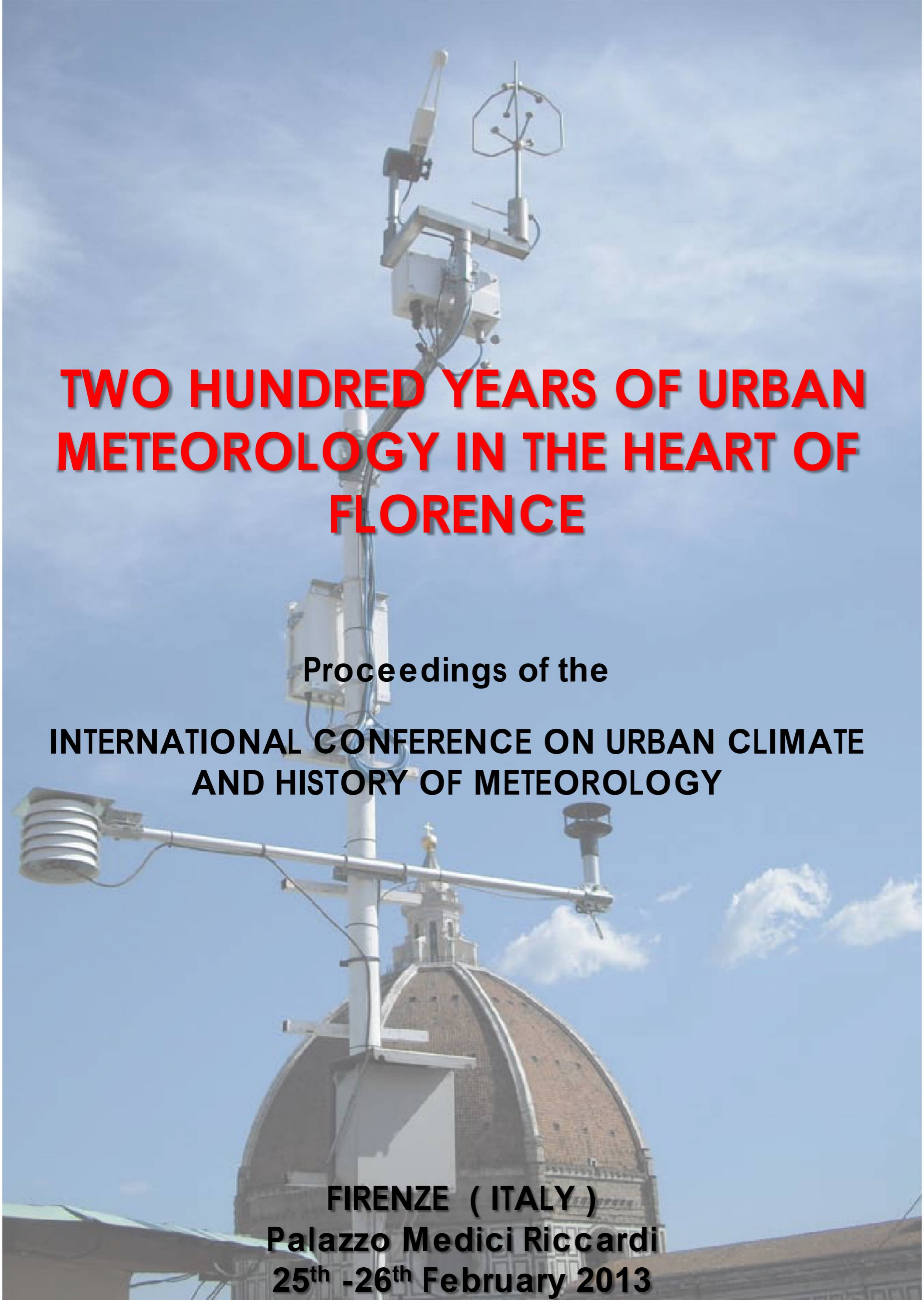


TWO HUNDRED YEARS OF URBAN METEOROLOGY IN THE HEART OF FLORENCE

Proceedings of the

INTERNATIONAL CONFERENCE ON URBAN CLIMATE AND HISTORY OF METEOROLOGY

FIRENZE (ITALY)
Palazzo Medici Riccardi
25th -26th February 2013

Ibimet ISTITUTO DI BIOMETEOROLOGIA
Consiglio Nazionale delle Ricerche

PROVINCIA DI FIRENZE

Osservatorio Ximeniano di Firenze
Fondazione onlus

TWO HUNDRED YEARS OF URBAN METEOROLOGY IN THE HEART OF FLORENCE

Proceedings of the International Conference On Urban Climate And History Of Meteorology

Firenze, Italy, 25th /26th February 2013

Edited by
T. GEORGIADIS, M. A. LOKOSHCHENKO , C. SCRETI, C. VAGNOLI

Firenze, Italy, June 2013
ISBN 9788895597188

FOREWORD

The International Conference “Two hundred years of urban meteorology in the heart of Florence” held in Florence, Palazzo Medici Riccardi, on 25th and 26th of February 2013 was an occasion to join the scientific communities of historical climatologists along with the urban climatologists and meteorologists, in order to share methodologies and results to provide a common vision of the urban environment to allow the development of new instruments both theoretical and practical to planning our urban future. Humankind it is expected in few dozens of years to transform itself in a community of citizens in terms of persons living within the borders of cities or, better, megalopolis.

Within these borders it will be a matter of facts that the concept of citizenship could assume a high relevant value if the expectations and wellness of the populations are respected, or a badly representing the animus of the people just only allow to live inside the city without dignity.

Not only the social arrangement, or the political inclusion are issues of paramount importance in the frame to live together: the physical environment plays a crucial role in determining the conditions for the proper wellbeing perceived as a physiological optimum. This condition can be achieved bearing in mind the specific genius loci of the city itself and its development of the urban structure during the course of the years, of the centuries, along with the transformations of the land use as morphology and materials changes.

The Conference allowed to deeply exchange information in order to built a common language between scientists of different disciplines and to understand the fundamental role of the urban observatories in monitoring the changes over hundred years collecting data that represent not only a diagnosis of the past but a tool to forecast our common future.

AN AUTOMATIC METHOD TO CRATE AN URBAN VEGETATION DATABASE USING 4 BAND AERIAL PHOTOGRAPHS FOR SKY VIEW FACTOR CALCULATION – A CASE STUDY IN SZEGED, HUNGARY

Gál T.[1], Unger J.[2] and Kiss M.[3]

[1] Department of Climatology and Landscape Ecology, University of Szeged, assistant professor, Szeged, Hungary
[2] Department of Climatology and Landscape Ecology, University of Szeged, associate professor, Szeged, Hungary
[3] Department of Climatology and Landscape Ecology, University of Szeged, assistant lecturer, Szeged, Hungary

tgal@geo.u-szeged.hu

Summary

Studying the altered urban environment is important because of the high number of the involved inhabitants. The surface cover and the surface geometry differ from the rural surfaces, and the water and energy balances are modified. The urban climate research focuses on these modified local climates. These modifications are connected primarily to the alteration of the geometry and surface characteristics, and the Sky View Factor (SVF) is the most important parameter for quantifying this complex 3D surface.

For the software based calculation of the SVF a detailed building and vegetation database is needed. For most of the urban areas some kind of urban building database is available from the local authorities, however there is a lack of the detailed information related to the tree-crown data in general. The vegetation and especially the tree-crowns are crucial parts of the urban 3D geometrical configuration and they likely play a major role in regulating long-wave radiation heat loss, therefore a new method for the evaluation of this kind of information is needed.

The aim of this study is to develop a new method for automatic tree-crown database evaluation using the most simple and widely available kind of input data, namely the 4 band aerial photographs. This method uses digital photogrammetric methods for tree height measurement, and it also uses the spectral information from the aerial photographs. The final aim is the calculation of the SVF in urban areas using this new database in order to analyze the effect of the complex urban geometry for the elements of the urban climate.

Keywords: Sky View Factor, tree-crown database, automatic method, urban environment

INTRODUCTION

Studying the altered urban environment is important because of the high number of the involved inhabitants. The surface cover and the surface geometry differ from the rural surfaces, and the water and energy balances are modified (Oke, 1987). Urban climate research focuses on these modified local climates. This is a priority topic since the prediction of the possible impacts of global climate change for urban areas is impossible without an in-depth knowledge of the features of urban climate. The two most important modifications of the climate in these areas are the alteration of the thermal environment and the different airflow conditions, and booth of these climate modifications are primarily connected with the alteration of the geometry and material characteristics of the surface (Landsberg, 1981; Oke, 1987).

In urban environments the water and energy balances are modified which often results in higher urban temperature compared to the surroundings (urban heat island– UHI). The largest UHI and the stronges t urban-rural contrast appear at night, while in the daytime the temperature difference is moderate or vanish. The main reason of the UHI is the urban-rural difference in the nocturnal cooling processes. These are primarily forced by outgoing long wave radiation. In urban areas, narrow streets and high buildings create deep canyons. This 3D geometrical configuration plays an important role in regulating long-wave radiative heat loss. Due to the fact that only a smaller part of the sky is seen from the surface (because of the horizontal and vertical unevenness of the surface elements), the outgoing long wave radiation loss is more restricted here than in rural areas. Therefore, urban geometry is an important factor contributing to intra-urban temperature variations below roof level (e.g. Oke, 1981; Eliasson, 1996). The most common parameter used to describe the urban geometry is the sky view factor (SVF) (Oke, 1981; Upmanis and Chen, 1999; Svensson, 2004). By definition, SVF is the ratio of the radiation received (or emitted) by a planar surface to the radiation emitted (or received) by the entire hemispheric environment (Watson and Johnson, 1987). It is a dimensionless measure between zero and one, representing totally obstructed and free spaces, respectively (Oke, 1988).

For the determination of the SVF several solutions is known: methods using scale model (Oke, 1981), analytical methods (field survey, distance and angle measurements) and graphical estimating (e.g., Watson and Johnson, 1987; Bottyán and Unger, 2003), manual or software based assessments of fisheye-lens photographs (e.g., Steyn, 1980; Bradley et al., 2001; Grimmond et al., 2001; Chapman et al., 2001; Blankenstein and Kuttler, 2004), evaluations of GPS signals (Chapman and Thornes, 2004), evaluations of thermal video made by video camera mounted with fisheye-lens (Chapman, 2008), and computer algorithms, if a 3D database is available for the study area (e.g. Souza et al., 2003; Lindberg, 2007).

In the past decade, several software methodologies have been devised. These methods can be grouped on the basis of the used input data. Most of the software methods are raster-based procedures. These methods utilize high resolution raster DEMs (containing the terrain and the buildings) for computing images of continuous sky view factors. Their advantage is that the roof of buildings can be more easily managed; however, the selection of the resolution of the input data is significantly affects the accuracy of the results (Lindberg, 2007). Most of the building databases for cities are in vector format (e.g. AutoCad files, ESRI shapefiles), thus for these raster-based methods a vector-raster conversion is needed as a preprocessing. During this conversion data loss can be occurred and the rasterization of the buildings could alter the results of the SVF calculation (Gál et al., 2009).

There are some examples for vector-based methods as well. Souza et al. (2003) have developed an algorithm using an Avenue script language of the ESRI ArcView GIS. This script can calculate the SVF values more accurately because the buildings are in vector format, thus the locations of the building walls are unequivocal and do not depend on resolution.

The most of the software based SVF calculation methods do not take into account the vegetation. However the tree-crowns are important part of the urban 3D geometrical configuration and likely play a major role in regulating long-wave radiation heat loss. The reason of disregarding of the vegetation is the lack of detailed vegetation database. Recently the current trend in this topic is the development of the software based methods for the consideration of vegetation data. For example the current development of the SOLVEIG method (Lindberg et al., 2008; Lindberg and Grimmond, 2010) is aiming this. The other example is the SkyHelios software (Matzarakis and Matuschek, 2010; Hämmerle et al., 2011), however it needs very detailed vegetation database which can be obtained via time consuming field measurements.

In our department a new vector based algorithm has been developed for SVF calculation. This is an Avenue script, and it uses building database in ESRI shapefile format (Gál et al., 2009). It was developed using the 3D database of Szeged but it can be used in any other settlement if a similar database exists. The precision of this algorithm have checked (Gál et al., 2007) and it has been compared to other calculation methods (Gál et al., 2009; Hämmerle et al., 2011).

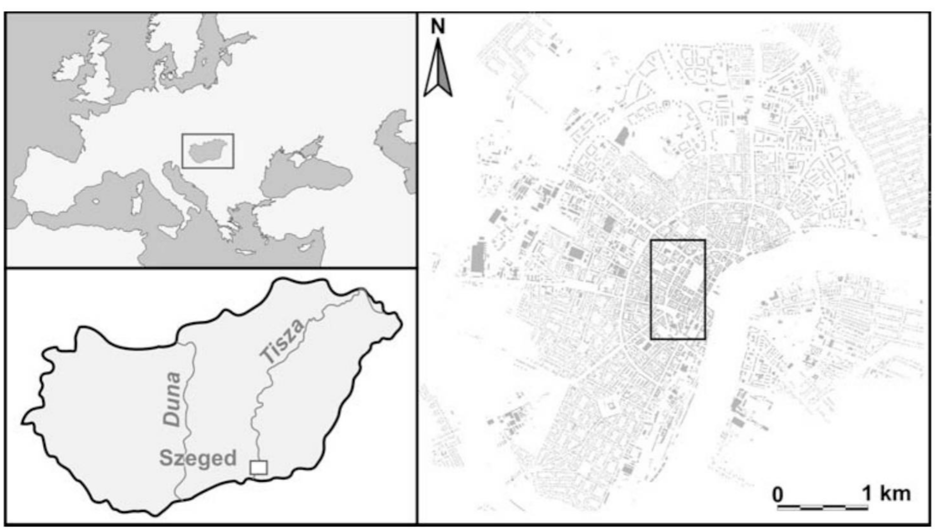
The objective of this study is to develop an automatic tree-crown evaluation method. This method has to calculate the shape and the elevation of the tree-crowns. Our second objective is to develop a new method for SVF calculation using the output of the tree-crown evaluation or other similar data. Both of the methods have to operate without using any GIS software and without the interaction of the user.

STUDY AREA AND METHODS

Study area

Szeged (46ºN, 20ºE) is located in in the southern part of the Great Hungarian Plain at 79 m above sea level (Figure 1). According to Köppen's classification the city belongs to the climatic type Cfb (warm temperate climate with annually uniform precipitation distribution and with warm summer), similarly to the predominant part of the country (Unger, 1999). The administrative area is 281 km² and the area of the most urbanized part is approximately 30 km². In the city core there are mostly four-story buildings that lead to relatively narrow street canyons. Numerous squares and parks offer open spaces. In the other parts of the city there are 1-2-story buildings, and there are several districts where the 5-10-story buildings are dominant with large open spaces. The amount of the vegetation is high, and there are trees in most of the streets, even in the city core. The study area (600 × 1100 m) is located in the city core (Figure 1) with an extension of 0.65 km^2. Within this area there are two urban parks and several streets with significant tree cover.

Figure 1: Study area in Szeged, in Hungary and in Europe.



Input data

For the automatic evaluation of the tree-crowns 2 input data are needed. The firs one is the elevation and the second one is the NDVI (Gál and Unger, 2012). The source of the elevation data can be different, in our case we used 3D point cloud calculated with photogrammetric method however LIDAR measurements are also suitable for this.

For the evaluation of the 3D point cloud and the calculation of NDVI we used 4-band digital aerial photographs made by the Hungarian Institute of Geodesy, Cartography and Remote Sensing in 2007. The resolution of the photographs is approximately 0.5 m. The photographs have 4 spectral bands, 3 visible bands and 1 near infrared band. Thanks to their spectral and spatial resolution these bands are suitable for calculating high resolution spectral indices (e.g. NDVI), and with photogrammetric methods they are suitable for height measurements in the same time. This kind of areal photographs are commonly used for cartography issues, thus it can be easy to procure them in most of the countries.

For this study a detailed 3D building database was also used. This 3D building database of Szeged contains the footprints and the building heights of all of the buildings in the urbanized part of the city. The elevation values of the building tops were measured with photogrammetric methods (Unger, 2006).

Elevation measurement

With the LPS (Leica Photogrammetric Suite) module of the ERDAS IMAGINE 2011 we generated a block file (ERDAS, 2010a). This block file contains the aerial photographs, and these photographs are connected to each other and to points with known geographical coordinates using as check points. Using the camera parameters, the information about the flight and these check points the triangulation can be made. After the triangulation the elevation of any point can be measured with LPS, if that point is located in at least 2 aerial photographs (Gál and Unger, 2012).

We used the eATE (enhanced Automatic Terrain Extraction) module of the LPS in order to determine the height of the tree-crowns. The eATE module is designed to carry out automatic photogrammetric 3D coordinate determination using the block file (ERDAS, 2010b). It localizes the points in the overlapping parts of the aerial photographs with digital image matching algorithm. As a result a 3D point cloud is generated in ESRI shapefile format; it contains all of the points where the robust algorithm can determine the 3D coordinates (Gál and Unger, 2012).

NDVI calculation

Using the NDVI the areas of the different vegetation (trees and grass) can be distinguished, therefore, in order to localize of the tree-crowns we used this index (Gallo and Owen, 1999). The NDVI image was calculated with the ERDAS IMAGINE 2011 (Gál and Unger, 2012)

DEVELOPMENT OF THE AUTOMATIC METHODS

Tree-crown mapping tool

The mapping of the tree-crowns was carried out by the Tree-crown mapping tool (TCM). This stand alone automatic software tool was developed in C++ language and it is compatible with Windows and Linux environment also (Fábián, 2012) and currently it is under development. It reads the input data (3D point cloud, NDVI) from two comma-separated values (CSV) file. As an optional input it can use building footprints and tree-crown border lines in ESRI shape files. If these files are available the calculation time can be significantly shorter. If the building footprint dataset is available, than the TCM calculate the building heights also. The localization of the tree-crowns is based on the NDVI values and the shapes of the tree-crowns are calculated using Thiessen polygons (or Vornoi diagrams) (Aurenhammer, 1991) around the points in the 3D point cloud. The output of the TCM is a shapefile containing the tree-crowns and optionally an other shapefile containing the buildings. The elevation values are stored in the attribute table of the shapefiles.

Software tool for SVF calculation

For the SVF calculation a new software tool was developed based on our earlier software methods (Gál et al., 2009). This new stand-alone software tool is developed in Java language thus it is compatible Windows and Linux platforms also. The method of the calculation of the SVF is basically same as the earlier Avenue script described in Gál et al. 2009, but this tool is more advanced as it calculates the SVF using the buildings and the tree-crowns too. For the tree-crowns a transparency value has to be defined that represents the transparent threshold of the trees (Gál and Unger, 2012). The calculation time is significantly lower comparing the earlier script (Gál et al., 2009), in this case the calculation of the SVF for one point takes approximately only 0.6 s in a common PC (core i7 processor and 4 GB memory).

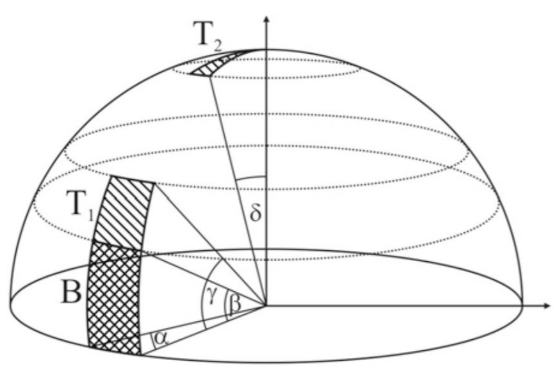
For the calculation a detailed building database and a point database are necessary. The building data have to be stored in an ESRI shapefile. This polygon shape have to contain the building footprints and the elevation of the top of the buildings (m, above the see level). The software takes into account all of the buildings with flat roofs, therefore only one elevation value is necessary. The point database contains the SVF calculation sites. This file has to be an ArcView shapefile but it has to be a point shape. This point shape contains the locations of the points where the SVF calculation will take place (x, y coordinates and the elevation). The tree-crowns are only optional input, and this input has to be stored in the same polygon shapefile as the shapefile of the buildings.

The equation of SVF calculation is modified form of the equation in Gál et al. (2009), but it takes into the consideration of the different types of tree-crowns also. For the calculation 3 types of objects have to be identified from the input data: highest building (B) in a given direction, highest tree (T_1) in a given direction and the tree (T_2) over the point where the SVF calculation has taken place (Figure 2). The SVF value will be one minus the sum of the view factors for these objects:

$$SVF = 1 - \sum_{i=1}^{n} \frac{\alpha}{360} \cdot \sin^2 \beta_i - \sum_{i=1}^{n} \tau \cdot \frac{\alpha}{360} \cdot \sin^2 \gamma_i - \sum_{i=1}^{n} \tau \cdot \frac{\alpha}{360} \cdot \sin^2 \delta_i$$

where τ is the transparency of the tree-crowns.

Figure 2: The polygon in the hemisphere corresponding to a building and to the 2 types of tree-crowns.



RESULTS

Sample of the tree-crown database

The tree-crown mapping tool was used in the study area of 600 × 1100 m. The resolution of the NDVI data was 0.5 m and it contained 2.64 million points, while the 3D point cloud was a slightly smaller (~1 million points). The calculation time of the tree-crown and building database for this area (Figure 3) was about 24 hours. However the TCM is under development thus this time may decrease when the final version of the tool will be ready.

In the study area most of the trees are localized (Figure 3). There are few places where the tree-crown localization was unsuccessful, for instance in the wide curved-shape road in the centre of the study area. Along this wide road the trees have very transparent crowns and under the trees there is asphalt and pavement cover thus the NDVI value is lower than in the case of most of the other trees.

For this study the building elevation values were also evaluated with the TCM using the building footprints from the 3D building database of Szeged. Within each building footprint several polygons can be found, and each polygon represents the more or less equal elevation part of each roof (Figure 3).

This automatically generated tree-crown and building database may have errors in this stage of the development of the methods, but the calculation time is negligible comparing to the manual measurements, and the calculation for a whole urbanized area is only need more computation time or higher performance computers.

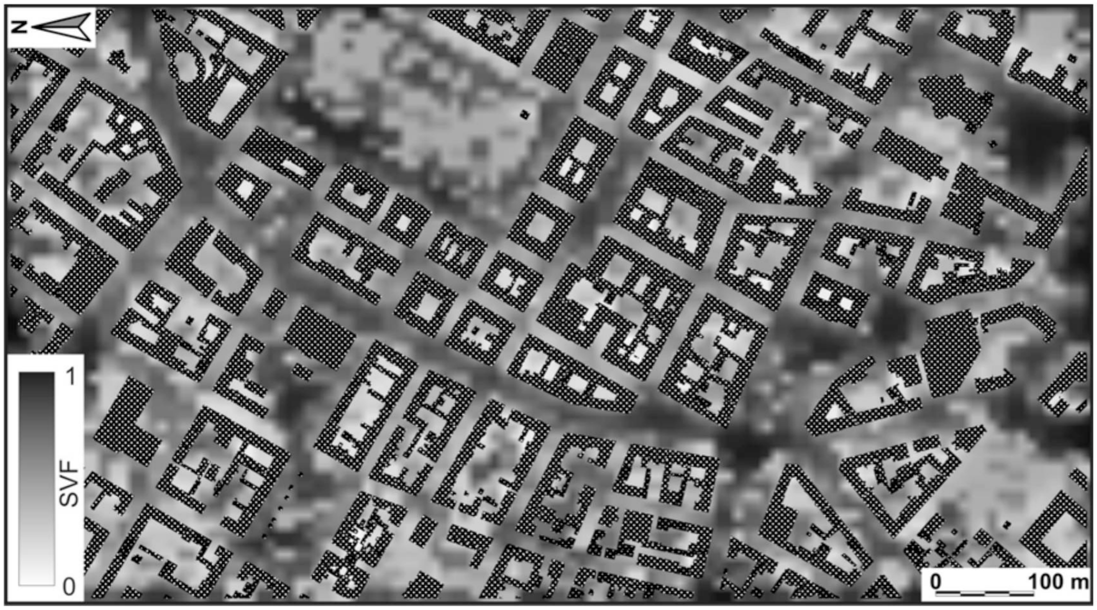
Figure 3: Elevations and shapes of the tree-crowns and buildings in the study area.

Application of the database for SVF calculation

The building and tree-crown databases were used for SVF calculation applying the software tool described in Section 3.2. in a 10 m resolution point grid inside the study area (Figure 4). The calculation time was about 1 hour for this almost 7000 points. In the spatial distribution of the SVF the effect of the buildings and the vegetation is observable. In the eastern part of the study area, there is a large urban park, and in this part the lower SVF values can be found (Figure

4). By the results the different types of the street canyons can be compared: for instance the same wide street canyons, if there are no tree-cover the SVF value is significantly higher.

Figure 4: Spatial distribution of the SVF calculated using vegetation and the automatically evaluated building data.



CONCLUSIONS

This paper presents only the preliminary results of this research. In this stage the basics of these methods are ready. We can automatically generate a tree-crown (and building) database if the necessary input data is available. Moreover we can calculate the SVF from this tree-crown and building database (and from any database if that is similar to this input), and this calculation is fast enough and it can be as precise as any vector based calculation method. We can assume that both of the software methods have to be develop, however these first results are promising. When the final version of the tree-crown mapping tool and the SVF calculation software will be ready than it will be available (in the website of our department) for scientist who are interested in.

ACKNOWLEDGMENTS

The research was supported by the Hungarian Scientific Research Fund (OTKA PD-100352).

REFERENCES

Aurenhammer, F. (1991). Vornoi diagrams – A survey of fundamental geometric data structure. ACM Computing Surveys 23: 345-405.

Blankenstein, S. and Kuttler, W. (2004). Impact of street geometry on downward longwave radiation and air temperature in an urban environment. Meteorologische Zeitschrift 15: 373-379.

Bottyán, Z. and Unger, J. (2003). A multiple linear statistical model for estimating the mean maximum urban heat island. Theoretical and Applied Climatology 75: 233-243.

Bradley, A.V., Thornes, J. E. and Chapman, L. (2001). A method to assess the variation of urban canyon geometry from sky view factor transects. Atmospheric Science Letters 2: 155-165.

Chapman, L. (2008). An introduction to 'upside-down' remote sensing. Progress in Physical Geography 32/5: 529-542.

Chapman, L. and Thornes, J. E. (2004). Real-time sky-view factor calculation and approximation. Journal of Atmospheric Oceanic Technology 21: 730-741.

Chapman, L., Thornes, J. E. and Bradley, A. V. (2001). Rapid determination of canyon geometry parameters for use in surface radiation budgets. Theoretical and Applied Climatology 69: 81-89.

Eliasson, I. (1996). Urban nocturnal temperatures, street geometry and land use. Atmospheric Environment 30: 379-392.

ERDAS, (2010a). LPS Project Manager User's Guide. Erdas, Inc, Norcross, USA.

ERDAS, (2010b). eATE User's Guide. Erdas, Inc, Norcross, USA.

Fábian, P. Á. (2012). Derivation of tree-crown database using spectral and height information in an urban area (in Hungarian). MSc thesis, University of Szeged, Szeged, Hungary.

Gál, T. and Unger, J. (2012). Surface geometry mapping for SVF calculation in urban areas. Proceeding of 8th Conference on Urban Climate, Dublin, Paper 168.

Gál, T., Rzepa, M., Gromek, B. and Unger, J. (2007). Comparison between Sky View Factor values computed by two different methods in an urban environment. Acta Climatologica et Chorologica Univ. Szegediensis 40-41: 17-26.

Gál, T., Lindberg, F. and Unger, J. (2009). Computing continuous sky view factor using 3D urban raster and vector databases: comparison and an application for urban climate. Theoretical and Applied Climatology 95: 111-123.

Gallo, K. P. and Owen, T. W. (1999). Satellite-based adjustments for the urban heat island temperature bias. Journal of Applied Meteorology 38: 806-813.

Grimmond, C. S. B., Potter, S. K., Zutter, H. N. and Souch, C. (2001). Rapid methods of estimate sky-view factors applied to urban areas. International Journal of Climatology 21: 903-913.

Hämmerle, M., Gál, T., Unger, J. and Matzarakis, A. (2011). Comparison of models calculating the sky view factor used for urban climate investigations. Theoretical and Applied Climatology 105: 521-527.

Landsberg, H.E. (1981). The urban climate. Academic Press, New York.

Lindberg, F. (2007). Modelling the urban climate using a local governmental geo-database. Meteorological Applications 14: 263-273.

Lindberg, F. and Grimmond, C. S. B. (2010). Continuous sky view factor maps from high resolution urban digital elevation models. Climate Research 42: 177-183.

Lindberg, F., Holmer, B. and Thorsson, S. (2008). SOLWEIG 1.0 – Modelling spatial variations of 3D radiant fluxes and mean radiant temperature in complex urban settings. International Journal of Biometeorology 52: 697-713.

Matzarakis, A. and Matuschek, O. (2010). Sky View Factor as a parameter in applied climatology – Rapid estimation by the SkyHelios Model. Meteorologische Zeitschrift 20: 39-45.

Souza, L. C. L., Rodrigues, D. S. and Mendes, J. F. G. (2003). The 3DSkyView extension: an urban geometry acces tool in a geographical information system. In Klysik, K., Oke, T. R., Fortuniak, K., Grimmond, C. S. B. and Wibig, J. Proceed. Fifth Int. Conf. on Urban Climate Vol. 2. University of Lodz, Lodz, Poland, 413-416.

Steyn, D. G. (1980). The calculation of view factors on fisheye-lens photographs. Athmosphere-Ocean 18: 254-258.

Svensson, M. (2004). Sky view factor analysis – implications for urban air temperature differences. Meteorological Applications 11: 201-211.

Oke, T.R. (1981). Canyon geometry and the nocturnal urban heat island: comparison of scale model and field observations. Journal of Climatology 1: 237-254.

Oke, T. R. (1987). Boundary layer climates. Routledge, London and New York.

Oke, T. R. (1988). Street design and urban canopy layer climate. Energy and Buildings 11: 103-113.

Unger, J. (1999). Comparisons of urban and rural bioclimatological conditions in the case of a Central-European city. International Journal of Biometeorology 43: 139-144.

Unger, J. (2006). Modelling the annual mean maximum urban heat island with the application of 2 and 3D surface parameters. Climate Research 30: 215-226.

Upmanis, H. and Chen, D.L. (1999). Influence of geographical factors and meteorological variables on nocturnal urban-park temperature differences - a case study of summer 1995 in Göteborg, Sweden. Climate Research 13: 125-139.

Watson, I.D. and Johnson, G.T. (1987). Graphical estimation of sky view-factors in urban environments. Journal of Climatology 7: 193-197.

INDEX

ISBN 9788895597188