The importance of software's and weather file's choice in dynamic daylight simulations

Laura Bellia – Department of Industrial Engineering, University of Naples Federico II – laura.bellia@unina.it
Alessia Pedace – Department of Energy, Information Engineering and Mathematical Models, University of Palermo; Department of Industrial Engineering, University of Naples Federico II – alessia.pedace@unipa.it
Francesca Fragliasso – Department of Industrial Engineering, University of Naples Federico II – francesca.fragliasso@unina.it

Abstract

The prediction of daylight availability in indoor environments is nowadays an extremely relevant topic in the design practice for many reasons: it affects the design of the electric lighting system and therefore the calculation of the related energy consumption; it also has an impact on evaluation of comfort. Dynamic daylight simulations are a helpful tool to predict daylight availability in indoor environments and consequently to evaluate the possible reduction in energy consumptions. However, there are different software packages that perform dynamic daylight simulations and they use different engines and calculation methods which may be a source of differences in the results. Moreover this type of analysis requires a weather data file of the building's location to be performed. Since there are many of them available, which are developed from historical sets of weather measurements using different methods, the use of one or another can affect the simulations' results. Therefore in this paper an example of the impact on dynamic daylight simulations' results of different weather data files (IWEC, Meteonorm, TRY and Satel-Light) and different software (Daysim and 3ds Max Design®) will be reported.

1. Introduction

The reduction of energy consumption is an extremely important topic in the field of building design. Lighting design is also involved in the pursuit of this goal since, by maximizing the use of daylight (while avoiding overheating and glare), the use of electric light is reduced as well as the heating and cooling loads.

Software simulations are an extremely helpful tool to evaluate the energy consumption of different design options but daylight simulations present a series of problems.

The first problem concerns the approach to daylight simulations: static or dynamic. The static approach is based on the calculation of the daylight factor (DF) (Waldram, 1950; Moon & Spencer, 1942) and it has been criticized over the years.

The dynamic approach is based on dynamic daylight simulations and dynamic daylight metrics: Daylight Autonomy (DA) (Reinhart & Walkenhorst, 2001), Continuous Daylight Autonomy (DAcon) (Rogers, 2006), Useful Daylight Illuminances (UDI) (Nabil & Mardaljevic, 2005 and 2006). This approach allows us to better analyze daylight availability (Mardaljevic et al., 2009). Moreover the use of these metrics is recommended by some new laws and green building rating systems. In particular the IESNA introduced the use of Spatial Daylight Autonomy (sDA) and Annual Sunlight Exposure (ASE) (IES LM-83-12, 2013), and the USGBC set them as

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evaluation parameters in the LEED protocol (USGBC, 2014).

There are different software packages that allow us to perform dynamic daylight simulations and they use different engines and calculation methods. Therefore the use of one software or another may affect the results.

Moreover calculation software needs a weather data file referring to the environment's location to perform the simulation. For a given location, different files may be available and final results obviously depend on the weather data used as input. The effects of the use of different weather data files referred to the same location on daylight simulation results have not been widely studied (Iversen et al., 2013).

Given these principles, the goal of this paper is on one hand to investigate differences in simulation results provided by different software and, on the other hand, to compare final results obtained by using the same software but different weather data file.

The simulations were carried out modelling a simple environment with a south-facing window and located in Rome (Italy). The comparison between software was carried out using Daysim and 3ds Max Design®. The choice of the latter software was made because, contrary to Daysim, it has not been widely studied and so far only one research project on it has been carried out (Reinhart & Breton, 2009). For these simulations IWEC data file was used.

For the analysis of differences in simulation results obtained with different weather files, the simulations were performed using only Daysim software and four different weather files: IWEC, Meteonorm, Satel-Light and TRY.

2. Simulations

2.1 Method

The geometric characteristics of the room and the analysis grid (3m x 3m) can be seen in Figure 1.

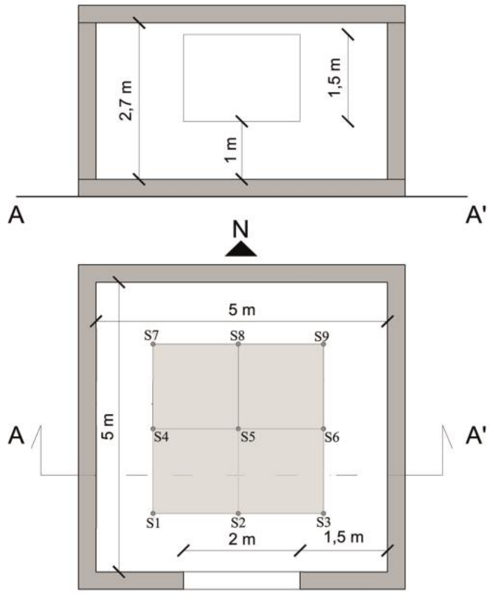

Fig. 1 – Model's measured plan and section

The room has only a south-oriented window with a double pane glazing (4-16-4 mm), characterized by a visual transmission equal to 82%.

The reflectances of the internal surfaces in the modelled environment are the following: walls 65%; floor 30%; ceiling 80%. A ground plane (45 x 45 m) was also modelled with a 20% reflectance.

300 lux is the target illuminance considered on the workplane (EN 12464-1 Light and Lighting of work places - Part I: Indoor work places, 2011). Annual daylight simulations were carried out considering an occupancy schedule that goes from Monday to Friday from 8:00 to 16:00 without breaks; Daylight Saving Time goes from April 1st to October 31st.

2.2 Software information

Daysim is one of the most widespread and studied software for dynamic daylight simulations and, like the majority of this type of software, it is based on the Radiance simulation engine. The simulation parameters are seen in Table 1.

Table 1 – Daysim simulation parameters

Parameter	Value
Ambient bounces	7
Ambient divisions	1500
Ambient super samples	100
Ambient resolution	300
Ambient accuracy	0.05
Limit reflection	6
Specular threshold	0.1500
Specular jitter	1.0000
Limit weight	0.004000
Direct jitter	0.0000
Direct sampling	0.200
Direct relays	2
Direct pretest density	512

3ds Max Design® is not based on Radiance but on the Exposure® technology and, starting from its 2009 release, it includes the possibility of performing static and dynamic daylight simulations. The simulation parameters referred to 3ds Max Design® can be seen in Table 2.

Table 2 – 3ds Max Design® simulation parameters

Render Dialog Rollout	Section	Parameter
Rendering Algorithms	Scanline	Off
Rendering Algorithms	Raytracing	On Max Trace Depth, Reflections, Refractions : 10
Shadows & Displacement	Shadows	On Mode: Simple
Final Gather	Advanced	Noise Filtering: None Max Depth, Reflections, Refractions: 10 Use Falloff (Limit Ray Distance): Off
Final Gather	FG Point Interpolation	Use Radius Interpolation Method: Off
Caustics & Global Illumination	Caustics	Off
Caustics & Global Illumination	Global Illumination	Off

2.3 Weather data files information

To carry out this study, four weather data files were selected: IWEC, Meteonorm, TRY and Satel-Light. Generally, weather data files represent a typical year, which includes 8760 hourly data that provide typical meteorological characteristics of a given location. These hourly data are deduced from historical sets of annual weather measurements (at least 20 years) using different statistical calculation processes. This is the case of IWEC, Meteonorm and TRY weather data files.
IWEC files are freely available online (U.S. Department of Energy, Energy Efficiency & Renewable Energy) and were developed by ASHRAE (ASHRAE, 2001); these weather data files

are built selecting the most representative months from up to 18 years of data using a statistical method.

Meteonorm weather files can be bought online (Meteonorm) and are generated from data obtained by meteorological stations using a stochastic model to build a typical year.

The European Test Reference Years were developed under contract of the Commission of the European Communities in Brussels. A TRY file is built from a true sequence of 12 months of measured weather data (CEC, 1985) using a statistical method named "Belgian".

A separate discussion has to be had for Satel-Light. This database was funded by the European Union to generate a European solar radiation database based on data measured by Meteosat satellites. At the present time it only includes the years from 1996 to 2000, so it is not possible to derive a typical year.

Nonetheless comparing the results obtained using Satel-Light with those achieved using the other weather files can give interesting insights about if and how a typical year differs from a real one. Therefore to perform this study the year 1998 was chosen from the Satel-Light database to build a weather file to use as input in the simulation software, for the other weather data files (IWEC, TRY and Meteonorm) the available files for Rome were used.

3. Discussion and results analysis

Both the comparison between the results obtained from the different weather data files and that obtained with the two software packages were carried out referring only to sensors S2, S5 and S8 (see Figure 1). Moreover in some of the graphs reported in this section, the following abbreviations will be used: I for IWEC file, M for Meteonorm, T for TRY, S for Satel-Light, 3ds for 3ds Max Design® and D for Daysim, $E_{glob\text{-}3ds}$ and $E_{glob\text{-}D}$ for global illuminances referred respectively to 3ds Max Design® and Daysim, $E_{dir\text{-}3ds}$ and $E_{dir\text{-}D}$ for direct illuminances referred respectively to 3ds Max Design® and Daysim.

3.1 Software comparison

The analysis of the results obtained using the two software was carried out by comparing them in terms of global and direct components of daylight (since the diffuse component can be obtained as a difference of these two) and dynamic daylight metrics (UDI).

Figure 2 shows cumulative frequency for which the percentage ratio $|E_{glob\text{-}3ds}-E_{glob\text{-}D}|/E_{glob\text{-}3ds}$ is lesser or equal to certain values on the x axis.

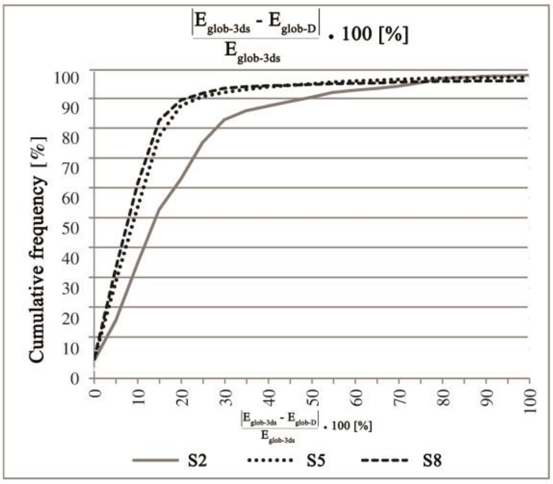

Fig. 2 – $|E_{glob\text{-}3ds} - E_{glob\text{-}D}| / E_{glob3ds} \cdot 100$ calculated for each sensor

It can be observed that S5's and S8's trends are quite similar whereas S2's trend differs. For S5 and S8m, differences are lower than 20% for 90% of the year whereas for S2 only for 60% of the year. This may depend on a different calculation of the direct component of daylight since S2 is the sensor closest to the window and therefore the contribution of direct daylight is more significant.

Figure 3 shows the annual frequencies for which only Daysim, only 3ds Max Design® or both softwares calculate the presence of the direct component of daylight.

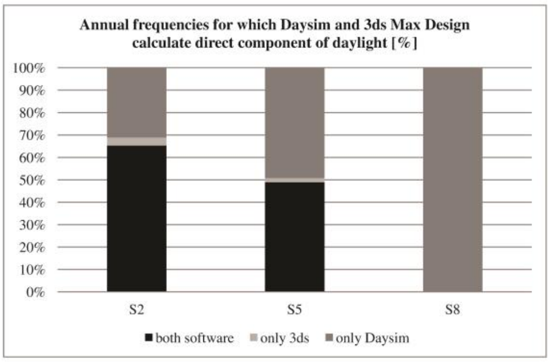

Fig. 3 – Annual frequencies for which Daysim and 3ds Max Design calculate direct component of daylight

It is interesting to highlight that the percentage of the year during which only 3ds Max Design calculates the presence of the direct component of daylight is small and for S8 is even equal to zero and only Daysim calculates the presence of the direct component of daylight.

For S2 during the greater part of the year both softwares predict the presence of direct daylight whereas for S5 only Daysim calculates it for the majority of times. To further analyze differences in direct daylight calculation, Figure 4 was developed. It shows the cumulative frequencies for which the percentage ratio $|E_{dir-3ds}-E_{dir-D}|/E_{dir-3ds}$ is less or equal to the values on the x axis.

These cumulative frequencies were calculated considering only the hours during which both softwares calculate the presence of the direct component of daylight. For this reason in the graphs there are only the curves related to S2 and S5 since, as was demonstrated in Figure 3, for S8 only Daysim calculates the presence of direct daylight.

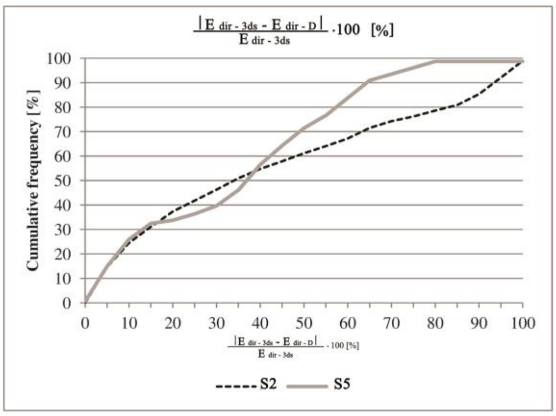

Fig. 4 – $|E_{dir-3ds} - E_{dir-D}| / E_{dir3ds} \cdot 100$ calculated for each sensor

The trends related to the two sensors vary considerably and if a percentage difference equal to 30% is taken as a reference, the corresponding cumulative frequency is about 38% for S5 and about 48% for S2.

Figure 5 shows UDI values calculated for each sensor and software. As for the weather file comparison, it was decided to divide UDI in four steps.

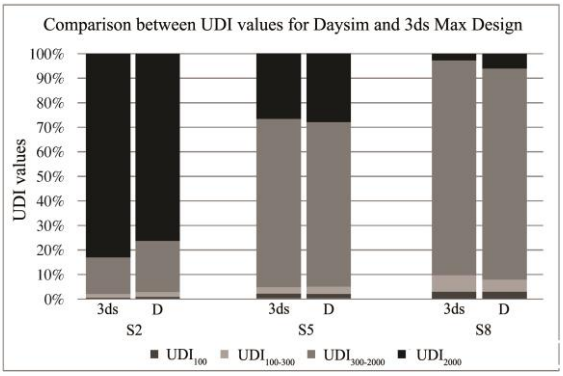

Fig. 5 – UDI values calculated with each software

It is interesting to notice that the greatest differences between the two softwares can be found between UDI_{2000} values.

For S2 (the sensor closest to the window) 3ds Max Design® calculates values higher than Daysim ones whereas for S8 (the sensor farthest from the window) the opposite is true. However, in all the cases the differences are quite limited.

3.2 Weather data files comparison

The comparison between the results obtained with the different data files was carried out by analyzing global and diffuse irradiances, Annual and Monthly Light Exposures and UDI.

Figure 6 and 7 show, for each weather data file, cumulative frequency curves referred to global and diffuse irradiances.

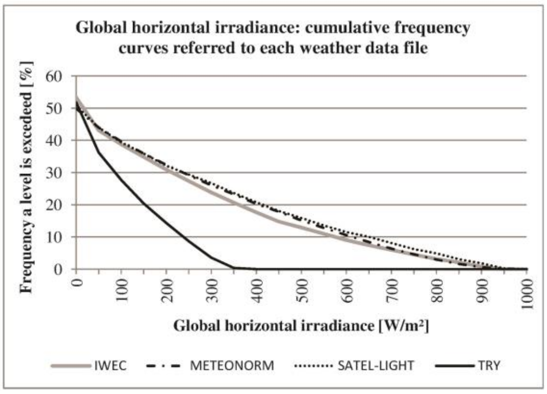

Fig. 6 – Cumulative frequency curves for global horizontal irradiance

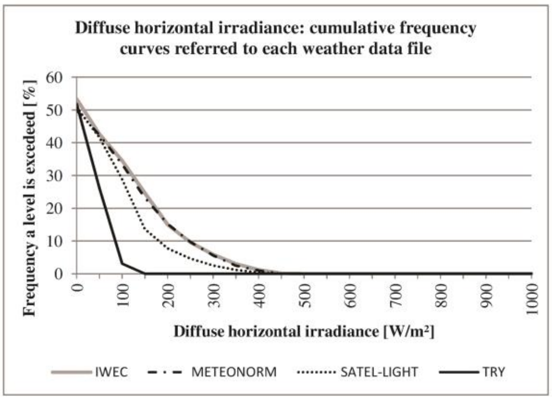

Fig. 7 – Cumulative frequency curves for diffuse horizontal irradiance

What is interesting to notice is that TRY weather files always show values considerably lower than those referred to the other files. IWEC and Meteonorm show almost coincident diffuse irradiance's trends whereas for global irradiance there is more difference. However, it has to be pointed out that IWEC, Meteonorm and Satel-Light have really close trends.

Figure 8 shows Annual Light Exposures calculated for each weather file and sensor.

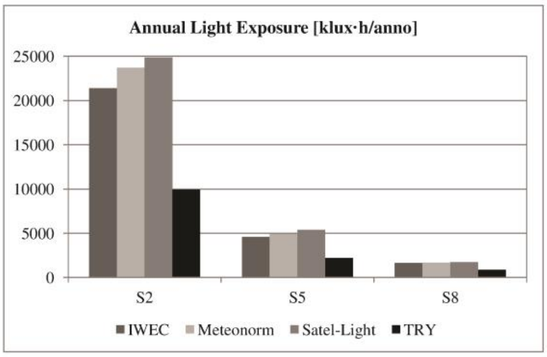

Fig. 8 – Annual Light Exposures for each weather file and sensor

Again, it can be noted that TRY values are remarkably lower than those related to the other weather files. It is also interesting to highlight that Annual Light Exposures calculated for Meteonorm and Satel-Light are almost coincident for all the sensors while IWEC's values are always a little lower.

Figures 9a,b,c show Monthly Light Exposures calculated for each sensor and weather data file.

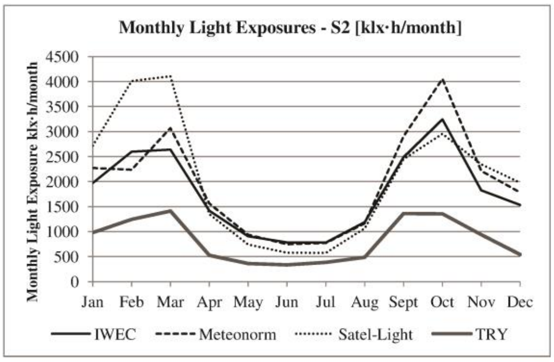

Fig. 9a – Monthly Light Exposure for S2

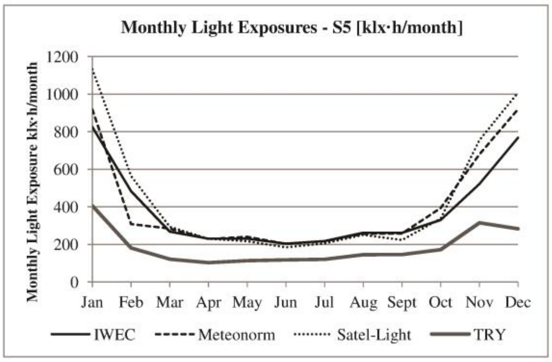

Fig. 9b – Monthly Light Exposure for S5

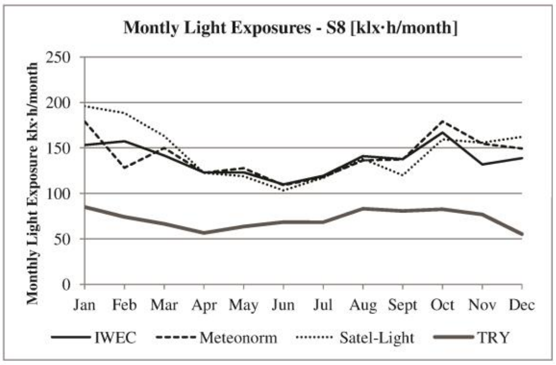

Fig. 9c – Monthly Light Exposure for S8

It is interesting to observe that the trends remain similar for the sensors farthest from the window and that only the order of magnitude varies.

In more detail, TRY again shows the lowest values and IWEC, Meteonorm and Satel-Light ones are very close from March to September. During the other months, differences increase and reach their maximum values in December and January.

Figure 10 shows the comparison between UDI values calculated for each sensor and weather data file. UDI were divided in four steps: E (illuminance) <100, 100<E<300, 300<E<2000, E>2000. This choice was made in order to perform a more detailed analysis of daylight variation inside the room.

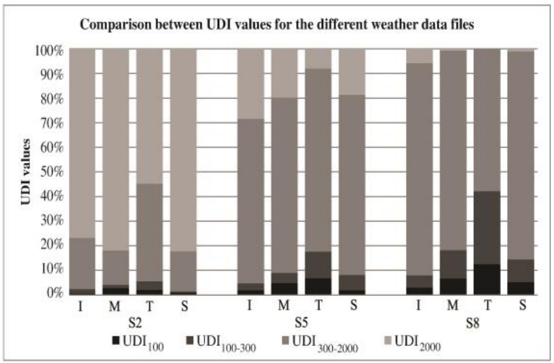

Fig. 10 – UDI values calculated with the different weather data files

One of the most evident findings is that the use of TRY determines results that are very different from those obtained with the other weather data files. In more detail, the greatest differences are observed for $UDI_{100-300}$ for which TRY always calculates values considerably higher than those related to the other weather data files.

With regard to IWEC, Meteonorm and Satel-Light weather files, differences are more limited. It is interesting to notice that Meteonorm always determines UDI_{100} values slightly higher than IWEC and Satel-Light ones; moreover, Meteonorm and Satel-Light determine almost coincident $UDI_{300-2000}$ values.

4. Conclusion

From the results reported in the previous sections, it can be stated that for the examined case the use of IWEC, Meteonorm and Satel-Light weather files determines results with small differences. The same conclusion does not apply to TRY weather file, which always shows results considerably lower than those obtained using the other weather files.

The analysis of differences in simulation results obtained with Daysim and 3ds Max Design® highlighted that these differences vary much depending on a sensor's position.

In more detail, the greatest differences are found for the sensors located in positions where the contribution of direct daylight is more significant. Indeed, it was found that generally Daysim calculates the presence of the direct component of daylight for a greater number of hours compared to 3ds Max Design®.

However, it is important to highlight that when analyzing UDI values, differences are reduced both in the case of software and weather data file comparison.

Differences in results can affect both the prevision of energy savings due to daylight and the evaluation of visual discomfort, consequently a progression of this research project would be beneficial

Further investigation into the two topics should include the analysis of other locations, exposures and weather data files as well as comparisons between the results obtained from the simulations and field measurements.

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