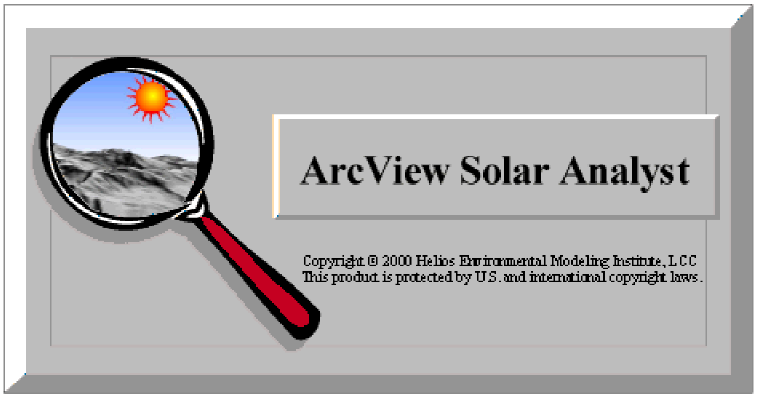
The Solar Analyst 1.0

User Manual

Helios Environmental Modeling Institute, LLC



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Importance of Understanding Landscape Patterns of Solar Radiation

Incoming solar radiation (insolation), with a continual input of 170 billion megawatts to the earth, is the primary driver for our planet's physical and biological processes (Geiger 1965, Gates 1980, Dubayah and Rich 1995, 1996). A broad spectrum of human activities (agriculture, forestry, building design, and land management) ultimately depend upon insolation. At a global scale, the latitudinal gradients of insolation, caused by the geometry of Earth's rotation and revolution about the sun, are well known. At a landscape scale, topography is the major factor modifying the distribution of insolation. Variability in elevation, surface orientation (slope and aspect), and shadows cast by topographic features create strong local gradients of insolation. This leads to high spatial and temporal heterogeneity in local energy and water balance, which determines microenvironmental factors such as air and soil temperature regimes, evapotranspiration, snow melt patterns, soil moisture, and light available for photosynthesis. These factors in turn affect the spatial patterning of natural processes and human endeavor. Accurate insolation maps at landscape scales are desired for many applications. Although there are thousands of solar radiation monitoring locations throughout the world (many associated with weather stations), for most geographical areas accurate insolation data are not available. Simple interpolation and extrapolation of point–specific measurements to areas are generally not meaningful because most locations are affected by strong local variation. Accurate maps of insolation would require a dense collection station network, which is not feasible because of high cost. Spatial solar radiation models provide a cost-efficient means for understanding the spatial and temporal variation of insolation over landscape scales (Dubayah and Rich 1995, 1996). Such models are best made available within a geographic information system (GIS) platform, whereby insolation maps can be conveniently generated and related to other digital map layers.

Spatial Solar Radiation Models

Spatial insolation models can be categorized into two types: point specific and area based. Point-specific models compute insolation for a location based upon the geometry of surface orientation and visible sky. The local effect of topography is accounted for by empirical relations (Buffo *et al.* 1972, Frank and Lee 1966, Kondrtyev 1969), by visual estimation (Swift 1976, Flint and Childs 1987), or, more accurately, by the aid of upward-looking hemispherical (fisheye) photographs (Rich 1989, 1990, Rich *et al.* 1999). Point-specific models can be highly accurate for a given location, but it is not feasible to build a specific model for each location over a landscape. In contrast, area-based models compute insolation for a geographical area, calculating surface orientation and shadow effects from a digital elevation model (DEM) (Hetrick *et al.* 1993a, 1993b, Dubayah and Rich 1995, 1996, Rich *et al.* 1995, Kumar *et al.* 1997). These models provide important tools for understanding landscape processes. The SolarFlux model (Hetrick *et al.* 1993a, 1993b, Rich *et al.* 1995), developed for use within the ARC/INFO GIS platform (Environmental Systems Research Institute [ESRI], Redlands, CA), simulates the influence of shadow patterns on direct insolation using the ARC/INFO Hillshade function at discrete intervals through time. Solarflux was implemented in the Arc Macro Language (AML), which strongly limits its computation speed and its accessibility. Kumar *et al.* (1997) developed a similar model using ARC/INFO and the GENAMAP GIS software (GENASIS, Australia). Whereas point-specific models can be highly accurate for a specific location, area-based models can calculate insolation for every location over a landscape. A new generation of spatial models is needed that combines these respective advantages, providing rapid and accurate maps of insolation over landscape scales.

The Solar Analyst

The Solar Analyst draws from the strengths of both point-specific and area-based models. In particular, it generates an upward-looking hemispherical viewshed, in essence producing the equivalent of a hemispherical (fisheye) photograph (Rich 1989, 1990) for every location on a DEM. The hemispherical viewsheds are used to calculate the insolation for each location and produce an accurate insolation map. The Solar Analyst can calculate insolation integrated for any time period. They account for site latitude and elevation, surface orientation, shadows cast by surrounding topography, daily and seasonal shifts in solar angle, and atmospheric attenuation. It is implemented as an ArcView GIS extension. The Solar Analyst has the following advantages over previously developed models:

- **Versatile output:** calculates direct, diffuse, global radiation, and direct radiation duration, sunmaps and skymaps, and viewsheds;
- **Simple input:** requires only DEM, atmospheric transmittivity, and diffuse proportion (latter two parameters calculated from nearby weather stations or using typical values);
- **Flexibility:**
  - calculates insolation for any specified period (instantaneous, daily, monthly, weekly …);
  - calculates insolation for any region (whole DEM, restricted areas, or point locations);
  - allows specification of receiving surface orientation (from DEM, field survey, or orientations of surfaces such as sensors or leaves) and height offsets for ground features;
- **Fast and accurate calculation:** uses advanced viewshed algorithm for calculations; accounts for viewshed (sky obstruction by near–ground features), surface orientation, elevation, and atmospheric conditions; calculation engine implemented in C++ library format and dynamically loaded;

- **Broad accessibility**: the Solar Analyst runs within ArcView and does not require expensive, high–end GIS software;
- **User friendly interface:** implements user interface with ArcView Dialog Designer and ArcView Avenue; benefits from ArcView's mapping, query, graphing, & statistics functions;
- **Programmable capabilities**: improves user efficiency by allowing task automation; permits development of custom models (e.g., energy balance and water balance models) by programming the Solar Analyst along with Avenue or other model libraries.

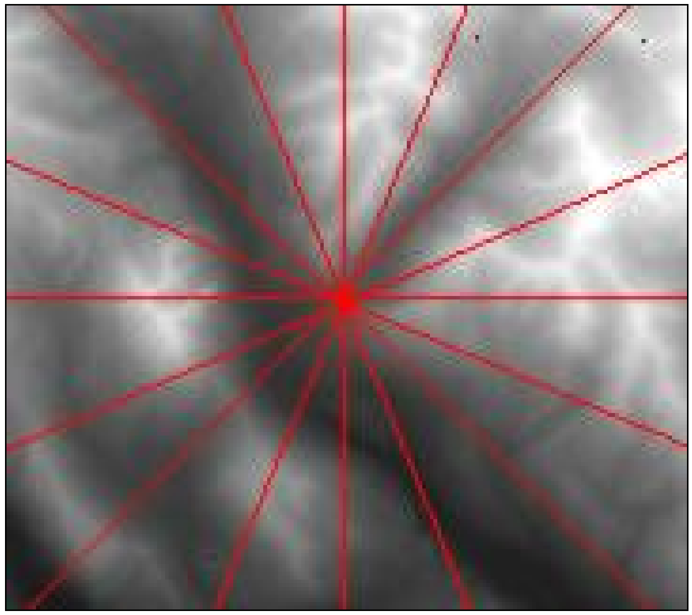
Theory

Hemispherical Viewshed Algorithm

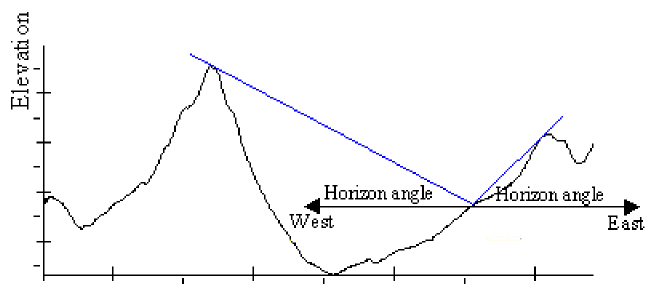
Solar Radiation originating from the sun travels through the atmosphere, is modified by topography and other surface features, and then is intercepted as direct, diffuse, and reflected insolation components. Generally, direct radiation is the largest component of total radiation, and diffuse radiation is the second largest component. Radiation reflected to a location from surrounding topographic features generally accounts for a small proportion of total incident radiation and for many purposes can be neglected (Gates 1980, Rich 1989, 1990, Hetrick *et al.* 1993a, 1993b, Kumar 1997). Rich (1989) and Rich *et al.* (1994) developed an hemispherical viewshed algorithm for rapid insolation calculation which, until now, has only been partially implemented in point-specific models including Canopy (Rich 1989, 1990) and Hemiview software (Rich *et al.* 1999) used for analysis of hemispherical photography. This algorithm serves as the core of the Solar Analyst.

Viewshed calculation

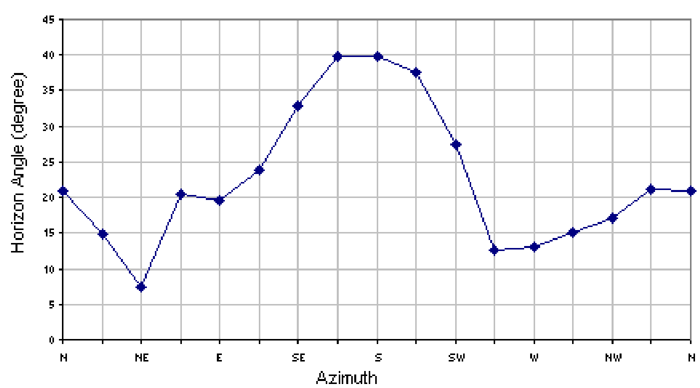
Viewsheds are calculated for each cell of an input DEM. A viewshed is the angular distribution of sky visibility versus obstruction. This is similar to the view provided by upward-looking hemispherical (fisheye) photographs. A viewshed is calculated by searching in a specified set of directions around a location of interest (Fig. 1A), determining the maximum angle of sky obstruction, sometimes referred to as effective horizon angle, in each direction (Fig. 1B) (Dozier and Frew 1990). For other unsearched directions, horizon angles are calculated using interpolation (Fig. 1C). Then the horizon angles are converted into a hemispherical coordinate system, in particular utilizing an equiangular hemispherical projection, which represents a three-dimensional hemisphere of directions as a two-dimensional grid (Fig. 1D). The resolution of the viewshed grid must be sufficient to adeduately represent all sky directions, but small enough to enable rapid calculations, e.g., 200 x 200 cells, 512 x 512 cells. Each grid cell is assigned a value that corresponds with visible versus obstructed sky directions. The grid cell location, row and column, corresponds to a zenith angle θ (angle relative to the zenith) and an azimuth angle α (angle relative to north) on the hemisphere of directions.



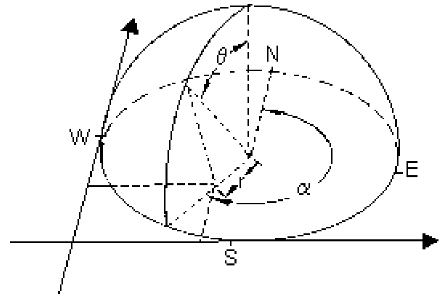
A) Directions for Horizon Angle Calculations



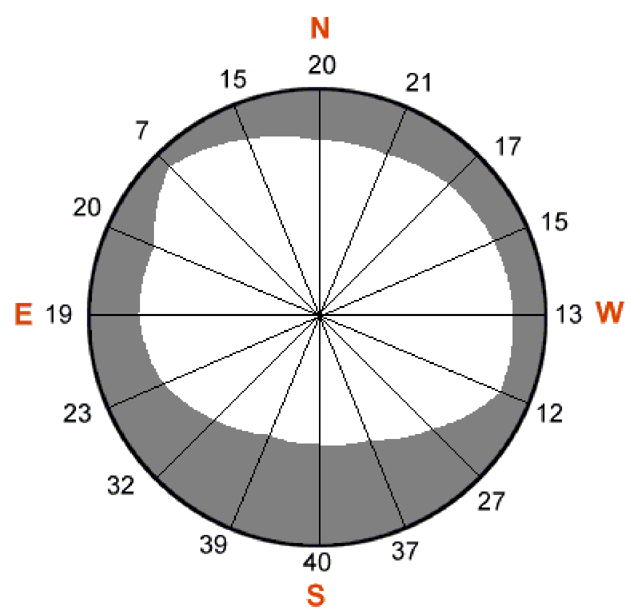
B) Calculation of Horizon Angles



C) Interpolation of Horizon Angles



D) Conversion to Hemispherical Coordiates

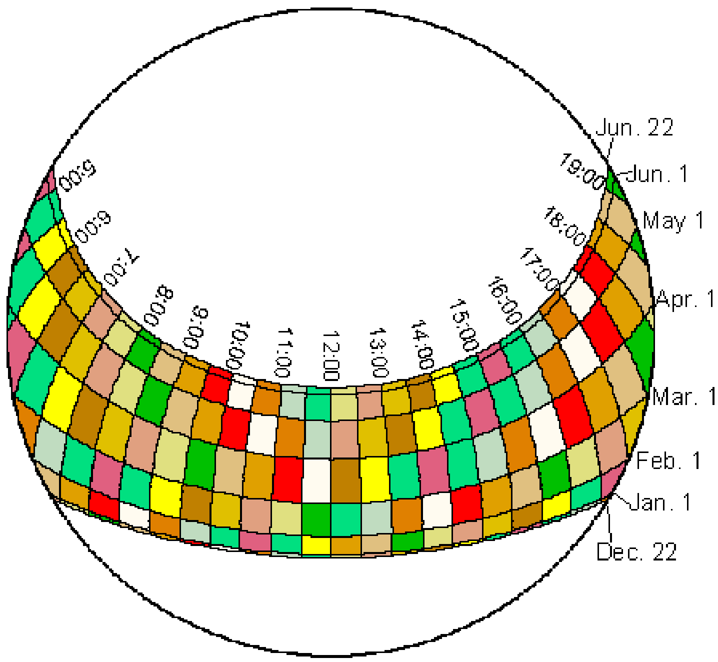


E) Resultant Viewshed

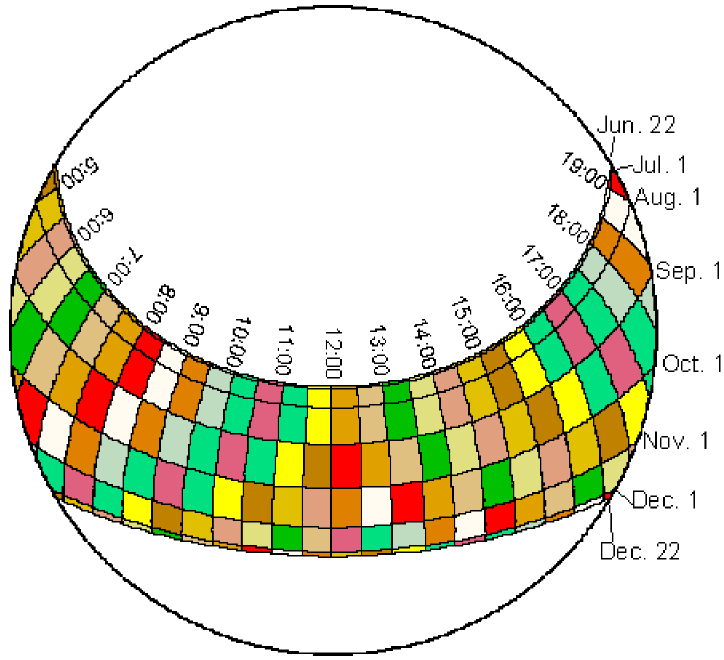
Fig 1. Calculation of the viewshed for one cell of a DEM. A) Horizon angles are traced along a specified set of directions; B) horizon angles are calculated for each direction; C) horizon angles are interpolated for all directions; D) horizon angles are converted to a hemispherical coordinate system; and E) the resulting viewshed for a location represents which sky directions are visible and which are obscured. Numbers represent the calculated horizon angles.

Sunmap calculation

The amount of direct solar radiation originating from each sky direction is represented by creating a sunmap in the same hemispherical projection as for the viewshed (Fig. 2). The sunmap consists of a raster representation that specifies suntracks, the apparent position of the sun as it varies through time. In particular, suntracks are represented by discrete sky sectors, defined by sun position at intervals through the day and season (e.g., half-hour intervals through the day and month intervals through the season). The position of the sun (zenith and azimuth angles) is calculated based on latitude, day of year, and time of day using standard astronomical formulae (modified version of Gates 1980). Zenith and azimuth angles are projected into two-dimensional grids with the same resolution used for viewsheds. Two sunmaps are created, one to represent periods between the winter solstice and the summer solstice (December 22 to June 22) and the other to represent periods between the summer solstice and the winter solstice (June 22 to December 22). Each sky sector of the sunmap is assigned a unique identification number. For each sector, the associated time duration, the azimuth and zenith at its centroid are calculated. This calculation also accounts for partial sectors near the horizon.



A) Sunmap for Winter Solstice to Summer Solstice



B) Sunmap for Summer Solstice to Winter Solstice

Fig. 2. Annual sunmaps for 39° N latitude using 0.5 hour intervals through the day and month intervals through the year, A) from the winter solstice to the summer solstice, and B) from the summer solstice to the winter solstice.

Penumbral effects: Penumbral effects refer to decreased direct beam radiation at the edge of shadow due to partial obscuration of the solar disc. For sunmaps that represent one day or less, penumbral effects must be taken into account. Currently, the Solar Analyst use a constant solar disc semidiameter of 0.00466 radians (0.2668°).

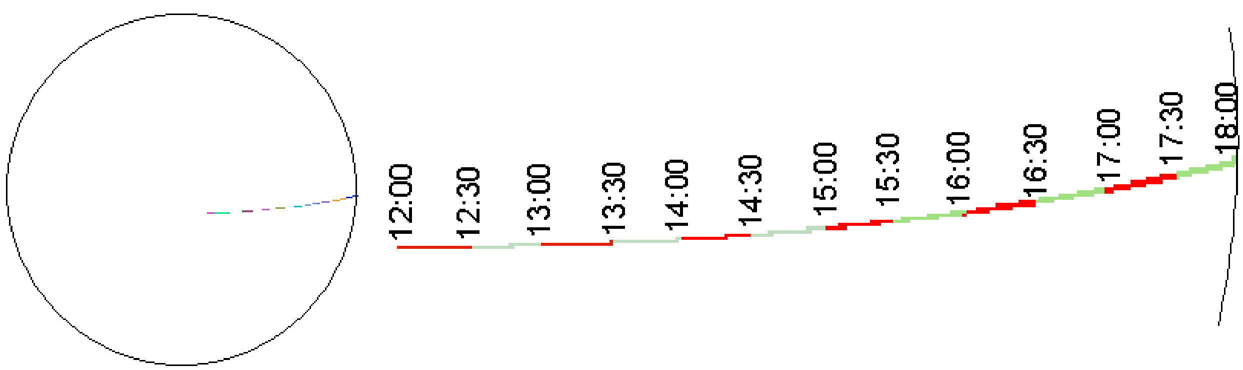


Fig. 3. Penumbral effects are accounted for by constructing sunmaps with consideration of the apparent size of the solar disc.

Skymap calculation

Unlike direct insolation, which only originates from directions along the suntrack, diffuse solar radiation can originate from any sky direction. Skymaps are raster maps constructed by dividing the whole sky into a series of sky sectors defined by zenith and azimuth divisions. Each sector is assigned a unique identification number (Fig. 4). The zenith and azimuth angles of the centroid of each sector are calculated. Sky sectors must be small enough that the centroid zenith and azimuth angles reasonably represent the direction of the sky sector in subsequent calculations. For example, a skymap with 16 evenly spaced zenith divisions and 16 evenly spaced azimuth divisions has sky sectors that represent 5.625^o zenith intervals and 22.5^o azimuth intervals (Fig. 4).

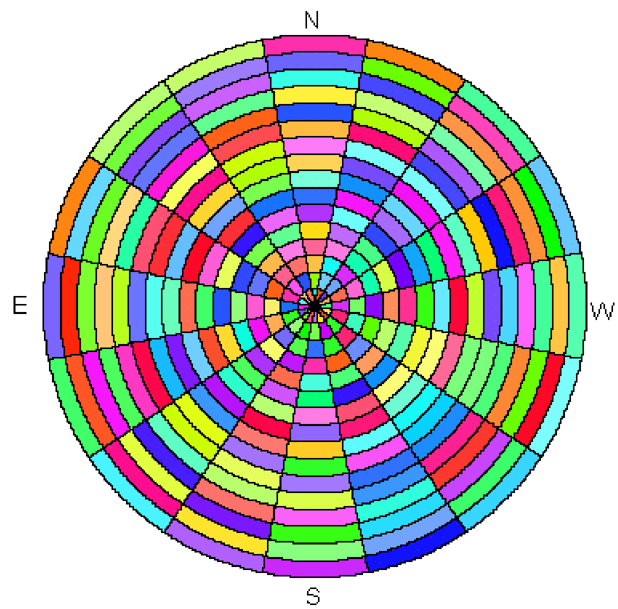
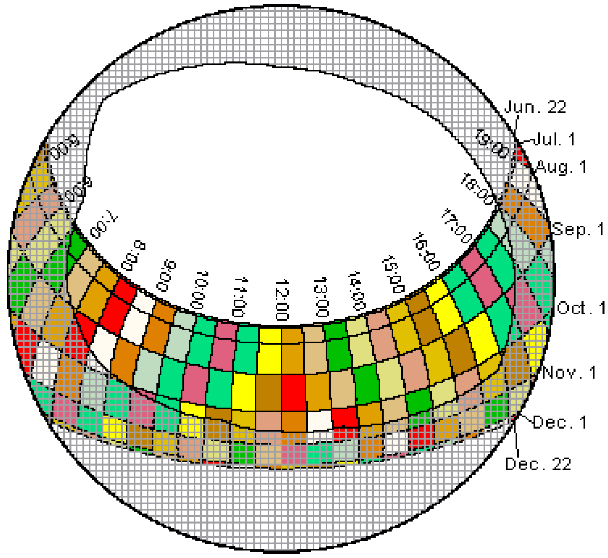


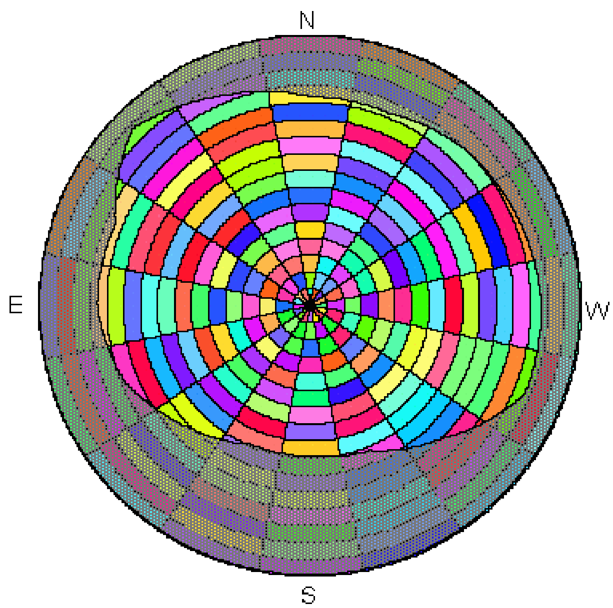
Fig. 4. A skymap with sky sectors defined by 16 zenith divisions and 16 azimuth divisions.

Overlay of viewsheds with sunmaps and skymaps

The viewshed is overlaid on skymap and sunmaps (Figure 5) to enable calculation of diffuse and direct radiation received from each sky direction. Gap fraction, the proportion of unobstructed sky area in each skymap or sunmap sector, is calculated by dividing the number of unobstructed cells by the total number of cells in that sector.



A) Overlay of Viewshed with Sunmap



B) Overlay of Viewshed with Skymap

Fig. 5. Overlay of a viewshed on A) a sunmap and B) a skymap. Shaded areas are obstructed sky directions.

Direct Solar Radiation Calculation

For each sunmap sector that is not completely obstructed, solar radiation is calculated based on gap fraction, sun position, atmospheric attenuation, and ground receiving surface orientation of the intercepting surface. The Solar Analyst implements a simple transmission model (Rich 1989, 1990, Pearcy 1989, Monteith and Unsworth 1990, Gates 1980, List 1971), which starts with the solar constant and accounts for atmospheric effects based on transmittivity and air mass depth.

Total direct insolation ($\mathbf{Dir_{tot}}$) for a ground location is the sum of the direct insolation ($\mathbf{Dir}_{\theta,\alpha}$) from all sunmap sectors:

$$\mathbf{Dir_{tot} = \Sigma Dir_{\theta,\alpha}} \quad \textbf{(1)}$$

The direct insolation from the sunmap sector ($\mathbf{Dir}_{\theta,\alpha}$) with a centroid at zenith angle θ and azimuth angle α is calculated using the following equation:

$$\mathbf{Dir_{\theta,\alpha} = S_{Const} * \tau^{m(\theta)} * SunDur_{\theta,\alpha} * SunGap_{\theta,\alpha} * cos(AngIn_{\theta,\alpha})} \quad \textbf{(2)}$$

where:

$\mathbf{S_{Const}}$ is the solar flux outside the atmosphere at the mean earth-sun distance, know as solar constant. Estimates of the solar constant range from 1338 to 1368 WM^{-2}. As a result of more precise measurements, the Commission for Instruments and Methods of Observation in 1981 agreed to adopt the World Radiation Center (WRC) solar constant (1367 WM^{-2}), as is used in the Solar Analyst. Solar constant fluctuates slightly, a few tenths of a percentage over periods of years (Iqbal 1983), and this can be accounted for by differences in the distance between the earth and sun from the mean earth-sun distance;

τ is transmittivity of the atmosphere (averaged over all wavelengths) for the shortest path (in the direction of the zenith);

m(θ) is the relative optical path length, measured as a proportion relative to the zenith path length (see equation 3, below).

$\mathbf{SunDur_{\theta,\alpha}}$ is the time duration represented by the sky sector. For most sectors, it is equal to the day interval (e.g., a month) multiplied by the hour interval (e.g., a half hour). For partial sectors (near the horizon), the duration is calculated using spherical geometry;

$\mathbf{SunGap_{\theta,\alpha}}$ is the gap fraction for the sunmap sector;

$\mathbf{AngIn_{\theta,\alpha}}$ is the angle of incidence between the centroid of the sky sector and the axis normal to the surface (see equation 4, below).

Relative optical length (**m(θ)**) is determined by the solar zenith angle and elevation above sea level. For zenith angles less than 80°, it can be calculated using the following equation:

$$\mathbf{m(\theta) = EXP(-0.000118 * Elev - 1.638 * 10^{-9} * Elev^2) / cos(\theta)} \quad \textbf{(3)}$$

where:

θ is the solar zenith angle;

Elev is elevation above sea level in meters.

The effect of surface orientation is accounted for by multiplying by the cosine of the angle of incidence. Angle of incidence ($\mathbf{AngInSky_{\theta,\alpha}}$) between the intercepting surface and a given sky sector with a centroid at zenith angle θ and azimuth angle α is calculated using the following equation:

$$\mathbf{AngIn_{\theta,\alpha} = acos[Cos(\theta)*Cos(G_z)+Sin(\theta)*Sin(G_z)*Cos(\alpha-G_a)]} \quad \textbf{(4)}$$

where:

G_z is the surface zenith angle;

G_a is the surface azimuth angle.

For zenith angles greater than 80° refraction is important. Various astronomical tables provide corrections for refraction at zenith angles greater than 80° (e.g., List 1971, Table 137; Monteith and Unsworth 1990, p. 40).

Diffuse Solar Radiation Calculation

For diffuse radiation the uniform diffuse model and the standard overcast diffuse model are typically implemented (Rich 1989, 1990, Pearcy 1989) with satisfactory results. In a uniform diffuse model, sometimes referred to as a "uniform overcast sky (UOC)" but often applied in clear sky conditions, incoming diffuse radiation is assumed to be the same from all sky directions. In a standard overcast (SOC) diffuse model, diffuse radiation flux varies with zenith angle according to an empirical relation (Moon and Spencer 1942). Both these models are implemented in the Solar Analyst. Other models can readily be implemented in the future, including anisotropic models, based on assigning each sky sector an appropriate value for diffuse radiation originating in that direction. For each sky sector, the diffuse radiation at its centroid ($Dif_{\theta,\alpha}$) is calculated, integrated over the time interval, and corrected by the gap fraction and angle of incidence using the following equation:

$$Dif_{\theta,\alpha} = R_{glb} * P_{dif} * Dur * SkyGap_{\theta,\alpha} * Weight_{\theta,\alpha} * \cos(AngIn_{\theta,\alpha}) \quad (5)$$

where:

R_{glb} is the global normal radiation (see equation 6 below);

P_{dif} is the proportion of global normal radiation flux that is diffused. Typically it is approximately 0.2 for very clear sky conditions and 0. 7 for very cloudy sky conditions;

Dur is the time interval for analysis;

$SkyGap_{\theta,\alpha}$ is the gap fraction (proportion of visible sky) for the sky sector;

$Weight_{\theta,\alpha}$ is proportion of diffuse radiation originating in a given sky sector relative to all sectors (see equation 7 and 8, below);

$AngIn_{\theta,\alpha}$ is the angle of incidence between the centroid of the sky sector and the intercepting surface.

The global normal radiation (R_{glb}) can be calculated by summing the direct radiation from every sector (including obstructed sectors) without correction for angle of incidence, and then correcting for proportion of direct radiation, which equals to $1-P_{dif}$:

$$R_{glb} = (S_{Const}\, \Sigma\, (\tau^{m(\theta)}))/ (1 - P_{dif}) \quad (6)$$

For the uniform sky diffuse model, $Weight_{\theta,\alpha}$ is calculated as follows, based on the derivation of Rich (1989):

$$Weight_{\theta,\alpha} = (\cos\theta_2 - \cos\theta_1) / Div_{azi} \quad (7)$$

where:

θ_1 and θ_2 are the bounding zenith angles of the sky sector;

$\mathbf{Div_{azi}}$ is the number of azimuthal divisions in the skymap.

For the standard overcast sky model, $\mathbf{Weight}_{\theta,\alpha}$ is calculated as follows based on the empirical model of Moon and Spencer (1942):

$$\mathbf{Weight_{\theta,\alpha} = (2\cos\theta_2 + \cos 2\theta_2 - 2\cos\theta_1 - \cos 2\theta_1) / 4 * Div_{azi}} \qquad \mathbf{(8)}$$

Total diffuse solar radiation for the location ($\mathbf{Dif_{tot}}$) is calculated as the sum of the diffuse solar radiation ($\mathbf{Dif}_{\theta,\alpha}$) from all the skymap sectors:

$$\mathbf{Dif_{tot} = \Sigma Dif_{\theta,\alpha}} \qquad \mathbf{(9)}$$

Global Solar Radiation Calculation

Global radiation ($\mathbf{Global_{tot}}$) is calculated as the sum of direct and diffuse radiation of all sectors.

$$\mathbf{Global_{tot} = Dir_{tot} + Dif_{tot}} \qquad \mathbf{(10)}$$

The above calculation of viewshed, overlay of viewshed on sunmaps and skymaps, and calculation of direct, diffuse and global insolation are repeated for each location on the topographic surface, thus producing insolation maps for an entire geographic area.

Getting Started

System Requirements

Hardware: Pentium computers with a minimum of 32M RAM. The calculation also requires a large disk space to store model results. The actual disk space required depends on your input DEM size and output you need. Generally you should have 100M free space before running the model. More than a gigabyte of disk space can be required for handling large DEMs and multiple outputs.

Operating System: MS Windows NT 4.x, Windows 95/98, or Windows 2000.

Software: ArcView 3.x and the Spatial Analyst extension.

Installation

Download the installation file, click the setup button, the installation wizard will guide through the rest of the installation. The installation directory should be where ArcView is installed, e.g. c:\esri\av_gis30\arcview.

The installation program will install SolarExt.Avx to the ext32 directory, and several DLLs to the bin32 directory. These files will be removed when the Solar Analyst is uninstalled.

Tutorial

Preparing the Sample Data

First, you will download the sample data (size <350 KB compressed), set up a working directory, extract the data, load the Solar Analyst extension, and load the data into ArcView.

Download Sample Data

Download the sample data from the following web site:

http://www.hemisoft.com/download/solaranalyst/samples.exe.

Make a directory (e.g., d:\samples), and unzip the sample data to this directory. The following data will be extracted.

Dem (DEM grid),

Demm (mask grid),

Dema (aspect grid),

Dems (slope grid),

Pntcov (point coverage), and

Pntxy.txt (X/Y coordinate file with slope and aspect).

Create an Output Directory

This tutorial will generate many output files. It would be good to create an output directory (e.g. d:\tutorial) and store output files in this directory. Be sure that at least 10 Mbytes is available on the disk where the directory is located.

Load the Solar Analyst

Start ArcView, and then choose the **Extensions…** dialog from the **File** menu. Check **Solar Analyst**; then click OK. Start a new view window (by default, the name of the view is “view1”. The menu **Solar** will appear in the view menu bar, and three new icons will appear (a button and two tools).

Load Sample Data

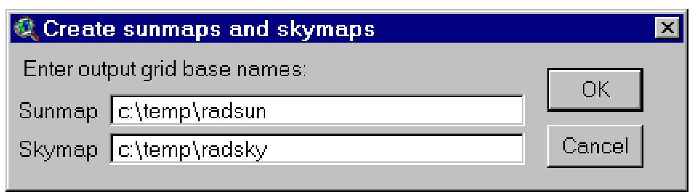
Add the following sample data to view1: **Dem** as a grid theme and **Pntcov** as a point theme. Make **Dem** the active theme. Observe that the Solar Analyst tools are now enabled.

Using the Buttons and Tools

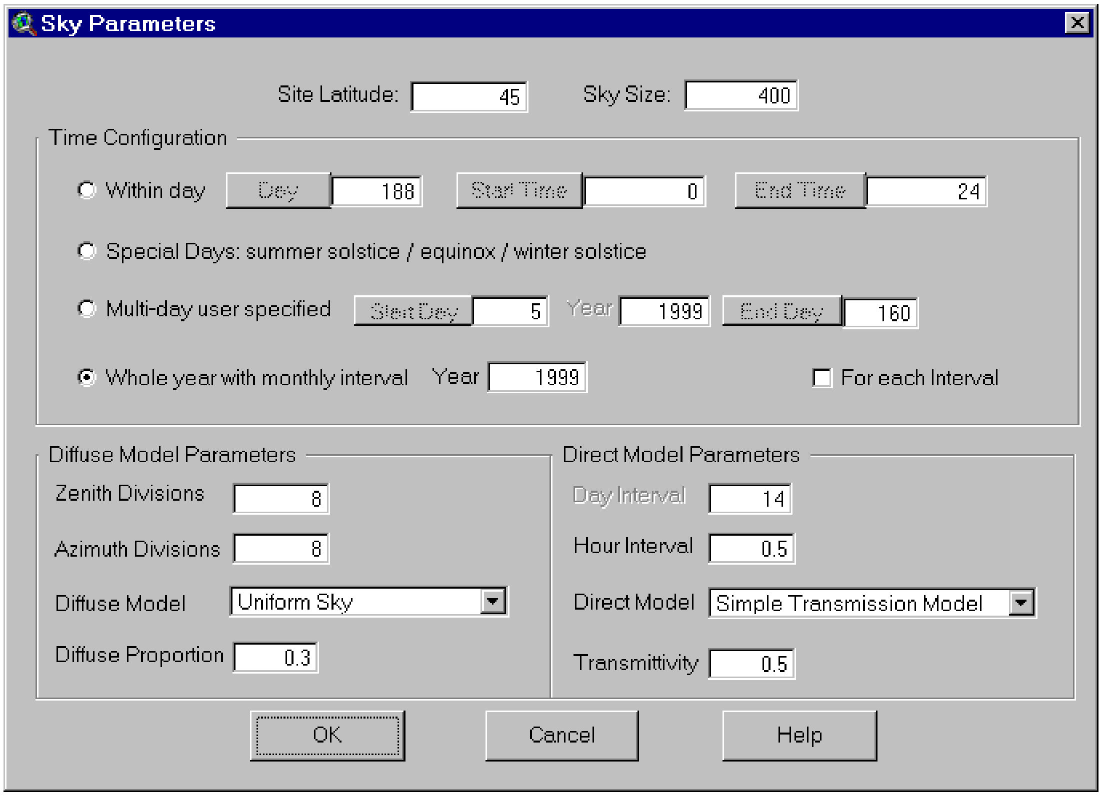
Now you can start using the Solar Analyst to produce sunmaps and skymaps with the skymap/sunmap button, to produce viewsheds with the viewshed tool, and to calculate insolation with the insolation tool. These capabilities enable interactive selection of locations for which calculations are performed. Further capabilities are available via the **Solar** menu.

Skymap/Sunmap Button

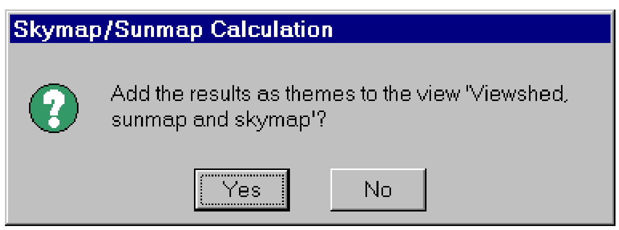
Click the skymap/sunmap icon  on the view button bar. The following dialog window will appear.



Change the default directory to the your output directory. Click **OK**.



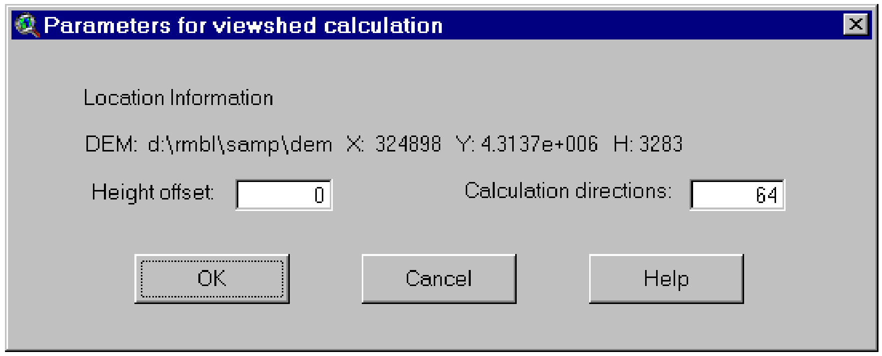
You may change the default parameters. Change the **sky size** to 400 and the **latitude** to 45. Change the **time configuration** to **Whole year with monthly interval**. Then click **OK**.



Click **Yes**. You will see a view named “Viewshed, sunmap and skymap” is created and the skymaps and sunmaps you just created are displayed in this view.

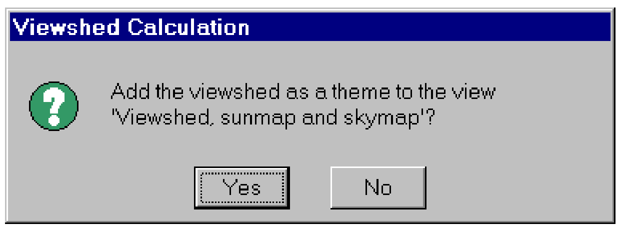
Viewshed tool

Make **View1** the active window, and make **dem** the active theme. Observe that the viewshed tool icon  on the view tool bar is enabled. Click the viewshed tool icon. Then choose a location for calculating a viewshed by clicking anywhere in **view1**. The following dialog window will appear.



You may change these parameters. Leave **height offset** as 0, to perform the calculation for ground level. Change **calculation directions** to 64, to specify that horizon angle will be traced in 64 directions. Click **OK**. You will then be prompted for the output viewshed names:

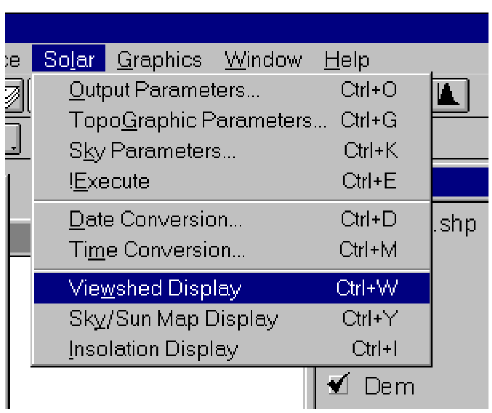
Change the directory to your output directory and click **OK**.



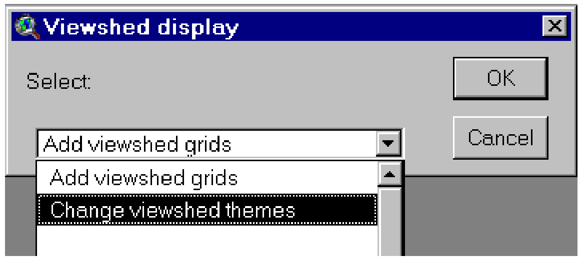
Click **Yes**. You will see the viewshed you just created is displayed in the view “Viewshed, sunmap and skymap”. The dark green area is obstructed and the light cyan area is open sky.

Change the open sky to transparent

Make the view “Viewshed, sunmap and skymap” the active window, and click the viewshed theme you just created to make it the active theme. Select the **Solar** menu:



Select **Viewshed Display**. The **Viewshed display** dialog window will appear:

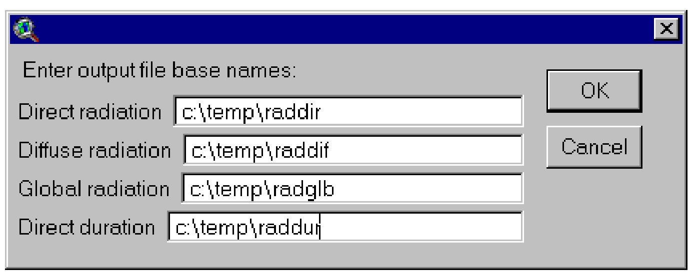


Select **Change viewshed themes**. You will then be prompted for the following question:

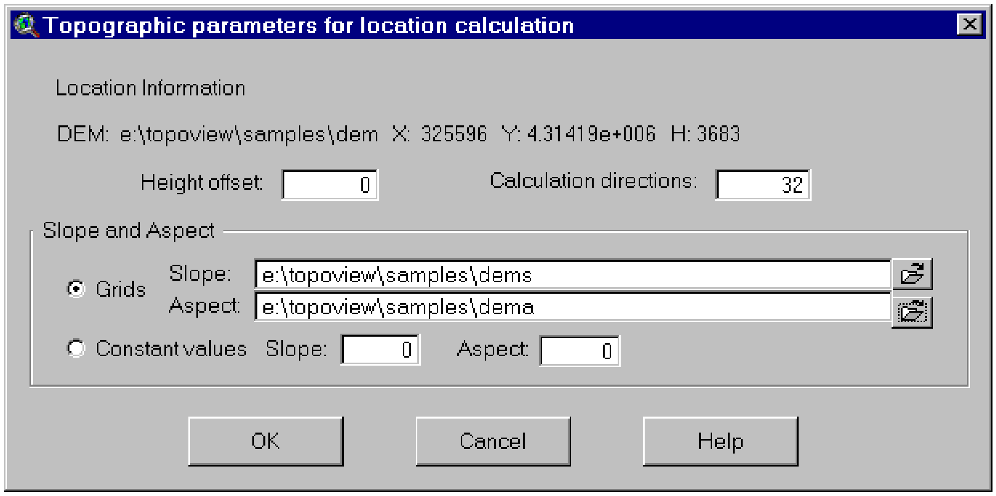
Click **Yes**. The open sky in the viewshed is now displayed as transparent. The sunmap will now be visible in the open sky directions. Note which part of the sun track is blocked and which part is open. Check off the sunmaps so that the skymap is visible in the open sky directions. Note which part of the sky is blocked and which part is not.

Insolation Tool

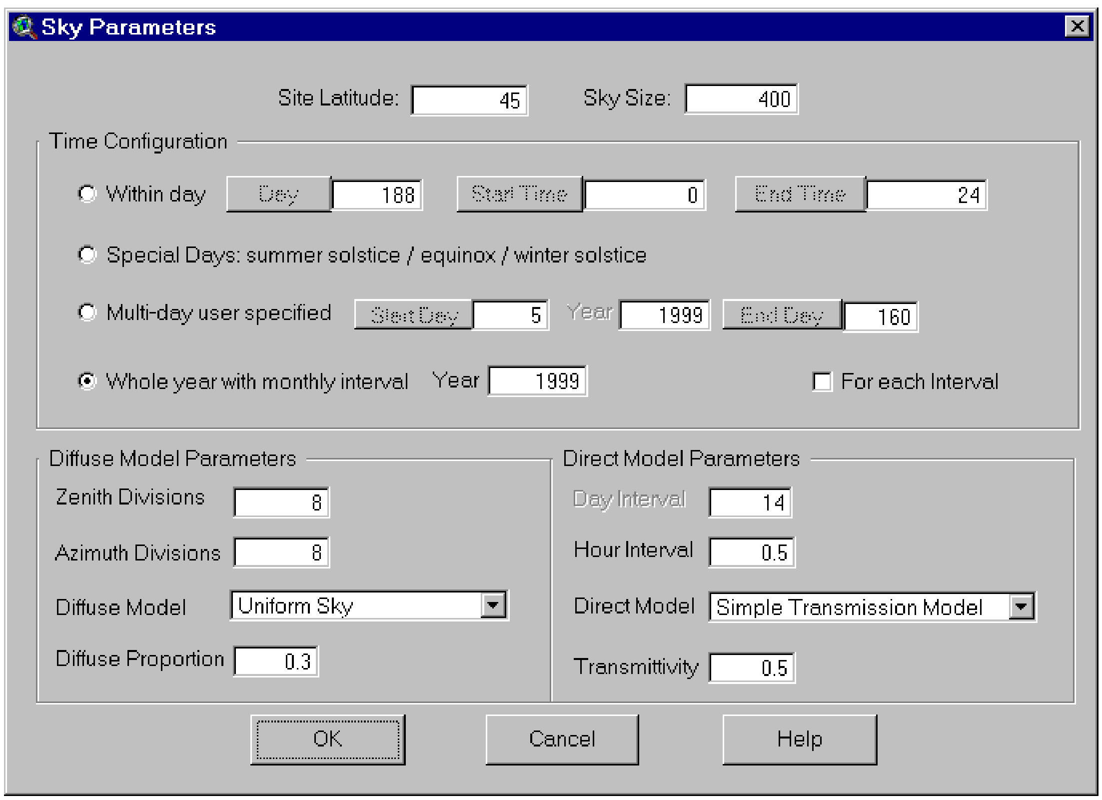
Make **View1** the active window, and make **dem** the current theme. The insolation tool icon  will be enabled in the view tool bar. Click the insolation tool icon. Then select a location for which insolation will be calculated by clicking anywhere in **view1**. The **Insolation output files** dialog window will appear:



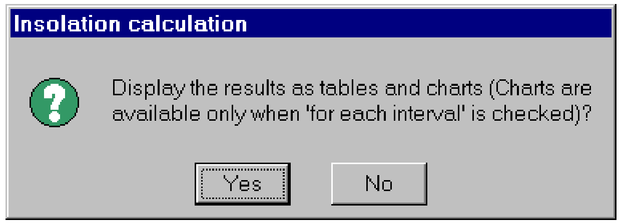
Change the directory to your output directory. Click **OK**. The **Topographic parameters for location calculation** window will appear:



You may change any of these parameters. Slope and aspect can be given constant values or can be derived from a grid. Choose the slope file dems and the aspect file dema in your sample data directory. Note that if the slope and aspects grids did not exist, they would be automatically created from the DEM. Click **OK**. The **Sky Parameters** window will appear:



You may change these parameters. For example, set **latitude** to 45. Select **Whole year with monthly interval**. Thencheck the **For each interval** option. This option will cause insolation to be calculated for each month, since the interval is monthly. If we had preferred to calculate hourly patterns, we could have selected **Within day** and checked the **For each interval** option. Click **OK** to initiate calculations. The following **Insolation calculation** dialog box will appear:



Click **Yes**. The monthly insolation patterns will be displayed as tables and charts. Enlarge each of the charts and inspect your results. (Note: Limitations of ArcView may only permit view of part of the data, although all of the data is present in the output files.)

Menus

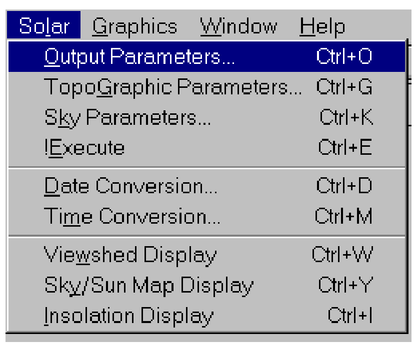
The **Solar** menu provides more capabilities than the buttons and toolbars. The buttons and toolbars are only useful for interactive calculations for selected locations. The Solar menu enables batch calculation, including insolation maps and calculations for many locations. This tutorial includes three exercises to familiarize users with the menus of the Solar Analyst.

Exercise 1

In this exercise the user calculates insolation (direct, diffuse, global, and direct duration), skymap/sunmaps, and viewsheds for locations in a point theme.

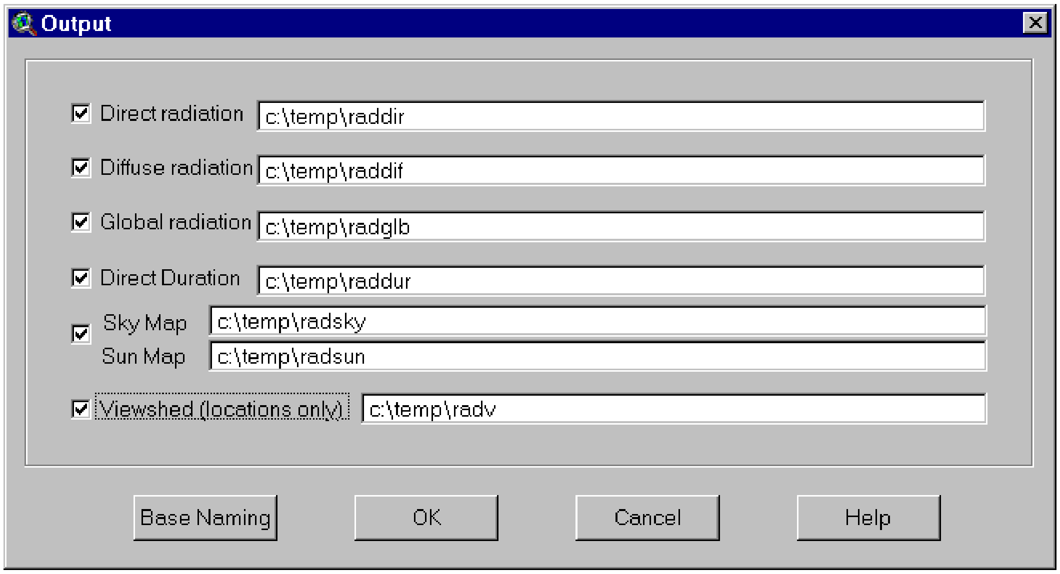
Step 1

Select the **Solar** menu. The following choices will appear.



Step 2

Select **Output Parameters**. The **Output** window will appear:



Results will be calculated for each kind of output for which the box is checked. Select all types of output by checking all the boxes, as above. Enter a base name to be used for all output files by entering a a name for the **direct radiation** output file. For example, enter d:\{your_output_directory}\raddir. Click **Base Naming**. Observe that the Solar Analyst fills in names for all the other output file names. Click **OK** to continue.

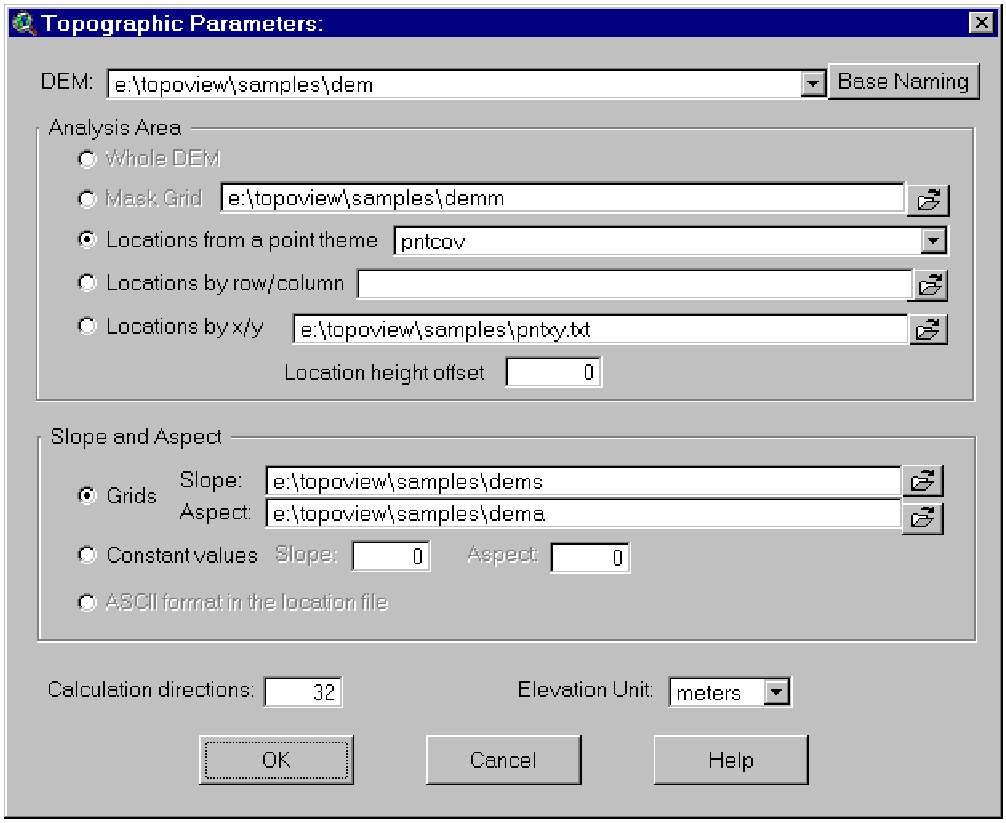
Step 3

In many cases the user will now specify additional calculation paramters by first choosing **topographic parameters** and then choosing **sky parameters**. In this exercise we will use a shortcut.

Choose **!Execute** in the **Solar** menu. A dialog window will appear asking whether you wish to review parameters before initiating calculations. Because insolation calculations can be time consuming, it is very important to be sure all parameters are correct. In this exercise calculations are rapid because the sample data set is small. Calculation for a large DEM can take hours, and a very large DEM can take days. Click **Yes** to review paramaters and initiate calculations.

First, the **output parameters** window appears again. Make sure that all of the settings are correct and then press **OK**. Note that pressing **Cancel** will cancel the execution of calculations.

Next, the topographic parameter window will appear:



The **DEM** drop box, selected by clicking the small downward arrow, enables choice of input DEM theme. In our case there is only one choice, the sample DEM theme in **view1**.

Click **Base Naming** and note how this causes the mask, slope, and aspect input grids to use the same base name as the DEM.

Observe that **Whole DEM** and **Mask Grid** are disabled because you previously checked **viewshed output** in the **output parameters** window, and because viewshed can only be calculated for specific locations. It would not be practical to store viewsheds for all locations in a DEM, although they are all calculated when producing insolation maps.

Select **Locations from a point theme**. The point theme **pntcov** will appear. If multiple points themes are available, the desired theme should be selected with the drop box.

The **Slope and Aspect** dialog enables specification of surface orientation either from a **Grid** or from a user-specified **Constant value**. Select **Grids**. Note that the slope and aspect grids were included with the sample data.

Alternatively, the same location data could be entered from a text file that contains map coordinates, slope, and aspect values, as follows:

x,y,slope,aspect

0.3255412E+06, 0.4314769E+07,10,330

0.3251693E+06 0.4313907E+07,20,270

0.3258740E+06; 0.4313134E+07;20,90

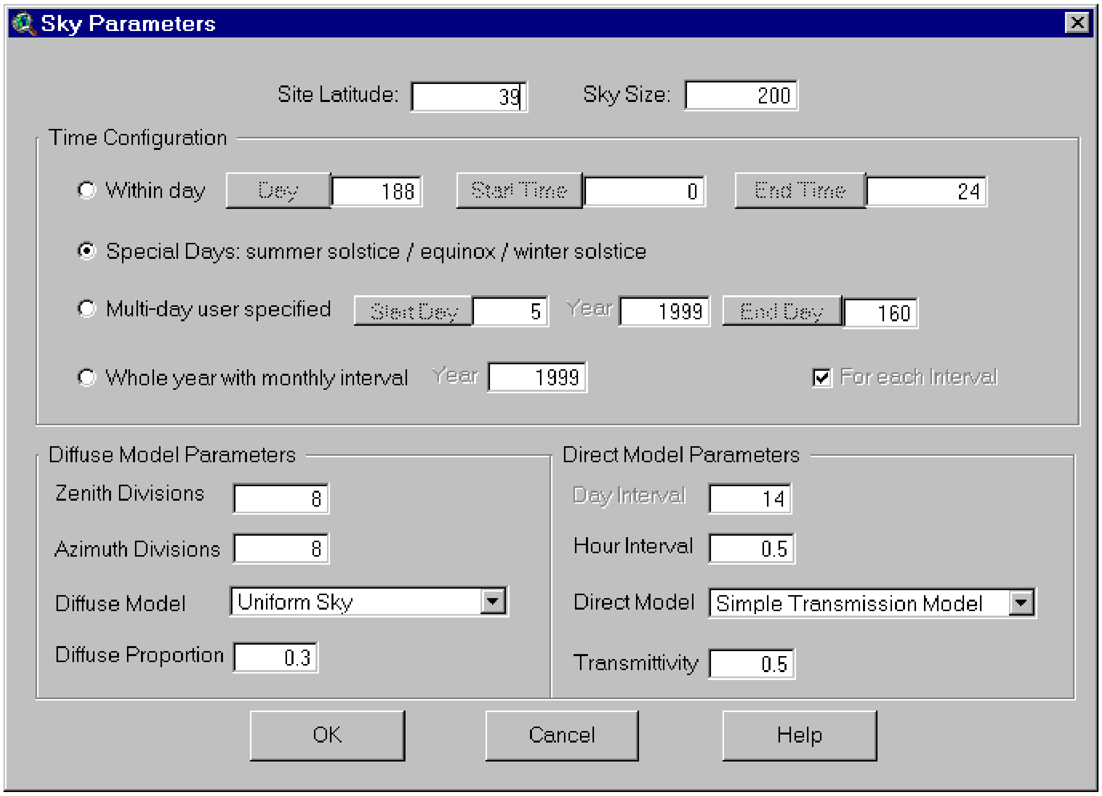
0.3258251E+06 0.4314182E+07;15,180

In this case, we would choose **Locations by X/Y** as the **Analysis Area** and **ASCII format in the location file** as the **Slope and Aspect** source.

Click **OK** to continue.

Step 4

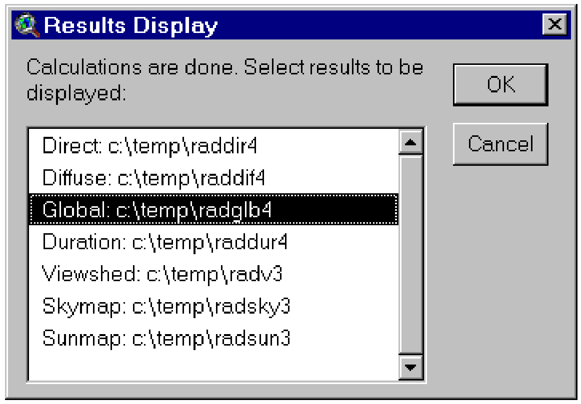
The **sky parameter** window will appear:



Set **latitude** to 39 and **sky size** to 400. Select the **Time configuration** as **Special Days: summer solstice / equinox / winter solstice**. This choice performs calculations for these three "special" days. Click **OK** to continue. As before, clicking **Cancel** would cancel the execution of calculations. Now that the output, topographic, and sky parameters have been review, calculations are initiated.

Step 5

The Solar Analyst will take different amounts of time to complete calculations depending upon the computer being used. Calculations for this exercise typically take one to several minutes. Once calculations are complete, you will hear a beep and a **Results Display** dialog box will appear:



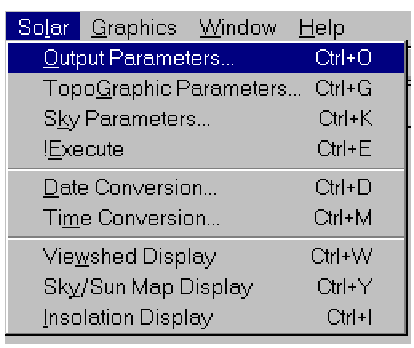
The **Results Display** permits choice of which output results to display as a table, chart, or view. Highlight **Global** and **Viewshed**. Then press **OK**. The global insolation will be displayed in a table and a chart. The viewsheds will be displayed as separate themes in the view **viewshed, sunmap and skymap**. Examine your results. You can observe four new viewshed themes in the view, four curves in the chart, and four rows in the table, one for each of the four locations in the point theme. For the global insolation table, the order of the rows corresponds to the order of the location labels in **view1**. Similarly, the viewshed grids use the base name plus a unique number that corresponds to the label order in **view1**.

Exercise 2

In this exercise the user calculates insolation maps (direct, diffuse, global, and direct duration) for a specified area.

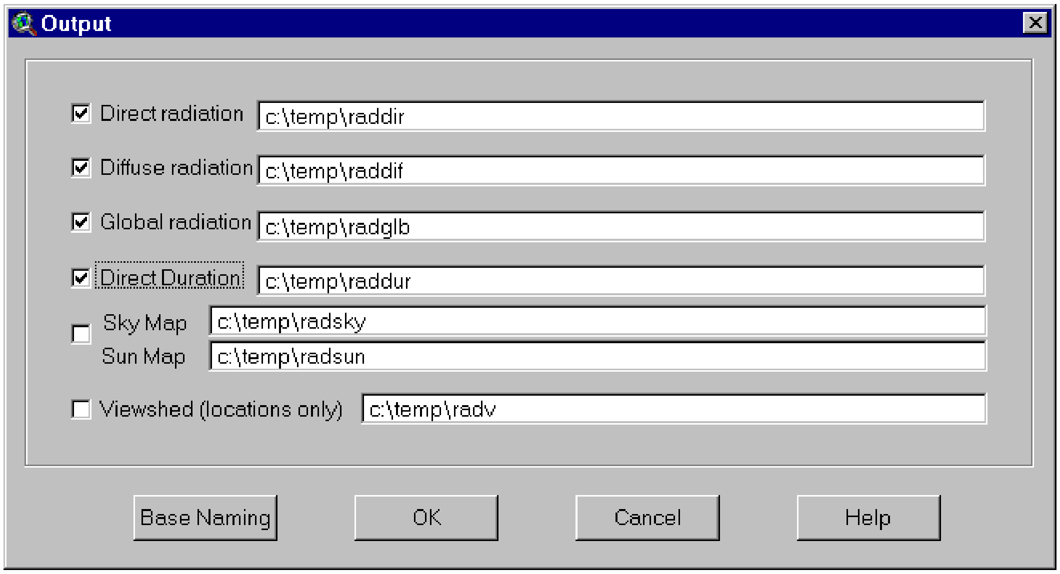
Step 1

Choose the **Solar** menu. The following choices appear:



Step 2

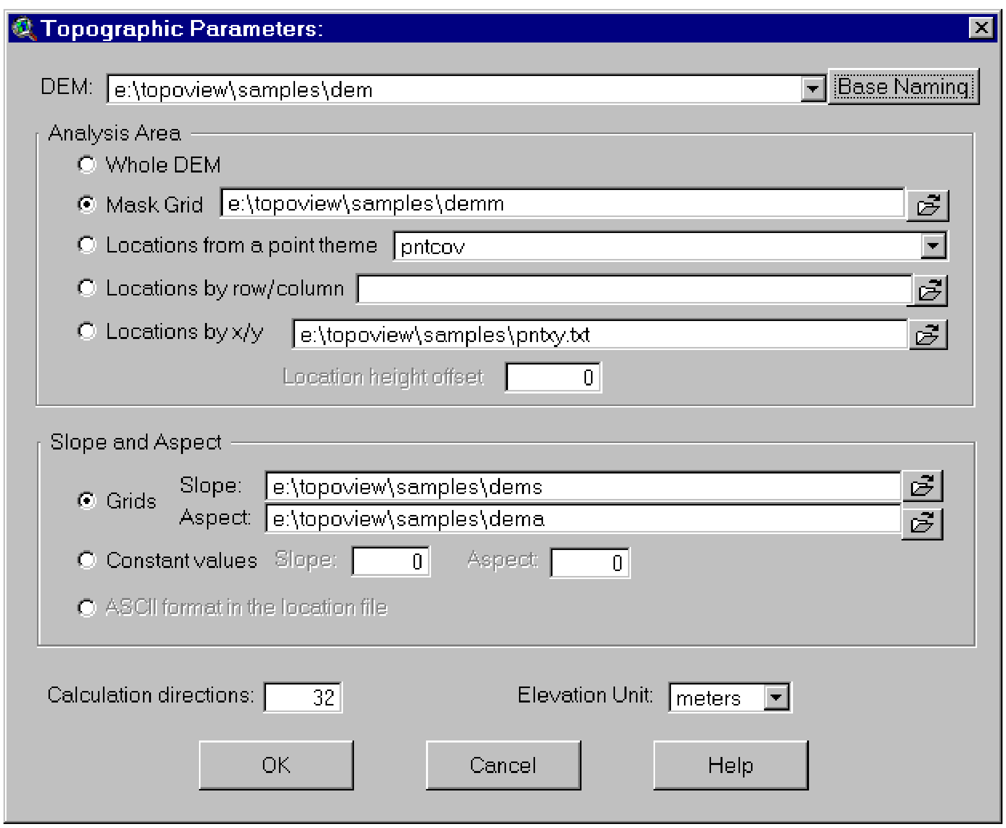
Select **Output Parameters** to bring up the **Output** window:



Check the boxes for direct, diffuse, global, and direct duration. Enter a path and filename for the **Direct radiation** output. Press **Base Naming** to automatically assign names for the other output based on the **Direct radiation** file name.

Step 3

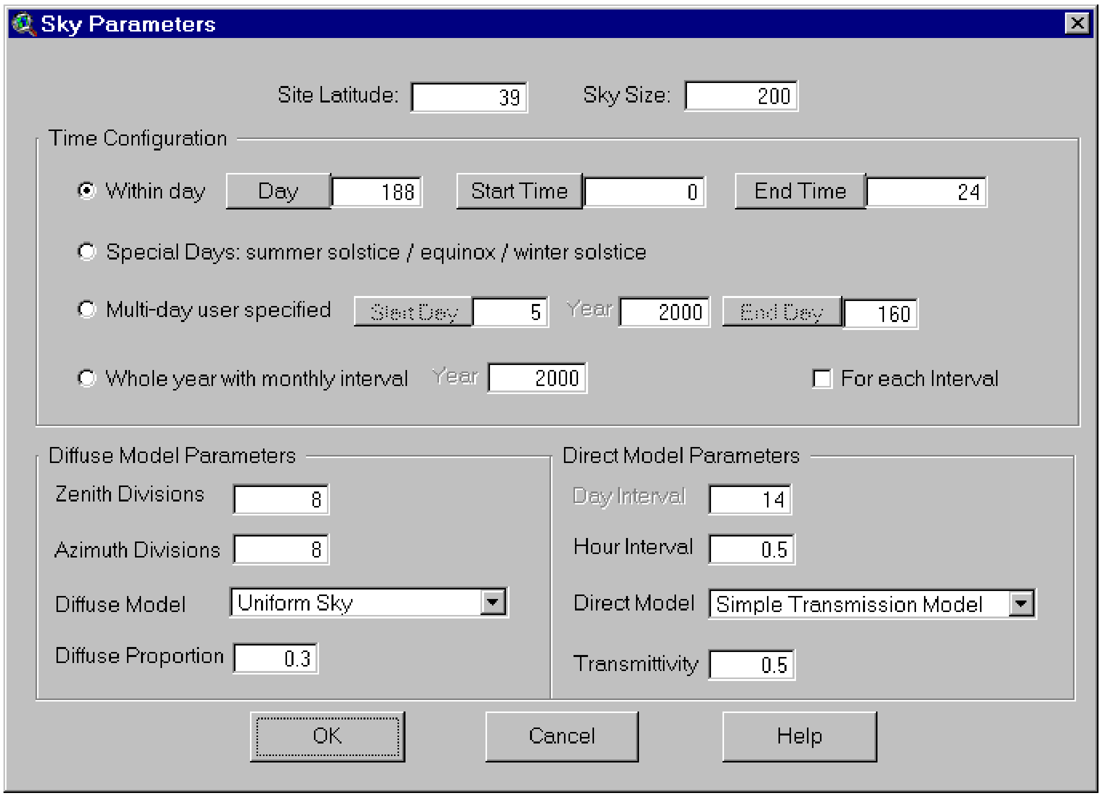
Choose **Topographic Parameters** in the **Solar** menu to bring up the **Topographic Parameters** window:



Verify that **dem** is specified as the input DEM. Then click **Base Naming** to automatically assign names for other input files. For **Analysis Area**, choose **Mask Grid** and verify that **demm** is the mask grid. For **Slope and Aspect** choose **Grids** and verify that **dems** and **dema** are the slope and aspect grid names, respectively. Choose **OK** to continue.

Step 4

Choose **Sky Parameters** in the **Solar** menu to bring up the **Sky Parameters** window:

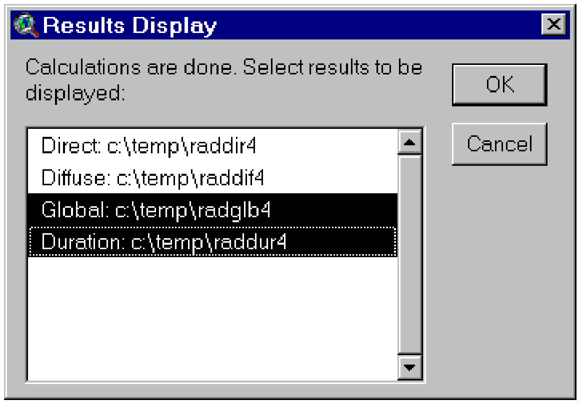


Set **latitude** to 39 and **sky size** to 200. For **Time Configuration** select **Within day** and set **Day** (Julian day) to 188, **Start Time** to 0, and **End Time** to 24 , . Be sure the box **For each Interval** is <u>not</u> checked. If this box is checked, a separate grid will be produced for each 0.5 hour. Choose **OK** to continue.

Step 5

Choose **!Execute** in the **Solar** menu to initiate calculations. Click **Yes** to review the **Output**, **Topographic**, and **Sky Parameters**. For each of the parameter windows press **OK**. After you press **OK** for the **Sky Parameters**, calculations will start. It may require several minutes to complete calculations for the sample DEM, depending upon the computer configuration. Larger DEMs can require hours or days to complete calculations.

When the calculations are complete, the **Display Results** dialog box will appear:

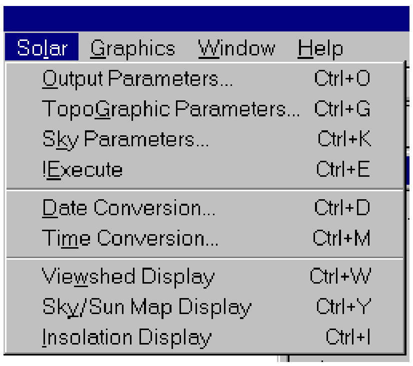


Highlight **Global** and **Duration** and Click **OK**. The results will be displayed in **view1** using the predefined classification method and shade color ramp. Inspect the maps to see how annual global insolation and direct duration differ according to topographic position.

Menu References

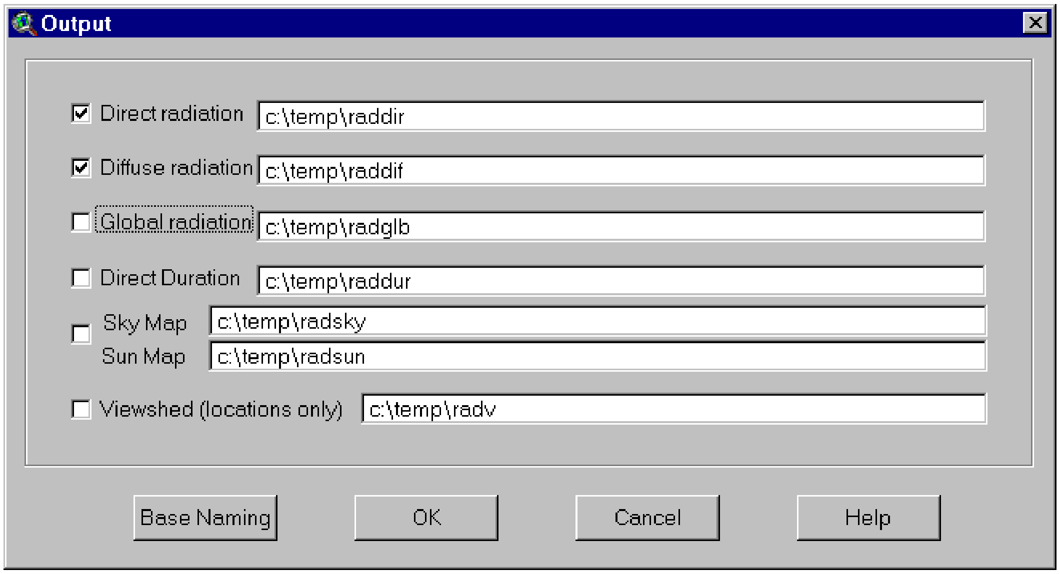
Solar menu

The Solar Analyst adds a **Solar** menu to the view menu bar. This menu provides access to an array of solar modeling capabilities.



Output parameters

This window enables the user to specify details of calculations to be performed and output files. Check each type of output to be calculated and specify a filename (including directory) where results are to be placed. **Base Naming** enables automatic naming based on the direct solar radiation name. Explanations of each output choice are provided below. Important notes are provided at the end of this section and should be read carefully by users.



Direct solar radiation:

Check this box to output direct radiation files. This choice specifies that direct incoming solar radiation will be calculated. The output has units of WH/m^2. The specified file name is used as the base file name for other outputs (see **Base Naming**). Output format can be either grid or ASCII text.

Diffuse solar radiation

Check this box to output diffuse radiation files. This choice specifies that diffuse incoming solar radiation will be calculated. The output has units of WH/m^2. When this choice is selected, direct solar radiation output is also automatically selected. Output format can be either grid or ASCII text.

Global solar radiation

Check this box to output global radiation files. This choice specifies that global (direct + diffuse) incoming solar radiation will be calculated. The output has units of WH/m^2. When this choice is selected, direct and diffuse solar radiation outputs are also automatically selected. Output format can be either grid or ASCII text.

Direct radiation duration

Check this box to output direct radiation duration files. This choice specifies that the duration of direct incoming solar radiation will be calculated. The output has units of hours. When this choice is selected, direct solar radiation is also automatically selected. Output format can be either grid or ASCII text.

Output Formats:

Outputs for direct, diffuse, global, and direct duration all use either grid or ASCII text formats:

- **ESRI Grid format** when calculating for whole grids or masked areas.

The program automatically adds numbers to the output name(s). For example, when using an input file with the name ***myfile***, the output files will be named ***myfile0***, ***myfile1***, ***myfile2***… The number of output grids depends on settings in the Solar parameters window, in particular, the ***for each interval*** checkbox.

- If ***for each interval*** is not checked: the actual output is myfile0, which is the total direct radiation for the calculated duration.
- If ***for each interval*** is checked: the actual outputs are ***myfile0***, ***myfile1***, ***myfile2***… Each grid stores the direct radiation for each time interval (hour of day interval when duration is less than one day, or day of year interval when duration is longer than one day).

- **In ASCII text format** when calculating for selected locations. The actual output file is named as ***myfile.txt***. Its format depends on the ***for each interval*** checkbox in the Solar Parameters window.

  - If ***for each interval*** is not checked, the output ASCII file format is as follows:

    row, column, value

    …

    where ***row*** and ***column*** specify the location of the selected cell and ***value*** is the radiation or duration value for the whole interval specified in the solar parameter window.

- If the ***for each interval*** checkbox is checked, the output ASCII file format is as follows:

    row, column, value0, value1, value2…

    …

    where ***value0, value1, value2,…*** indicate radiation or duration values for each time interval (hour of day interval when duration is less than one day, or day of year interval when duration is longer than one day).

Skymap and Sunmap

Check this box to output skymap and sunmap files. This choice specifies that the skymap and sunmap will be output in ESRI Grid format. The resolution of these grids is specified in the Solar Parameters window.

Skymap: Only one grid is generated for the skymap.

Sunmap: One or two sunmap grids may be generated, depending upon whether the interval includes overlapping sun positions for different times of year. A number is attached to the name of each sunmap (e.g., ***sunmap0*** and ***sunmap01***).

Viewshed

Check this box to output viewshed files. This choice enables calculation of viewsheds for specified locations. A list of locations for calculation can be specified in the Topographic Parameters window by X, Y coordinates or by cell row and column. The output is in ESRI Grid format at the same resolution as the skymap and sunmap.

Base Naming (output)

Press the ***Base–naming*** button to name all outputs according to the output name for the direct insolation calculation. First check the direct radiation output, next specify a name, and then press the ***Base–naming*** button. (If direct radiation is not a desired output, it can be checked off again after base naming has been performed.) The naming convention is as follows:

Direct solar radiation: ***{basename}dir***

Diffuse solar radiation: ***{basename}dif***

Global solar radiation: ***{basename}glb***

Direct radiation duration: ***{basename}dur***

Skymap: ***{basename}sky***

Sunmap: ***{basename}sun***

Viewshed: ***{basename}v***

Important Notes (output)

Base Names and Actual Output File Names

All names specified in the output parameter windows are base names. They are not the actual output file names. The actual file names add number indices to the base names. ArcView decides the number indices by avoiding file overwriting. For example, if the base name for direct radiation is raddir and a grid with a name raddir0 already exists, the next output for the direct solar radiation grid will be raddir1. You may wish to record a log of output to keep track of file contents while using the Solar Analyst.

By using base naming, users do not have to specify output names for each calculation. Protection against overwriting files also prevents data loss and crashes of ArcView.

Directory Creation

The Solar Analyst creates output grids or ASCII files, but it does not create the directories to contain these grids or ASCII files. For example, if you set your output direct solar radiation grid as ***d:\my_directory\insolation\raddir***, then the directory ***d:\my_directory\insolation*** must first be created before you can start the calculations. If the directory does not exist, the Solar Analyst report an error and calculations will not proceed.

No Float Grid

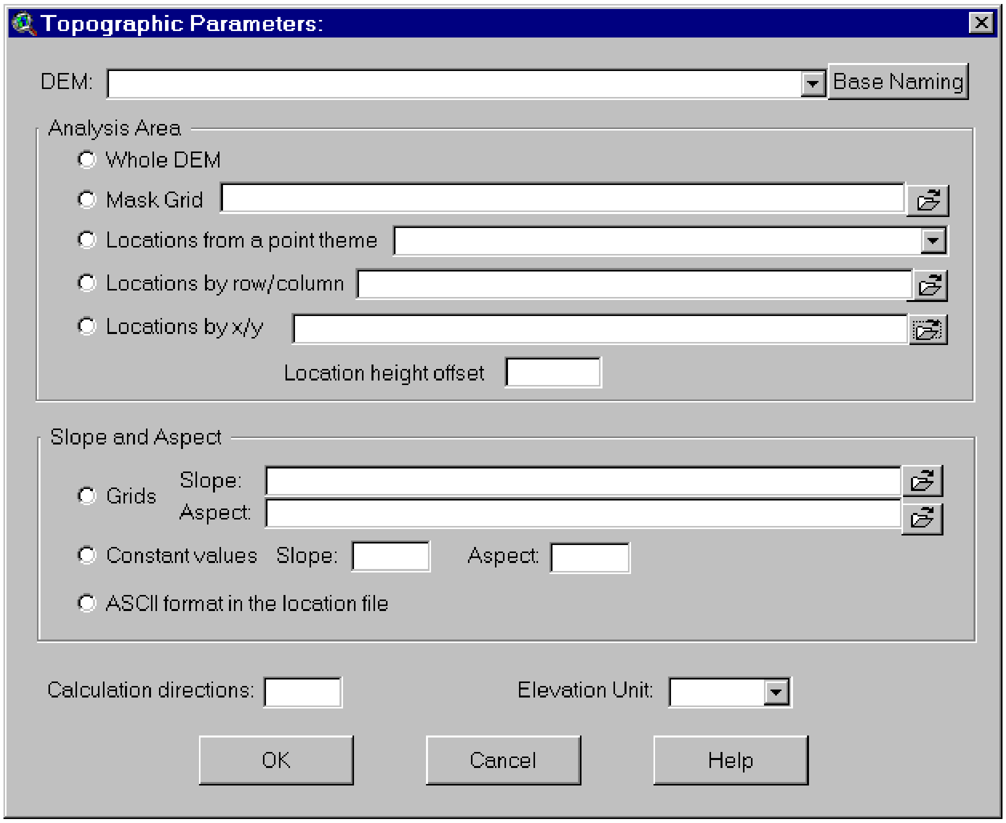
Output grids (including direct, diffuse, global, and direct duration) are all of integer type (because of a limit with creating float grids using C++). For calculations of instantaneous time periods, values are small, so results are multiplied by 100 to retain accuracy These grids should be divided by 100 to obtain their float values:

e.g., Grid: gridinst = float(outgrid / 100.0)

Topographic Parameters

This window specifies the input DEM, slope and aspect files, calculation area, and parameters related to viewshed calculations. Explanations of each parameter choice are provided below.

Before selecting this menu, the view with the input DEM should be active.



DEM

This specifies the filename of the DEM to use for calculation. All grid themes in the active view will be added to the drop-down list of available DEM choices. In cases where there are more than one grid in the active view, the DEM grid must to be selected.

The user can specify five types of analysis areas:

Whole DEM

Choose this option to perform calculations for all cells of a DEM. Calculations are performed for all cells except cells with NODATA values.

Mask grid

Choose this option to perform calculations for an area specified by a mask grid. A mask grid should be an existing ESRI Grid. When cells of the mask grid that have NODATA values, viewsheds and solar radiation values will not be calculated for corresponding cells in the DEM. When mask grid cells have any value other than NODATA, then calculations are performed for corresponding cells. Note that the entire DEM is still used for calculating viewsheds.

Locations from a point theme

Choose this option to perform calculations for a list of locations in a point theme. The theme can be an ARC/INFO coverage or an ArcView shape file. If particular locations have been selected in ArcView, then calculations will be performed only for those locations.

Locations by row and column

Choose this option to perform calculations for a list of locations specified in a row/column file. The row/column file should be an existing ASCII text file. Each line in the file should contain a row and column pair separated by space(s), comma(s), or semicolon(s). Blank lines and headlines will be filtered out when the file is read. The following is an example:

Row, col

8, 6

200; 500

700 1000

Locations by x and y coordinates

Choose this option to perform calculations for a list of locations specified in an X,Y coordinate file. The X,Y coordinate file should be an existing ASCII text file. Each line in the file should contain an X,Y pair separated by space(s), or comma(s), or semicolons (s). Blank lines and headlines will be filtered out when the file is read. The following is an example:

X, Y

12989.8; 28934.5

12345.567, 89453.213

700.456 1000.432

Location height offset

Enter the height offset appropriate for your calculations (default = 0). This value specifies the height (in meters) above the DEM surface for which calculations are to be performed. The same height offset will be applied to all locations specified in the X,Y coordinate file or row/column file.

For example, weather station sensors and solar powered devices are usually positioned at a height above ground level. Height offsets can make significant differences for viewshed and insolation calculations.

Slope and aspect

Specify the names (along with the directories) of the slope and aspect grids to be used for calculations. The user can specify three types of slope and aspect information:

Grids

Slope and aspect are derived from slope and aspect grids. Specify the names for the slope and aspect grids. Typically, these are calculated using either the ARC/INFO GRID ***slope*** and ***aspect*** commands, or using the ***Derive Slope*** and ***Derive Aspect*** menu choices of the Spatial Analyst extension of ArcView. Note, when using ArcView, the resultant slope and aspect grids are placed in a temporary directory (usually ***c:\temp***). Slope and aspect grids can also be constructed by users according to field measurements or other rules. If the specified slope and aspect grids do not exist, the Solar Analyst will automatically create them.

Constant values

Specify constant values for slope and aspect. For example, users need use slope 0 and aspect 0 corresponding to solar radiation sensors, or other orientations for surfaces such as leaves.

ASCII format in the location file

Specify slope and aspect in the location files (X/Y or R/C). The location file should be an existing ASCII text file. Each line in the file should contain a row/column or a x/y along with the slope and aspect. The values in each line should be separated by space(s), comma(s), or semicolon(s). Blank lines and headlines will be filtered out when the file is read. The following is an example:

Row, col, slope, aspect

8, 6, 15, 20

200; 500, 40,180

700 1000,32;275

The following is another example:

X, Y

12989.8; 28934.5, 15, 20

12345.567, 89453.213, 40,180

700.456 1000.432; 32;275

Directions

Enter the number of azimuth directions used when calculating viewsheds. Because the viewshed calculation is highly intensive, horizon angles are only traced for the number of directions specified. Valid values must be multiples of 8 (8, 16, 24, 32…). Typically, a value of 8 or 16 is adequate for areas with gentle topography, whereas a value of 32 is adequate for complex topography.

Elevation unit

Choose the units of measurement (meters, feet, etc.) of the input DEM. The Solar Analyst automatically converts the DEM elevation values into meters for calculation of air mass (the atmospheric path through which solar radiation travels).

Base Naming (Topographic parameters)

Pressing the **Base Naming** button automatically names all outputs according to the output name for the DEM. First specify the DEM name and then press the **Base Naming** button. The naming convention is as follows:

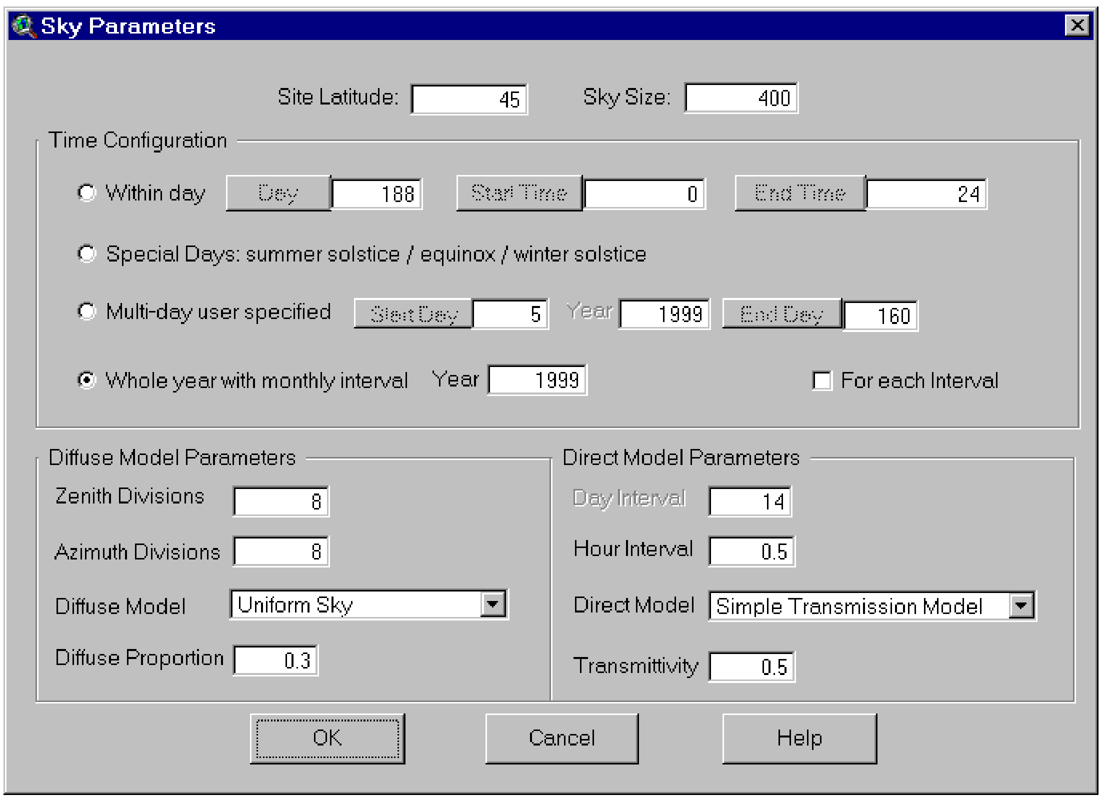
Mask grid: ***{DEM name}m***

Slope grid: ***{DEM name}s***

Aspect grid: ***{DEM name}a***

Solar Parameters

This window specifies important parameters relevant to calculation of solar radiation, including site latitude, the time period for calculations, atmospheric conditions (transmittivity and diffuse proportion), and the resolution of the sky map. Explanations of each parameter choice are provided below. Important concerning solar parameters are provided at the end of this section and should be read carefully by users.



Site latitude

Enter the latitude for the site area (units: decimal degree, positive for the north hemisphere and negative for the south hemisphere). Latitude is used in such calculations as solar declination and solar position. Because The Solar Analyst is designed for landscape scales and local scales, it is acceptable to use one latitude value for the whole DEM. For broader geographic regions it is necessary to divide the study area into zones with different latitudes.

Sky size

Enter the resolution of the viewshed, skymap, and sunmap grids (units: cells per side). These grids are upward–looking maps of sky direction in a hemispherical coordinate system. Note that these grids are square (equal numbers of rows and columns). Increasing this value increases calculation accuracy but also increases calculation time considerably. Typically, a value of 200 is sufficient for calculations for whole or masked DEMs, and a value of 512 is good for calculations at specific locations where calculation time is not an issue.

Zenith and azimuth divisions

Enter values for the number of divisions used to create sky sectors in the skymap. The number of divisions does not change calculation speed. Satisfactory results can be obtained with as few as 8 zenith and 8 azimuth divisions. The hemispherical photography scientific literature typically uses 18 zenith divisions (5° sectors) and 8 azimuth divisions (45° sectors).

Diffuse radiation model

Choose a diffuse model from the dropdown list. Currently, choices include the uniform diffuse model and the standard overcast diffuse model.

Diffuse proportion

Enter the proportion of the global normal radiation flux that is diffuse. Values range from 0 to 1. This value should be set according to atmospheric conditions. Typical values are 0.2 for very clear sky conditions and 0.3 for generally clear sky conditions.

Within year interval

Enter the time interval through the year that is used for calculation of sky sectors for sunmaps (units: days). For calculations of the **whole year with monthly interval**, this is disabled and the program internally uses calendar month intervals. Day interval should be usually be larger than 3 because sun tracks within 3 days may overlap depending upon the **sky size**. Typically values should be set to 7 (weekly) or 14 (biweekly).

Within day interval

Enter the time interval through the day that is used for calculation of sky sectors for sunmaps (units: hours). Typically values should be set to 1 hour.

For each interval

This check box gives users the flexibility to calculate total insolation or insolation **For each interval**. For example, for multiple day and **Within year interval** of 7, checking this box will create weekly insolation, otherwise, only the total insolation during the start day and end day is calculated. In another example, for **Within day** and **Hour interval** of 1, check this check box will create hourly insolation, otherwise, only the total insolation over the day is calculated.

Direct radiation model

Choose a direct model from the dropdown list. Currently, only a simple transmission model is available.

Transmittivity

Enter a transmittivity value to be used in calculations. This value is the transmittivity of the atmosphere (averaged over all wavelengths), expressed as the proportion of exoatmospheric radiation transmitted as direct radiation along the shortest atmospheric path (i.e., from the direction of the zenith). Values range from 0 (no transmission) to 1 (all transmission). Because The Solar Analyst corrects for elevation effects, transmittivity should always be given for sea level. Typical values are 0.6 or 0.7 for very clear sky conditions and 0.5 for generally clear sky. Note that transmittivity has an inverse relation with the diffuse proportion parameter.

Time configuration

This group of choices specifies the time periods used for calculations.

Within day

Choose this option to perform calculations for a specified time period within a day. Enter start time and end time.

Instantaneous

When the start time and the end time is the same, instantaneous insolation will be calculated. Note that the current implementation outputs integer grids, with values multiplied by 100 to retain calculation accuracy for direct, diffuse, global, and duration grids. This implementation was necessary because of limitations of the ArcView GRIDIO library, whereby float grid can not be generated using C++. Instantaneous ouput grids (including direct, diffuse, global, and duration) should be divided by 100 to obtain their correct float values:

Grid: instantaneousgrid = float(calculatedgrid / 100.0)

Whole day

When the start time is before the sunrise and the end time is after the sunset, insolation will be calculated for the whole day.

Special Days

Choose this option to calculation insolation for **summer solstice/equinox/winter solstice** days. Note that the **For each interval** option is disabled for the latter choice.

Multi day User Specified

Choose this option to perform calculations for a specific multiple day period within a year. Specify the **start day**, **start year**, **end day**, **within year interval**, and **within day interval**. When **end day** is smaller than **start day**, the **end day** is considered to be in the following year.

Whole year with monthly interval

Choose this option to perform calculations for an entire year using monthly intervals for calculations. If the **For each interval option** is checked, then output files will be created for each month. Otherwise, output files will be created for the whole year. Note that The Solar Analyst uses calendar months, with different number of days per month. Users should use caution when comparing insolation for months that have different numbers of days (e.g., January vs. February).

Important Notes (Solar parameters)

For each interval checkbox

This parameter changes the numbers of output files, names of output files, and formats of output files. In turn, it changes the disk space required. Always verify that sufficient disk space is available before initiating calculations.

Results for instantaneous time configuration

The current implementation outputs integer grids, with values multiplied by 100 to retain calculation accuracy for direct, diffuse, global, and duration grids. This implementation was necessary because of limitations of the ArcView GRIDIO library, whereby float grid can not be generated using C++. Instantaneous output grids (including direct, diffuse, global, and duration) should be divided by 100 to obtain their correct float values:

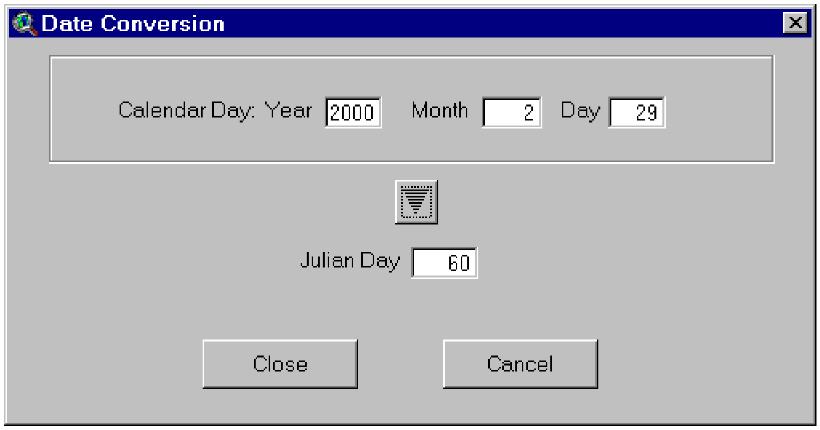
Grid: instantaneousgrid = float(calculatedgrid / 100.0)

Execute

The **!Execute** choice initiates calculations. First, users are prompted to confirm the output, topographic, and sky parameters. Next, calculations are performed. Finally, results are displayed.

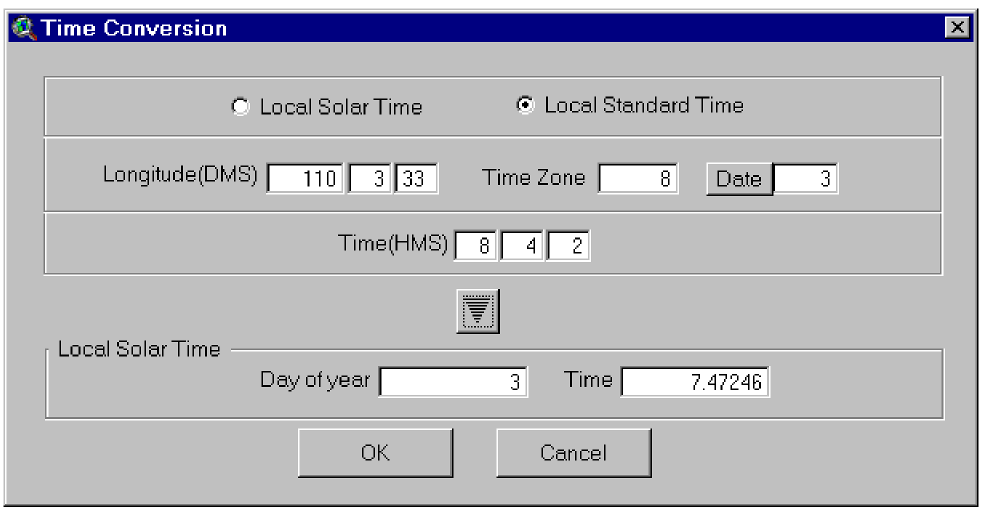
Date Conversion

This window converts calendar day to julian day. This window is also available in the sky parameter dialog by clicking the day buttons.



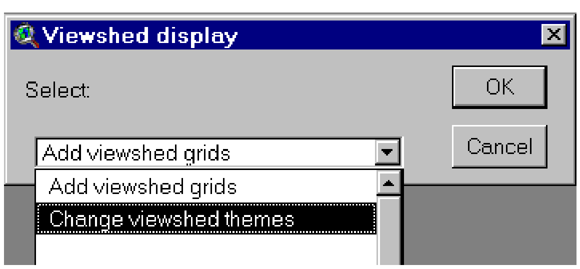
Time Conversion

This window converts local solar time (HMS) or local standard time to local solar time (decimal hours). When converting local standard time to local solar time, the program accounts for equation of time. This window is also available in the sky parameter dialog by clicking the time (start time and end time) buttons.



Viewshed Display

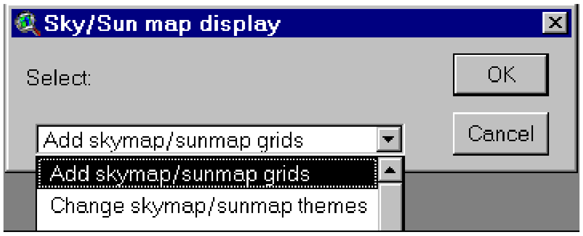
This choice allows users to display viewshed grids using a predefined legend. It brings up the following window.



The choice “add viewshed grids” allows users to add viewshed grids, while “change viewshed themes” changes the legends of the current active themes in the current views. The latter one allows users to specify whether or not open sky in the viewsheds be transparent or not.

Sky/Sun Map Display

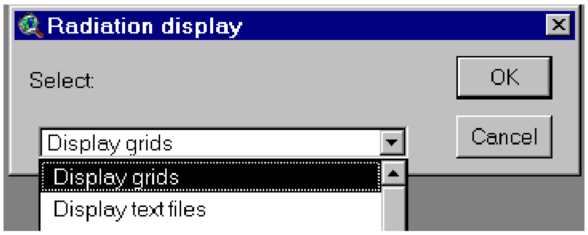
This choice allows users to display viewshed grids using a predefined legend. It brings up the following window.



The choice “add viewshed grids” allows user to add viewshed grids, while “change viewshed themes” changes the legends of the current active themes in the current views.

Insolation Display

This choice enables users to display calculated direct/diffuse/global insolation and direct radiation duration. It brings up the following window.



The choice “Display grids” allows user to add insolation/duration grids into the current view using a predefined legend. The legend classifies the grids into 14 classes, using a combination of natural interval and linear stretch. The grids are displayed using a color ramp from blue to green to red to yellow to white. Note: when the grids are large and have too many unique values, their VATs are not built automatically when the grids are created. Without the VATs, these grids can not be displayed using the predefined legend. In such cases, the program builds the VATs for such grids, the resultant VATs can be large (up to several hundred kilobytes or more). The choice “Display text files” allows user to add the insolation/duration text files as tables and charts.

Error Codes

Error Codes

Error codes of generated by the Solar Analyst are listed below. They can help user understand the problems encountered while using the Solar Analyst. These codes can also help users report bugs.

1 Solar.cpp: Can not initialize GRID environment

2 Sky.cpp: Latitude out of range

100 Solar.cpp: Can not open file of horizon zeniths

110 Solar.cpp: Too few directions

111 Solar.cpp: Can not allocate memory for storing horizon zenith angles

112 Solar.cpp: Can not allocate memory for reading the DEM grid

113 Solar.cpp: Can not set the DEM grid IO mode to REGIONIO

114 Solar.cpp: Error reading the DEM grid into memory

115 Solar.cpp: Can not allocate memory for reading the DEM grid

116 Solar.cpp: Error reading the DEM grid into memory

131 Solar.cpp: Can not open input grid

132 Solar.cpp: Can not get grid boundary

133 Solar.cpp: Can not set grid access window

134 Solar.cpp: Can not open file for horizon zeniths

140 Solar.cpp: Viewshed calculation is designed for location calculation mode.

150 Solar.cpp: Row and column do not make pairs or are out of DEM boundary

151 Solar.cpp: Row and column do not make pairs or are out of DEM boundary

160 Solar.cpp: Mask grid does not exist

163 Solar.cpp: Can not read mask grid boundary

163 Solar.cpp: Mask grid and DEM grid do not overlap

164 Solar.cpp: Can not set access window for mask grid

170 Solar.cpp: Output viewshed file name is blank

172 Solar.cpp: Output global radiation file name can not be blank

173 Solar.cpp: Output direction radiation file name can not be blank

174 Solar.cpp: Output diffuse radiation file name can not be blank

180 Solar.cpp: Input slope grid does not exist

181 Solar.cpp: Input aspect grid does not exist

182 Solar.cpp: Can not open slope grid

183 Solar.cpp: slope grid is not float

184 Solar.cpp: Can not open aspect grid

185 Solar.cpp: Aspect grid is not float

186 Solar.cpp: Can not get slope grid boundary

187 Solar.cpp: Can not get aspect grid boundary

188 Solar.cpp: Slope and aspect grids do not overlap DEM grid

189 Solar.cpp: Slope and aspect grids do not overlap mask grid

190 Solar.cpp: Can not set the access window for slope and aspect grids

191 Solar.cpp: Can not set the access window for slope and aspect grids

200 Solar.cpp: Number of output files less than 1

210 Solar.cpp: Can not delete the existing grid file.

211 Solar.cpp: Can not create output grid file.

212 Solar.cpp: Can not set access window.

220 Solar.cpp: Can not open output direct radiation file for pixel calculation

221 Solar.cpp: Can not open output diffuse radiation file for pixel calculation

222 Solar.cpp: Can not open output global radiation file for pixel calculation

223 Solar.cpp: Can not open output direct duration radiation file for pixel calculation

231 Solar.cpp: wrong output file name for direct radiation

304 Sky.cpp: Can not allocate memory for diffuse sky

305 Sky.cpp: Can not allocate memory to store the skymap sector information

306 Sky.cpp: Can not allocate memory to store total pixels for each skymap sector

307 Sky.cpp: Can not allocate memory to store open pixels for each skymap sector

308 Sky.cpp: Can not allocate memory to store gap fractions for skymap

310 Sky.cpp: Can not delete the existing grid file.

311 Sky.cpp: Can not create output grid file.

312 Sky.cpp: Can not set access window.

313 Sky.cpp: Can not delete the existing grid file.

314 Sky.cpp: Can not create output grid file.

315 Sky.cpp: Can not set access window.

330 Sky.cpp: Sky size too small

331 Sky.cpp: Can not allocate memory for sky fill

332 Sky.cpp: Can not allocate memory for viewshed sky

339 Sky.cpp: Zenith divisions are not correct

340 Sky.cpp: File name for sky map and sun map can not be blank.

341 Sky.cpp: Night, no sun

342 Sky.cpp: Zenith sector is not correct

351 Sky.cpp: Can not allocate memory to store sunmap sector information

352 Sky.cpp: Can not allocate memory to store sunmap sector pixels

353 Sky.cpp: Can not allocate memory to store sunmap sector open pixels

354 Sky.cpp: Can not allocate memory to store sunmap sector gap fractions

355 Sky.cpp: Can not allocate memory for sunmap I

356 Sky.cpp: Can not allocate memory for sunmap II

360 Sky.cpp: Can not open file

370 Sky.cpp: End hour is smaller than start hour

371 Sky.cpp: All night

372 Sky.cpp: night, no sun

382 Sky.cpp: Time interval can not be negative

383 Sky.cpp: Not suit for single day calculation

391 Sky.cpp: Diffuse proportion is out of range (0–1)

392 Sky.cpp: Diffuse proportion is out of range (0–1)

400 Segment.cpp: Can not allocate memory for flood–fill buffer

401 Sky.cpp: Sky transmittivity is out of rang (0–1)

430 Solar.cpp: Input grid does not exist

701 Solar.cpp Invalidate calculation area

702 Solar.cpp Point Array full

703 Solar.cpp Point Array full

705 Solar.cpp Slope and aspect values are out of range

706 Solar.cpp Number of calculation directions can not be negative

707 Solar.cpp invalidate elevation unit

708 Solar.cpp Latitude is out of range

709 Solar.cpp Sky size can not be negative

710 Solar.cpp Time configuration for within day is out of range

711 Solar.cpp Time configuration for multiday is out of range

712 Solar.cpp Hour interval is out of range

713 Solar.cpp Hour interval is out of range

714 Solar.cpp Zenith and azimuth divisions are out of range

715 Solar.cpp Time has not been configured

720 Solar.cpp "No output configured, can not continue"

721 Solar.cpp Viewshed calculation is for location calculation only

777 Solar.cpp Number of points can not be negative

778 Solar.cpp Point buffer has not been allocated

779 Solar.cpp Slope and aspect buffer has not been allocated

788 Solar.cpp Transmittivity is out of range (0-1)

789 Solar.cpp diffuse proportion is out of range (0-1)

801 Sun.cpp: Latitude not set yet for CSun

902 Sky.cpp: Can not allocate memory to store skymap duration

More Solar Radiation Models

TopoView

What is TopoView?

TopoView is a spatial solar radiation model that uses digital elevation models (DEMs) for input and produces a variety of outputs, including accurate incoming solar radiation (insolation) maps.

TopoView generates upward-looking hemispherical viewsheds, in essence producing the equivalent of an upward looking hemispherical photograph for every location on a DEM. The hemispherical viewsheds are used to calculate the insolation for each location and to produce accurate insolation maps. TopoView can calculate insolation integrated for any time period. It accounts for site latitude and elevation, surface orientation, shadows cast by surrounding topography, daily and seasonal shifts in solar angle, and atmospheric attenuation. See the TopoView Manual to learn more. TopoView is currently available for MS Windows NT4.0 and MS Windows 95/98.

TopoView Features

Versatile output: calculates direct, diffuse, global radiation; direct radiation duration; sunmaps and skymaps; and viewsheds;

Simple input: requires only DEM, atmospheric transmittivity, and diffuse proportion (latter two parameters calculated from nearby weather stations or using typical values);

Flexibility:

- calculates insolation for any specified period (instantaneous, daily, monthly, weekly ...);

- calculates insolation for any region (whole DEM, restricted areas, or point locations);

- allows specification of receiving surface orientation (from DEM, field survey, or orientations of surfaces such as sensors or leaves) and height offsets for ground features;

Fast and accurate calculations: uses an advanced viewshed algorithm for calculations; accounts for viewshed (sky obstruction by near-ground features), surface orientation, elevation, and atmospheric conditions; calculation engine implemented in C++ library format and dynamically loaded.

TopoView vs. Solar Analyst

TopoView runs as a standalone program, runs as an extension within. However, TopoView still requires that ArcView be installed because it uses the ArcView GRIDIO library. The two programs offer similar capabilities and use the same calculation engine.

Calculation engine: TopoView and the Solar Analyst use the same calculation engine (same software libraries) and produce identical output.

Software requirement: TopoView uses the ArcView GRIDIO library and requires that Arcview be installed. The Solar Analyst uses ArcView and the Spatial Analyst and requires that both be installed. ArcView and the Spatial Analyst are sold separately by Environmental Systems Research Institute (ESRI).

User interface: The Solar Analyst is somewhat more user-friendly than TopoView.

RAM requirement: The Solar Analyst requires that ArcView and the Spatial Analyst be running, while TopoView does not. This causes the Solar Analyst to use about 20M RAM more than TopoView, which can be a consideration when computer RAM is limited.

Integration with ArcView: The Solar Analyst takes advantage of the mapping, query, graphing, & statistic analysis functions of ArcView. TopoView is separate from the GIS environment, so it requires somewhat more work to display, query, graph, and analyze TopoView's results.

Interactive calculation: The Solar Analyst can calculate for interactively selected locations or areas.

Programmability: The Solar Analyst is programmable and permits development of custom models (e.g., energy balance and water balance models) by programming the Solar Analyst along with Avenue or other software libraries.

HemiView

What is HemiView?

HemiView is a program for analyzing hemispherical photography. Hemispherical photography provides an upward–looking view of all or part of the sky. Typically hemispherical photographs are acquired with either a standard film camera or a digital camera fitted with a hemispherical (fisheye) lens pointed upward. The resulting photographs provide a permanent record that can be analyzed to determine which parts of the sky are visible and which parts are obstructed by landscape features, plant canopies, or human–built structures. Based on these measurements of the geometry of sky visibility and sky obstruction, hemispherical photographs can be used to calculate solar radiation regimes and plant canopy characteristics such as leaf area index (LAI). Hemispherical photography can greatly expand the field sample measurements that are possible as compared with direct solar radiation sensor measurements or direct leaf area measurements. Computer analysis with HemiView, involving advanced digital image analysis techniques, enables efficient analysis of large numbers of photographs.

HemiView vs. TopoView and the Solar Analyst

HemiView is dedicated to analysis of hemispherical photographs, and is generally used for study of plant canopies. By contrast, TopoView and the Solar Analyst are designed for calculation of solar radiation in a GIS environment, and are generally used for study of insolation over landscape scales. HemiView uses a point insolation model, which is used to calculated detailed viewsheds from photographs taken at specific locations. TopoView and the Solar Analyst use both point and area insolation models, with viewshed from DEMs, and therefore often not as accurate as viewsheds from photographs.

HemiView calculates insolation for under canopy locations, while the insolation calculated by TopoView and the Solar Analyst can be considered as above the canopy.

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