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COMPUTERS IN URBAN PLANNING
AND URBAN MANAGEMENT

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A GIS tool named 3DSkyView was recently created and incorporated into ArcView GIS 3.2 in order to estimate sky view factors (SVF) of urban canyons. The first version of the extension showed a good performance for allowing the automatic delineation and determination of SVF (Souza, Rodrigues & Mendes, 2003). Its performance was later enhanced with the development of other features, and the third release is now available. While the original 3DSkyView version was limited to a single observer point, it is now possible to calculate simultaneous SVF for many viewpoints, making the creation of a continuous SVF map for an entire area an easy task. Moreover, the third release allows the user to visualize sun path diagrams along with the representation of the sky view factor. That makes possible a solar analysis of urban canyons for any latitude, at any time of the day and period of the year. In addition, the 3DSkyView new interface is more flexible, in a way that the user may choose the kind of output (graphical or tabular) desired. Showing the potentiality of the 3DSkyView as an urban environmental tool, a case study was carried out. Twenty urban canyons in a residential area of a Brazilian medium sized city were studied. Air and surface temperatures were registered, and data showing the electrical energy consumption patterns of the area were collected. The data were stored and manipulated in ArcView GIS 3.2. Afterward, the 3DSkyView extension release 3 was plugged in and the sky view factors and sun path diagrams calculated for each canyon. A continuous SVF map for the neighborhood of those canyons was created and the thermal data cross-examined in the GIS environment. This methodology allowed the identification of thermal tendencies within the neighborhood, which can be useful in the conception of guidelines for urban planning purposes.

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Souza, L.C.L.; RODRIGUES, D.S., MENDES, J.F.G. (2003) A 3D-GIS extension for sky view factors assessment in urban environment, **Proceedings of the 8th International Conference on Computers in Urban Planning and Urban Management**, 2003, Sendai, Japan, 27-29.

INCORPORATING SUNPATHS FOR SOLAR ANALYSIS IN THE 3DSKYVIEW EXTENSION

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Abstract: The 3DSkyView extension was recently created to estimate sky view factors (SVF) of urban canyons. In a second version it was made possible the calculation of simultaneous SVF for many viewpoints. Now in the third version the user is able to visualize sunpath diagrams along with the representation of the sky view factor. By applying the extension, a case study was carried out allowing the identification of thermal tendencies within a neighborhood.

Keywords: sky view factors, urban temperature, urban geometry, energy consumption

1 INTRODUCTION

In order to show the potentiality of GIS in helping not only environment specialists, but also urban architects in deciding shapes and configurations for healthier cities, a tool named 3DSkyView was developed in 2003 as an extension of *ArcView GIS 3.2* (a product of ESRI - Environmental Systems Research Institute), to promote the calculation and visualization of sky view factors (SVF).

The first version of that extension (Souza et al., 2003) showed a very good performance, allowing the automatic delineation and determination of SVF. That was, although, limited to a single observer point. The simulation of SVF for several view points in urban canyons was only possible by applying the extension as many times as the number of observers considered. Enhancing the performance of that tool, a second release (Rodrigues et al., 2004) allowed simultaneous determination of SVF for many view points. A third version allows now the visualization of sunpaths diagrams along with the representation of sky view factors. That makes possible a solar analysis of urban canyons for any latitude, at any time of the day and period of the year. In addition, the 3DSkyView new interface is more flexible, in a way that the user may choose the kind of output (graphical or tabular) desired.

Applying the 3DSkyView as an urban environmental tool, a case study was carried out. Twenty urban canyons in a residential area of a Brazilian medium sized city were studied. Air and surfaces temperatures were registered, and data showing the electrical energy consumption patterns of the area were collected. The data were stored and handled in GIS. In the sequence, the 3DSkyView extension release 3 was plugged in and the sky view factors and sunpaths diagrams were calculated for each canyon. A continuous SVF map for the neighborhood of those canyons was created and the thermal data cross-examined in the GIS environment. This methodology allowed the identification of thermal tendencies within the neighborhood, what can be useful in the conception of guidelines for urban planning purposes.

In this paper the new features of the extension, the methodology and the results of the case study are presented.

2 AN OVERVIEW OF 3DSKYVIEW VERSIONS

In this overview, the principles of the original version are pointed out to briefly identify the context inherent to 3DSkyView extension, and then, the new features of the other releases are shown.

2.1 About the 3DSkyView original extension

Summarizing the description of the 3DSkyView already presented in CUPUM 2003, one might say that the extension is a simplified method developed by Souza et al. (2003) aiming the calculation and representation of sky view factors (SVF). The SVF represents an estimation of the visible area of the sky from an Earth viewpoint, being defined as the ratio between the total amount of radiation received from a plane surface and that received from the whole radiant environment. It is thus a dimensionless parameterization of the quantity of visible sky at a location. In this way

the sky area results from the limits of urban canyons generated by the tri-dimensional characteristics of urban elements and their mutual relationships.

For the determination of the amount of visible sky from a view point on Earth, 3DSkyView identifies the angular dimensions – horizontal and vertical angles - between the observer and the urban element obstructions caused to the sky vault. These angles allow the urban canyon to be projected in a bi-dimensional plane, as seen in Figure 1. Then the sky vault can be homogeneously divided and its parts projected stereographically onto the equatorial plane, creating a stereonet. By overlaying this stereonet on the equatorial plane projection of the obstructions, their parts (i.e., sky and obstruction areas) can be compared to the total area of the whole sky, determining their ratio (i.e., the SVF).

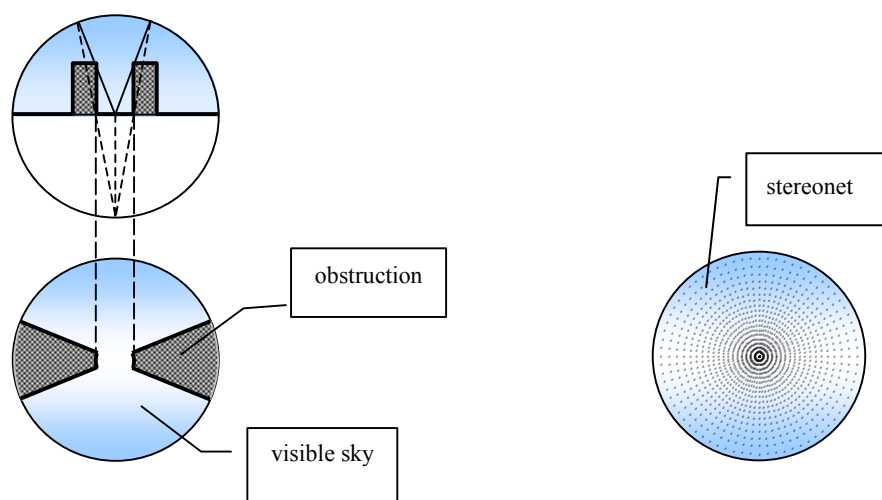


Figure 1 – Stereographic projection of an urban canyon and the stereonet

In practical terms, the aim of the 3DSkyView is to identify a new coordinate system for the tri-dimensional urban elements, so they could be represented in a stereographic projection on a bi-dimensional plane, in this way allowing the calculation of the SVF parameter.

2.2 The new features

In the latest releases the principles of that original version in determining SVF and those presented in the previous sub-section are exactly the same. However, the ability of applying the algorithm in a simultaneous and automatic way for multi-observer points is unique. This is the main feature of version 2 (Rodrigues et al) and also integrated to release 3, while the simulation time has also been taken care of. Release 3 is, although, even more useful for environmental analysis, because it allows the representation of sunpaths diagrams, together with the representation of the sky view factors.

The new users' interface presented in Figure 2 has six input data groups so that the process can be started. They are the process information, skynet data, information about the observer points, polygons information, radius of the circle projection, and the desired outputs.

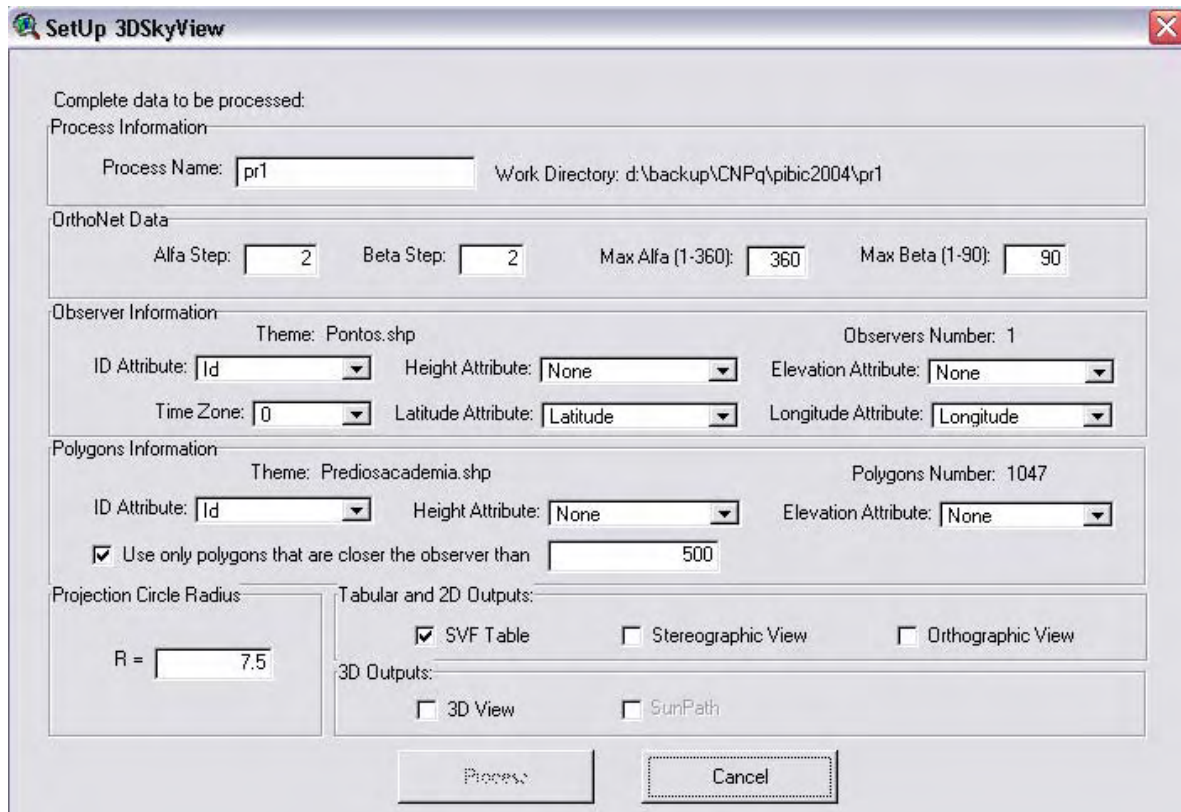


Figure 2 – User Interface of 3DSkyView version 2

The process information refers to the name the user designates the process. The directory, where the resulting data (tables, shapefiles) will be stored, appears automatically next to that field.

For the generation of the skynet (the orthonet) created in this calculation, the user must supply the information about the increment of alpha and beta angles – horizontal and vertical angles respectively - in relation to the observers position and the obstruction to the sky. The values of this increment have influence on the 3D model resolution. The lower the increment, the better the resolution shapes.

As the user should select both, the theme (layer) containing the observer points and the buildings (polygons) theme before running the routine, the software identifies the number of observers and the name of those themes. The observer information group requires the user identification of input data fields in the table of contents of the observers theme. Therefore, the fields on the input data table must include a unique identifier for each observer point. Also the height of the buildings and their elevations (contour line levels) are fields that ought to be available on that table of contents. The identifier will be then associated to the resulting data. For the generation of sunpaths diagrams this group also requires information about latitude and longitude, that should be available in the table of contents. The time zoning, although, will be an input data directly informed on the specific field of the interface.

For the polygons information group, those requirements are the same, except for the identifier field and the geographical inputs (time zoning, latitude and longitude), which is useless here.

The projection circle radius group allows the user to choose a radius for the graphical representation of the SVF in stereographic and orthographic projections.

At last, the outputs group highlights the flexibility of this new version in allowing the user to make choices of outputs. That means that the user can optimize the time of simulation getting only the outputs of interest.

These input data, followed by the click on the *Process* button, starts the process without any further user intervention.

The user' *outputs* selection is one of the advantages of version 2 and 3. It makes possible, for example, to use the extension only to get tabular results, without the graphical outputs. If the user selects only the *SVF Table* option, that will create a table of results. By means of the identifier number, its structure adds to each observer point the values of the sky area, the obstructed area (*CanyonArea*), and the relative area of visible sky (*SVF*).

It is then important to highlight that the simulation time is dependent on the number of observers in the input data. This happens because the final values are stored point by point in the table. This facet assures the availability of partial results, even if there is any sudden interruption on the process.

In comparison to the first 3DSkyView version, except for the sunpaths, the other results are basically the same. In release 3, the sunpaths for the whole year are overlaid with the sky view factor representation for any latitude and longitude. In Figure 3 an example of the resulting simulation can be seen. Note that in it the sun position is plotted for each hour of a day, on specific days of the year, which represents several seasons of the year. In this way it is possible to identify the solar access of any urban canyon. Where obstructions block the sun representation means that there is no sun penetration at that time of the day, while at times with sun positions are plotted inside the area of visible sky, the sun is available for that observer point.

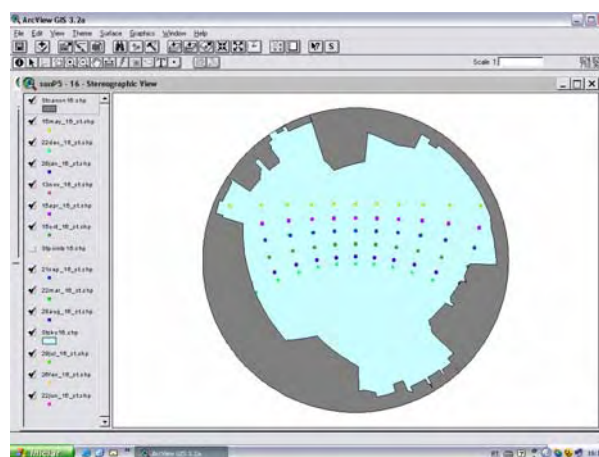


Figure 3 – Example of sunpaths in stereographic projection.

In other words, 3DSkyView allows the determination of urban geometry by calculating and representing sky view factors simultaneously viewed from multi-observer points, now also overlaying the sunpaths diagrams. Thus, as the outputs

are already stored in a GIS software, these data can be handled and plotted to create new databases and maps.

3 AN APPLICATION IN ACTUAL URBAN CANYONS

One way of demonstrating the 3DSkyView usefulness for environmental analysis is the application here conducted. In this research the features of the software ArcView GIS were explored so that urban geometry, electrical energy consumption and thermal parameters could be cross-examined, expressing their tendencies on the specific area studied. Twenty urban canyons of a residential neighbourhood settled in the city of Bauru - a medium sized Brazilian city - were studied. These canyons had their electrical energy consumption, diurnal air temperature and surface temperature data collected, while their sky view factors were determined by the 3DSkyView extension. All the parameters of urban geometry, electrical consumption and temperatures were stored on the GIS, and handled to generate maps, allowing the visualization and analysis of their spatial distribution.

3.1 The study area

The very first step taken here was to create an urban zoning map in order to identify the residential areas in the city of Bauru. This map will not be presented here due to the large number of classes (21), what makes visualization very difficult for maps in a small size.

Afterwards, the general residential areas were identified, from which one was selected to represent the study area. Each kind of residential area in Bauru was highlighted, allowing the determination of two main classes of land use - residential and non-residential areas. A map containing this classification is presented in Figure 4. A specific residential area was then selected taking into account the possibility of having a large range of sky view factors values in the same neighborhood. This was done by visual analyses of the heights of the buildings, aiming at a neighborhood sample that offers the largest range of heights for the Bauru standards. Figure 4 indicates the selected area.

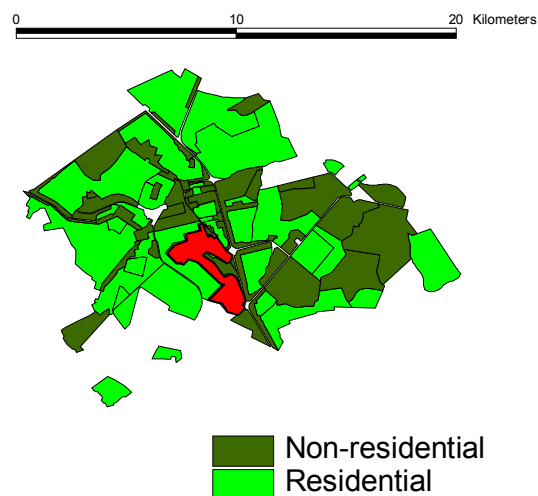


Figure 4 – Residential areas in Bauru and neighborhood selected as the study area

In that neighborhood, twenty points of measurements were considered important to represent the variability of building heights and sky view factors of canyons. Figure 5 contains the aerial photography that points out with letters the twenty urban canyons selected. The canyons are oriented either along the NE-SO axes outlining 60° in relation to the North, or along the SE-NO axes outlining 150° in relation to the North.



Figure 5 – Aerial photography with the selected points

Applying the 3D Analyst extension in ArcView GIS Figure 7 could be created expressing the pattern of building height in that neighborhood.

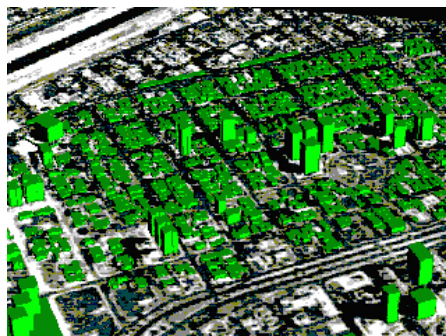


Figure 6 – A 3D View of the study area

3.2 Results and discussion

The 3DSkyView extension was simultaneously applied to the twenty urban canyons selected. The extension generated the values of the SVF and its representation with the sunpaths diagrams. They were put together in Table 1.

Creating a net for the whole neighbourhood the SVF values were also determined, so that a continuous SVF map could be developed, allowing an overview of the area – Figure 7.

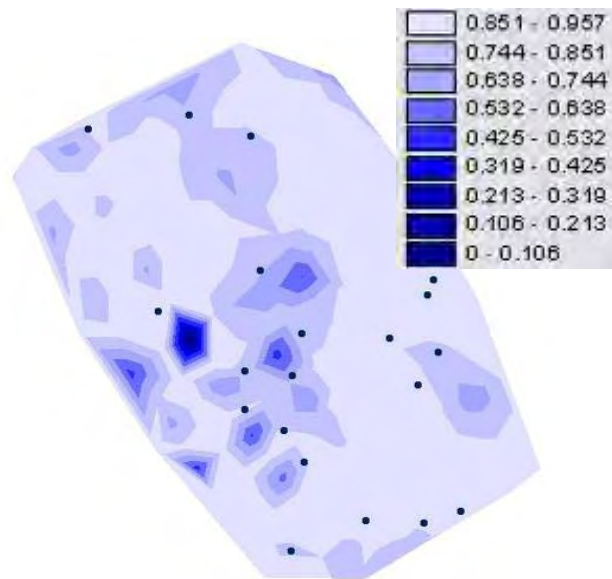
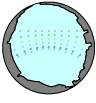
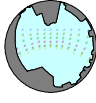
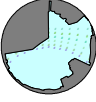
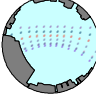

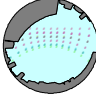
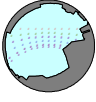
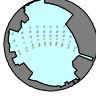

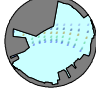



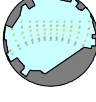
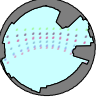
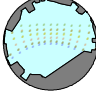

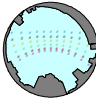
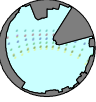
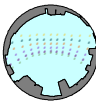
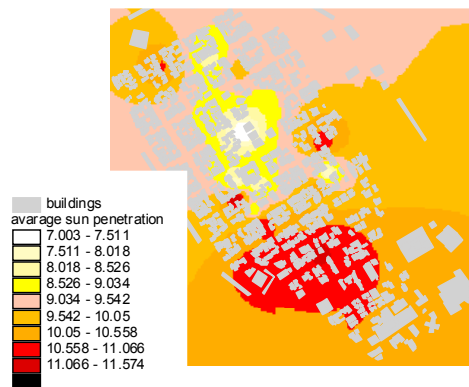


Figure 7 – Continuous SVF map of the study area

Also the sunpaths diagrams created by the same extension made possible the identification of the solar penetration in the neighbourhood. The data were handled to come up with a continuous map of the average sun incidence hours in a year (Figure 8).

Table 1 – The resulting data of 3DSkyView

Urban Canyon	Representation of SVF and sunpath	SVF Value	Urban Canyon	Representation of SVF and sunpath	SVF Value
CANYON A		0.91	CANYON K		0.85
CANYON B		0.71	CANYON L		0.88
CANYON C		0.81	CANYON M		0.87
CANYON D		0.82	CANYON N		0.83
CANYON E		0.70	CANYON O		0.76
CANYON F		0.77	CANYON P		0.85
CANYON G		0.75	CANYON Q		0.82
CANYON H		0.87	CANYON R		0.87
CANYON I		0.69	CANYON S		0.95
CANYON J		0.83	CANYON T		0.91



Using the GIS to cross-examining the thermal data collected with the data generated by 3DSkyView, developing maps and performing statistical analysis, many environmental issues could be discussed.

First of all, the spatial distribution of the average temperature collected in the urban canyons studied was examined, as shown in Figure 9. One can realize that there is a tendency in the diurnal average temperature, where the larger is the sky view factor, the higher its range, indicating how important the solar access is in relation to the degree of temperature reached during the day in an urban canyon.

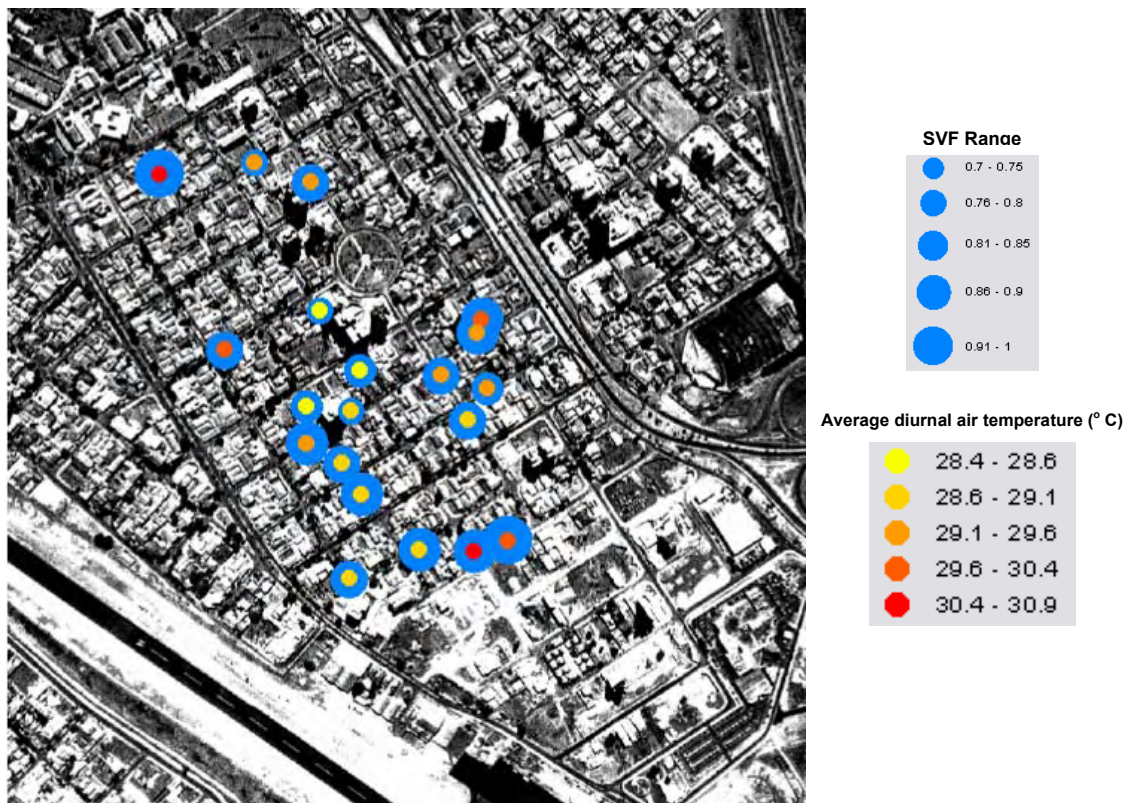


Fig. 9 – Diurnal average temperature X SVF

The same kind of analysis was performed to the average surface temperature inside the urban canyons. Table 2 shows numerically the same tendency found in the first case.

Table 2: Surface temperature by SVF ranges

SVF ranges	Surface Temperature
0.70 a 0.75	29.8
0.76 a 0.80	29.2
0.81 a 0.85	30.2
0.86 a 0.90	30.5
More than 0.91	32.0

Also the averages of minimum air and surface temperatures were analyzed. Table 3 reveals their tendencies. Here the behavior of the urban heat island can be verified by analyzing the averages of minimum air temperature. During the day, the larger the sky view factor, the higher the mean air temperature inside urban canyons. For minimum temperatures, occurring at early mornings, there is also a tendency that the larger the sky view factor, the higher its degree. Although this requires more data to be confirmed, this might reinforce that there is some heat storage due to the buildings blockage of the sky visibility.

Table 3 – Average minimum air and surface temperatures in °C

SVF Range	Minimum air	Minimum surface temperature
0.70 a 0.75	25.4	22.5
0.75 a 0.80	24.7	21.9
0.80 a 0.85	24.6	21.8
0.85 a 0.90	24.9	22.2
More than 0.90	25.6	22.0

For the averages of maximum air and surface temperatures, the relationships of sky view factors and temperature levels were also studied. Here, again, the larger the SVF, the higher the degree of maximum air temperature inside the urban canyon. The map for spatial representation of these data is shown in Figures 10 and 11.

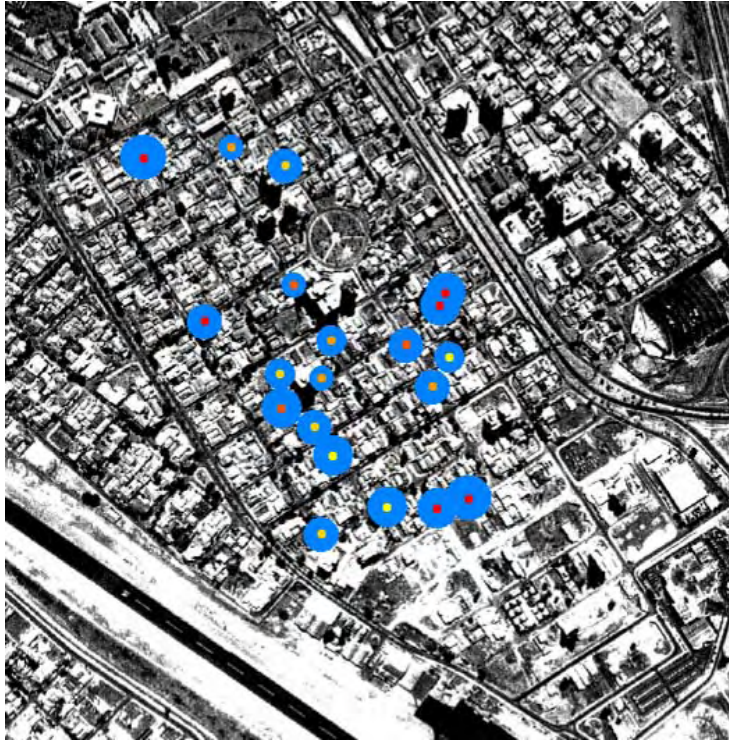


Figure 10 – Maximum air temperature x SVF



Figure 11 – Maximum surface temperature x SVF

The average thermal amplitude of the air and of the surface was also considered. Table 4 presents those values. There is a 1.4 °C difference on the temperature of the first range and that one of the last range. The lower the SVF value, the higher the thermal inertia of the urban canyon, also demonstrating the heat storage of the buildings.

Table 4 – Thermal Amplitude in Celsius degrees in relation to the SVF Ranges

SVF ranges	Air Amplitude	Surface Amplitude
0.70 a 0.75	13.37	14.9
0.75 a 0.80	14.33	15.0
0.80 a 0.85	13.78	14.8
0.85 a 0.90	14.63	15.3
0.90 a 1.00	14.13	16.3

The analysis also considered the ranges of energy consumption of the urban canyons in relation to the thermal characteristics of the air and the surface. This is what Figures 12 and 13 represent.

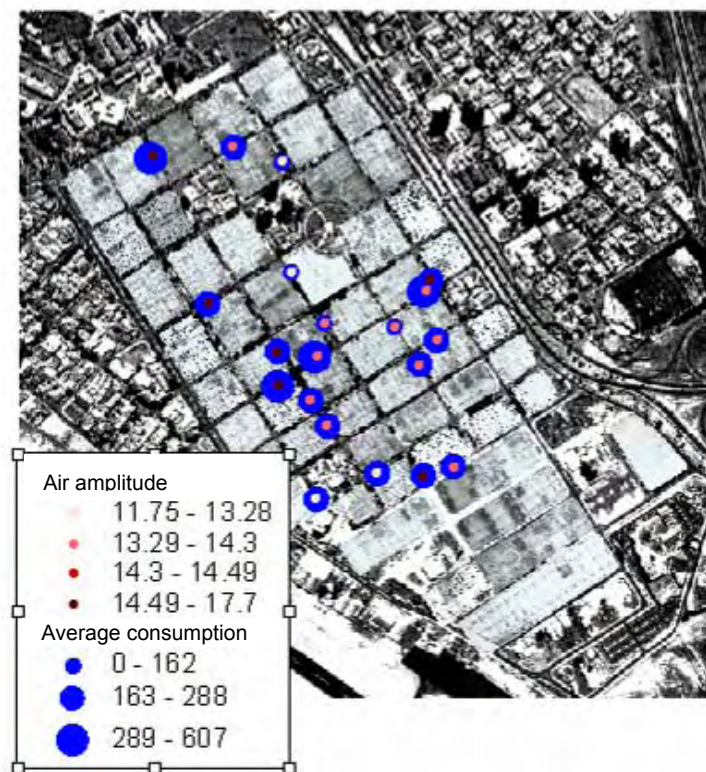


Figure 12 – Air amplitude X energy consumption

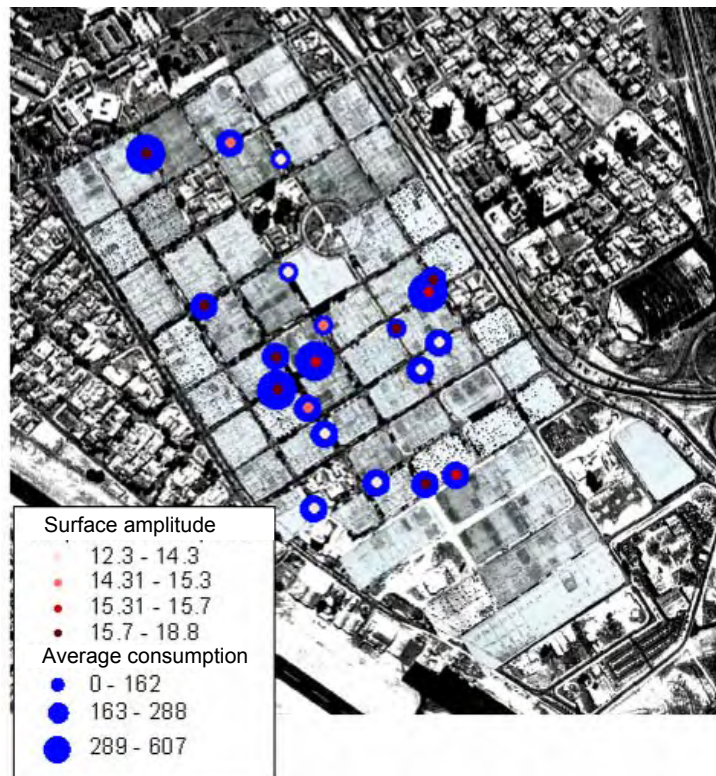


Figure 13 – Surface amplitude x energy consumption

The larger energy consumption range corresponds to the highest thermal amplitudes, meaning that thermal instability also represents the highest consumer buildings. For the air temperature and the surface temperature this result was the same.

4 CONCLUSIONS

The 3DskyView extension emphasizes the potential of GIS as an important supporting tool in urban thermal analysis. The feature of automatically determining sky view factors for several observers simultaneously helps on optimizing simulation time and generating important data for urban planners. Before, with the first version, it was only possible to do that by running the extension as many times as the number of observers considered. Furthermore, the sunpaths diagrams overlaying the stereographic projection of an urban canyon allow the determination of solar access at any time of the year.

The new features together enhanced the ability of the extension and, by means of the application here conducted, it was demonstrated the advantages it can offer to decision makers in cross-examining data.

It is although proper to highlight that a translation to the actual code of Visual-Basic for Applications should be studied in the near future in order to make the extensions also available to the more recent versions of Arcview.

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