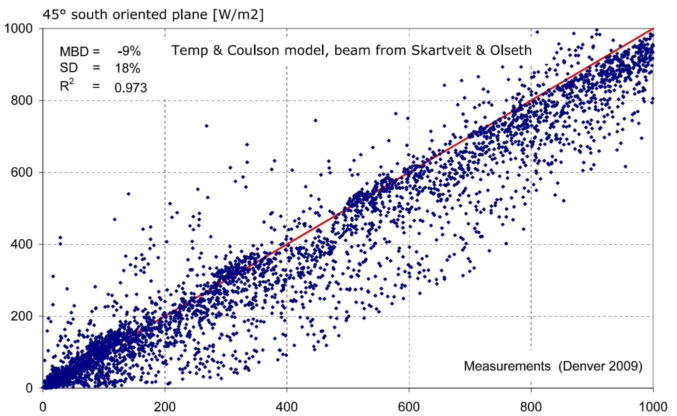

Vertical south global irradiance [W/m2]
MBD = -11%
SD = 17%
R2 = 0.986
Wilmott model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0 200 400 600 800 1000

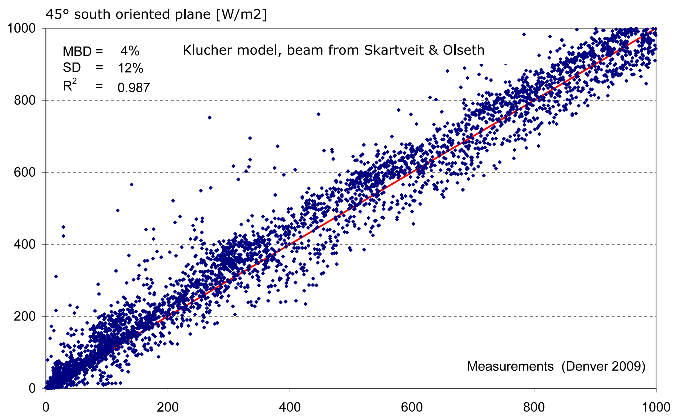

45° south oriented plane [W/m2]
MBD = -1%
SD = 13%
R^2 = 0.987
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

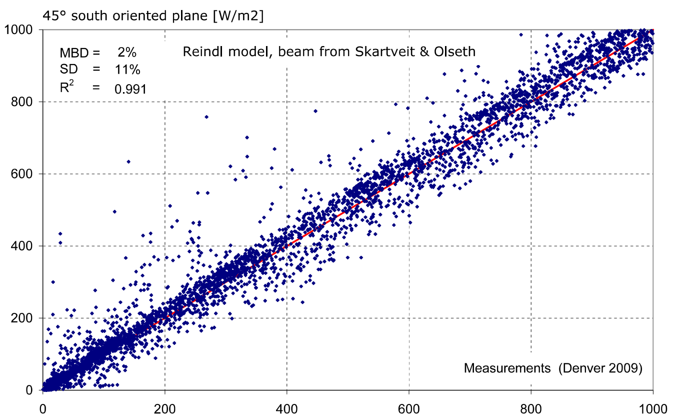

45° south oriented plane [W/m2]
MBD = 0%
SD = 12%
R^2 = 0.988
Gueymard model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

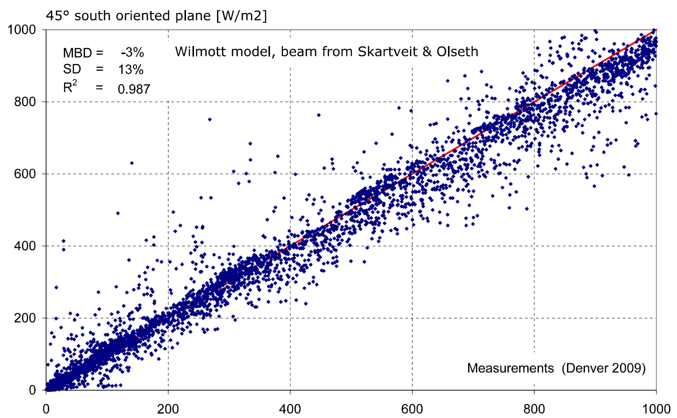

45° south oriented plane [W/m2]
MBD = 2%
SD = 11%
R^2 = 0.991
Hay model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

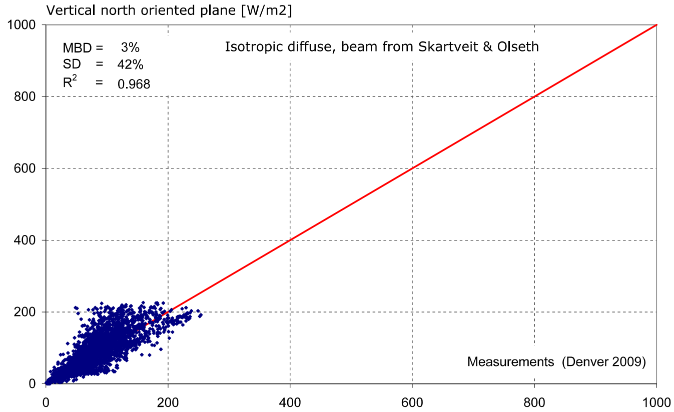

45° south oriented plane [W/m2]
MBD = 4%
SD = 11%
R^2 = 0.990
Perez model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

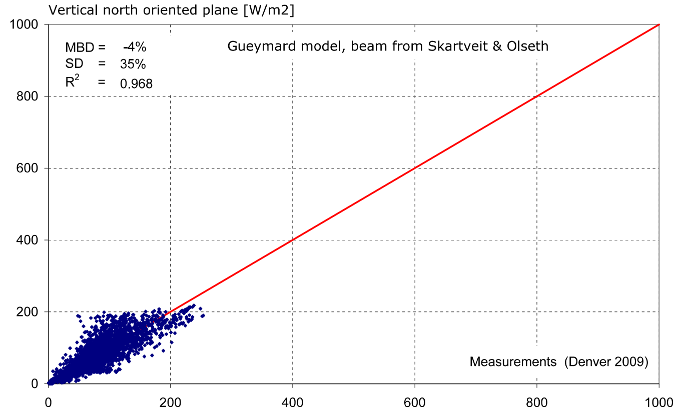

45° south oriented plane [W/m2]
MBD = -9%
SD = 18%
R^2 = 0.973
Temp & Coulson model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

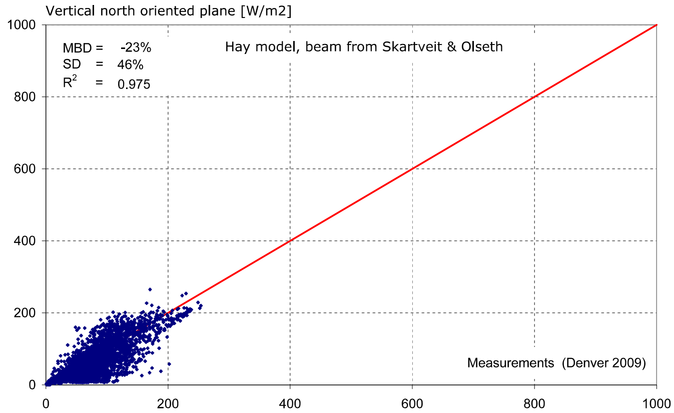

45° south oriented plane [W/m2]
MBD = 4%
SD = 12%
R^2 = 0.987
Klucher model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

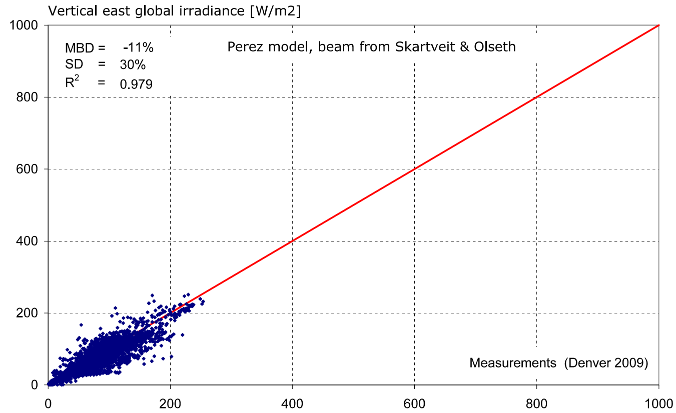

45° south oriented plane [W/m2]
MBD = 2%
SD = 11%
R^2 = 0.991
Reindl model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

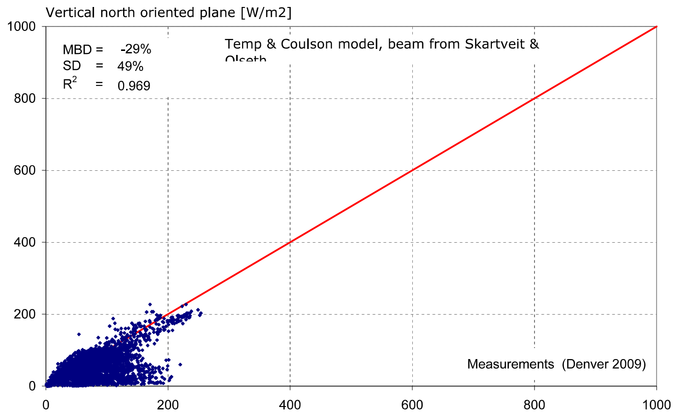

45° south oriented plane [W/m2]
MBD = -3%
SD = 13%
R^2 = 0.987
Wilmott model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

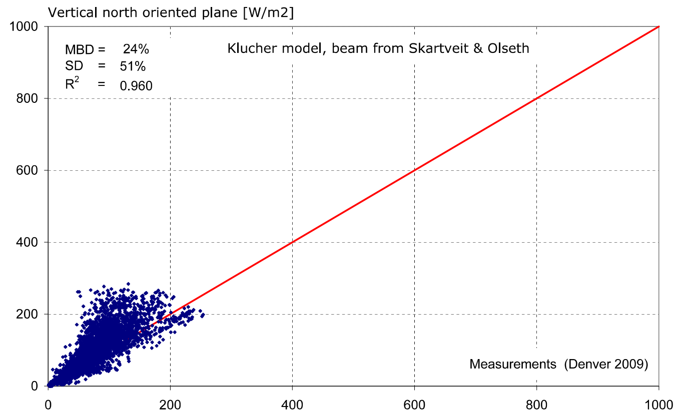

Vertical north oriented plane [W/m2]
MBD = 3%
SD = 42%
R^2 = 0.968
Isotropic diffuse, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

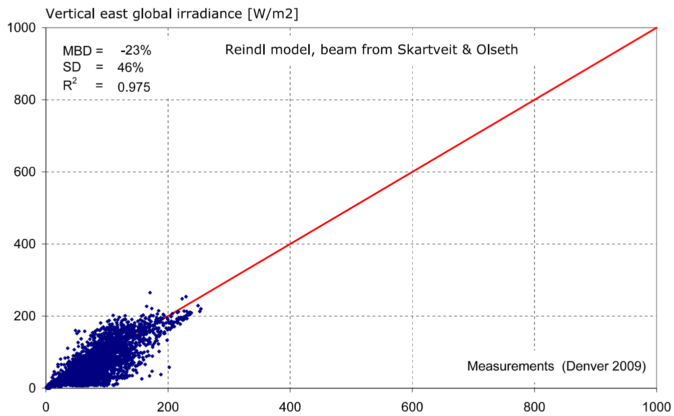

Vertical north oriented plane [W/m2]
MBD = -4%
SD = 35%
R^2 = 0.968
Gueymard model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000

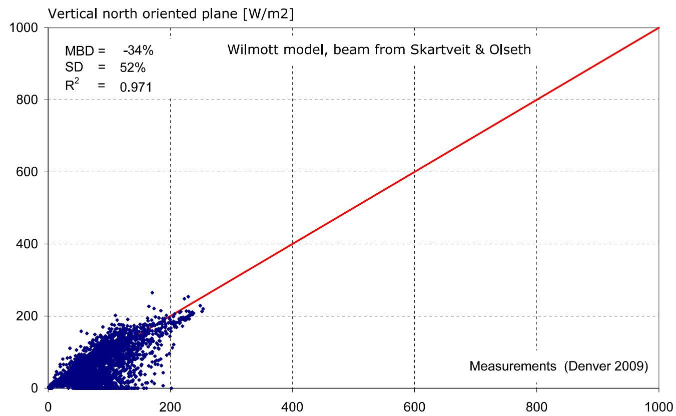

Vertical north oriented plane [W/m2]
MBD = -23%
SD = 46%
R^2 = 0.975
Hay model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = -11%
SD = 30%
R^2 = 0.979
Perez model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -29%
SD = 49%
R^2 = 0.969
Temp & Coulson model, beam from Skartveit &
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = 24%
SD = 51%
R^2 = 0.960
Klucher model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical east global irradiance [W/m2]
MBD = -23%
SD = 46%
R^2 = 0.975
Reindl model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000


Vertical north oriented plane [W/m2]
MBD = -34%
SD = 52%
R^2 = 0.971
Wilmott model, beam from Skartveit & Olseth
Measurements (Denver 2009)
0
200
400
600
800
1000