

RayMan and SkyHelios Model - Two Tools for Urban Climatology

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Abstract

For urban climatological information and data about climate and climate influencing factors are of importance in order to derive complex indices for the evaluation of climate in urban and other planning levels. The models RayMan and SkyHelios are two free available micro-scale models for the calculation and estimation of Sky View Factor (SVF), sunshine duration, shadow and in general radiation fluxes. In addition, RayMan is able to estimate the most modern thermal indices used in human biometeorology. The two models correspond and link several data formats e.g. GIS-outputs and transfer information for further processing in urban climatological studies and issues.

Introduction

Many climatic parameters and conditions are affected in their temporal and spatial behavior by the natural and artificial morphology on a meso- and micro scale. These effects are significant on different levels of regional and urban planning, i.e. design of tourism buildings, recreational facilities, urban parks, and a variety of other applications. With some modification, existing methods for assessing climate in human biometeorology and applied climatology can be used (MATZARAKIS, 2001).

For urban climatological or in general for micro climatic studies and their human-biometeorological assessment detailed and precise information are required. Important and demanded parameters and factors are in complex environments difficult to obtained and mostly have to be calculated or modeled (HWANG et al., 2011). The required parameters start from the knowledge and influence of Sky View Factor (SVF), the influence of sunshine duration and modification of radiation fluxes. Other information and parameters e.g. surface temperature or different surfaces which can influence the energy exchange of different urban structures are of importance. Radiation fluxes and wind speed are the parameters which are modified mostly in urban structures and have also the highest spatial and temporal variability.

For example, thermal indices, that are derived from the energy balance of the human body, can be of great advantage for tourism and regional/urban planning. Standard climate data, such as air temperature, air humidity and wind speed, are needed to calculate and quantify thermal bioclimatic conditions (HÖPPE, 1999; MATZARAKIS et al., 2001). The most important environmental parameters used to derive modern thermal indices, however, are short and long wave radiation (and the derived mean radiant temperature). These can be determined using special techniques that have been implemented in several models.

Models

RayMan

The „RayMan“ model, which is presented here, is developed to calculate short wave and long wave radiation fluxes affecting the human body. „RayMan“ estimates the radiation fluxes and the effects of clouds. The model, which takes complex building structures into account, is suitable for various planning purposes in different micro to regional levels. The final output of the model is the calculated mean radiant temperature, which is required in the human energy balance model and, thus, for the assessment of thermal bioclimate (MATZARAKIS et al., 2007, 2010). It is also relevant for thermal indices that facilitate the human-biometeorological assessment of the

thermal component of the climate. The thermal indices Predicted Mean Vote, Standard Effective Temperature, Physiologically Equivalent Temperature, Universal Thermal Climate Index and Perceived Temperature can be calculated. In addition for detailed thermo-physiological approaches the energy balance fluxes of the human body and body parameters i.e. core and skin temperature can also be calculated.

Additional features, which can be used for the evaluation of climate in a region or for diverse other applications, are: calculation of sunshine duration with or without sky view factor, estimation of daily mean, max or sum of global radiation; calculation of shadows for existing or future complex environments (MATZARAKIS et al., 2007, 2010).

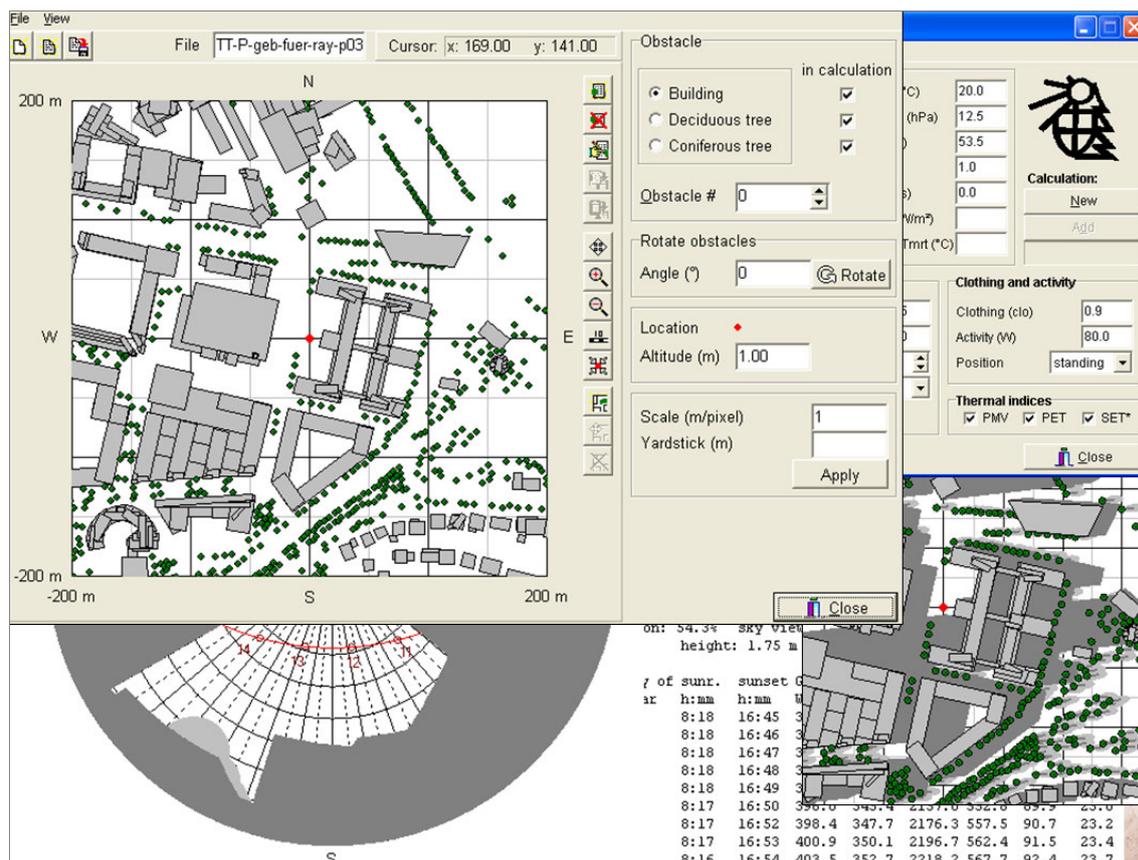


Figure 1: Screenshots from RayMan

When using the computer software “RayMan” an input window for urban structures (buildings, deciduous and coniferous trees) comes up. The opportunity of free drawing and output of the horizon (natural or artificial) are included for the estimation of sky view factors right). The implementation of fish-eye-photographs for the calculation of sky view factors is also possible. The amount of clouds covering the sky can be included by free drawing, while their impact on the radiation fluxes can be estimated (MATZARAKIS, 2001).

The most important question regarding radiation properties on the micro scale in the field of applied climatology and human-biometeorology is whether or not an object of interest is shaded. Hence, in the presented model, shading by artificial and natural obstacles is included. Horizon information (in particular the sky view factor) is required to obtain sun paths. Calculation of hourly, daily and monthly averages of sunshine duration, short wave and long wave radiation fluxes with and without topography, and obstacles in urban structures can be carried out with

RayMan. Data can be entered through manual input of meteorological data or pre-existing files. The output is given in form of graphs and text.

Advantage of RayMan is the user friendly environment and rapid running time. Disadvantage is the limitation of calculation for single points.

SkyHelios

For the spatial dimension of micro climate the SkyHelios model has been developed. SkyHelios uses graphic processors which can be integrated in simulation models computing e.g. visualization of sky view factor or radiation estimation. Going a step further it is even possible to use modern graphics hardware as general-purpose array processors. These ideas and approaches use a cheap mass production technology to solve specific problems.

This technology can be applied for modeling climate conditions or climate-relevant parameters on the micro-scale or with respect to urban areas. There are two major ways to utilize 3D graphics hardware in climate and meteorological research as well as an intermediary approach combining them. On the one hand, the graphics card can be used as intended by the manufacturer to visualize 3D environments. CUNTZ et al. (2007) developed a Graphic Processing Unit (GPU) based framework to visualize time dependent climate flow data. Employing the particle and shadow systems of their graphics hardware, they visualize typhoon and ocean circulations. A typical indicator for this kind of use of 3D graphics hardware is that data are written to the graphics card, but results are not read from it. On the other hand, computer scientists (THOMPSON et al., 2002) developed a framework to utilize the graphics hardware as a general purpose array processor. Utilizing the vertex programming capabilities of their graphics card, they solve typical time-consuming calculations such as matrix multiplication. THOMPSON et al. (2002) further show that in many cases modern graphics hardware can outperform the CPU. First we utilize the graphics hardware to perform a rendering of a three dimensional scene and then we use the graphics hardware to calculate SVF from this rendered scene data, lastly transferring the results back to main memory for further processing.

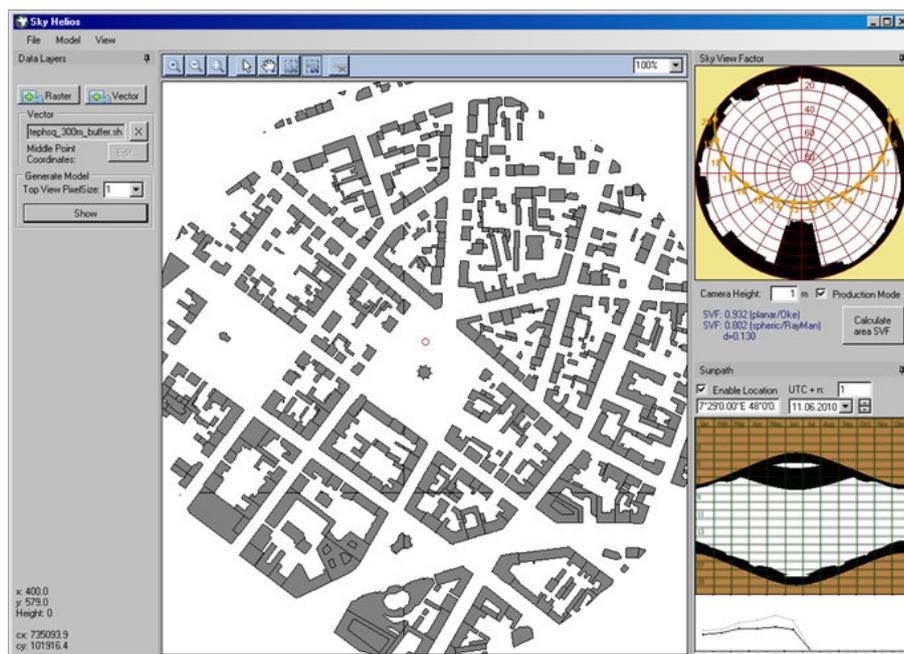


Figure 2: Screenshot from SkyHelios

To illustrate the simulation of the continuous sky view factor, thus the calculation of the SVF for each point of a complex area is included in SkyHelios. Digital elevation models (DEM), data concerning urban obstacles (OBS) or other digital files can serve as a data base in order to quantify relevant climatic conditions in urban and complex areas. The following benefits are provided by SkyHelios: (a) short computing time (b) short development time and (c) low costs due to the use of open source frameworks. Short computing time is reached by utilizing 3D graphics hardware to solve the complex calculations needed for 3D modeling. Short development time can be achieved since the most complex 3D algorithms have not been dealt with. The main focus lies on providing a 3D model of the environment to the graphics engine, and making the engine calculate SVF. It is not necessary to deal with low level visibility problems, face direction and other geometric algorithms, in contrast to previous approaches (e.g. TELLER and AZAR, 2001). Low costs have been reached by utilizing open source 3D graphics engines. These were originally developed for creating computer games. However, as is shown by this work, they can be used for scientific purposes as well.

The application of the developed model will be helpful to estimate radiation fluxes and the mean radiant temperature in urban and complex situations accurately, especially in combination with an urban microclimate model, e.g. the RayMan model.

Examples and Results

Linking of formats and models

With SkyHelios it can be shown, how the use of computer graphics hardware can improve 3D modeling in applied climatology esp. for complex environments. SkyHelios considers and implements diverse options, by not only using the graphic engine of the computer; but also running in the MS Windows environment and providing several visualization techniques. Imported data can be directly exported and viewed in the climate mapping tools (MATUSCHEK and MATZARAKIS, 2010). Frequently-used data formats (i.e., laser, satellite data or DTM) are supported. Direct implementation of RayMan obs files (MATZARAKIS et al., 2007) is a further advantage and allows for a combination of the two models.

In general, modeling cannot reproduce the full reality. Using photographs of the upper hemisphere can reproduce more details of the situation but is also more time-consuming. SkyHelios requires a potent graphics card to operate. Furthermore, on different graphic cards types, SkyHelios produces slightly different results lying in the order of fractions of per mill. A SkyHelios compatibility test ensures the correct operation of the model on a specific graphics card. The visualization of morphological factors (especially in urban areas) helps to understand micrometeorological processes. Here are several option for the import and processing of data. Data produced in SkyHelios e.g. Fish-Eye pictures of single points can be saved and imported directly in RayMan in order to run sunshine duration, radiation fluxes and if meteorological data for the calculation of thermal indices exist, to run calculation of them.

In addition the newly developed annual sunshine duration diagrams allow for a first estimation of the influence of topography and buildings on sunshine duration both on a yearly and diurnal scale in the spatial context. The sky view factor expresses the morphological factors for a specific site in one single value, and therefore allows an estimation of relevant climatological information. For estimation of radiation fluxes, beside the Sky View Factor, other additional features (such as shadow generation and sunshine duration) and also other morphological properties e.g. color or reflexion, heat storage capacity, etc. is required.

Finally 3D hardware is not only advantageous for visualization but can also be used for micro-scale modelling (i.e., for an estimation of maximum global radiation for solar energy devices and other background information in micro-climatology).

All produced graphs and calculated data can be saved and used for other possibilities (i.e., in RayMan or other GIS applications).

Discussion and conclusions

The presented model (RayMan and SkyHelios) provide diverse opportunities in applied climatology for research and education. With readily available climate or meteorological data, such as air temperature, air humidity, and wind speed radiation fluxes the thermal indices for simple and complex environments can be estimated. Additional information about clouds and global radiation imported in the model can be the basis for a more appropriate estimate of the radiation fluxes. Useful information in more detail can be derived in order to create climate oriented dwellings and facilities for urban planning (Matzarakis and Endler, 2010). It can also be used for the calculation of shade to be provided by special devices for recreation in urban areas and resorts in order to create more comfortable thermal conditions with protection from direct sunlight for tourists and visitors.

From the human-biometeorology point of view the presented thermal indices can describe and quantify not only mean conditions but also extremes like heat waves and other climate and health issues but also for popular places in cities (FRÖHLICH and MATZARAKIS, 2011). In order to quantify bioclimate conditions for future scenarios, the model can produce information through the use of global and regional climate model outputs (MATZARAKIS and ENDLER, 2010). Through the use of geo-statistical techniques and tools, the data can be regionalized and provide a more detailed information on the spatial conditions of present and future climate conditions (MATUSCHEK and MATZARAKIS, 2010). Through the implementation of different land use and their surface properties, a more appropriate and realistic picture can be created.

When used for education purposes, the model can be applied in exercises as how to operate these models and in what way land and urban morphology influences short and long wave radiation fluxes in simple and complex environments. Additionally, it can be used for the comparison between experimental and modeling studies in teaching.

Finally, both models can communicate with different options, common data and graphic formats. The models can be used for different approaches in micro scale and urban climatology issues.

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