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HORIZONTAL AND VERTICAL ILLUMINANCE/IRRADIANCE FROM THE IDMP STATION IN GENEVA

by

Arvid Skartveit and Jan Asle Olseth

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1. INTRODUCTION

Most radiation-driven processes are spectrally selective, like the photosynthesis or the erythemal response of human skin to ultraviolet radiation. Equally well-known is the concept of daylight, i.e. solar radiation evaluated in proportion to its capability of stimulating the human eye. Even though daylight data are in great demand, they frequently have to be estimated from prescribed luminous efficacies and observed or estimated beam and diffuse irradiance.

The present note deals with observed and modelled relationships between irradiance and illuminance measured on horizontal and vertical surfaces.

2. DATA

2.1 Meteosat/Heliosat data

The Heliosat procedure is described by Beyer et al. (1996). A measure of cloud cover is inferred from pixel counts in the VIS-channel (0.5 - 0.9 µm), and this measure is subsequently used to estimate surface global irradiance as a fraction of the irradiance under clear sky conditions. This procedure is carried out with a choice of alternative clear sky models, viz. Heliosat Versions 2a, 2b, 2c, 2d, and 3 (Hammer 1996). Global radiation data for 3 x 5 pixels centred around the ground pixel of the station, were estimated by the Heliosat procedure from Meteosat image acquisition each half hour for the period April 1994 - March 1995. According to Ineichen (1996), clear sky values of the Heliosat Version 2b agreed reasonably with his clear sky model for Geneva, and thus only Heliosat irradiances based on Version 2b is used in this paper. Frequency distributions (Fig. 1) of hourly clear sky indices (surface observed and Heliosat Version 2b) at Geneva reveal that Heliosat Version 2b fails to reproduce the significant number of low clear sky indices in a similar manner as for 9 northern stations (Olseth & Skartveit, 1997). It appears, however, that snow cover in the urban environment of Geneva does not distort the Heliosat vs surface conformity to the same degree as seen at the rural Norwegian stations Løken and Kvithamar (Olseth & Skartveit, 1997).

2.2 Ground truth data

Surface data from the European Research class station at Geneva (46°12'N, 6°06'E, 425 m above m.s.l.; April 1994 - March 1995) were gratefully received from Pierre Ineichen at GAP-Energie, Universite de Geneve. Global and diffuse horizontal irradiances are measured by Kipp&Zonen CM11 pyranometers, while normal beam irradiance is measured by a Eppley NIP. Global illuminance and vertical illuminances (towards North, East, South, and West) are measured by PRC910GV, diffuse horizontal illuminance by a LiCor instrument , and normal beam illuminance is measured by a LiCor instrument with tube. The sensors for diffuse irradiance/illuminance are shaded with shadow rings (8 cm width, 40 cm radius). Ground reflected radiation is screened off from the vertical sensors by a black screen (honeycomb). The data used in this paper are ten minute averages (± 5 min around the hours of Meteosat data).

3. MODELS

3.1 The luminous efficacy model

The luminous efficacy model (Olseth & Skartveit, 1989) is based on the CIE curve for photopic vision and spectral irradiances obtained by an interpolation between transmittance models for, respectively, cloudless sky (Bird & Riordan, 1986) and unbroken cloud cover (Stephens et al, 1984). This interpolation decomposes the diffuse irradiance into "blue sky", "dark cloud", and "bright cloud" irradiance. For partly cloudy cases, the model was slightly tuned to hourly global illuminance and irradiance from Bergen. The parameterized version of the model requires solar elevation, day of year, and diffuse and beam clearness indices as input. In the case of beam irradiation, the model is slightly modified here to explicitly account for variation in column amount of water vapour, under the assumption that water vapour extinction takes place solely at visible wavelengths. Moreover, in the case of diffuse irradiation the model is tuned to data from Albany, NY (gratefully received from R. Perez) by multiplying the difference between "dark cloud" efficacy and extraterrestrial efficacy by a factor 0.7. The luminous efficacy model is run with theclimatological average monthly water vapour amounts (WMO, 1982).

3.2 The slope algorithm

Given horizontal beam irradiance/illuminance, the beam irradiance/illuminance on a given slope is readily computed. To calculate the diffuse slope irradiance/illuminance requires additional information about surface reflectance and the horizontal diffuse skyirradiance/illuminance and its angular distribution.

We apply our slope algorithm (Skartveit & Olseth, 1986) for diffuse irradiance even for diffuse illuminance. This algorithm assumes Lambertian ground reflectance and may account for local horizon effects. Sky radiance anisotropy for cloudless as well as overcast skies is parameterized as follows: One fraction, equal to the beam transmittance, of the horizontal diffuse irradiance is treated as circumsolar radiation (Hay, 1979). Another fraction, decreasing from 0.3 at overcast to zero at beam transmittance = 0.15, is treated as collimated radiation from the zenith. The remaining horizontal diffuse irradiance is treated as isotropic sky radiance.

4. MODELLED VERSUS OBSERVED ILLUMINANCE.

"Modelled" horizontal diffuse/beam illuminance is obtained by transforming observed horizontal diffuse/beam irradiance into illuminance by the luminous efficacy model (Olseth & Skartveit, 1989). "Modelled" vertical illuminance is obtained by first transforming observed horizontal diffuse/beam irradiance into slope irradiance using the slope algorithm (Skartveit & Olseth, 1986). This slope irradiance is subsequently transformed into slope illuminance by the luminous efficacy model (Olseth & Skartveit, 1989) under the assumption that all components of the diffuse irradiance have the same luminous efficacy as the bulk horizontal diffuse skyirradiance.

With horizontal irradiances (observed at surface) as model input there is a nice agreement between modelled and observed global illuminance, while we see a slight model surplus for horizontal beam and a similar model deficit for horizontal diffuse (Fig. 2). Both for horizontal and vertical surfaces, the scatter (model vs observed) increases substantially when the model input is changed from observed horizontal irradiances to Heliosat 2b global irradiance (Figs. 2,3).

With surface based irradiances as input, the overall average modelled vertical illuminances are lower than the observed ones (Fig. 3 left) for foreground albedo A = 0.0, while this model deficit is almost completely removed by using A = 0.1 (Fig. 4). This is also evident from Fig. 5, where frequency distributions of observed half-hourly horizontal and vertical illuminances are plotted along with corresponding distributions of "deviations" (observed - modelled). These half-hourly deviations cover a reasonably narrow range. Moreover, the increase of A from 0.0 to 0.1 significantly narrows the deviation range and yields a median deviation close to zero. Figs. 3-5 thus indicate that the horizontal foreground (honeycomb) of the vertical sensors is more close to having A = 0.1 than to being completely black (A = 0.0). In fact, this is exactly the same conclusion as that drawn from one year of data from the Swedish General class IDMP stationGävle-Brynäs (Skartveit & Olseth, 1996a).

Table 1 shows that the annual average illuminance modelled from half-hourly horizontal irradiances is 3% lower than its observed counterpart on a horizontal surface (global), while it for foreground albedo A = 0.1 is 1% lower than its observed counterpart on the average vertical surface (N-E-W-S average). Similarly, the annual average illuminance modelled from half-hourly Heliosat Version 2b irradiance is 20% higher than its observed counterpart on a horizontal surface, while it is 25% higher than its observed counterpart on the average vertical surface (A = 0.1). Moreover, the model vs observed mean bias error differs in both cases substantially more between horizontal and vertical if A = 0.0 than what is the case if A = 0.1 (Table 1). This fact again indicates that the horizontal foreground of the vertical sensors is not completely black, and that A = 0.1 is more adequate.

Finally, Fig. 5 (top right) even shows frequency distributions of observed half-hourly global, beam, and horizontal diffuse luminous efficacy, along with distributions of corresponding efficacy "deviations" (observed - modelled). By comparing with similar plots in Skartveit & Olseth (1996b), we find that the efficacy deviations at the Research class station Geneva are slightly smaller than those observed at the Research class station Garston. Garston was found to have the smallest efficacy deviations among 1 Research class and 3 General class European IDMP stations (Skartveit & Olseth, 1996b).

5. CONCLUDING REMARKS

For a horizontal surface, we find a nice conformity between observed half-hourly illuminances and illuminances modelled from corresponding horizontal irradiances. The horizontal efficacy deviations (observed - modelled) found at Geneva are the smallest seen among 2 Research class and 3 General class European IDMP stations. For vertical surfaces, we find a similarly nice conformity, provided the foreground of the vertical sensors are assumed to have a non-black albedo of 0.1.

When the model input is changed from observed horizontal irradiances to Heliosat 2b global irradiance, the scatter (model vs observed) increases substantially and the mean bias error increases to some 20 - 30% for both horizontal and vertical surfaces.

6. REFERENCES

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Table 1 Annual average observed (Obs) illuminances on horizontal (Global), and on north (N90°), east (E90°), west (W90°), south (S90°), and average (All) vertical surfaces at Geneva. Mod_{surf} is the annual average modelled from half-hourly global and diffuse irradiances, while $Mod_{Heliosat}$ is the average modelled from half-hourly Heliosat 2b irradiances. The ratios Mod_{xx}/Obs are calculated for foreground (horizontal) albedo A = 0.0 and A = 0.1.

		Mod_{surf} / Obs		**$Mod_{Heliosat}$ / Obs**	
Target	**Obs (klux)**	**A = 0.0**	**A = 0.1**	**A = 0.0**	**A = 0.1**
N90°	7.2	0.82	1.06	1.00	1.29
E90°	13.6	0.83	0.96	1.13	1.28
W90°	15.2	0.85	0.96	1.06	1.20
S90°	21.9	0.89	0.97	1.13	1.23
All vertical	14.5	0.85	0.99	1.08	1.25
Global	31.8	0.97	0.97	1.20	1.20

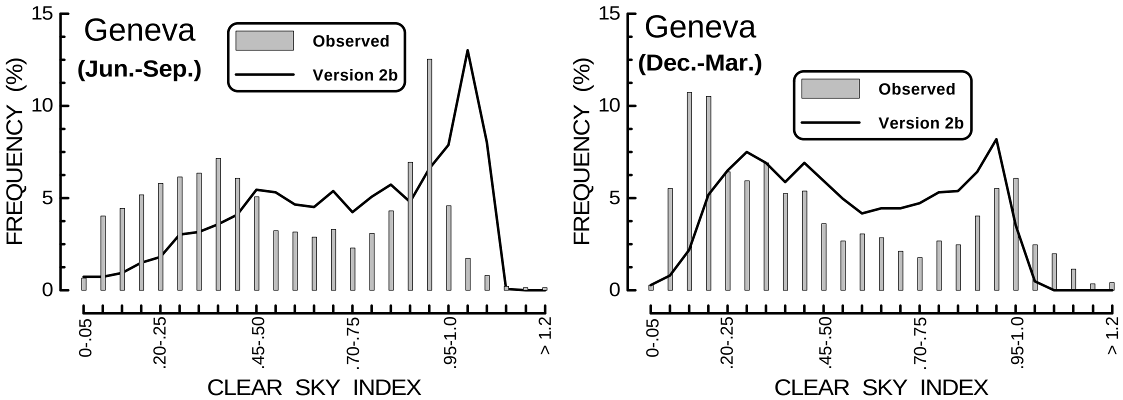

Fig. 1 Frequency distriubutions of observed surface based and Heliosat Version 2b half-hourly clear sky indices (observed irradiance/modelled clear skyirradiance).

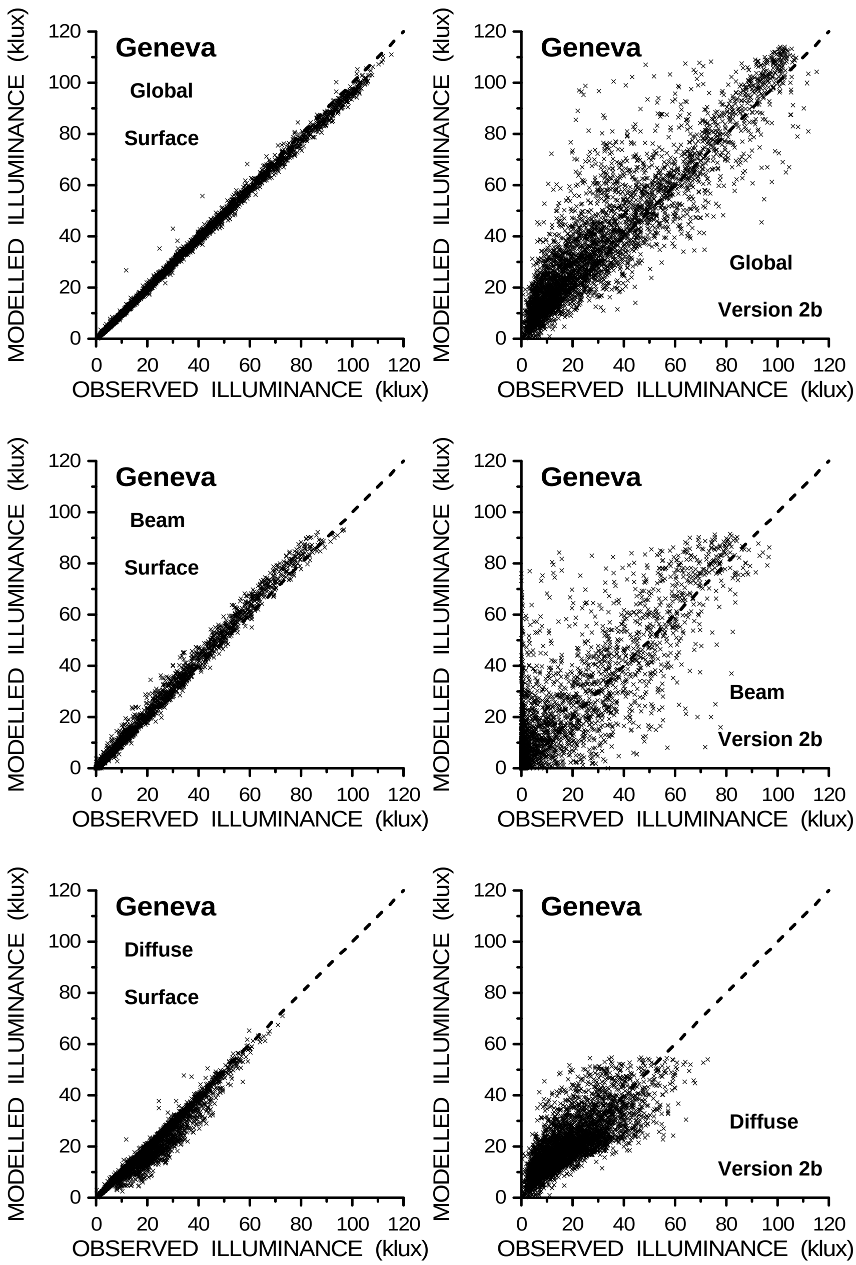

Fig. 2 Observed vs modelled half-hourly global, beam, and diffuse horizontal illuminances. Illuminances modelled from observed (surface) horizontal irradiances to the left and from Heliosat Version 2b irradiances to the right.

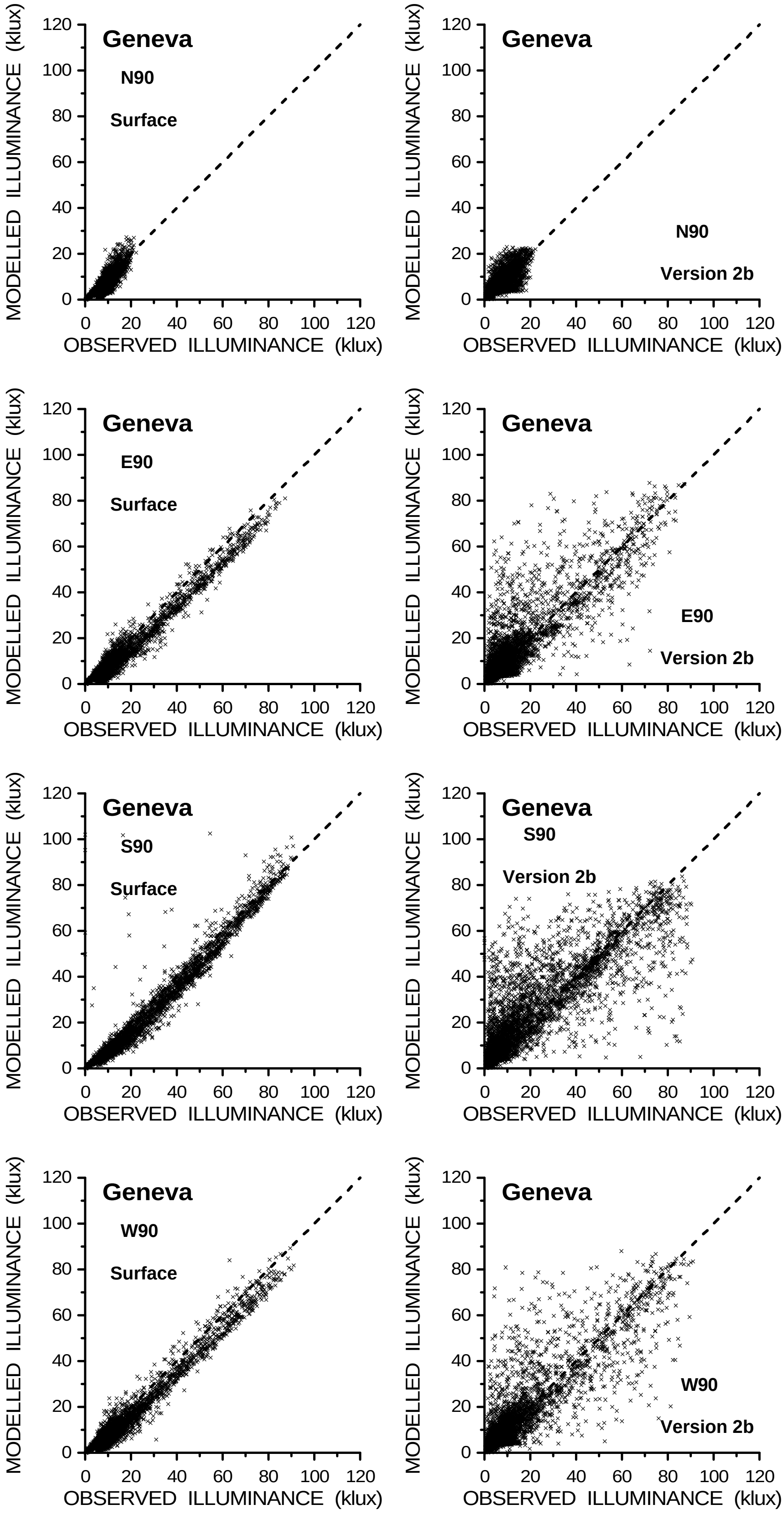

Fig. 3 Same as Fig. 2, but for vertical surfaces facing north (N90), east (E90), south (S90), and west (W90). Modelled values are estimated using foreground albedo A = 0.0.

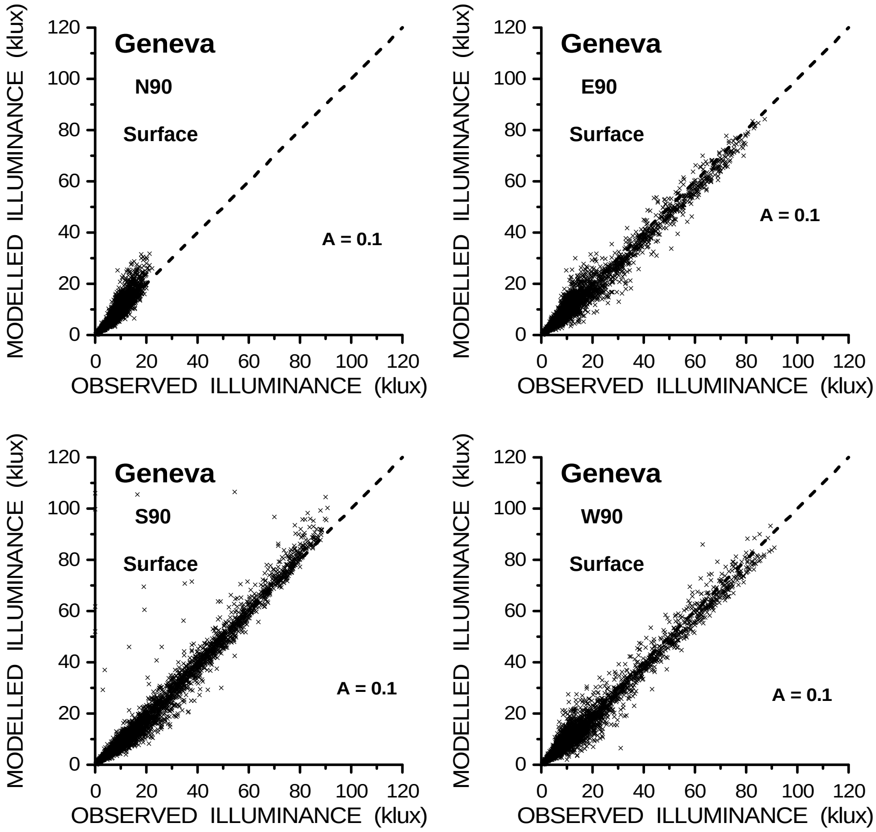

Fig. 4 Same as Fig. 3 (left side), but for vertical surfaces facing north (N90), east (E90), south (S90), and west (W90). Modelled values are estimated using foreground albedo A = 0.1.

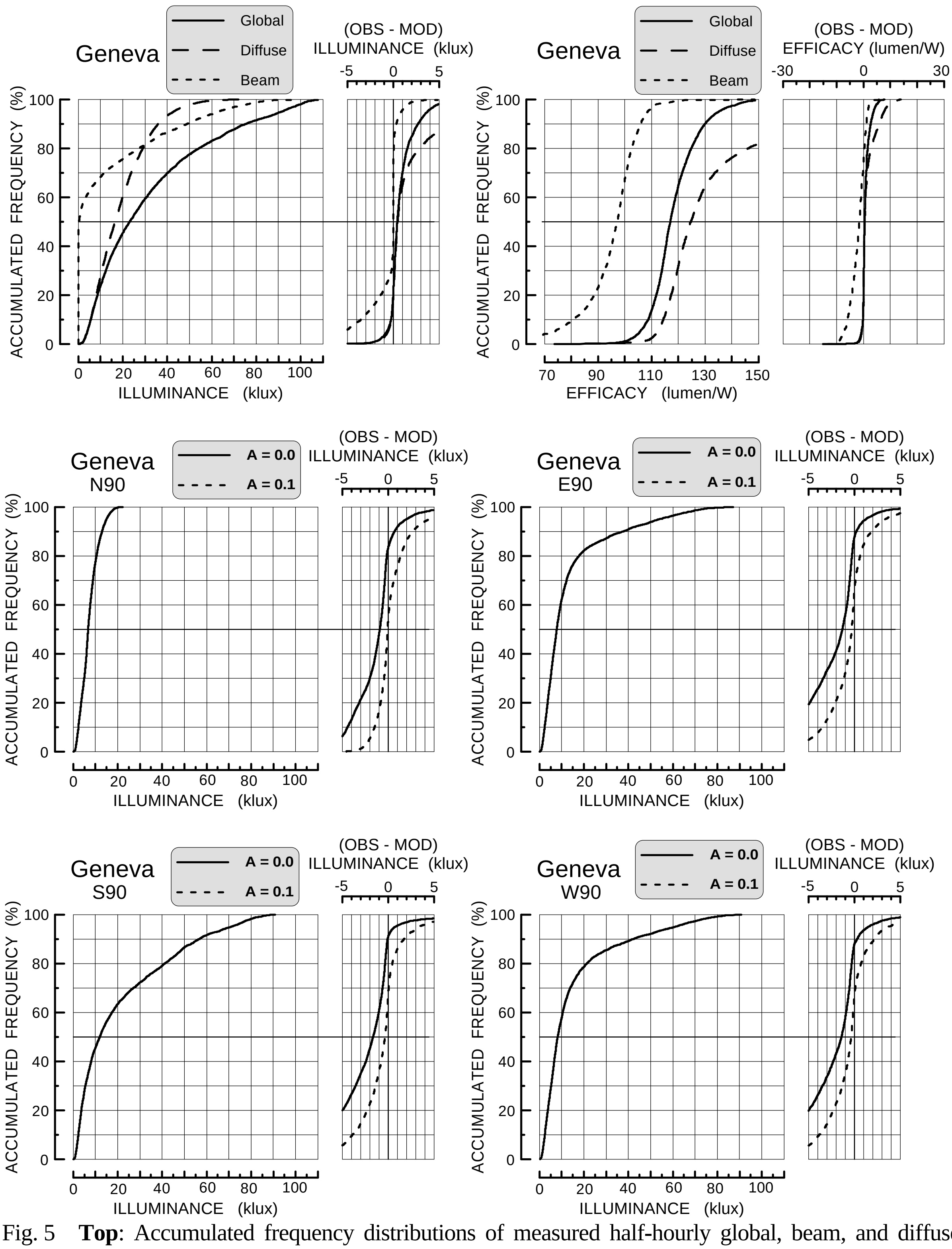

Fig. 5 **Top**: Accumulated frequency distributions of measured half-hourly global, beam, and diffuse horizontal illuminances (left) and luminous efficacies (right), together with distributions of "deviations" (observed - modelled) relative to illuminances/luminous efficacies modelled from horizontal irradiances.

Bottom: Corresponding distributions of illuminances on north (N90), east (E90), south (S90), and west (W90) verticals, with "deviation" distributions plotted for two values of foreground albedo A.