Additional features of the RayMan model

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Abstract

The RayMan model, developed for the calculation of the mean radiation temperature and thermal indices in simple and complex environments, is based only on data of air temperature, air humidity and wind speed. The relevant radiation fluxes (short and long wave) are calculated by using existing or non global radiation in different ways and the modification of them by the obstacles (natural or artificial). Additional features build the calculation of sunshine duration, shade and global radiation for simple and complex environments. The calculation of the energy fluxes of the human body and relevant body parameters is also included.

Key words: RayMan, shade, sky view factor, urban structures

1. INTRODUCTION

The RayMan model, developed for the calculation of the mean radiation temperature and thermal indices in simple and complex environments, is only based on data of air temperature, air humidity and wind speed (Matzarakis et al., 2007, VDI, 1998). RayMan can be used for the assessment of urban bioclimate and thermal indices such as Predicted Mean Vote (PMV), Physiologically Equivalent Temperature (PET) and Standard Effective Temperature (SET*). The model is developed based on the German VDI-Guidelines 3789, Part II: Environmental Meteorology, Interactions between Atmosphere and Surfaces; Calculation of the short- and long wave radiation and VDI-3787: Environmental Meteorology, Methods for the human-biometeorological evaluation of climate and air quality for the urban and regional planning at regional level. Part I: Climate.

The relevant radiation fluxes (short and long wave) are calculated by using existing or non global radiation in different ways and the modification of them by the obstacles (natural or artificial). For this reason the input of the environmental morphological properties is of importance and is required for the calculation of the mean radiant temperature. The calculation of the global radiation or, in general, of the short wave radiation fluxes also delivers some additional information being quite of importance for urban climate studies. These are the calculation of the sky view factors based on fish eye pictures, free drawing of the solid elements in the hemispherical view, input of the geometrical dimensions of the buildings and trees. These factors can be also used for other urban climate studies as example for shade quantification or information about the effects of different trees and urban structures on the sunshine duration.

2. METHODS

The RayMan model, which has been developed for urban climate studies, has a broader application spectrum, e.g. urban and tourism climatology (Matzarakis and Rutz, 2005). Further outputs as sunshine duration and shadow can be helpful in the design and urban structures and parks. An additional feature is the sky view factor and it is not only of importance for the radiation fluxes but also for the wind field. Another possibility is based on the maximum sunshine duration (based on theoretical calculations) to detect the time of the day and of the year where the sunshine duration is influenced of the solid elements of the surroundings (topography, urban structures and urban vegetation). This also leads to the calculation of shade in different environments in temporal and spatial terms. Daily values of sunshine duration and global radiation can be also calculated for different cloud cover and morphological elements.

Horizon information (in particularly Sky View Factor) needs to be known to obtain sun paths (Fig. 3 left). Calculation of hourly, daily and monthly averages of sunshine duration, short and long wave radiation fluxes with and without topography and obstacles in urban structures can be carried out by *RayMan* (Fig. 3 left). Data can be entered through manual input of meteorological data or pre-existing files. The output is given in form of graphs and text data (Fig. 2 right, Fig. 3 left and right).

3. RESULTS AND EXAMPLES

The following examples have been selected as additional features of RayMan:

- Calculation of sun paths and sky view factor in a complex urban structure,
- Detailed calculation of shade in complex urban structure,
- Monthly calculation of sunshine duration for a complex urban environment,
- Detailed calculation for thermal comfort and human energy fluxes based on the **M**unich **E**nergy Balance **M**odel for **I**ndividuals (MEMI).

Sun paths and sky view factor

Fig. 1 shows a specific configuration in urban structures with dense buildings and trees (Fig. 1 left side). The right side of the Fig. 1 shows the sun path (for the centre of the left configuration) for the 21st June for a location with a latitude of 7°45' and longitude 48°31' and with a calculated sky view factor of 0.245.

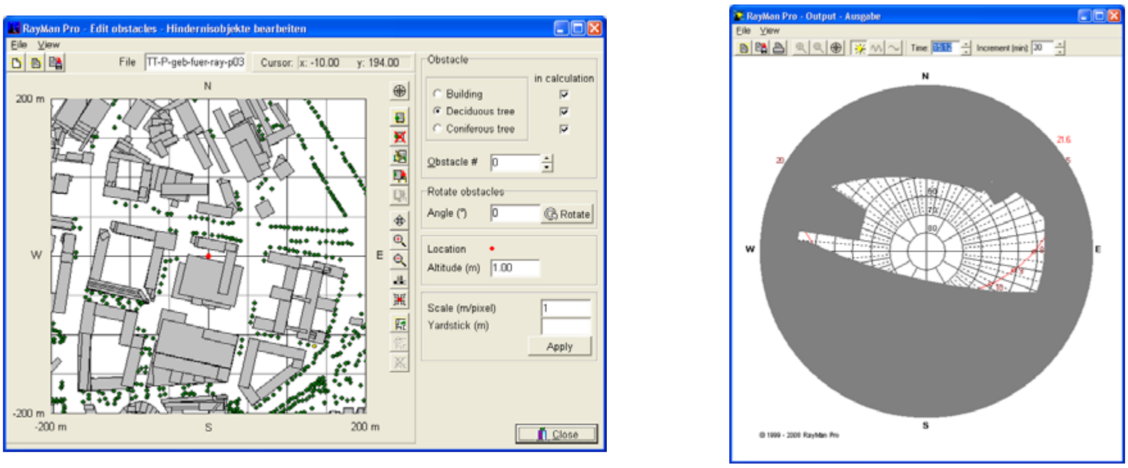

Fig. 1: Sun paths for 21 June in Freiburg (right) for an urban configuration of structures (left).

Shade in complex structures

The shade condition for the same configuration and location of Fig. 1 for 10 CET and 15 CET are shown in Figure 2. RayMan offers the possibility to change directly the location of the input configuration of the urban structure in order to have other point in the urban structures.

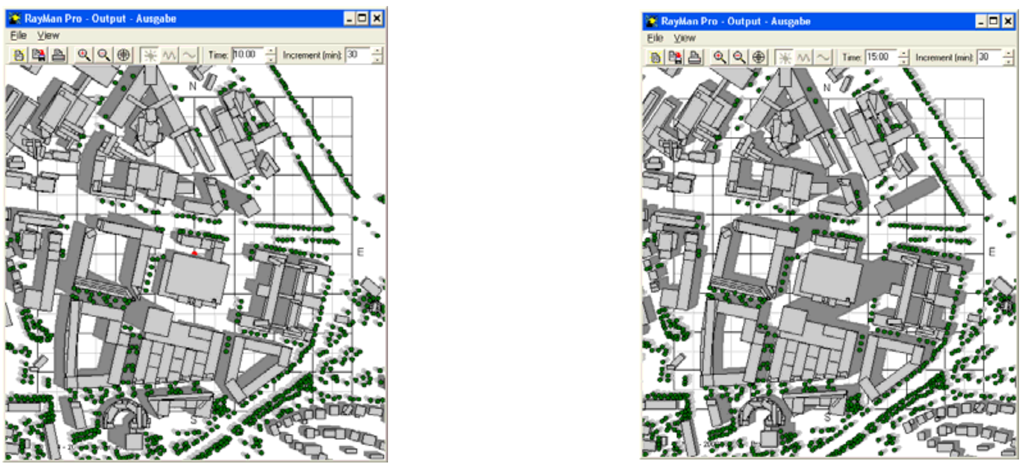

Fig. 2: Shade areas for 21 June in Freiburg (10 CET, left and 15 CET, right).

The day of the year and the time resolution can be changed in a very easy way in order to follow (like an animation) the changes of the shadow areas of the specific urban configurations.

Mean sunshine duration for urban structures

Important for thermal comfort is the radiation or shade in specific areas in cities. Both obstacles types (buildings and trees) provide shadow and influence thermal comfort conditions in parks and urban structures in a positive or negative way. Usually, it depends during the year what kind of trees are available (deciduous or needle trees). RayMan offers the possibility for calculating the sunshine duration for any urban structure and their modification for every day of the year.

RayMan Pro © 1999 - 2008
Meteorological Institute, University of Freiburg, Germany
place: 1_Enzheim
geogr. longitude: 7°45' latitude: 48°31' timezone: UTC +1.0 h
horizon limitation: 75.5% sky view factor: 0.245

date d.m.yyyy	day of year	sunr. h:mm	sunset h:mm	SDmax min	SDact min	GmaxMax W/m²	GactMax W/m²	GmaxSum Wh/m²	GactSum Wh/m²	GmaxAvr W/m²	GactAvr W/m²
1.1.2009	1	8:21	16:44	503	14	376.0	78.3	2008.4	418.1	83.7	17.4
2.1.2009	2	8:21	16:45	504	13	377.7	78.6	2021.4	420.8	84.2	17.5
3.1.2009	3	8:20	16:46	505	11	379.5	79.0	2035.6	423.8	84.8	17.7
4.1.2009	4	8:20	16:47	506	9	381.5	79.4	2051.0	427.0	85.5	17.8
5.1.2009	5	8:20	16:48	508	10	383.6	79.9	2067.4	430.4	86.1	17.9
6.1.2009	6	8:20	16:49	509	10	385.9	80.3	2085.0	434.0	86.9	18.1
7.1.2009	7	8:20	16:50	510	11	388.3	80.8	2103.6	437.9	87.7	18.2
8.1.2009	8	8:19	16:51	512	9	390.8	81.3	2123.4	442.0	88.5	18.4
9.1.2009	9	8:19	16:52	514	12	393.5	81.9	2144.7	446.6	89.4	18.6
10.1.2009	10	8:18	16:54	515	11	396.3	82.5	2167.4	451.1	90.3	18.8
11.1.2009	11	8:18	16:55	517	12	399.2	83.1	2191.1	456.0	91.3	19.0
12.1.2009	12	8:17	16:56	519	11	402.3	83.7	2216.0	461.1	92.3	19.2

Fig. 3: Output for daily calculation of sunrise, sunset, maximum sunshine duration without any horizon, sunshine duration for the urban configuration of Fig. 1 and the additional global radiation values for the specific location.

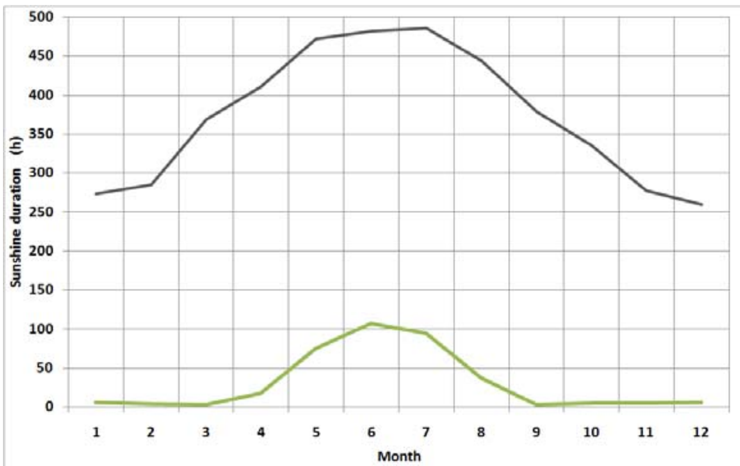

Fig. 4. Mean monthly sunshine duration in hours with and without urban configuration (Fig. 1).

Fig. 3 shows the beginning of the daily calculations output file and calculated parameters. In Fig. 4 the mean monthly sunshine duration for the urban configuration of Fig. 1 is shown. The two graphs show the annual pattern for the area without obstacles and with obstacles. It can be shown that specific configuration only gain in the summer period direct sunshine in the level of 20 % of the maximum possible.

Human energy balance calculation

Fig. 5 shows the human energy balance calculation for the energy fluxes and the related parameters i.e. meteorological and thermo-physiological and the calculated body parameters like core temperature, skin temperature and skin moisture, which build the base for the calculation of PET. The calculations are based on the **M**unich **E**nergy Balance **M**odel for **I**ndividuals (MEMI) (Höppe, 1984, 1994).

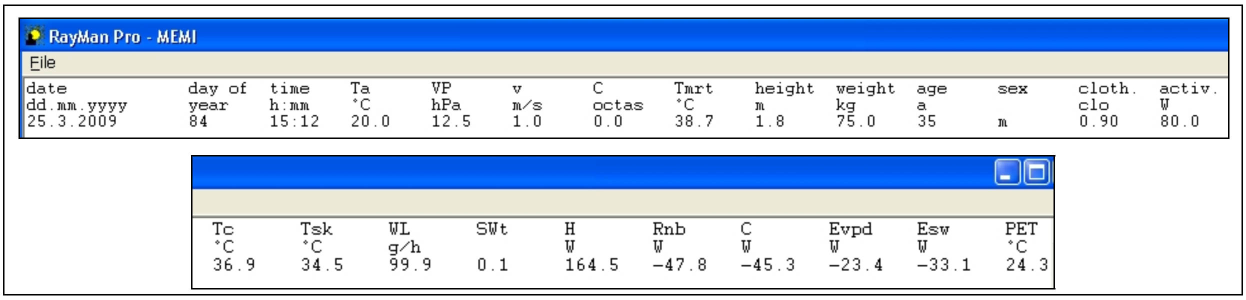

Fig. 5: Output for detailed calculation for the human energy balance by MEMI

4. CONCLUSIONS

The presented model provides diverse opportunities in applied climatology and urban climatology. Useful information can be derived in order to create climate oriented dwellings and facilities for urban structures. It can also be used for the calculation of shade to be provided by special devices in urban areas in order to create more comfortable thermal conditions with protection from direct sunlight for leisure and recreation.

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