
DIVA Documentation

Release 4.1

Aug 19, 2020

1	Installation	3
2	Setting Up a Rhino Model for Daylight Analysis	5
2.1	Units	5
2.2	Orientation	5
2.3	Layers	5
2.4	DIVA Layers	7
2.5	Hidden Layers	7
2.6	Locked Layers	7
2.7	Sublayers	7
2.8	Ground Plane	7
2.9	Geometry	7
2.10	Thickness	7
2.11	Visibility, Locking and Hiding Layers	7
3	File Naming and Storage	9
3.1	File Naming in DIVA	9
3.2	Important! Spaces in your file name	10
4	The DIVA User Interface Part 1	11
4.1	The Toolbar	11
4.2	Location	11
4.3	Nodes	12
4.4	Surface Normals	12
4.5	Node Offset and Spacing	12
4.6	Nodes and the Test Surfaces Layer	12
4.7	Materials	12
4.8	Custom Materials	14
5	The DIVA User Interface Part 2	15
5.1	Metrics	15
6	Custom Radiance Materials	17
6.1	A Note of Caution	17
6.2	Defining a Custom Metal Material	17
6.3	Defining a Custom Glass Material	18

7	Advanced Shading - Climate Based Metrics (CBM)	19
7.1	No Dynamic Shading	20
7.2	Conceptual Dynamic Shading	20
7.3	Detailed Dynamic Shading	20
7.4	Mechanical Dynamic Shading	20
7.5	Switchable Dynamic Shading	21
7.6	Dynamic Shading Control Systems	22
8	Lighting Controls	23
8.1	Manual Controls	25
8.2	Automated Controls	25
8.3	Occupancy Sensors	25
8.4	Standby Power	25
8.5	Ballast Loss Factor	25
9	Simulating Luminaires with IES Files	27
9.1	What You Will Need for This Tutorial	28
9.2	The IES Files	28
9.3	Step 0: Precautions	28
9.4	Step 1: Setup the Luminaire Test Rhino Model	28
9.5	Step 2: Converting IES Files into the Radiance Format with ies2rad	28
9.6	Step 3: Getting the Radiance data into DIVA	31
9.7	Step 4: Getting the Geometry into DIVA	32
9.8	Step 5: Finally Rendering Luminaires with Associated IES Information	34
9.9	Concluding Remarks	37
10	Simulations in General	39
10.1	Image Quality and Radiance Parameters	39
10.2	Sky Condition	41
10.3	Date and Time	41
10.4	Hide Dynamic Shading	41
10.5	Geometric Density	41
10.6	Camera Type	42
10.7	Camera Views	42
10.8	Generate.tiff	42
10.9	Open With	42
10.10	Image Size	42
10.11	Cleanup Temporary Directory	42
11	Visualization	43
12	Timelapse Images	45
13	Radiation Maps	47
14	Point-in-Time Glare	49
15	Annual Glare	51
15.1	A Warning Regarding Simulation Time	51
16	Daylight Factor and Illuminance	53
16.1	Daylight Factor	53
16.2	Illuminance	54
16.3	Units	54
16.4	Solar Date and Time	54

17 LEED-IEQ-8.1 Compliance	55
17.1 LEED Test	55
17.2 LEED Points	55
18 Climate-Based Metrics	57
18.1 Daylight Autonomy, Continuous Daylight Autonomy, Daylight Availability, Useful Daylight Illuminance	57
18.2 Units	57
18.3 Occupancy Schedule	57
18.4 Target Illuminance	59
18.5 Show Daysim Report	59
18.6 Use DGP schedules	59
18.7 Adaptive Comfort	59
18.8 Loading Metrics	59
19 CHPS Simulations	61
20 Radiation Maps-Grid Based	63
20.1 Metric	63
21 Thermal Analysis	65
21.1 Geometry Creation	65
21.2 Running Thermal Simulations	66
22 Load Metrics	73
22.1 Min/Max Illuminance	73
22.2 Min/Max Irradiance	75
22.3 Min/Max Daylight Factor	75
22.4 Color Scheme	75
22.5 Label 1% Peak Nodes	75
22.6 Label All Nodes	75
22.7 Color Extreme Values	75
22.8 Display Footcandles	75
22.9 Create Variant Label	75
23 Scripts for Converting Geometry	77
23.1 Revit models	77
23.2 TAS models	77
23.3 Sketchup models	77
23.4 Loading and Running Scripts in Rhino	78
24 Understanding Results Files	79
24.1 DIVA Grid-Based Results	79
24.2 Viewing Grid-Based Results	79
24.3 Understanding Grid-Based Results	80
25 References	83
26 Indices and tables	85

DIVA-for-Rhino is [Solemma's](#) legacy daylighting and energy modeling plug-in for Rhinoceros. DIVA-for-Rhino allows users to carry out a series of environmental performance evaluations of individual buildings and urban landscapes including Radiation Maps, Photorealistic Renderings, Climate-Based Daylighting Metrics, Annual and Individual Time Step Glare Analysis, LEED and CHPS Daylighting Compliance, and Single Thermal Zone Energy and Load Calculations.

CHAPTER 1

Installation

Getting Started We recommend that you go through the DIVA tutorials for [Rhino](#) and/or [Grasshopper](#) on the Solemma web site.

What others have done with DIVA can be seen in the proceedings of our [Solemma Symposia/DIVA Days](#). Please feel free to explore our user guide using the sidebar to the right.

Missing the DIVA toolbar or receiving an ‘unknown command’ error? If you do not see the DIVA toolbar docked at the top of the screen, you will need to browse to the C:\DIVA\ folder and open either the 32bit-PluginFiles or the 64bitPluginFiles folder depending on the version of DIVA you have installed. Once in the appropriate 32/64-bit folder, drag the DIVA.rui and DIVA.rhp files into the Rhino viewport.

Having troubles installing DIVA-for-Grasshopper? If the DIVA and ArchSim components do not show up on the Grasshopper canvas, then the C:\DIVA\64bitPluginFiles\DIVA.Daylight.ghlink and C:\DIVA\64bitPluginFiles\ArchSim\ArchSim.ghlink files can be saved in the Grasshopper components folder, C:\Users\YourUserName\AppData\Roaming\Grasshopper\Libraries.

Licensing By default, DIVA comes with a 30-day trial license that functions the same as the full version. Students are eligible to register for a free educational license. Professional users may purchase a perpetual license for individual computers. Large institutions and schools may contact us to discuss pricing for a floating site license.

Setting Up a Rhino Model for Daylight Analysis

The following includes information about proper set-up of the Rhino model for use with the toolbar. To make sure that all geometry is being used in the analysis, it is a good idea to first run the “Visualization” Metric, and to examine the image for unexpected problems such as “holes” or gaps.

If you do not have a Rhino model available, the MIT reference model can be downloaded [here](#).

2.1 Units

It does not matter what units are used for the Rhino modeling: meters, millimeters, inches, feet, parsecs, etc.

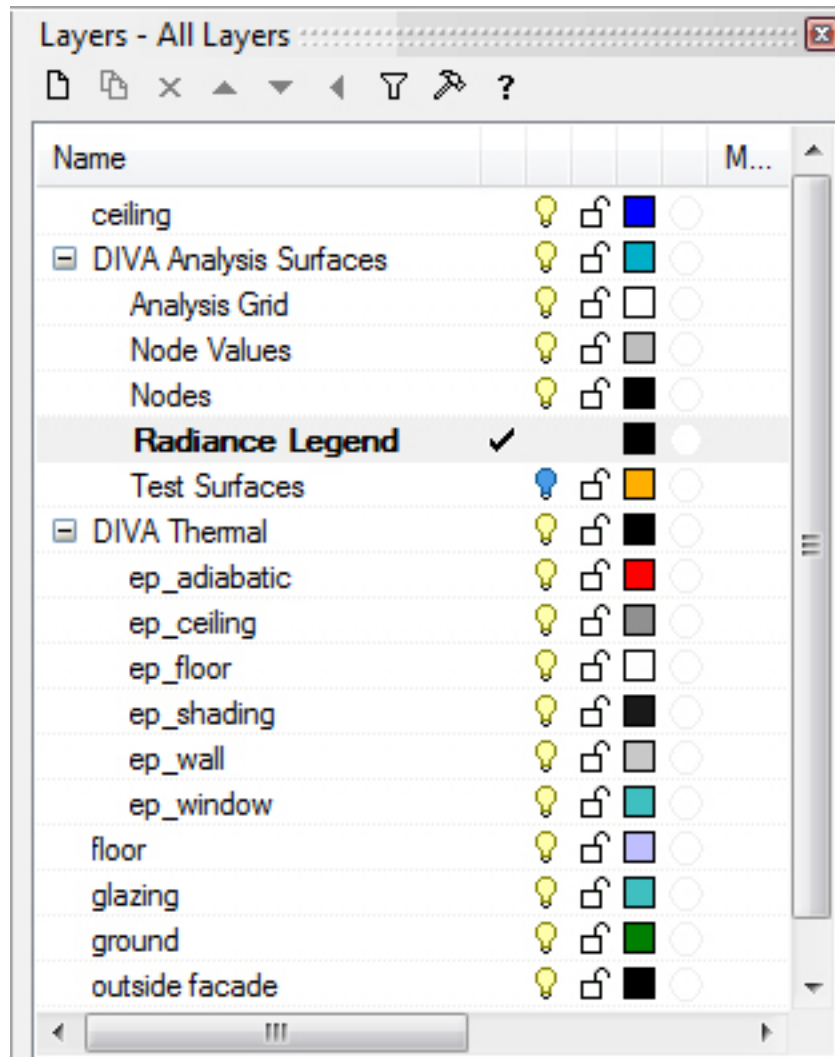
2.2 Orientation

It is important that your project is oriented properly within Rhino with regards to North. In Rhino, as most other software, North is the top of the screen when viewing the model in a “Top” or “Plan” view such that the positive Y-axis is North.

2.3 Layers

DIVA does not require any specific naming conventions for layers; however, materials will be associated by layer, so you can’t keep geometry with different materials on the same layer.

Layer panel showing DIVA-Created Layers



2.4 DIVA Layers

When you run the DIVA **Location** button, several DIVA layers are created. These layers store the various nodes, node values, grid and legend information that DIVA generates.

2.5 Hidden Layers

Layers turned off will not be exported.

2.6 Locked Layers

Locked layers will not be exported.

2.7 Sublayers

There are no restrictions to using sublayers.

2.8 Ground Plane

A ground plane should always be modeled and assigned a DIVA material.

2.9 Geometry

Models can be built using surfaces, polysurfaces and/or meshes, although all geometry is “invisibly” converted to temporary meshes through the DIVA process. Complicated geometry can be “pre-meshed” before running the metrics.

2.10 Thickness

Glass should be modeled using single surfaces, as opposed to polysurfaces or solids.





2.11 Visibility, Locking and Hiding Layers

Only geometry on visible, unlocked layers will be exported to Radiance. Keep this in mind when running simulations.

Remember to always check that your geometry is being exported correctly by running the “Visualization” Metric and performing a visual check.

3.1 File Naming in DIVA

You are free to name your Rhino file whatever you like, and store it wherever you like on your computer. When you run DIVA, a results folder is created which stores all of your results files. This folder is created in the same folder that your Rhino file is stored, and is given the name of your Rhino file plus " - results". For example, say you name your file: **My House.3dm**, and you keep the file in **C:\Users\yourname\Documents\RhinoModels**. When you run DIVA, a results file will be created in that folder called: **C:\Users\kera\Documents\RhinoModels\My House - DIVA**.

 Grid-Based	10/30/2013 9:09 AM
 Resources	10/30/2013 9:01 AM
 Thermal	10/30/2013 9:01 AM
 Visualizations	10/30/2013 9:01 AM

Contents of the results folder that DIVA creates for each Rhino file

As part of the process of using the toolbar, a folder is created in which necessary auxiliary files are kept. These supplemental files are located in, **C:\DIVA\Temp**. In this example, they would be stored in **C:\DIVA\Temp\My**

3.2 Important! Spaces in your file name

You will notice that in the Temp folder, the entire name of the example file is not preserved. This is because there is a **SPACE** in the Rhino file name. This does not affect anything EXCEPT, if you were to run DIVA on another file (anywhere on your computer) called, say, **My Dogs House.3dm**, the original files in the Temp folder will be overwritten causing potential problems the next time you go to run a DIVA simulation in the My House.3dm file.

If you want to avoid any potential issues, simply do not use spaces when naming your Rhino files if you are going to use DIVA.

4.1 The Toolbar

After following the instructions in Installation, the DIVA toolbar will be visible within Rhinoceros. The toolbar contains four buttons: Location, Nodes, Materials, and Metrics.



The four buttons of the DIVA 2.0 toolbar

These buttons are primarily designed to be used in order from left to right to run daylight and energy simulations. Several of the DIVA toolbar buttons have two functions: one is accessed by a mouse left click and the other via a mouse right click. In essence, there is no “Undo” for the buttons. If you have made a mistake, or you wish to change any option, simply press the appropriate button and change the settings.

4.2 Location

The “Project Info” button has two functions. The first is similar to “New File” or “Save As” in other programs. It sets up a folder and a naming convention for results files. The second function is to establish the latitude, longitude and timezone of a project by associating it with a climate (.epw) file. For climate-based simulations and radiation maps, the hourly solar insolation is also read from the EPW file.

The Boston climate file is loaded with the DIVA plug-in into the folder C:\DIVA\WeatherData. There are a plentiful amount of free EPW files available for download from the [US Department of Energy’s Website](#). Save these files to the same C:\DIVA\WeatherData directory.

4.3 Nodes

The sensor nodes are the points at which the light levels are calculated.



Nodes Button

Left-clicking on the button sets up an analysis grid for any nodes-based simulations in DIVA. The nodes array size, location and orientation are based on a piece of geometry from your model that you select. This can be a floor, wall, or any other surface, or multiple surfaces, and can be in any orientation (horizontal vertical, at an angle, etc.).

4.4 Surface Normals

The normal direction of the surface determines the orientation of the sensors. This is visualized by the direction the nodes are offset from the surface. If the point objects appear below the analysis surface, the normal of the surface should be flipped and the above process followed again. The 'Dir' command in Rhino can be used to visualize and flip surface normals.

4.5 Node Offset and Spacing

Typically, the sensor nodes are offset a specified distance off of the selected surface, and a specified distance apart. DIVA will prompt you to select these values, and suggests default values. Those values are always shown in the current model units. This can be feet, inches, meters, etc.

Tip: For typical workplane simulations, the sensor grid is set 30" off the floor and the nodes are no more than 36" apart.

4.6 Nodes and the Test Surfaces Layer

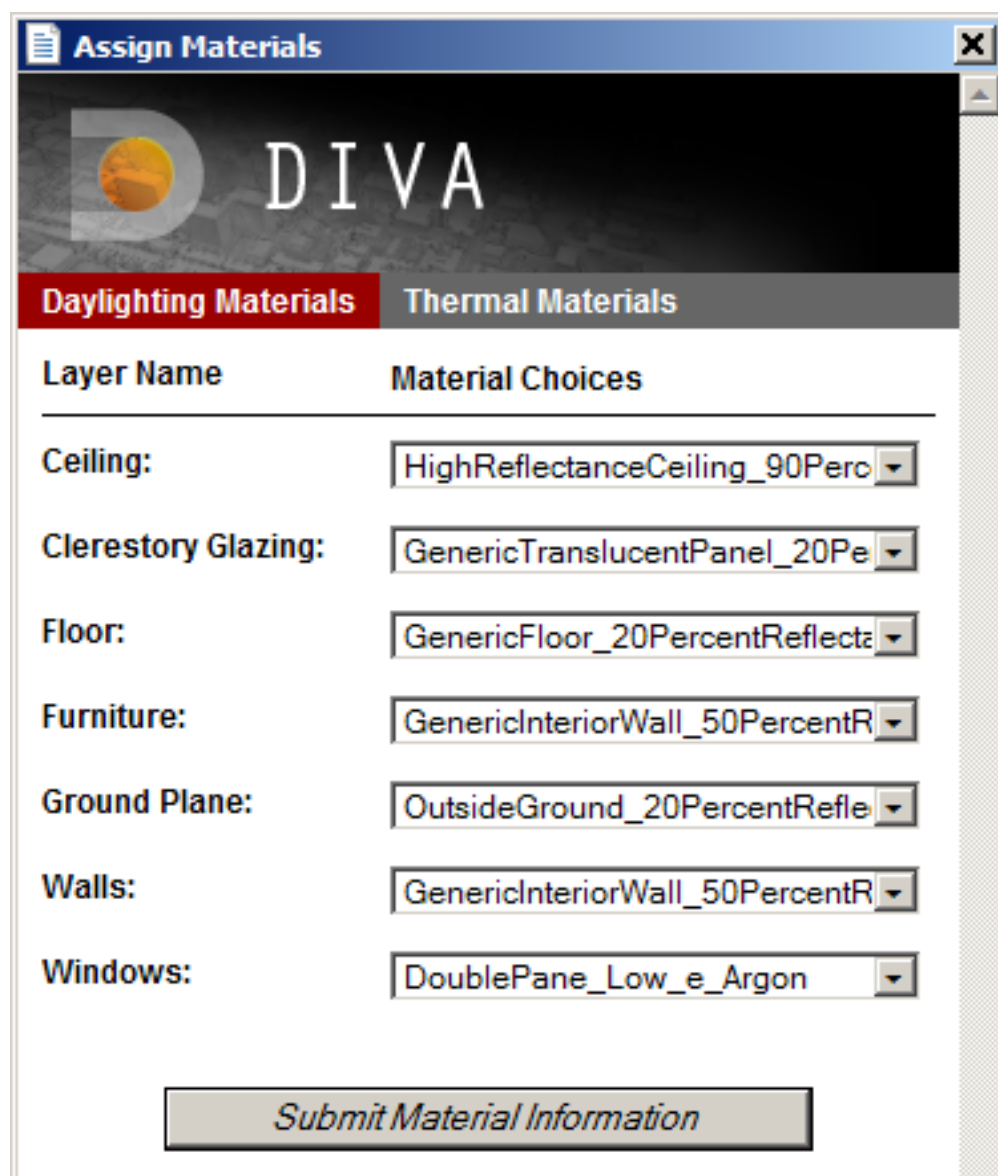
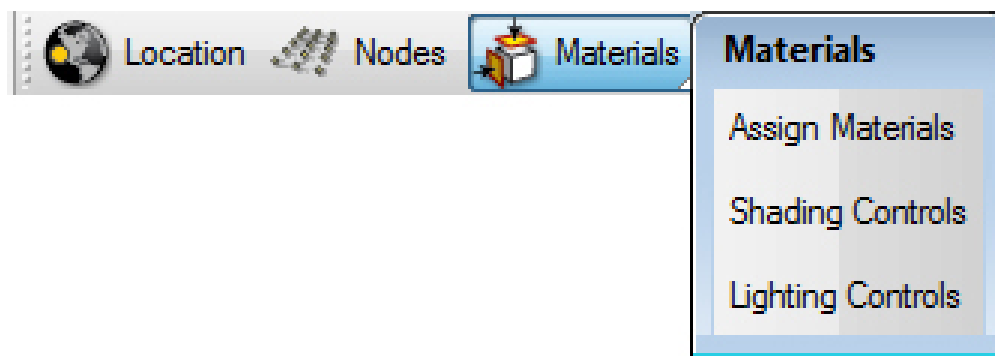
The "Test Surfaces" DIVA sublayer is a helpful place to store a reference surface if that surface does not exist as part of your built geometry. For instance, if you want to test only part of the floor or wall, you can make a surface on the "Test Surfaces" layer which is the size of the area you want to focus on.

4.7 Materials

Materials must be assigned to the project geometry in order for it to be analyzed for daylight or energy performance.

Materials button sub-menu

Once your project location and sensor grid is established, Radiance materials must be applied to layers in the Rhino model. Each layer that the user wants to include in the simulation needs to have a material associated with it. To assign materials, use the Materials button and the "Assign Materials" option. A small library of useful materials is included with DIVA, and will show up as options in the pull-down menus.



Materials Menu

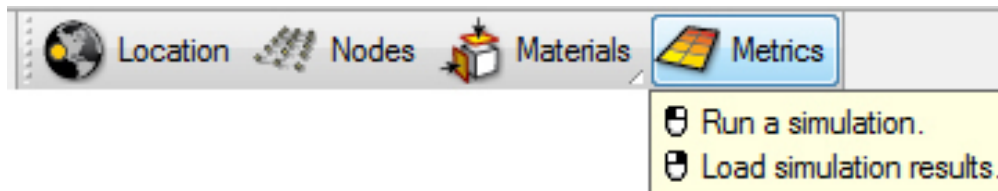
4.8 Custom Materials

Note that customized Radiance materials can be added to the material choices. See the page, Custom Radiance Materials for more information. By default, DIVA instantiates each project with the default materials file, located in **C:\DIVA\Daylight\material.rad**. Project-specific materials can be defined in the **.ProjectName - DIVA\Resources\material.rad file**. The ProjectName - DIVA directory is located in the same folder as your Rhino file.

The materials menu has two tabs: Daylight Materials and Thermal Materials. Use the one appropriate for the simulations you will be running, or both you are running both.

The DIVA User Interface Part 2

5.1 Metrics



Metrics Button

The Metrics button has two functions. Left-clicking the button brings up the dialog box that allows the user to run the various simulations. Right-clicking on the button allows the user to load in previous simulation data. The dialog box displays different information for each simulation type, but generally allows you to set things like: simulation type, quality or “resolution” of simulation, sky condition, date and time or schedule, lighting units, image size, image output and image viewer.

The Radiance parameters are automatically set, however, there is always a text-editable box where you can edit your own Radiance parameters. Before doing so however, you should read carefully the Radiance documentation to learn more about the commands and their values. Information on that can be found [here](#).

Custom Radiance Materials

By default, DIVA instantiates each project with the default materials file, located in **C:\DIVA\Daylight\material.rad**. Project-specific materials can be defined in the **.\ProjectName - DIVA\Resources\material.rad** file. The ProjectName - DIVA directory is located in the same folder as your Rhino file. When the materials button is clicked, materials are always loaded from the project-specific material.rad file. The project-specific file can be overwritten with the default file by running the **Location** command.

Any Radiance material primitive can be defined in these files and selected for use in daylighting simulations.

There are several websites which document possible Radiance materials,

- [LBL's Radiance Materials Page](#)
- [Radiance Materials Notes at Artifice](#)
- [Design Integration Laboratory's Basic Radiance Materials Library](#)
- [BPS Wiki's Radiance Material Database](#)

6.1 A Note of Caution

If a Radiance material primitive is incorrectly defined, the Radiance program `oconv` will fail, causing all DIVA simulations to fail. If your simulations suddenly do not work after adding a new material, check that it is defined appropriately in material.rad and re-run the **Materials** command.

6.2 Defining a Custom Metal Material

For example, to add a custom reflective metal material into DIVA, we can see from [Radiance Materials Notes at Artifice](#) that the 'Metal' primitive is defined as below, where specularity is typically greater than 0.9 and roughness is typically in a range from 0-0.2.

```
modifier metal material_name
```

```
0
```

```
0
5 red_reflectance green_reflectance blue_reflectance sp
```

Thus, the following lines can be added to the C:DIVADaylightmaterial.rad file to define a metal material type for use in simulations,

```
void metal SimpleMetal_0.44
0
0
5 0.44 0.44 0.44 0.9 0.125
```

6.3 Defining a Custom Glass Material

For glass definitions, Radiance requires that the user translates transmission (T_n) to transmissivity (tn).

For instance if you wanted to define a glass material with a 65% transmission, the definition would be:

```
void glass Glass_Transmission_65
0
0
3 0.7085 0.7085 0.7085
```

Above, the R, G, and B transmissivity factors are derived from the transmission of the glass. For more information, see: <http://radsite.lbl.gov/radiance/refer/ray.html#Materials>.

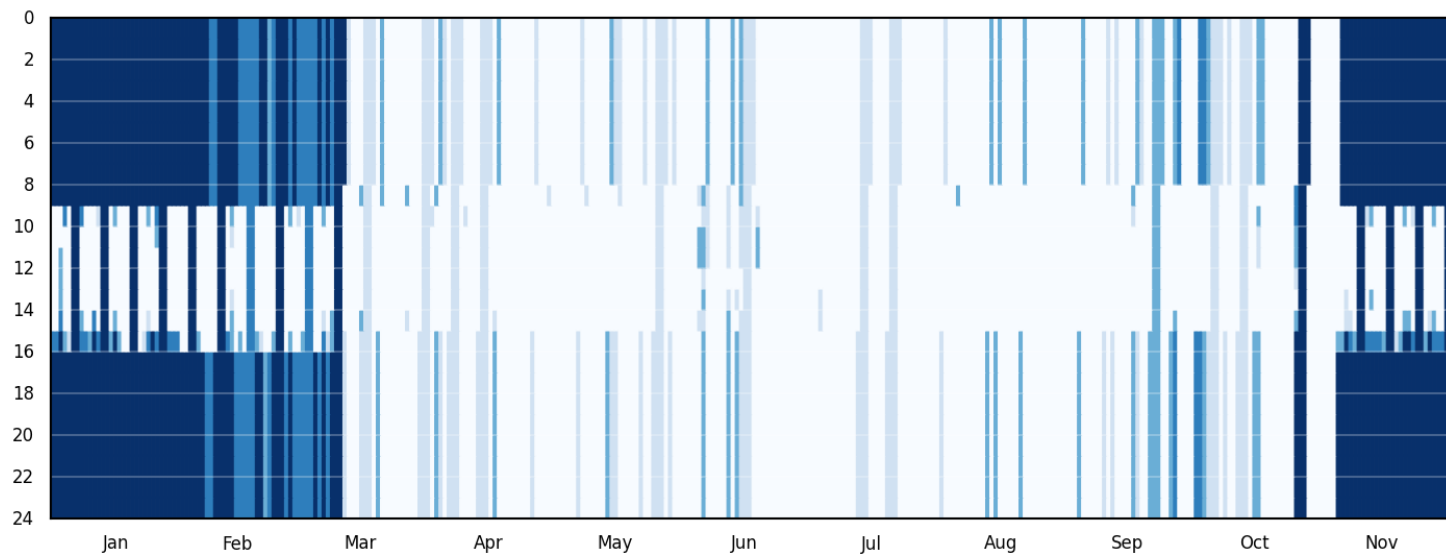
For an easy way to convert transmission to transmissivity, you can use the Excel converter below.

Download the Radiance Material Generator [here](#).

Advanced Shading - Climate Based Metrics (CBM)

In a real building, shading devices are not all opened and closed at the same time but can be operated independently. DIVA therefore implements shading controls for up to two independent shading groups that can be controlled independently of each other. The shading groups can for example correspond to venetian blinds for different facade orientations or a facade may have two sets of blinds, one in the upper and one in the lower part.

These shading controls can be implemented in any Climate-Based Metrics (DAYSIM) simulation and will affect the amount of available daylight, view to the outside, and any lighting control systems in the space.



Example of an hourly shading schedule output from a DIVA climate-based simulation

The shading control options dialog is located in, **Materials >> Shading Controls**

7.1 No Dynamic Shading

When this option is selected, no shading systems are considered beyond what is modeled in Rhino as exported geometry. In effect, windows are modeled as ‘open’ at all times and no blinds or operable shading devices influence the available daylight, even if occupant discomfort might be a problem.

7.2 Conceptual Dynamic Shading

Conceptual dynamic shading considers the operation of an idealized blind that covers all windows in the scene **without** the need for modeling the device geometrically. The effect of this blind is to reflect all direct sunlight and allow only 25% of diffuse sunlight into the space. Using conceptual shading is very fast and takes the same amount of time as running an identical simulation with no dynamic shading. Conceptual shading devices are limited in their control, and it can be considered that all are down or all are up at the same time.

No Dynamic Shading	Conceptual Dynamic Shading	Detailed Dynamic Shading
<h3>Conceptual Dynamic Shading</h3> <p>Conceptual shading description here.</p> <div style="text-align: center;"> <div>Choose workplane sensors.</div> <div>Submit</div> </div>		

Choosing workplane sensors is necessary for results with dynamic shading to be meaningful.

The control of dynamic shading devices uses the Lightswitch algorithm (Reinhart, 2004). If an annual glare calculation has been run, then the predicted occupant discomfort is used to determine whether an occupant will lower a shade or not (lowered when $DGP > 0.4$). Otherwise, occupants decide whether or not to lower the conceptual shading system by the presence of direct sunlight at each time step in the annual simulation. For this, it is necessary to define where occupants sit by choosing workplane sensors. If workplane sensors are **not chosen**, then the presence of direct light on any sensor (even those near the window) will cause shading to be lowered.

7.3 Detailed Dynamic Shading


Detailed dynamic shading controls have two shading-type modes: Mechanical and Switchable (electrochromic). The **mechanical** mode is used to control dynamic geometric shading such as blinds or rotating louvers which are modeled on separate layers in Rhino. The **switchable** mode is used to control glazing which changes state from mostly transparent to mostly opaque by switching out material definitions for a specific glazing material.

7.4 Mechanical Dynamic Shading

Mechanical shading systems take Rhinoceros layers as their input. For example, to model a dynamic venetian blind, it is necessary to actually create the geometry of the blind on a discrete layer and to [assign a material](#) to it. Then under

the field **Base Geometry Layer**, “No fixed shading state (blank.rad)” will be selected since in the default state the blind is pulled up and is not present in the scene. Under **State 1 Layer**, the Rhino layer with the geometry will be selected.


Detailed Dynamic Shading Control Groups

Shading Group no. 1		<div>Select Nodes</div>	<div>Select Exterior Nodes</div>
Shading Type :		<div>Mechanical</div>	<div>▼</div>
Operation :		<div>Manual</div>	<div>▼</div>
Base Geometry Layer :		<div>No fixed shading state. (blank.ra</div>	<div>▼</div>
Glazing State 1 Layer :		<div>ShadingLowered</div>	<div>▼</div>

A dynamic mechanical shading system for a venetian blind

7.5 Switchable Dynamic Shading

Switchable shading systems accept Radiance materials as inputs. For example, an electrochromic window system that transitions from clear to 30% transmission to 2% transmission would be defined using a **Base Glazing Material** of “EC_clear”, a **State 1 Material** of “EC_Tinted30Percent” and a **State 2 Material** of “EC_Tinted02Percent.”

<h2>Detailed Dynamic Shading Control Groups</h2>			
Shading Group no. 1		<div>Select Nodes</div>	<div>Select Exterior Nodes</div>
Shading Type :		<div>Switchable (electrochromics)</div>	<div>▼</div>
Operation :		<div>Manual</div>	<div>▼</div>
Base Glazing Material :		<div>EC_clear</div>	<div>▼</div>
Glazing State 1 Material :		<div>EC_Tinted30Percent</div>	<div>▼</div>
Glazing State 2 Material :		<div>EC_Tinted02Percent</div>	<div>▼</div>
			<div>Add</div>

A dynamic switchable shading system

7.6 Dynamic Shading Control Systems

Manual Control This control applies to a standard, manually controlled mechanical shading system such as venetian blinds or manually controlled dynamic glazing. Occupants will activate shading systems as their visual discomfort increases ($DGP > 0.4$) or direct light is present on their workplane as defined by the location of workplane sensors.

Automated Thermal Control The shading system is controlled in a way that excessive interior daylighting levels are avoided. For this case it is assumed that the reference sensor for the system is either an internal and / or external illuminance sensor. If internal, the sensor would typically face the nearest facade and be ceiling mounted or on the window or curtain wall frame. When the illuminance at the control sensor rises beyond a user specified threshold, the system automatically adjusts the shading system to the next lower setting ($Base > State\ 1 > State\ 2$). For a venetian blind system this would mean that the slat angle is further closed or the blinds are further lowered. For an electrochromic glazing system this would mean that the glazing is further tinted. On the other hand, once the illuminance threshold falls below a second user specified illuminance threshold the system switches to the next higher state ($State\ 2 > State\ 1 > Base$).

Automated Glare Control In combination with the thermal control, it is also possible to further adjust the dynamic shading system to avoid glare from direct sunlight. In order to do so, the system requires a second, exterior illuminance sensor. This would typically be a facade mounted sensor facing perpendicular to the facade plane. The control is timed and received as inputs upper and lower solar altitude and azimuth levels. When the facade illuminance is above a user defined threshold level and the sun is located within the user-specified azimuth-altitude range, the system is fully closed to avoid glare from direct sunlight. The system is only opened once the sun leaves the azimuth-altitude range.

Control Systems with Cooling Period If an cooling period is provided, start and end dates of the cooling period for the controlled zone must be provided. When in the defined cooling period, the shading device is fully lowered. Otherwise, the shading system is controlled as decided by the above rules. Cooling period control rules can be applied to automated glare and automated thermal control systems.

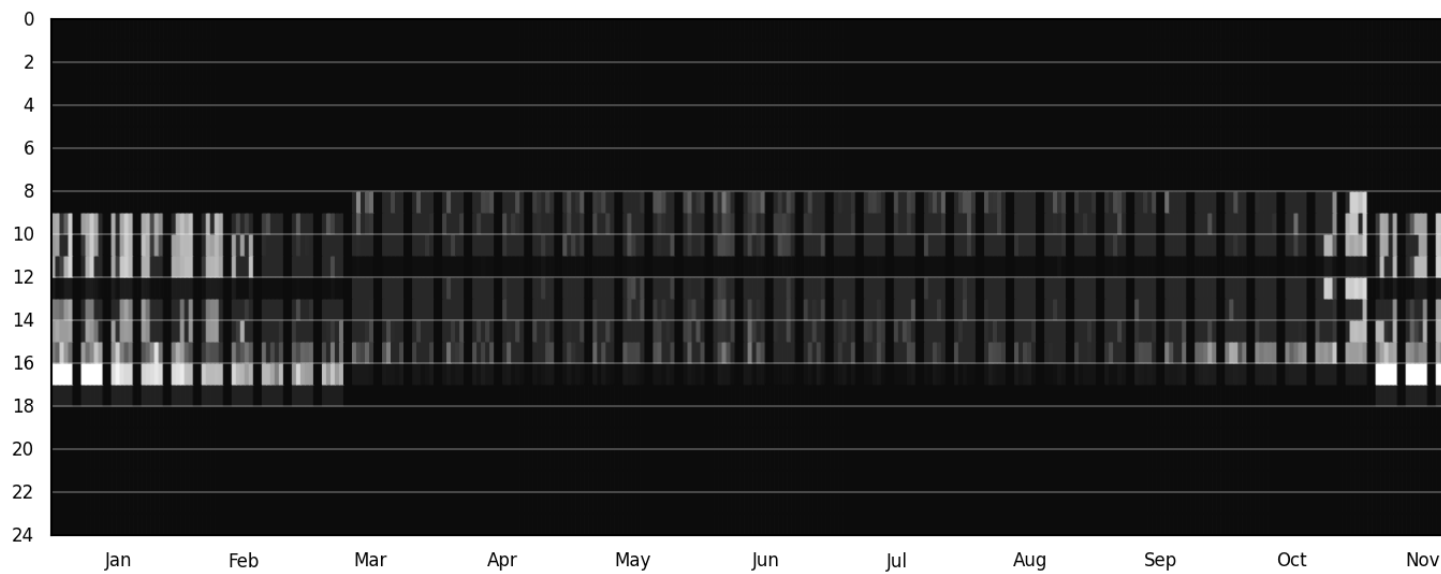
For further information on the Advanced Dynamic Shading Module go to the [DAYSIM web site](#).

Note on Detailed Dynamic Shading Controls In case there are several shading groups in the same facade, DAYSIM assumes that for an automated system the signal at the control illuminance sensor for one group is not influenced by the setting of the independent control group. For example, if a venetian blind is combined with an electrochromic blind system and the EC glazing is automatically control via an internal illuminance sensor, Daysim assumes that the venetian blinds do not block the view of the illuminance sensor when lowered. If they do, this would in reality lower the signal at the EC control point and switch the EC glazing into a clear state. DAYSIM will not reproduce this because the illuminances for different shading groups are assessed independently from each other.

CHAPTER 8

Lighting Controls

Materials >> Lighting Controls

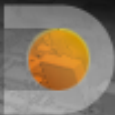


Example lighting schedule output from a DIVA climate-based simulation

Lighting controls can be implemented in any Climate-Based Simulation, with or without dynamic shading devices. After running a climate-based analysis, hourly lighting schedules will be generated, and a falsecolor visualization of the schedules will be provided.


Lighting Control Interface

Detailed Lighting Control Options

 DIVA

Electric Lighting OffDetailed Electric Lighting Controls

Lighting Control Groups ?


Lighting Group no. 1 

Select Nodes

Operation : Manual On/Off Switch

Lighting Power (W): 250.0

4 nodes have been selected for shading group no. 1.

Lighting Group no. 2 

Select Nodes

Operation : Dimming w. Occupancy On/Off S

Lighting Power (W): 250.0

Lighting Setpoint (lx): 300

Ballast Loss Factor (%): 12

Standby Power (W): 15.0

4 nodes have been selected for shading group no. 2.

Add Lighting Group

Remove Lighting Group

Submit

8.1 Manual Controls

Manual controls (Lighting Group no. 1 above) mimic the behavior of a user based on the statistical analysis of the 2002 Lightswitch study. Users occupying a space (defined by selected sensor nodes) are likely to turn off the lights at levels of around 250lx.

8.2 Automated Controls

Automated controls (Lighting Group no. 2 above) mimic a continuous dimming sensor with a user-defined setpoint, ballast loss factor and sensor standby power. The location of sensors are defined by the selected sensor nodes.

8.3 Occupancy Sensors

Switch Off Controls with the “Switch Off” option makes sure that occupants do not leave the lights on at night; however, as DIVA/DAYSIM considers conscientious occupants, the statistical likelihood is low.

Switch On/Off Switch On/Off maintains lights always on while occupants are in the space. This mode is especially useful when modeling a scheduled continuous dimming system without a physical light switch.

8.4 Standby Power

Standby power refers to small amount of energy drawn by some automatically lighting systems even when the system is “off”.

8.5 Ballast Loss Factor

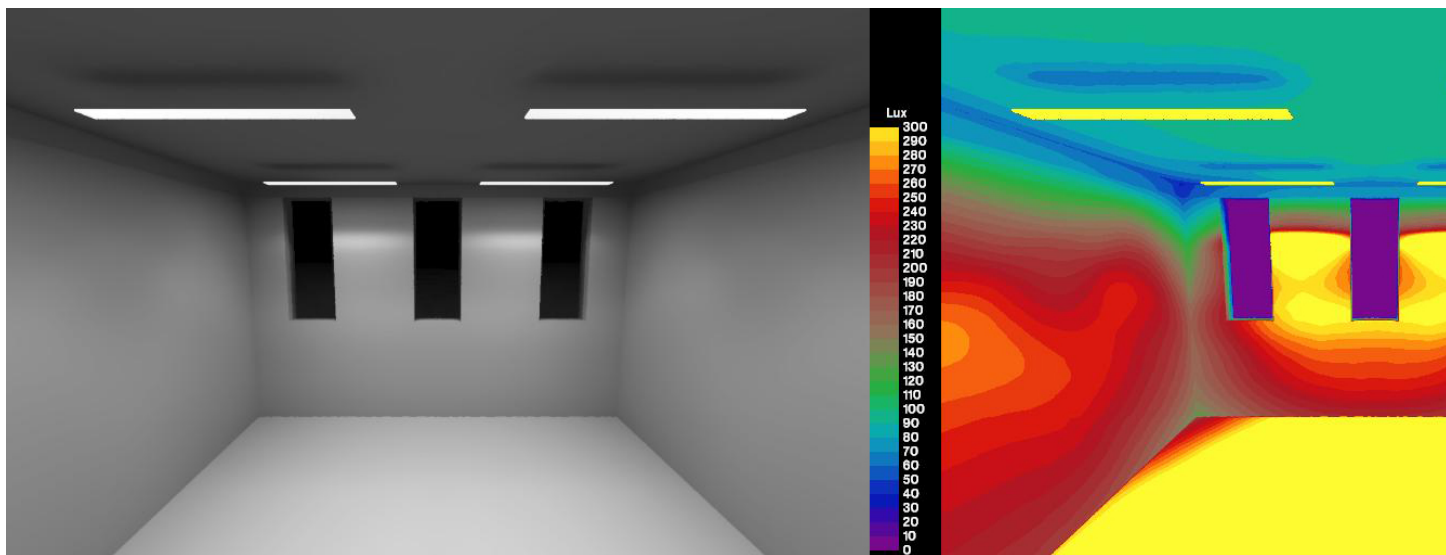
Percentage of peak energy used by a dimming system when fully dimmed down.

CHAPTER 9

Simulating Luminaires with IES Files

Note: A video tutorial on how to set up an electric lighting scene in DIVA-3.0 or DIVA 4.0 can be found [here](#). The tutorial below applied for DIVA-2.0 users.

Radiance, the simulation engine behind many of DIVA's metrics, is not only constrained to daylight. It is possible to simulate the resulting light distributions from luminaires based on measured data. This is accomplished by associating IES files, a standard file format for the electronic transfer of photometric data, with geometry in DIVA. This page serves as a tutorial for getting such data into DIVA.



Illuminance rendering, calibrated for human perception (left) and falsecolor (right)

9.1 What You Will Need for This Tutorial

Most luminaire manufacturers provide IES format files for their products. In this tutorial we are using two ies files from Phillips. You can go to most lighting manufacturer sites and download ies files of their products.

Furthermore, I built a small test room ideal for loading in IES files because its ceiling is slightly higher than $Z=0$, where IES files center the ‘rough geometry’ they contain.

I recommend to download two IES files that you are interested in testing and use a Rhino scene of a simple space such as the [MIT Reference Office](#). In Windows 8 you can create a command prompt easily in any folder, but if you’re using an older version, C:\luminaire_test\will work well.

9.2 The IES Files

As mentioned in the introductory paragraph, IES files contain measured photometric data. You are probably familiar with the following kinds of figures to describe the photometric distribution of luminaires. The blue lines represent a vertical plane cut through the lighting distribution, and the red lines represent the horizontal distribution.

9.3 Step 0: Precautions

This tutorial requires the use of DIVA 2.1.1.0 or later, which was released on October 30, 2013. If you have an older version of DIVA, please download a more recent version from the Solemma website. When upgrading to a newer version of DIVA, we strongly recommend to delete the C:\DIVA folder before installing. Backup your DIVA license files, custom materials and schedules first!

9.4 Step 1: Setup the Luminaire Test Rhino Model

Go ahead and open the luminaire_test_model Rhino model. Click through the Location, Nodes and Materials buttons. I assigned standard materials to the layers. I set the grid spacing to 0.125 meters in order to have a finely meshed grid to visualize the lighting distribution.

Assign the default DIVA materials to your layers like so.

Next, let’s make sure everything is setup correctly by running a simple visualization. This should look like the below rendering.


Test daylight rendering of the luminaire test room

If all of the geometry shows up properly in the rendering, it is safe to continue. It is noticeable that the Radiance ambient parameters aren’t perfect for this scene as indicated by the blotchy corners, but we’ll worry about that later.

9.5 Step 2: Converting IES Files into the Radiance Format with ies2rad

Open a command prompt and browse to the location where you saved the IES files. We will execute a command that comes with Radiance specifically for the purpose of importing measured luminance data, `ies2rad`. Since our Rhino file is in meters and the IES file will by default be converted into meters, no extra command parameter is necessary; however, if you are working in other units make sure to read about the `-d` command flag in `ies2rad`.

To convert the Microslot IES file (20277.ies) into a Radiance format, we will execute the following command,

 **DIVA**

Daylighting Materials Thermal Materials

Layer Name	Material Choices
Ceiling:	<input type="text" value="GenericCeiling_80"/>
Default:	<input type="text" value="--"/>
Exterior Facade:	<input type="text" value="OutsideFacade_35"/>
Exterior Ground:	<input type="text" value="OutsideGround_20"/>
Floor:	<input type="text" value="GenericFloor_20"/>
Luminaires:	<input type="text" value="--"/>
Asymmetric_Downlight:	<input type="text" value="--"/>
Downlight:	<input type="text" value="--"/>
Walls:	<input type="text" value="GenericInteriorWall_50"/>
Windows:	<input type="text" value="Glazing_DoublePane_LowE_65"/>

Submit Material Information



```
ies2rad -o downlight 20277.ies
```

The `-o` option specifies the output filename and material name. “downlight” is a much better material name than 20277! We should do the same for the Designer Asymmetric KSH 3EA Lens Recessed file (17170.ies) with the `-o` option set to “asymmetric_downlight.” You will note that an error about lamp type not being recognized is thrown when running the command on the asymmetric light. This isn’t really important unless you are trying to compare the coloration of multiple disparate lamp types in a scene and is outside of the scope of this tutorial.

Another important thing to note is that by default, this process does not consider dirt depreciation factors. If you wish to apply a 15% reduction in luminous distribution due to dirt accumulation, include “-m 0.85” in your `ies2rad` command.

From running these two commands, four files should be created: `downlight.dat`, `downlight.rad`, `asymmetric_downlight.dat` and `asymmetric_downlight.rad`. The DAT files are a converted datafile containing information about the luminous distribution of the light source. The RAD files contain Radiance format ‘rough’ geometric representations of the luminaires and material definitions.

9.6 Step 3: Getting the Radiance data into DIVA

The two DAT files should be copied to the `C:\DIVA\Temp\luminaire_test_model_***` folder. We will be putting them in the Temp folder so that they are only accessible to the current simulation model. If you want to keep a luminaire for all future DIVA models, save the files in `**C:\DIVA\Radiance\lib`.

Now that the luminous distribution files are accessible by the simulation program, let’s open one of the RAD files in a plain text editor such as Notepad or Notepad++. I’ll use the Microslat downlight as the example here (`downlight.rad`). You should see the following,

```
# ies2rad -o downlight
# Dimensions in meters
#<IESNA:LM-63-1995
#<[TEST] 20277
#<[DATE] 01/03/2000
#<[LUMCAT] MSG128-W-1/1-EB
#<[LUMINAIRE] DAY-BRITE 4' MICROSLAT W/SOLID WHITE ARCHITECTURAL BLADES
#<[LAMP] F28T5
#<[BALLAST] ENERGY SAVINGS ES-1-T5-28-120-F
#<[MANUFAC] PHILIPS DAY-BRITE
#<[_TIFF_FILE_NAME]
#<[_VERSION] 2.0u
#<[OTHER] Reflection factor 0.95, Test distance = 26 ft.
#<[MORE] Shielding angle: normal 0, Parallel 30
# CIE(x,y) = (0.333300,0.333300)
# Depreciation = 100.0%
# 30 watt luminaire, lamp*ballast factor = 0.94
A description of mostly plain text fields in the original IES file.
void brightdata downlight_dist
```

```
5 flatcorr downlight.dat source.cal src_phi4 src_theta
0
1 8.13698
downlight_dist light downlight_light
0
0
3 1 1 1
```

Radiance material definitions that reference downlight.dat.

```
downlight_light polygon downlight.d
0
0
12
-0.606415 -0.047625 -0.00025
-0.606415 0.047625 -0.00025
0.606415 0.047625 -0.00025
0.606415 -0.047625 -0.00025
```

A Radiance-format four point polygon centered about X=0,Y=0 and slightly below Z=0.

The section described as, “Radiance material definitions that reference downlight.dat” can be copied directly into .luminaire_test_model_* - DIVAResourcesmaterial.rad to be used with the current simulation project. The modified section of my file looks like below.

Amended material.rad file in the - DIVAResources\folder

9.7 Step 4: Getting the Geometry into DIVA

The IES data is very dependent on the geometry size and direction (surface normal) to be correct. As noted in step 3, this is a four point polygon. IES files can also contain boxes or cylinders. It is important to note that one cannot, at this time, model a Radiance cylinder primitive in DIVA. Boxes and simple polygons work just fine though. Anyways, we want to create the exact geometry that comes from the ies2rad conversion within DIVA.

One way to ensure accuracy is to load the four vertices of the polygon into Rhino 5 as points. We could do this manually, but for a box with $6 \times 4 = 24$ points, it would be very tedious. I like to copy the point portion of the geometry into a new plain text file,

```
-0.606415 -0.047625 -0.00025
-0.606415 0.047625 -0.00025
0.606415 0.047625 -0.00025
0.606415 -0.047625 -0.00025
```

And replace the tabs separating the numbers with commas using find and replace,

```
-0.606415,-0.047625,-0.00025
-0.606415,0.047625,-0.00025
0.606415,0.047625,-0.00025
```

```

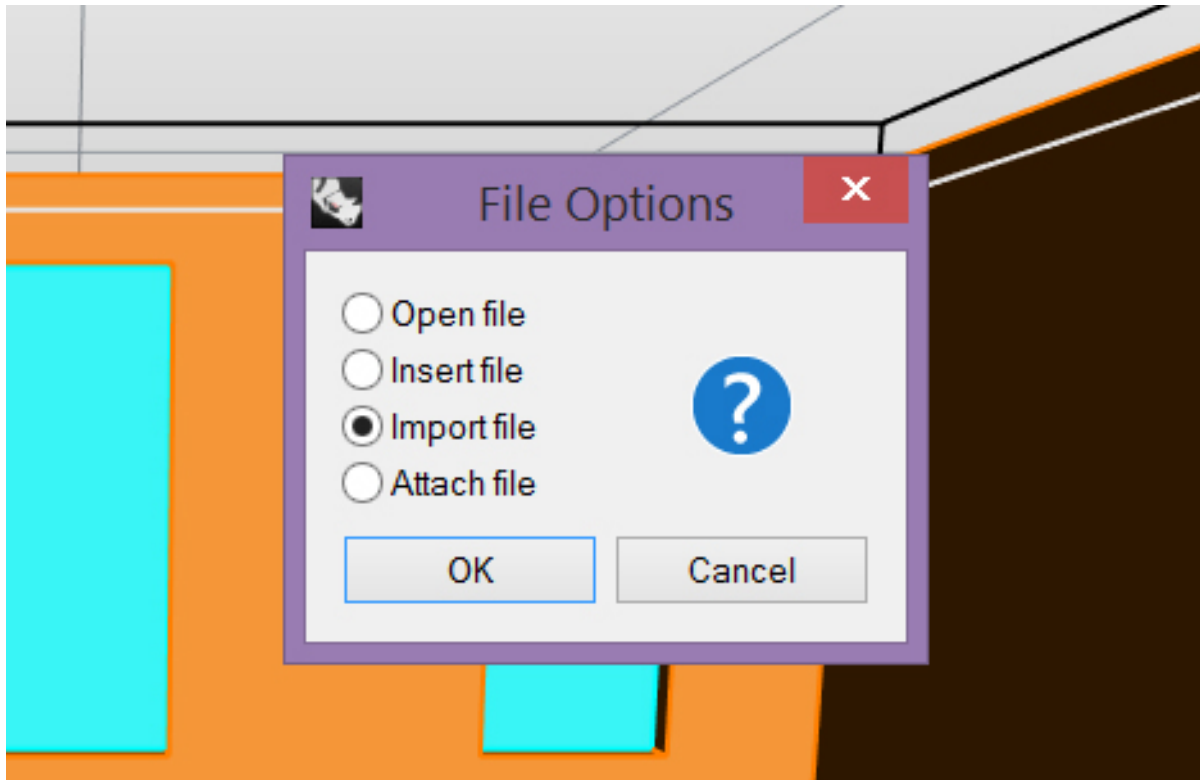
10 # to you to make sure that the Radiance material is correctly defined as
11 # Radiance is going to crash otherwise. You are encouraged to make a backup
12 # copy of this file before modifying it.
13
14 #####
15 # Luminaires from ies2rad ##
16 #####
17 void brightdata downlight_dist
18 5 flatcorr downlight.dat source.cal src_phi4 src_theta
19 0
20 1 8.13698
21
22 downlight_dist light downlight_light
23 0
24 0
25 3 1 1 1
26
27 void brightdata asymmetric_downlight_dist
28 5 flatcorr asymmetric_downlight.dat source.cal src_phi2 src_theta
29 0
30 1 3.2217
31
32 asymmetric_downlight_dist light asymmetric_downlight_light
33 0
34 0
35 3 1 1 1
36
37
38 #####
39 # Opaque Materials #####
40 #####
41
42 # material name: GenericCeiling_80
43 # material type: opaque
44 # comment: This is a purely diffuse reflector with a standard ceiling reflect.

```

Normal text file length: 6647 lines: 236 Ln: 36 Col: 1 Sel: 0 | 0 Dos\Wind

0.606415,-0.047625,-0.00025

Finally, we can save this file as `downlight.csv`. Make the “downlight” layer already created in the file your active layer. Later we will assign the downlight illuminating material to this layer. To load the points into Rhino 5, just drag-and-drop the CSV file into the Rhino window, select “Import file,” press “OK” and then press “OK” again, leaving the point import options as the defaults.



Select “Import file” when prompted.

Leave the other options as the defaults and press “OK.”

Now we’re almost done. Turn on the point Osnap in Rhino and draw a polygon between the four points using the Plane command. Use the Dir command to make sure that the surface normal is **pointing down**. This is very important, as otherwise the polygon will not illuminate the scene.

9.8 Step 5: Finally Rendering Luminaires with Associated IES Information

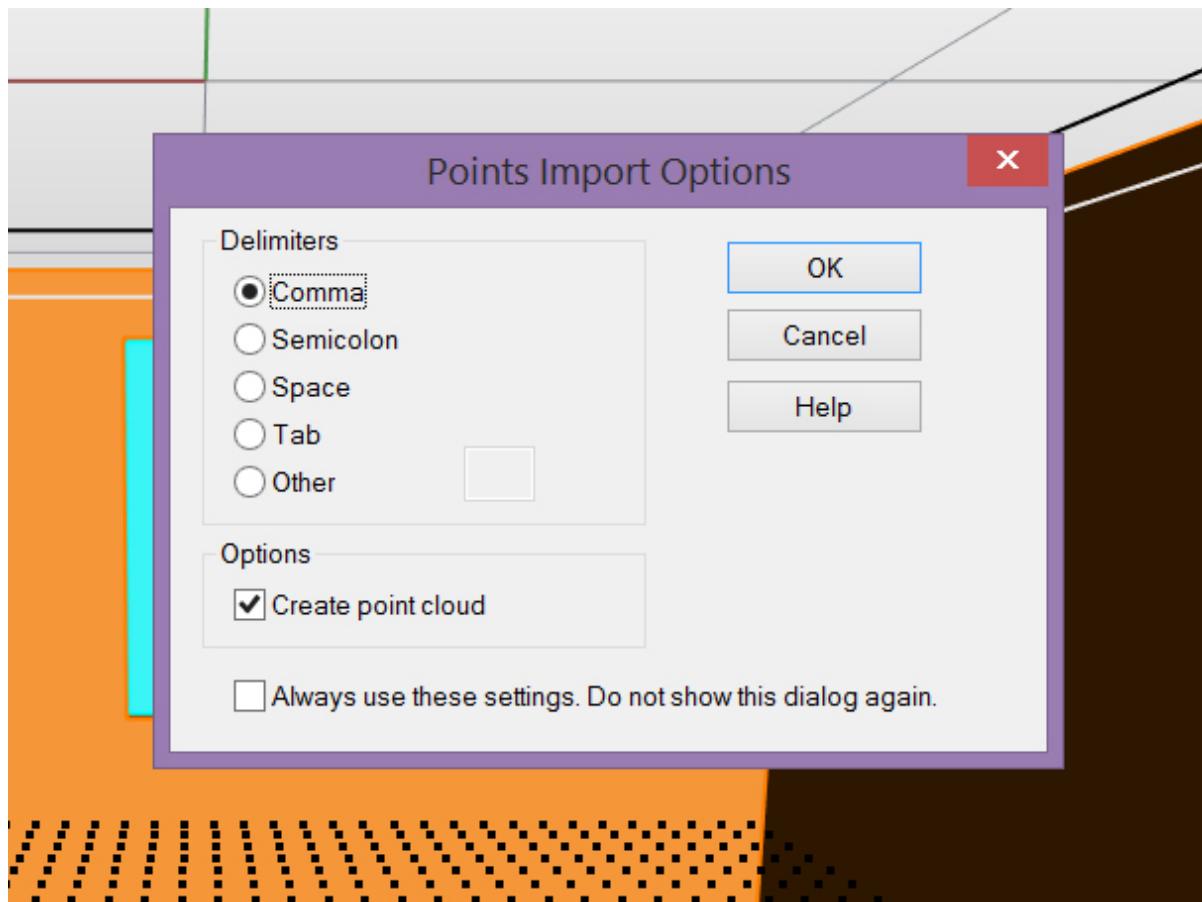
Run the Materials command again and apply the `downlight_light` material to the downlight layer that you created the polygon on.

Apply the appropriate materials created in Step 3 to your Rhino layers.

Finally at this point an image or grid-based simulation can be rendered! Make sure to set the time to a period when the sun isn’t up, such as 23:00.

Set the time to a dark period such as 23, 11:00 PM

And then run the metric by clicking “Run Simulation.”



Luminaires:

--

Asymmetric_Downlight:

asymmetric_downlight_light

Downlight:

downlight_light

Date and Time

09 21 23

Visualizations can also be rendered. I recommend to clear out the “Radiance parameters” box and replace it with the following,

```
-ab 3 -aa .1 -ar 500 -ad 1024 -as 512 -i
```

This allows many of the default Radiance ambient parameters that deal with sampling illuminating surfaces to be set without us having to worry about it. A brief explanation of what is left is explained below,

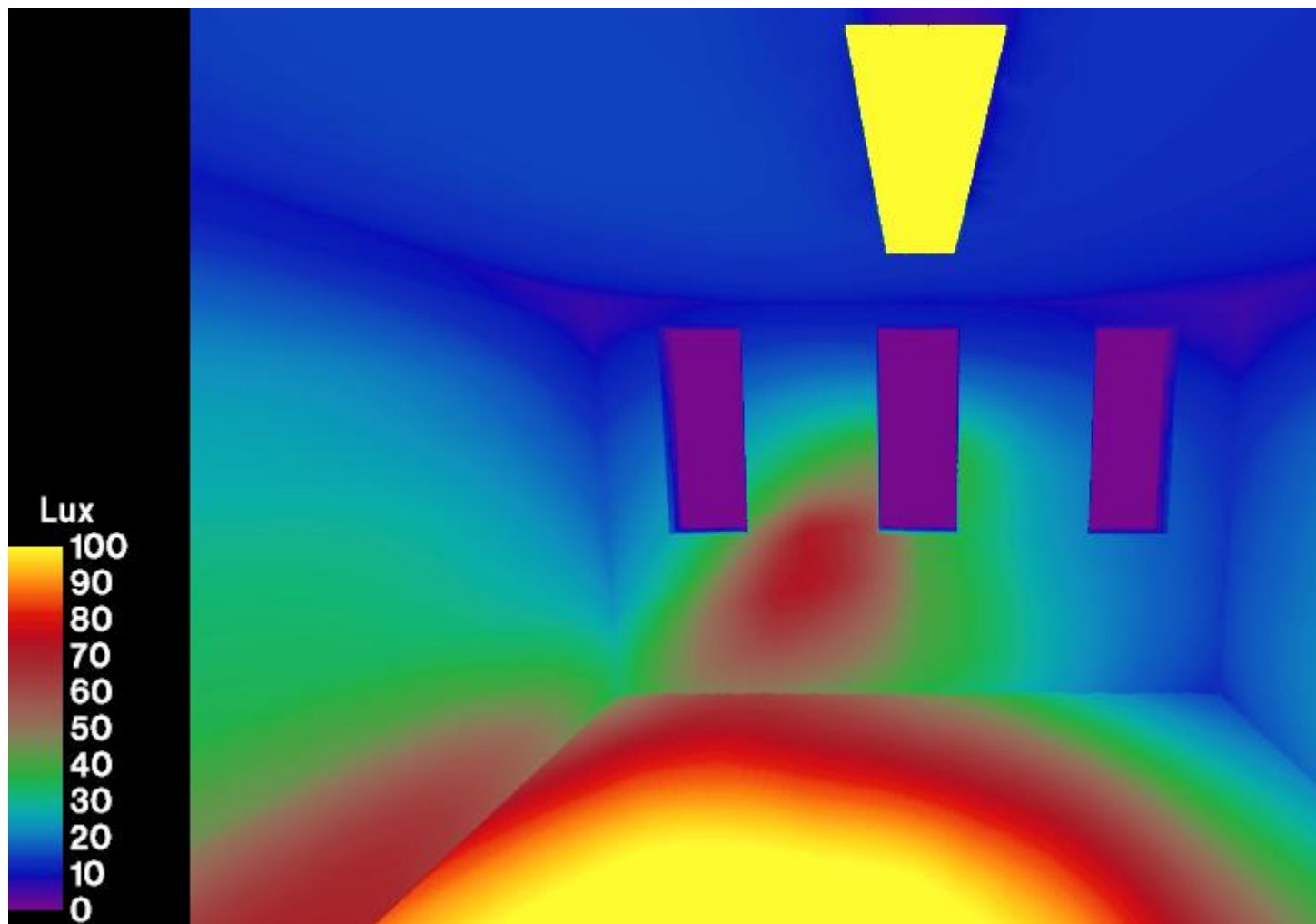
ab, ambient bounces: the light will bounce three times

aa, ambient accuracy and **ar**, ambient resolution: these control the level of interpolation between rays

ad, ambient divisions: 1024 rays are shot from each reflection

as, ambient supersamples: if there is a large luminous difference between nearby rays, the number of extra rays to be shot to resolve the transition accurately.

i, illuminance boolean trigger: render an illuminance rather than a luminance image



Falsecolor illuminance distribution of asymmetric downlight

9.9 Concluding Remarks

It is necessary to mention that the luminaire geometry can be moved and copied freely about the Rhino file. However, it **cannot be rotated or scaled** in any way at this time while maintaining the proper luminous distribution from the IES file.

This process will, one day, be fully automated within DIVA.

Simulations in General

In the Metrics dialog box, there are many options which are common to two or more simulation types. Since these are common to several simulation types, we will review them all in one place (this page).

These options include:

- Quality Preset and Radiance Parameters
- Sky Condition
- Date and Time
- Hide Dynamic Shading
- Geometric Density

And for Image-based simulations:

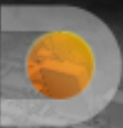
- Camera Type
- Camera Views
- Generate .tiff
- Open With
- Image Size

DIVA Simulation Menu

10.1 Image Quality and Radiance Parameters

Each quality preset relates to a set of Radiance parameters which can be seen and edited in the “Advanced Parameters” section of the dialog box. These settings set things like the number bounces and the number of rays that the Radiance engine will calculate for the simulation. It is not advisable to manually change these settings unless you have first understood the various Radiance commands and their respective values. For more information, see: [Radiance Manual](#)

Make sure that you follow the conventions for specifying variables (e.g. “-ab”, not “ab”).



DIVA

Daylight Images

Daylight Grid-Based

Thermal Single-Zone

Visualization

Timelapse

Radiation Map

Point-in-Time Glare

Annual Glare

Image Quality

Low Quality (quick render)

?

Sky Condition

Clear Sky with Sun

?

Date and Time

09 21 09

?

Camera Type

Perspective

?

Select Camera Views

Current Perspective View

?

Generate .tiff Image

☐

?

Advanced Parameters

Radiance Parameters

- ps 8 - pt .15 - pj .6 - dj 0 - ds .5 - dt .5 - dc .25 - dr 0 - dp 128 -
st .85 - ab 2 - aa .25 - ar 128 - ad 1024 - as 1024 - lr 4 -
lw .05

?

Image Size [x y]

800 600

?

Open With

wxfalsecolor

?

Hide Dynamic Shading

☒

?

Geometric Density

100

?

Cleanup Temporary Directory

☒

?

Run Simulation

Restore Defaults

For quick tests, the Low preset is fine, but for good, reliable results the High Preset is recommended. The Medium setting can be a good option for simulations that could possibly run extremely long if set to “High”. Since many Radiance simulations involve a stochastic process, re-running the exact same simulation can produce slightly different results each time. Higher resolution settings will reduce the variability in results, but at the expense of longer simulation times.

10.2 Sky Condition

You can specify a number of different sky conditions for your scene as explained below. The most common options typically used are Sunny or Cloudy.

- **Sunny Sky:** Uses the Radiance program gensky to model a CIE clear sky. This is a standard file defined by the International Commission on Lighting (CIE).
- **Cloudy Sky:** Uses the Radiance program gensky to model a CIE overcast sky. This is a standard file defined by the International Commission on Lighting (CIE). It is bright near the zenith and rotationally invariant, meaning that it looks the same in all orientations. This is the reference sky for the daylight factor.
- **Custom Sky:** In case you are interested in modeling a particular sky, for example when you have taking illuminance measurements of a space and you would like to model the space now under the same daylighting conditions. you can use the Perez sky model (Radiance program gendaylit) which requires as input date and time as well as measured direct and diffuse horizontal irradiances.
- **Clear sky without Sun:** Same as clear sky but without the solar disk. Some designers like using this theoretical (non physical) sky to distinguish between lighting contributions from the celestial hemisphere and from direct sunlight.
- **Uniform:** Uses the Radiance program gensky to model a completely uniform sky. The underlying uniform sky model was used before the CIE overcast and other sky models were introduced- .

10.3 Date and Time

The solar date and time are set by specifying month, day and hour in the format: mm dd hr (a single space between each entry). For instance: December 10 at 3:15pm would be: 12 10 15.25. Solar Date and Time mean that the sun position is calculate taking the Equation of Time into account, and WITHOUT daylight savings time.

10.4 Hide Dynamic Shading

If selected any Rhino layer that is modeled as a dynamic shading systems such as a lowered venetian blind is excluded from all calculations except for climate-based metrics and electric lighting simulations.

10.5 Geometric Density

To use a finer mesh resolution when running any of the Metrics, adjust the “Geometric Density” option. Values range between 0 and 100. “0” represents the crudest resolution of curves and complicated surfaces, where as “100” produces the most refined resolution.

10.6 Camera Type

DIVA Image simulations will only successfully run when the projection of the view you want to run is set to “Perspective Projection” in Rhino. If your view is set to an Orthographic Projection, an error will appear. To change the projection of your view in Rhino. Make sure that nothing is selected, and navigate to the “Properties” menu. Under “Viewport”, there is an option which says “Projection”. You can change the setting there.

The 180 degree fisheye automatically set when the Run Evalglare check box is checked.

10.7 Camera Views

By default, when running an Image simulation, DIVA will render the current view in Rhino. The “Saved Views Only” option allows you to run only the views you have saved under “Named Views” in Rhino. With either choice, remember to make sure they have a Perspective projection.

10.8 Generate.tiff

Image simulations automatically create a *.pic file which is effectively, an *.hdr (high-dynamic range) image. Unfortunately, these images cannot be opened by most photo previewers and NOT by Photoshop. In the wxfalsecolor window, you have the option to save the file that is generated as several file types, including a jpeg, but checking the “Generate .tiff” dialog box will save you the extra step of saving the image and will automatically generate and store the image as both a *.pic and *.tif in your results folder.

10.9 Open With

wxfalsecolor is a program developed by Thomas Bleicher and is automatically installed with DIVA. In order to use the Radiance IV option, you must have the Radiance Image Viewer installed on your computer.

10.10 Image Size

The dimensions of your output image can be set here. Values are entered in pixels x pixels in the format: integer integer. For instance 640 x 480 would be entered as: 640 480.

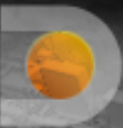
10.11 Cleanup Temporary Directory

Selecting this option will automatically clean up unnecessary files from the C:\DIVA\Temp\[RhinoFilename] directory.

Visualization

Metrics >> Daylight Images >> Visualization The Visualization simulation creates a Radiance rendering (*.pic) of the selected Rhino view of your model. This is a useful simulation to run **before all other simulations**, because it provides very useful information as to whether your model geometry is defined correctly and properly exporting. Sometimes surface normals are flipped, geometry is turned off or has not been defined a material, or other inconsistencies occur. The visual check allows you to preview the model the way Radiance sees it before running your simulation. Make sure your selected viewport is a perspective view and **not an orthographic projection** (Front, Top, etc. . .).

Metrics Menu: Visualization



DIVA

Daylight Images

Daylight Grid-Based

Thermal Single-Zone

Visualization

Timelapse

Radiation Map

Point-in-Time Glare

Annual Glare

Image Quality

Low Quality (quick render)

?

Sky Condition

Clear Sky with Sun

?

Date and Time

09 21 09

?

Camera Type

Perspective

?

Select Camera Views

Current Perspective View

?

Generate .tiff Image

☐

?

Advanced Parameters

Radiance Parameters

- ps 8 - pt .15 - pj .6 - dj 0 - ds .5 - dt .5 - dc .25 - dr 0 - dp 128 -
st .85 - ab 2 - aa .25 - ar 128 - ad 1024 - as 1024 - lr 4 -
lw .05

?

Image Size [x y]

800 600

?

Open With

wxfalsecolor

?

Hide Dynamic Shading

☒

?

Geometric Density

100

?

Cleanup Temporary Directory

☒

?

Run Simulation

Restore Defaults

CHAPTER 12

Timelapse Images

Metrics >> Daylight Images >> Timelapse This simulation was created to allow the user, with a single command, to run visualizations through a year, day or only on the Solstices and Fall Equinox.

Loop Over Months The year sequence runs the visualization for the same day of the month and time of day for each month of the year. So, for instance, if the user selected 15 for the day and 12 for the hour, the simulation would produce 12 images: January 15, at 12:00pm, February 15, at 12:00pm, March 15, at 12:00pm, etc.

Loop Over Day The day visualization sequence has the most variables. The user selects a month and day. They determine when to start the sequence (start hour) and when to end it (end hour) and how big an interval between images (timestep). For instance, for to produce one image for each hour from 9:00am to 3:00pm on June 01:

- Month: 06
- Day: 01
- Start Hour: 09
- End Hour: 15
- Time Step: 1

Entering minutes for time steps

To enter minutes for time step, enter the number as a decimal. For instance, to step every 15 minutes, enter 0.25 in the time step field; for one and a half hours, enter 1.5.

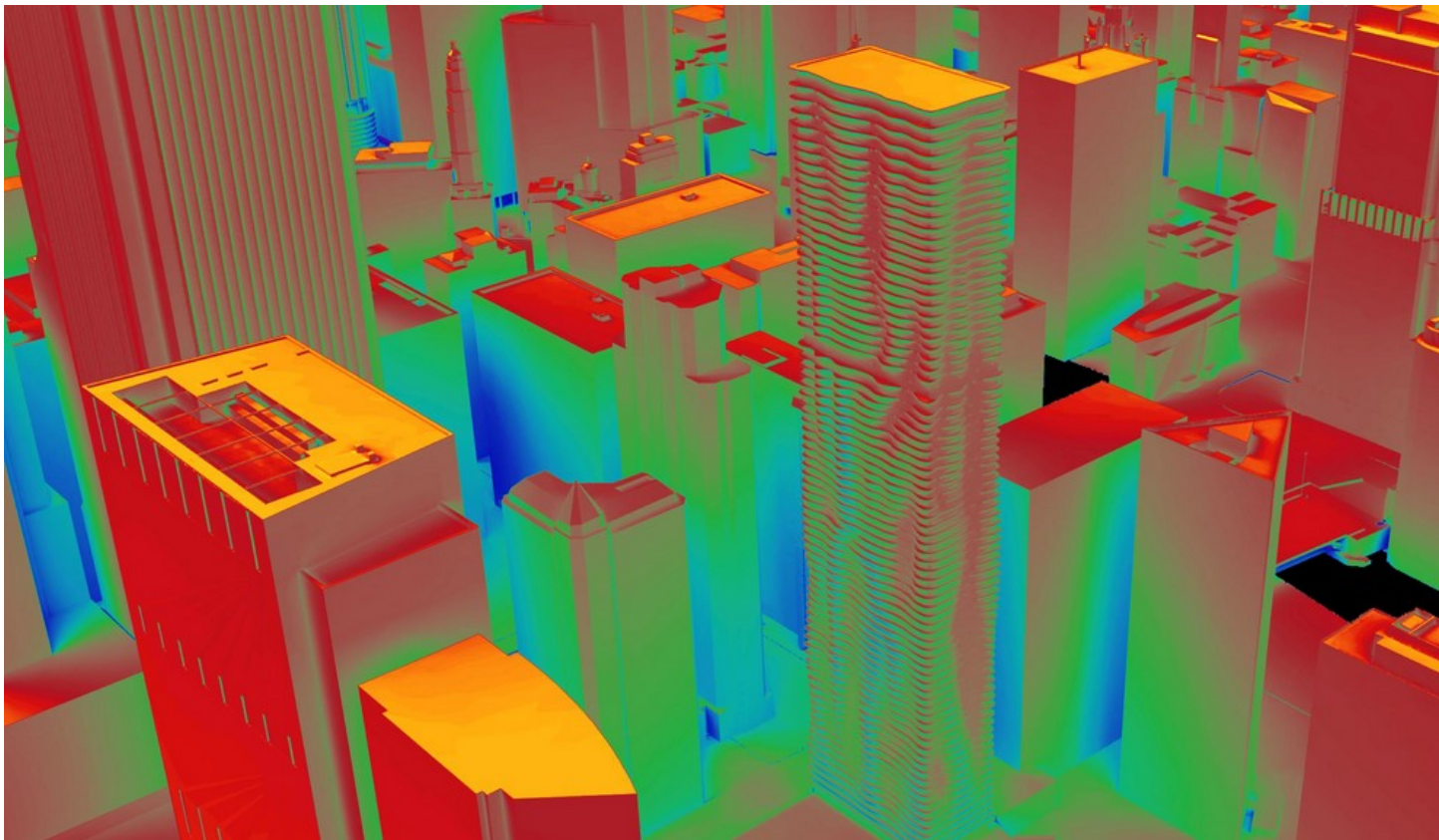
Loop Over Solstice and Equinox Days This sequence analyzes a user-determined hour on 3 dates: 6/21, 9/21, 12/21 (approximating the Summer and Winter Solstices and the Fall Equinox). For instance, if the user selects 10 for the hour, then three images will be produced at 10am on each of the three above dates.

Please note that only the Fall Equinox is used in this simulation (not the Spring Equinox).

Daylight Images		Daylight Grid-Based	Thermal Single-Zone	
Visualization	Timelapse	Radiation Map	Point-in-Time Glare	Annual Glare
Sequence Type	<input type="text" value="Loop over Day"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Image Quality	<input type="text" value="High Quality (long render times)"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Sky Condition	<input type="text" value="Clear Sky"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Month	<input type="text" value="09"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Day	<input type="text" value="21"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Start Hour	<input type="text" value="09"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
End Hour	<input type="text" value="15"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Time Step	<input type="text" value="0.5"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Select Camera Views	<input type="text" value="Current Perspective View"/>	<input type="text" value=""/>	<input type="text" value=""/>	<input type="text" value=""/>
Generate .tiff Image:	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Advanced Parameters				
Radiance Parameters				
<input type="text" value="-dp 512 -ar 128 -ms 0.57 -ds .05 -dt .05 -dc .75 -dr 3 -st .1 -ab 4 -aa .1 -ad 2048 -as 512 -av 0.01 0.01 0.01 -lr 12 -lw .002 -ps 2 -pt .05"/>				<input type="text" value=""/>
Image Size [x,y]	<input type="text" value="800 600"/>			<input type="text" value=""/>
Hide Dynamic Shading	<input checked="" type="checkbox"/>			<input type="checkbox"/>
Geometric Density	<input type="text" value="100"/>			<input type="text" value=""/>
<input type="button" value="Run Simulation"/> <input type="button" value="Restore Defaults"/>				

CHAPTER 13

Radiation Maps



Example of a radiation map generated in DIVA using rpict and gencumulativesky

DIVA-for-Rhino can generate climate-specific annual surface irradiation images or calculate annual irradiation at node locations. This is a powerful tool that can be used on an urban or building scale to identify locations with solar energy

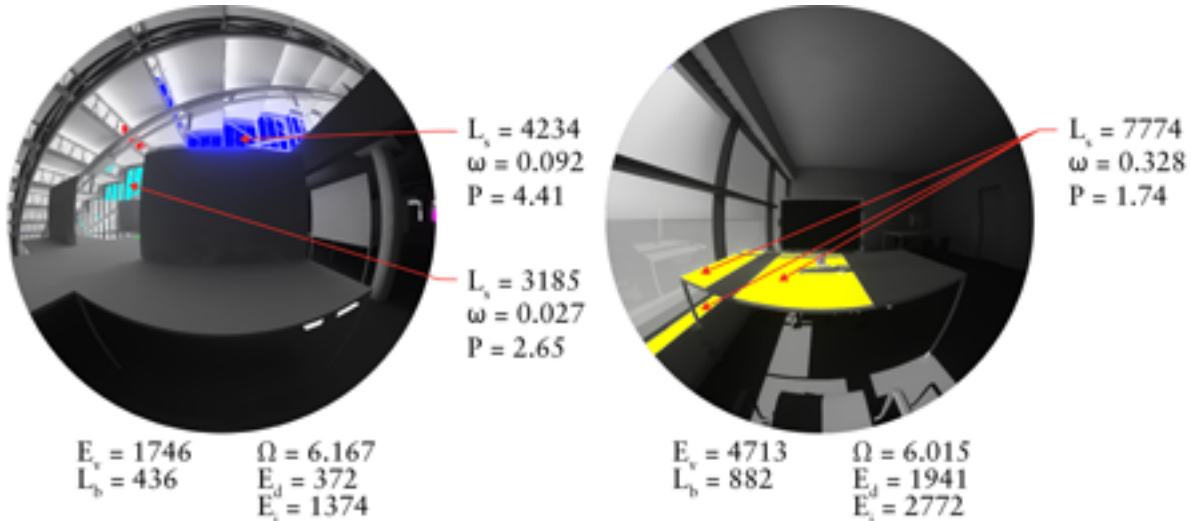
conversion potential or areas in need of shading due to excessive solar exposure. Comparing summer and winter period irradiation results could help optimize shading devices to maximize winter gain while minimizing summer exposure.

The analysis uses a method described by [Robinson and Stone](#) which harnesses a Radiance module called GenCumulativeSky to create a continuous cumulative sky radiance distribution. This cumulative sky is then used in a Radiance backwards ray-trace simulation. Compared to other approaches which use hourly calculations, this approach is significantly faster with a minimal sacrifice in accuracy.

Point-in-Time Glare

Metrics >> Daylight Images >> Point-in-Time Glare

Using a point-in-time glare simulation in DIVA, the visual comfort of a person under the simulated conditions at the camera viewpoint can be simulated. The Daylight Glare Probability (DGP) metric is used in the comfort evaluation which considers the overall brightness of the view, position of ‘glare’ sources and visual contrast.

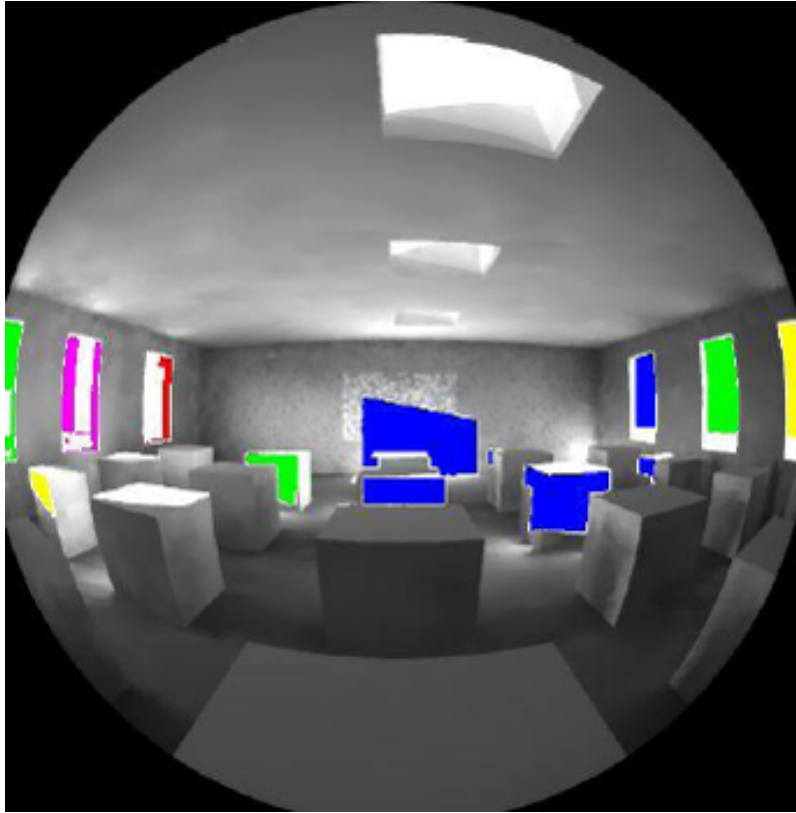


Examples of visual comfort analysis in DIVA. Areas of high contrast (3 times the mean image luminance) are highlighted in color.

Metrics Menu: Point-in-Time Glare

The **camera type** is automatically changed to a 180 degree fisheye lens for the visual comfort analysis. Multiple camera views can also be selected from the “Select Camera Views” option.

The simulation uses evalglare v1.0 to calculate Daylight Glare Probability (DGP) from a luminance image based on total vertical eye illuminance and contrast. One freely available paper on the method is found [here](#).

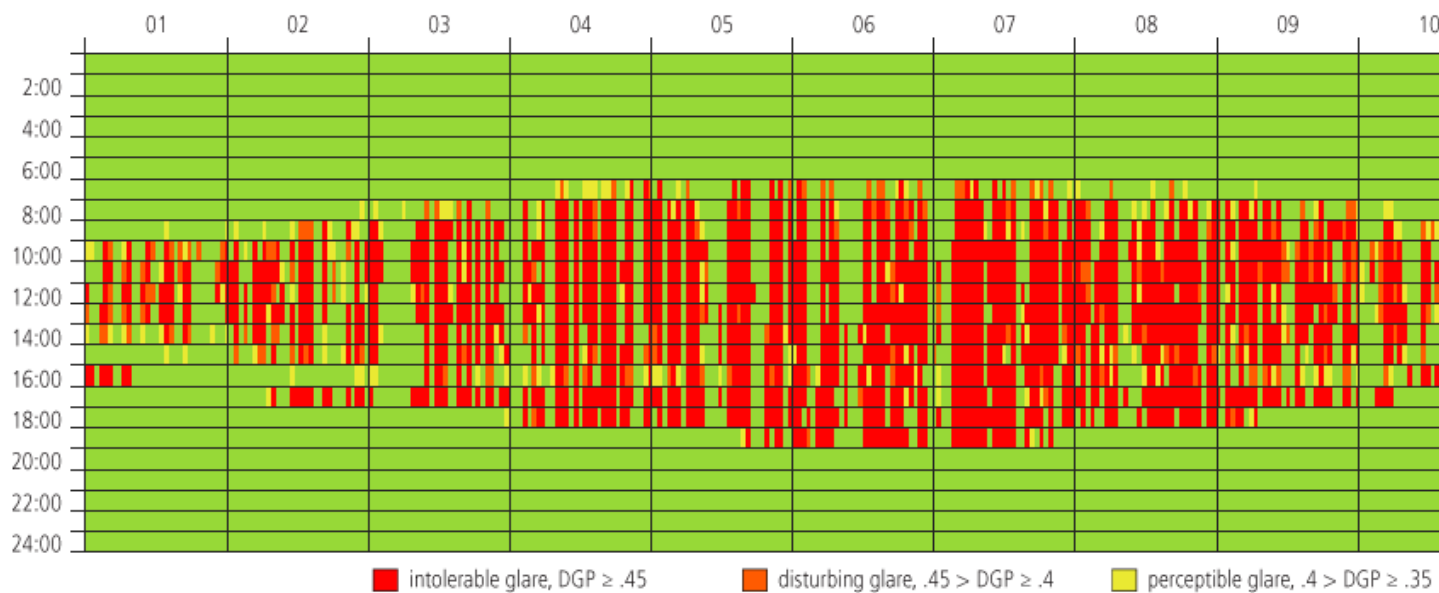


The resultant image shows contrast-based glare sources highlighted in color, and displays text at the top of the image showing the numeric DGP rating as well as a plain-text description of the predicted glare for the specific luminance image.

CHAPTER 15

Annual Glare

An annual glare calculation uses a similar methodology to a Point-in-Time Glare image; however, the process is repeated for each hour in the year by using an annual DAYSIM prediction to calculate vertical eye illuminance and images with the ambient calculation turned off to predict contrast from direct sunlight. This produces an annual evaluation of comfort within a space, pictured below.



Output from an annual glare calculation with no dynamic shading devices

15.1 A Warning Regarding Simulation Time

Each annual glare simulation will respond to the dynamic shading controls specified in the Rhino file. If a complex dynamic shading system is defined, annual glare will be calculated for each state of the system. This can take a long

time depending on the number of shading states and the complexity of the geometry. if you wish to absolve your computer of this computational responsibility, disable dynamic shading controls before running a simulation. This will illustrate visual comfort without shading.

Daylight Images		Daylight Grid-Based		Thermal Single-Zone	
Visualization	Timelapse	Radiation Map	Point-in-Time Glare	Annual Glare	
Select Camera Views	Current Perspective View				?
Occupancy Schedule	always_occupied.60min.occ.csv				?
Advanced Parameters					
Radiance Parameters	-ab 2 -ad 1000 -as 20 -ar 300 -aa 0.1				?
Adaptive Visual Comfort	User(s) cannot adapt. Simulation				?
Geometric Density	100				?

Metrics Menu: Annual Glare

Select Camera Views *Current Perspective View* will predict a simulation result for the current view in Rhino. If this is a saved view, the saved state of the view will be used.

Saved Rhinoceros Views will run a simulation for every saved viewport in the Rhino file. It will not calculate a simulation for the Perspective view.

Adaptive Visual Comfort Selecting *User(s) cannot adapt* results in the lowest value for all camera views in the file being selected when displaying the annual falsecolor result graphic. This mode is useful when one user's ability to move around a space in response to visual comfort is being evaluated.

Selecting *User(s) can adapt* shows the predicted annual visual comfort for each simulated view. This is useful when evaluating the perception of multiple users in a space.

Daylight Factor and Illuminance

16.1 Daylight Factor

Metrics >> Daylight Grid Based >> Daylight Factor A daylight factor is the ratio between exterior sky illuminance on an overcast day and illuminance inside a building. To run the metric, you must have first set up a sensor node grid using the **Nodes** button.

Daylight Images		Daylight Grid-Based		Thermal Single-Zone	
Daylight Factor		Point-in-Time Illuminance		Climate-Based	
Radiance Parameters	<input type="text" value="-ab 6 -ad 500 -as 16 -ar 300 -aa 0.1"/>				?
Hide Dynamic Shading	<input checked="" type="checkbox"/>				?
Geometric Density	<input type="text" value="100"/>				?
<input type="button" value="Run Simulation"/>		<input type="button" value="Restore Defaults"/>			

Metrics Menu: Daylight Factor

Since the sky condition is overcast, neither a sky condition nor a date and time for the calculation are needed. You have the option to manually change your Radiance parameters and the geometric density of your geometry.

16.2 Illuminance

Metrics >> Daylight Grid Based >> Point-in-Time Illuminance Illuminance calculations are also called “point-in-time” calculations because unlike the annual, or climate-based metrics, illuminance calculations measure light levels at a specific date and time. Like Daylight Factor, you will need to set up the sensor node grid, using the **Nodes** button before you run this metric.

16.3 Units

Select your preferred lighting units, (Lux, Footcandles.)

16.4 Solar Date and Time

Enter a date and time for the calculation. To enter minutes use an integer followed by a decimal point. For example, if you want to run a test on September 21 at 9:15am. Enter “09 21 9.25”.

LEED-IEQ-8.1 Compliance

Important Update: This function was updated to reflect the LEED IEQ 8.1 Addendum change to the evaluation bounds. The new LEED Illuminance bounds are 10 - 500 fc.

17.1 LEED Test

Metrics >> Daylight Grid Based >> Point-in-Time Illuminance >> LEED IEQ 8.1 This simulation tests a model for LEED NC IEQ 8.1 points. Refer to the LEED Guide for modeling information and other requirements. You only need to set your preference for units, respect dynamic shading and geometric modeling. The simulation will run **two** illuminance tests: September 21 at 9am and 3pm. The simulation tallies the percentage of the total calculation grid area that receives between 10 and 500 footcandles at each point-in-time. In order to qualify for the LEED points, a minimum of 75% of the project must be daylit at both of those times.

17.2 LEED Points

Percentage of area between 10 & 500 fc at 9am and 3pm

- <75%: 0 points
- 75% to 90%: 1 point
- 90% or more (schools only): 2 points

Results are displayed as follows: For a single point, if the value at 9am or 3pm is lower than 10fc, the node is categorized as “<10fc”. If the value at 9am or 3pm is greater than 500fc, then node is categorized as “>500fc”. If the values at 9am and 3pm both fall within the acceptable range, the results will display the average of the two.

When running the simulation, it is important to increase the ambient bounces to 5 or more. To do so, in the Radiance parameters editable field, change the item “-ab 2” to “-ab 5”.

Note: The DIVA LEED function gives one assessment for all of the nodes selected. It does not break the results down into node or panel groups.

18.1 Daylight Autonomy, Continuous Daylight Autonomy, Daylight Availability, Useful Daylight Illuminance

Metrics >>Daylight Grid Based >>Climate-Based Climate-Based Metrics use recorded climate data in the form of *.epw files to simulate the sun and sky conditions for various simulations including Daylight Autonomy, Daylight Availability, Continuous Daylight Autonomy and Useful Daylight Illuminance. The second important aspect of Climate-Based Metrics is that they are **annual** calculations which means they take the entire year into account. The metrics use Radiance and Daysim as their calculation engines.

Metrics Menu: Climate-Based

18.2 Units

(Lux, Footcandles)

Although Radiance and Daysim only use lux as a unit of illuminance, if you are working in an environment which reference footcandles, you select “Footcandles” as a unit here. The values will be converted over to lux in the simulation process and then back to footcandles for the display output.

18.3 Occupancy Schedule

In this dialogue annual hourly occupancy schedules can be selected. These occupancy schedules are used to determine when a lighting or shading group is occupied. These files are stored in csv (comma separated value) format under **c:\DIVA\Schedules**.

Daylight Images		Daylight Grid-Based		Thermal Single-Zone	
Daylight Factor		Point-in-Time Illuminance		Climate-Based	
				Radiation Map	
Metric	<input type="text" value="Daylight Autonomy"/>			<input type="button" value="v"/>	?
Occupancy Schedule	<input type="text" value="8to6withDST.60min.occ.csv"/>			<input type="button" value="v"/>	?
Target Illuminance	<input type="text" value="300"/>				?
Units	<input type="text" value="Lux"/>			<input type="button" value="v"/>	?
Show Daysim Report	<input checked="" type="checkbox"/>				?
Use DGP Schedules	<input checked="" type="checkbox"/>				?
Advanced Parameters					
Radiance Parameters	<input type="text" value="-ab 2 -ad 1000 -as 20 -ar 300 -aa"/>				?
Adaptive Visual Comfort	<input type="text" value="User(s) cannot adapt. Simuli"/>			<input type="button" value="v"/>	?
Geometric Density	<input type="text" value="100"/>				?
Cleanup Temporary Directory	<input checked="" type="checkbox"/>				?

18.4 Target Illuminance

Select a target illuminance level for your space. This level should depend on space type for example 500 lux of an office. For predominantly daylighted spaces it has become customary to assume a target illuminance of 300 lux.

18.5 Show Daysim Report

If selected a detailed Daysim report will be displayed in your browser.

18.6 Use DGP schedules

This option controls how a manually controlled dynamic shading system is being modeled. If the user has run an annual glare analysis beforehand and this option is checked, the Lightswitch model will close the blinds as soon as the DGP in the [annual glare schedule](#) is above 40% (disturbing glare or worse). If left unchecked or if no annual glare analysis has been conducted, the blinds will be closed once direct sunlight above 50w/m² is incident on the specified work place.

18.7 Adaptive Comfort

This parameter determines how annual glare simulations inform the use of a dynamic shading system. If the shading system is manual controlled and more than one view point was provided for the annual glare calculation, then the former selection assumes that a user can *adapt* to the space and pick the position with the least amount of glare. In the latter case several occupants are in the space and the occupant with the worst glare condition determines whether the shading device needs to be readjusted.

18.8 Loading Metrics

For detailed documentation of the climate-based metrics and methods, see: C F Reinhart and J Wienold, "The Daylighting Dashboard - A Simulation-Based Design Analysis for Daylit Spaces", Proceedings of SimBuild 2010, New York City, August 2010.

Reinhart C F, Mardaljevic J, Rogers Z, "Dynamic Daylight Performance Metrics for Sustainable Building Design", Leukos 3:1, 2006

Bourgeois D, Reinhart C F, Ward G, "An inter-model comparison of DDS and Daysim Daylight coefficient methods", Proceedings of the European Conference on Energy Performance & Indoor Climate in Buildings (EPIC), Lyon, France, November 2006.

CHAPTER 19

CHPS Simulations

CHPS stands for Collaborative for High Performance Schools and is an elective certification program intended to improve various aspects of schools' built environment. At present, DIVA provides the ability to test whether a space qualifies for points under the MACHPS or NECHPS point systems only.

Radiation Maps-Grid Based

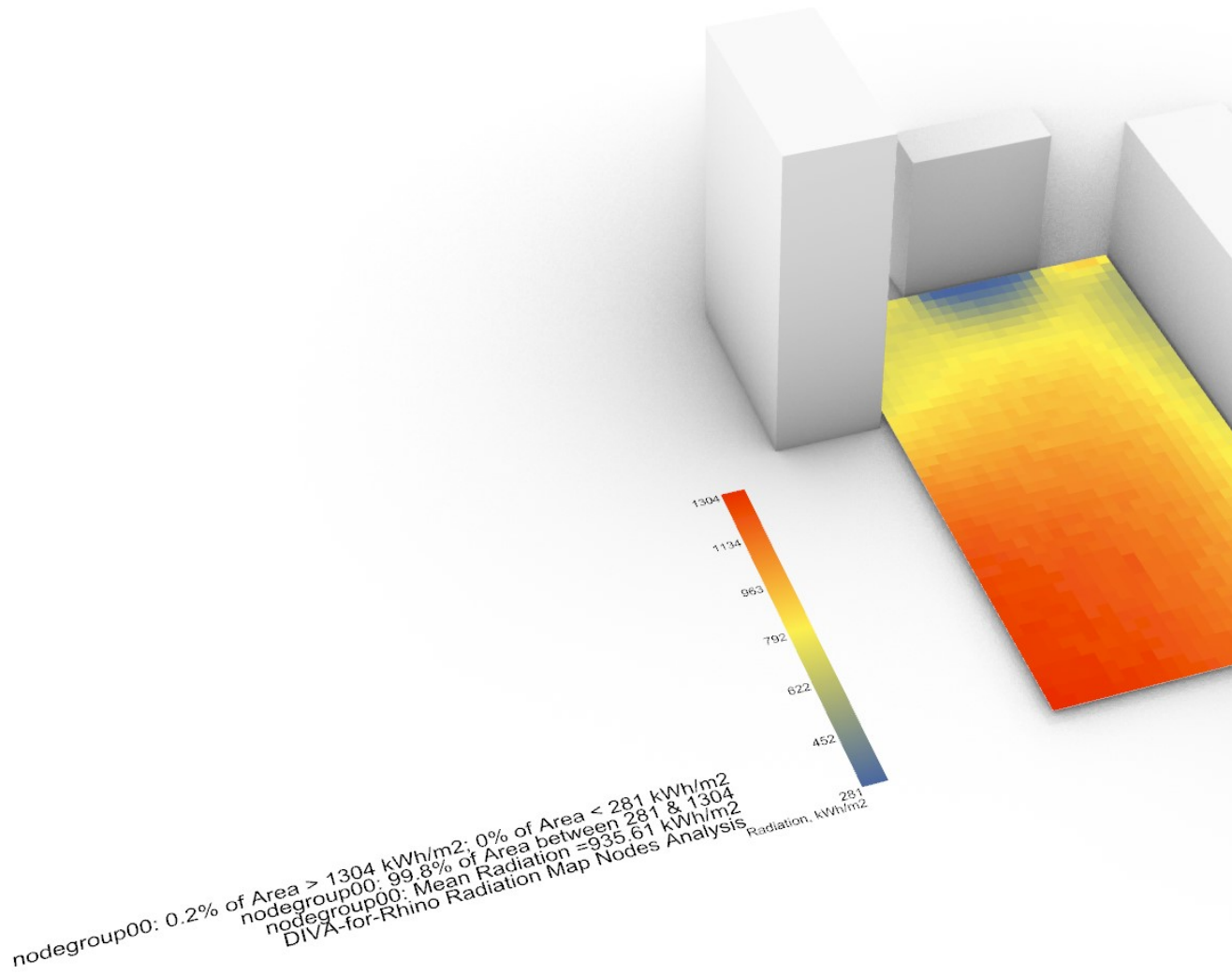
DIVA-for-Rhino can generate climate-specific annual surface irradiation images or calculate annual irradiation at node locations. This is a powerful tool that can be used on an urban or building scale to identify locations with solar energy conversion potential or areas in need of shading due to excessive solar exposure. Comparing summer and winter period irradiation results could help optimize shading devices to maximize winter gain while minimizing summer exposure.

Grid-based Radiation Map Simulation Options

20.1 Metric

The cumulative sky method is described by [Robinson and Stone](#) which harnesses a Radiance module called GenCumulativeSky to create a continuous cumulative sky radiance distribution. This cumulative sky is then used in a Radiance backwards ray-trace simulation. Compared to other approaches which use hourly calculations, this approach is significantly faster with a minimal sacrifice in accuracy.

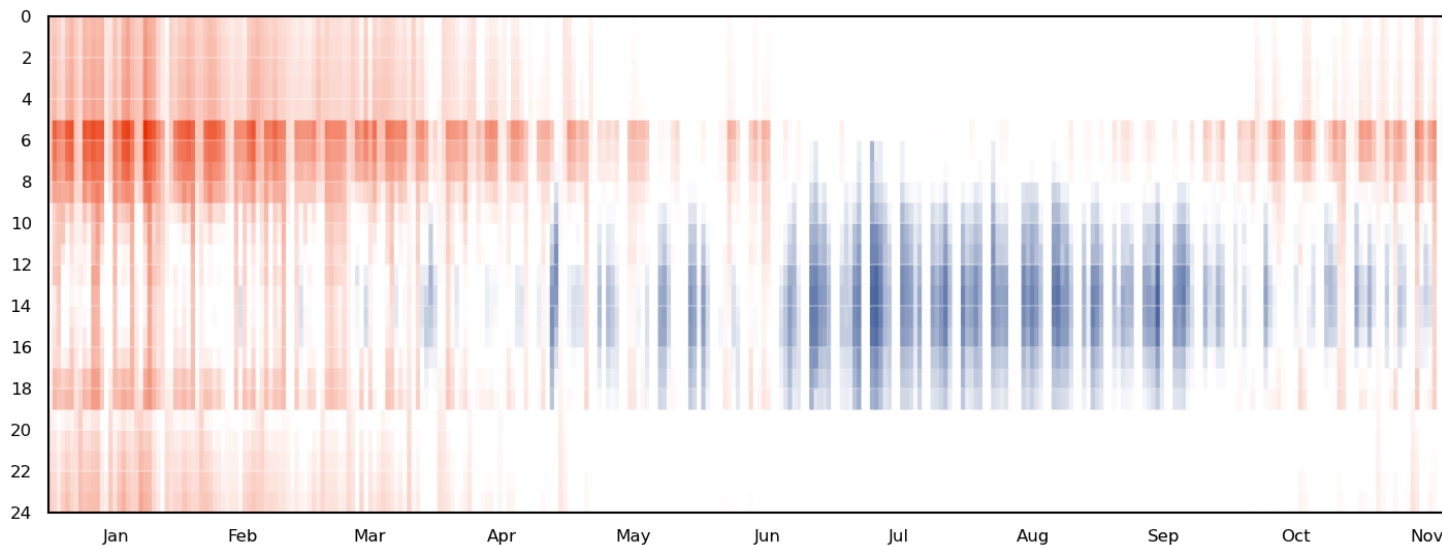
The Daysim-based hourly method utilizes the same engine behind climate-based metrics in DIVA to produce an hourly result file in addition to the time-cumulative irradiation map. Once a radiation map has been generated using this method, different portions of the year can be visualized very quickly.



CHAPTER 21

Thermal Analysis

DIVA-2.0 allows the modeling of single-zone thermal models using EnergyPlus. These models are automatically linked, through the software interface, with detailed lighting and shading schedules generated by DIVA/DAYSIM. In effect, this allows one to test the relative effect of different daylighting and controls strategies on the energy consumption of a typical daylit space.

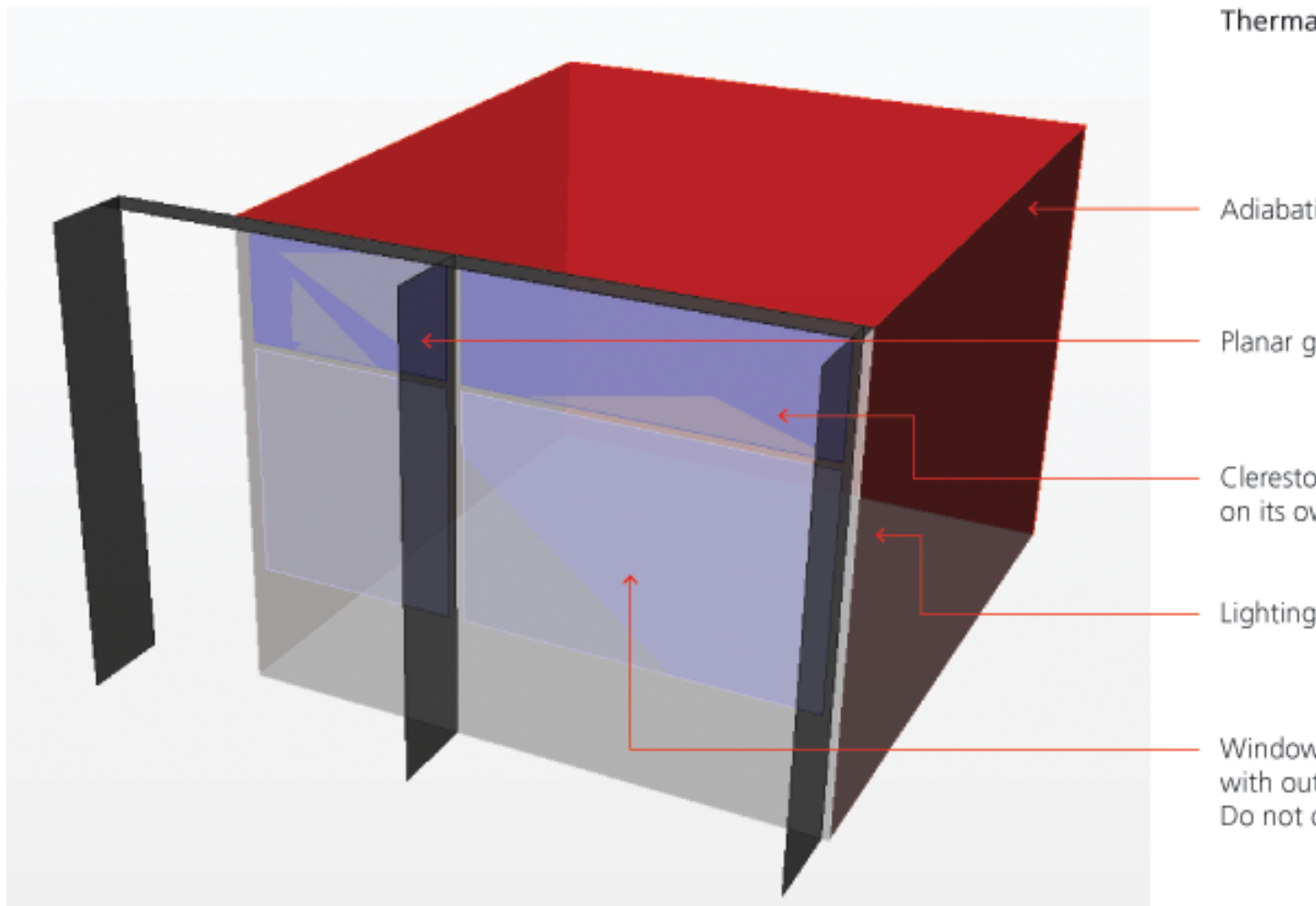


DIVA hourly heating and cooling energy consumption output

21.1 Geometry Creation

To translate a daylighting model into a thermal model, several simplifications must be made. While daylighting models can easily account for complex, volumetric geometry, thermal models must be built as planes. A layer structure under the parent layer name DIVA Thermal is automatically created for this purpose when the Location button is pressed.

The geometry on the DIVA Thermal layers will never be exported to DIVA-Daylighting simulations. The diagrams below are useful to show the differences between daylight and thermal models, and both are representations of the same space.



Note that in the planar thermal model that the blind system is not modeled explicitly as it is a dynamic shading device; however, the outside structural members have been modeled on the `ep_shading` layer as they are always present. Also in the thermal model it is very important not to punch holes for the window openings, and each window should only intersect with one wall or ceiling surface. A window should never touch the edge of a parent surface.

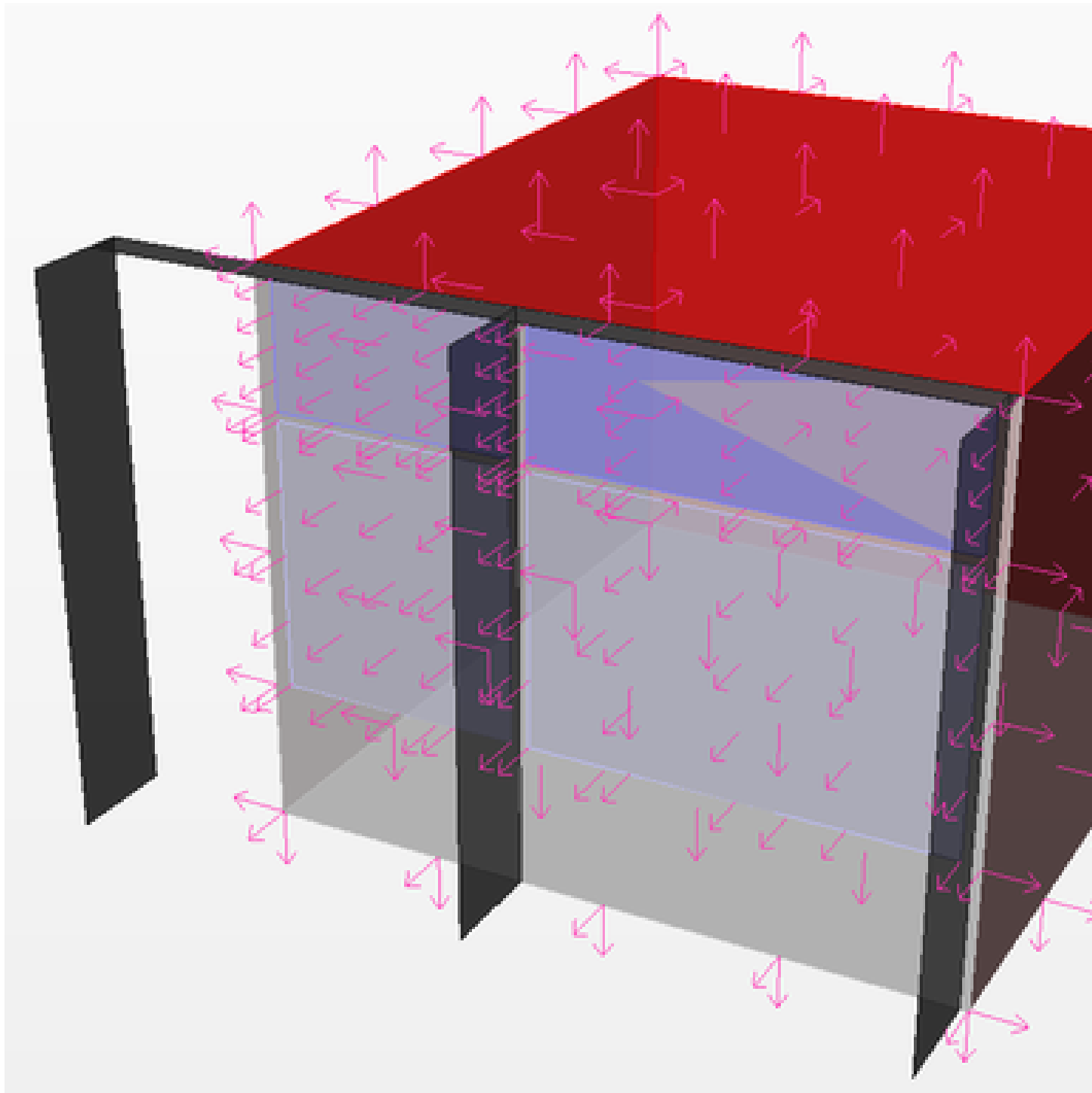
Thermal geometry must also have all surface normals pointing outwards from the space.

In this image, the Rhino “Dir” command is used to check and adjust surface orientation.

21.2 Running Thermal Simulations

Generating Shading, Lighting and Occupancy Schedules from Climate-Based Simulations Climate-based simulations including all desired shading and lighting schedules should be run before a thermal analysis. The generated schedules will be offered as input options into the thermal simulation.

Layer Structure and Applying Thermal Materials The layers automatically created under DIVA Thermal can all contain thermal simulation geometry. Also, any sublayer under the automatic layers can contain thermal simulation geometry. `ep_adiabatic` contains surfaces with mass, but no heat transfer occurs through them. `ep_ceiling`



contains roof or ceiling surfaces. ep_floor contains floor surfaces. ep_shading contains fixed exterior shades such as buildings or louvers. ep_wall contains exposed wall surfaces. ep_window contains windows associated with surfaces on ep_wall or ep_ceiling (see the geometry creation section above for details). In addition, in the example below the sublayer clerestory_windows also serves as a window layer with a different material definition and shading schedule.

Geometry can be modeled on the base DIVA-Thermal layers or on any sublayer, which allows multiple material types and dynamic shading locations in one simulation. In this example, there is a separate layer for the clerestory windows

The thermal tab under Materials > Assign Materials is used to set thermal material properties.

Running a Simulation / Simulation Parameters From the Metrics button, clicking the Thermal Single-Zone tab brings up the thermal simulations options menu.

Metrics Menu: Thermal Single-Zone

Occupant Density The area each occupant inhabits in square meters. For example, a value of 10m²/occupant in a space with a floor area of 100m² equates to 10 occupants in the space.

Equipment Power Density Watts of eternal equipment load per square meter of floor area. In the same 100m² space, a value of 4W/m² equates to an equipment load of 400W.

Air Changes Per Hour The frequency with which fresh air enters from the outside due to air leaks in construction assemblies. If our 100m² has a ceiling height of 4m and the air change rate is 0.5ACH, then 200m³ of fresh outdoor air enters per hour.

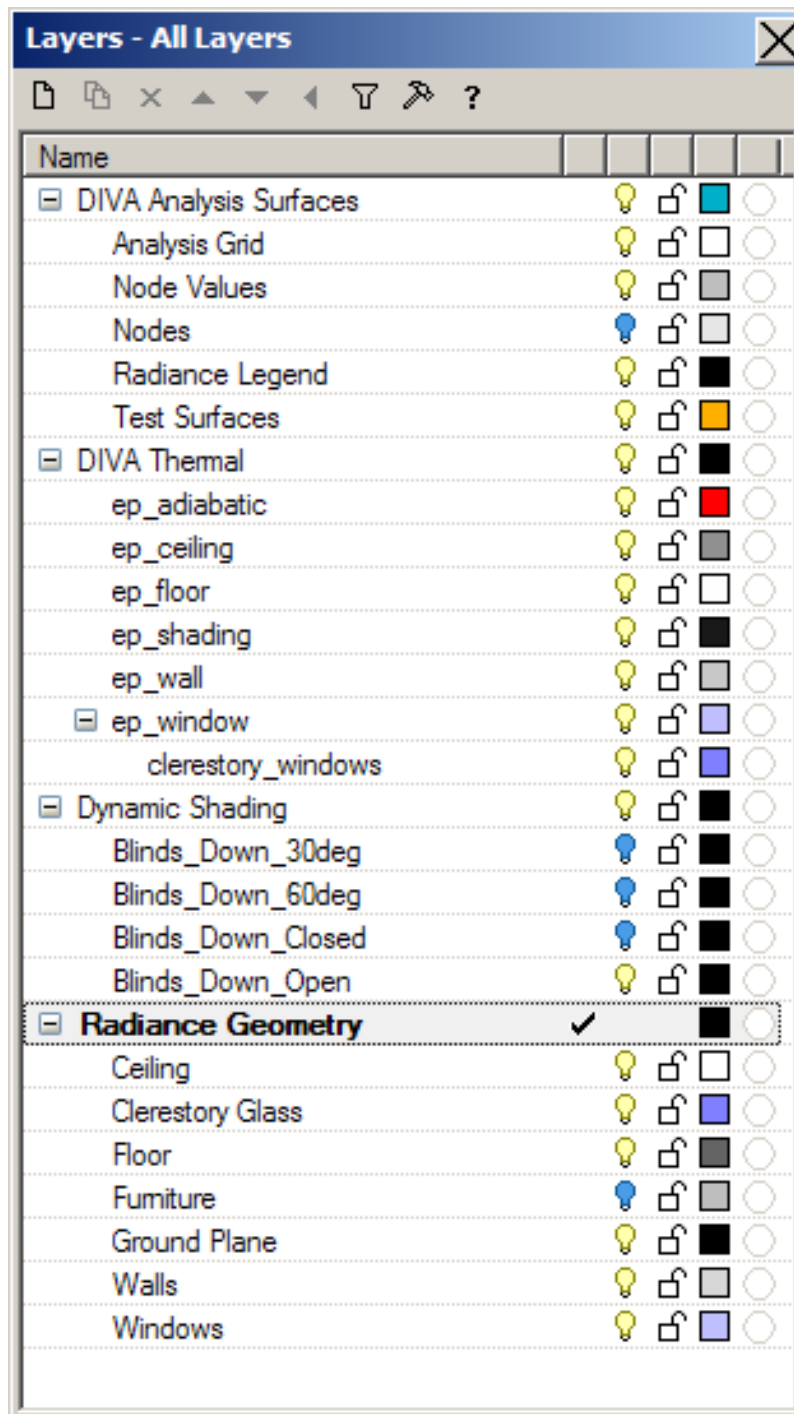
Heating Efficiency An efficiency factor which is applied to the calculated space heating loads. Load/Efficiency gives the predicted energy use.

Cooling Efficiency An efficiency factor which is applied to the calculated space cooling loads. Load/Efficiency gives the predicted energy use.

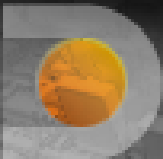
Setpoints The setpoint and setback temperatures (in degrees Celsius) for cooling and heating form a deadband zone during the entire year. Heating and cooling is, by default, available the entire year. The setpoint temperatures are used during typical occupied hours and the setback temperatures are used during unoccupied hours.

Natural Ventilation Forthcoming.

J A Jakubiec and C F Reinhart, "DIVA-FOR-RHINO 2.0: Environmental parametric modeling in Rhinoceros/Grasshopper using Radiance, Daysim and ""EnergyPlus"", Building Simulation 2011, Sydney, Australia.



Assign Materials

 DIVA

Daylighting MaterialsThermal Materials

Layer Name	Material Choices
ep_adiabatic:	Wall_Composite2x6WoodStud_
ep_ceiling:	--
ep_floor:	Floor_CastConcrete_Uninsulate
ep_wall:	Wall_Composite2x4WoodStud_
ep_window:	Glazing_DoublePane_LowE
clerestory_windows:	Glazing_DoublePane_LowE
ep_shading:	--

Submit Material Information

DIVA Simulation Options

DIVA

Daylight Images Daylight Grid-Based **Thermal Single-Zone**

Occupant Density	<input type="text" value="10"/>	?
Equipment Power Density	<input type="text" value="4"/>	?
Air Changes per Hour [1/h]	<input type="text" value="0.5"/>	?

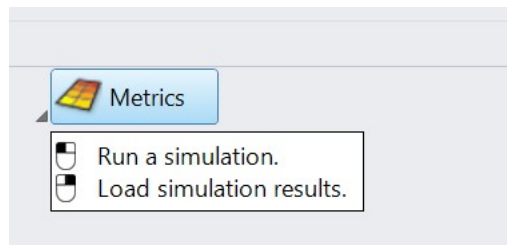
Conditioning Systems

Heating Efficiency	<input type="text" value="0.8"/>	?
Cooling Efficiency	<input type="text" value="3.0"/>	?
Cooling Setpoint:	<input type="text" value="26"/>	?
Cooling Setback:	<input type="text" value="32"/>	?
Heating Setpoint:	<input type="text" value="22"/>	?
Heating Setback:	<input type="text" value="15"/>	?
Natural Ventilation:	<input type="checkbox"/>	?

Run Simulation *Restore Defaults*

Load Metrics

To load previous results into your model, you right-click on the **Metrics** button. The **Choose** and **Load Metrics** boxes are displayed. The Load Metrics box is also displayed when any of the node-based metrics are finished running. The boxes provide options for how the results are displayed, and depend on which metric you are loading.



Right-click on metrics to load existing simulation results

Lighting Test prompts you to choose which metric to load. Most of these are self-explanatory; however, 'Illuminance from DA' is a new feature which allows visualization of the hourly illuminance results from Daysim / Climate-based metrics.

Choose **Select Metric to Load** if loading a grid-based result.

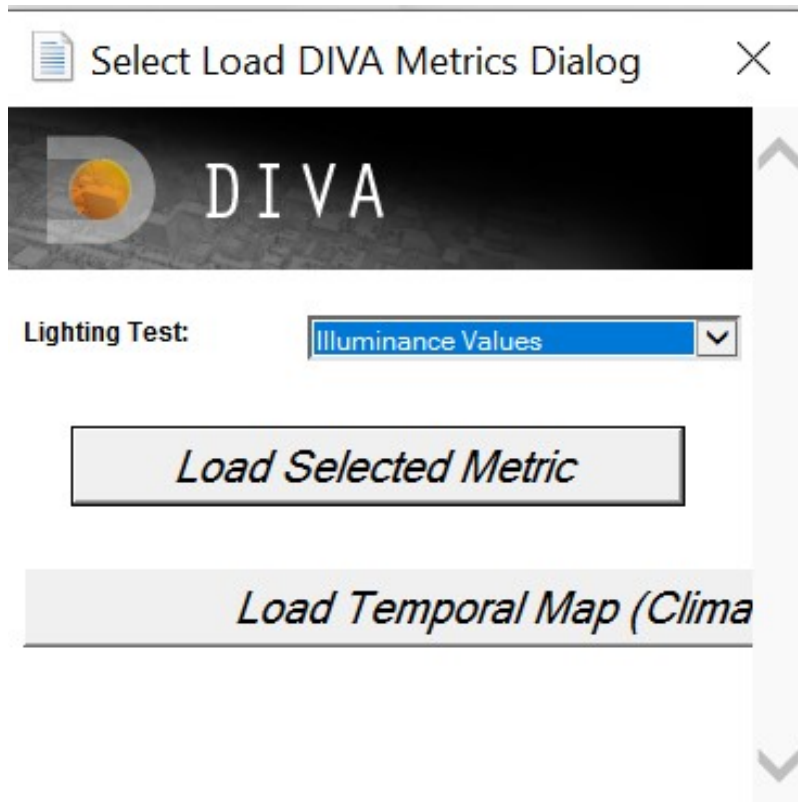
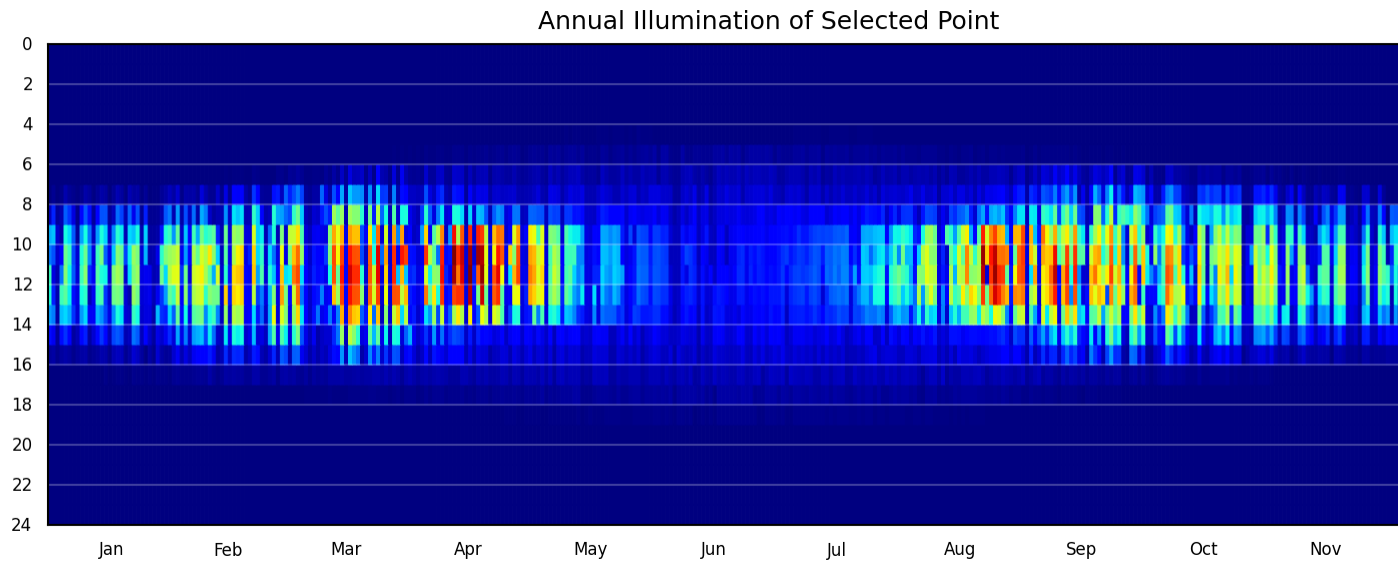
Choosing **Climate-Based Falsecolor** will allow an hourly temporal map of climate-based simulation results for a selected point.

A result of the climate-based falsecolor option

Load metrics dialog

22.1 Min/Max Illuminance

(Illuminance and Continuous Daylight Autonomy) The user can set the lower and upper bounds which correspond to the colors displayed on the false-color node grid.



22.2 Min/Max Irradiance

(Radiation Nodes) The user can set the lower and upper bounds which correspond to the colors displayed on the false-color node grid.

22.3 Min/Max Daylight Factor

(Daylight Factor) The user can set the lower and upper bounds which correspond to the colors displayed on the false-color node grid.

22.4 Color Scheme

(All Metrics) This option lets the user select which color scheme to use for the false-color node grid.

22.5 Label 1% Peak Nodes

(All Metrics) By checking this box, the 1% peak nodes will be highlighted.

22.6 Label All Nodes

(All Metrics) Checking this box will display the numeric result value at each node. These node labels are stored on their own DIVA sublayer called, “Node Values”.

22.7 Color Extreme Values

(Daylight Factor, Illuminance, Radiation Nodes, Continuous Daylight Autonomy) Panels whose values fall below the set range are shaded black and those that fall above are shaded bright pink.

22.8 Display Footcandles

(Illuminance, Continuous Daylight Autonomy, Useful Daylight Illuminance, Daylight Autonomy, Daylight Availability) This should be checked if the user selected “footcandles” as the “Lighting Units” in the Metrics dialog box before running the metric.

22.9 Create Variant Label

(All Metrics) In this space the user can enter a “variant” label (or title) for the calculation. This helps in remembering key options that were being tested during the metric.

Scripts for Converting Geometry

We have created several scripts for converting geometry imported from other software to usable geometry in DIVA.

23.1 Revit models

Clean Up Window Surfaces

Updated Clean Up Window Surfaces - includes polysurfaces - Beta

This script will convert windows modeled as solids (typically from imported Revit models) to usable single surfaces. If your surfaces are imported from Revit as polysurfaces instead of meshes, use the second script. For additional information go to the Video Tutorial on working with Revit models.

23.2 TAS models

Clean Up Window Surfaces-Double Surfaces

This script will convert windows modeled as double surfaces (typically from imported TAS models) to usable single surfaces.

23.3 Sketchup models

Organize Sketchup Geometry-Beta

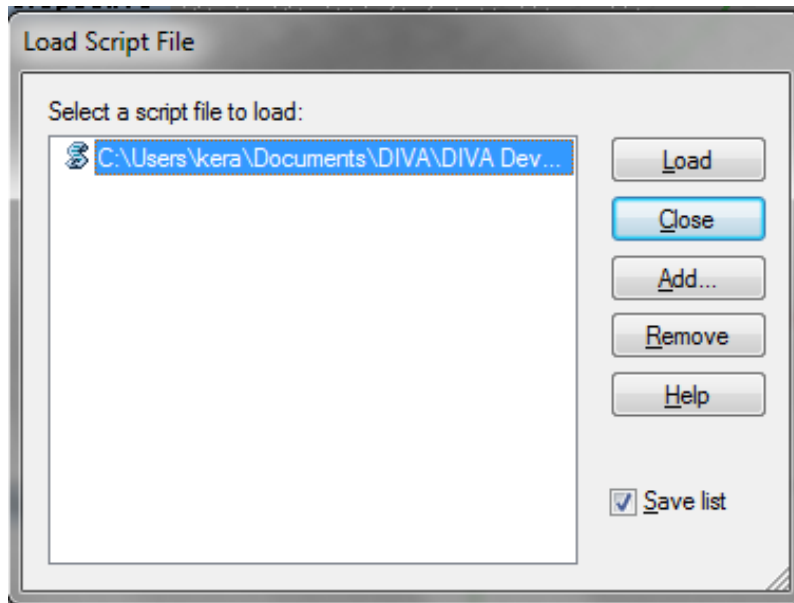
*This script will organize geometry from imported *.dxf Sketchup models, placing the exploded geometry on the appropriate layers. This script is still in beta testing. For help or feedback, email kera@solemma.net.*

Note: Dxf models exported from Sketchup can sometimes be too big to import into Rhino. To reduce the size, export the Sketchup model in parts if necessary, and turn off “Edges” in the Export Options dialog box.

23.4 Loading and Running Scripts in Rhino

There are 2 basic ways to load scripts in Rhino.

- a) Drag and drop the *.rvb file into an open Rhino viewport window.
- b) Type **LoadScript** in the command line → Click **Add** and browse to the *.rvb script that you want to load → Highlight the script in the LoadScript box → Click **Load**. To run the script in the future, type **RunScript** in the command line and select and run the script.



Understanding Results Files

24.1 DIVA Grid-Based Results

When you run a DIVA simulation, a directory of files is created for you, and depending on the metric you run, different file types will be created. For Daylight Grid-Based Simulations these files are basic text files with different file extensions. In this tutorial, we are going to take a look at the results files for Daylight Factor, Point-in-Time Illuminance, Climate-Based Metrics and Radiation Maps and learn what information they contain and how to use them to learn more about your analysis.

The two basic file types (file extensions) for the Daylight Grid-Based simulations are *.dat and *.da:

.dat files

- Daylight Factor *.df.dat
- Radiation Maps *_radmap*.dat
- Point-in-Time Illuminance *.dat

.da files

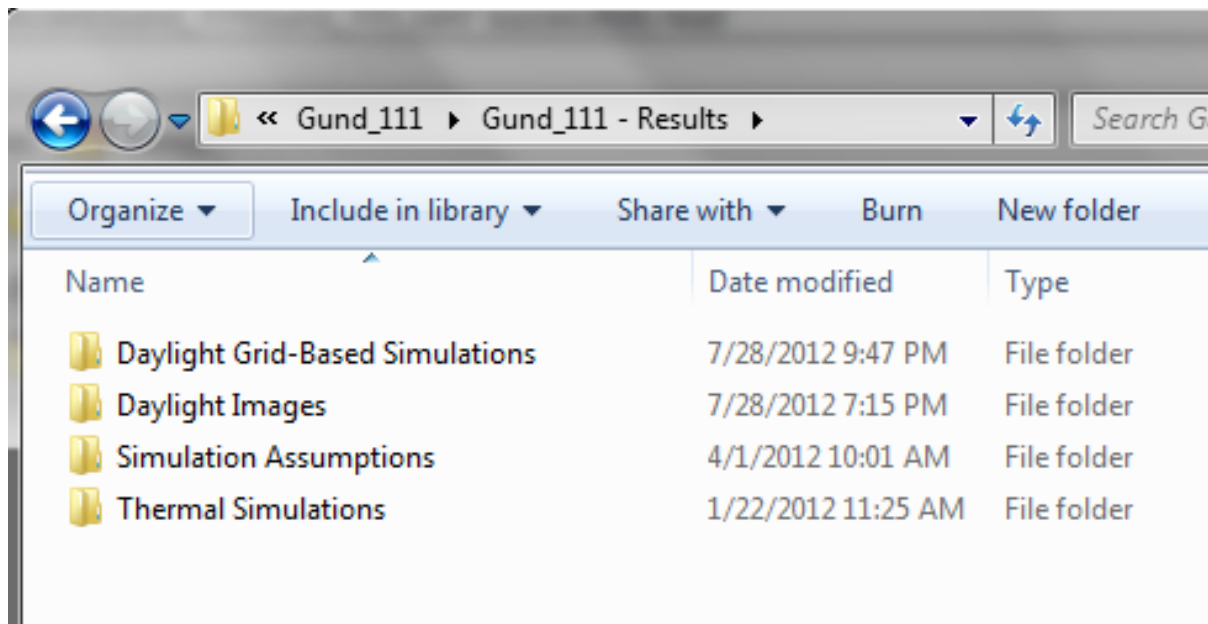
- Daylight Autonomy *_autonomy.shading.da
- Daylight Availability *_availability.shading.da
- Continuous Daylight Autonomy *.shading.cda
- Useful Daylight Illuminance *_UDI_100.shading.da, *_UDI_100_2000.da, *_UDI_2000.da

24.2 Viewing Grid-Based Results

These files can be easily viewed in any basic text editor, such as Text Pad, or they can be imported into spreadsheet programs, like Excel, for analysis. First, let's look at how we would import a .dat file into Excel.

DIVA Results Directory

- Step 1 Run a Point-in-Time Illuminance metric and locate the results file



- Step 2 Click File→Open
- Step 3 Change “File Type” to “All Files”
- Step 4 Browse to your results folder
- Step 5 Select the .da or .dat file that you want to open
- Step 6 Use the screen shots below to guide the rest of the import

24.3 Understanding Grid-Based Results

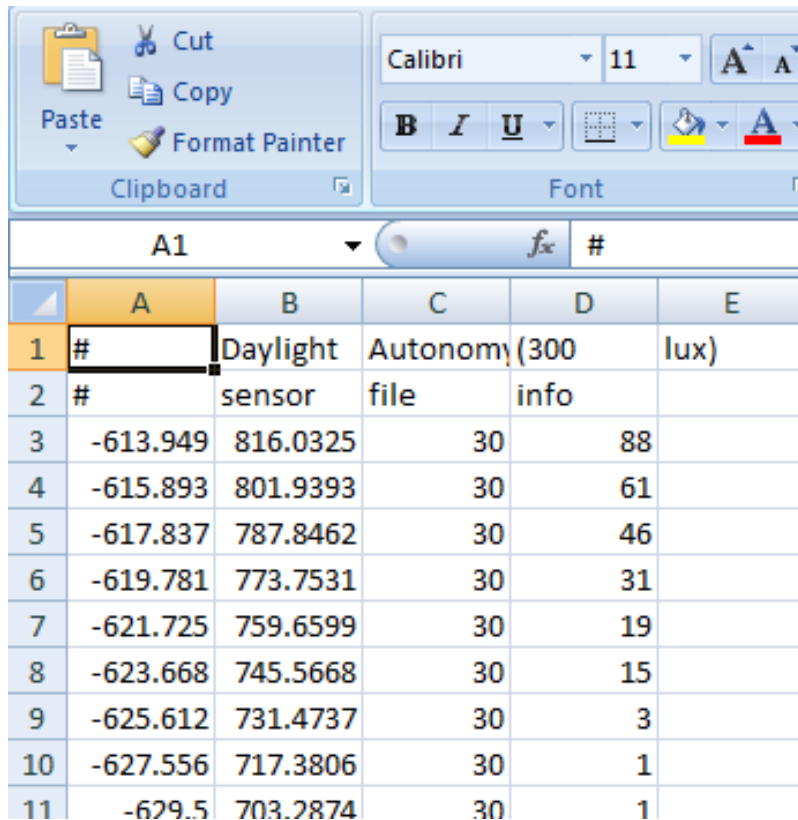
When you open any of these files, some parts are the same regardless of which file you look at. All .DA files will have some basic information at the top which identify the name of the metric, and some basic information such as the design illuminance threshold. The other information common to all files is a series of lines at the end of the file, all preceded by “#”. There is one set of these lines for each set of nodes in your model (a nodegroup is the group of nodes associated with one surface in your model). For the most part, you don’t need this information. It is primarily used by DIVA for loading in files.

.da file in Excel

The important part of the files is the middle section. Regardless of the results file, each line contains information for one of the sensor nodes in your model. The first three numbers of each line are the x, y and z coordinates of a given sensor node. For the all of the .dat files, there are a second set of three numbers which are the x, y, and z components of the node vector (this gives the node orientation).

The last numbers are the metric value for the associated node. For the .dat files there are three numbers which are the R, G and B components of the Daylight Factor, Irradiation, and Illuminance. In the file they are in this order: R-value, G-value, B-value. You may notice that none of the columns contain values that equal the node values displayed by the same file in the model. These three values represent a weighted contribution to the final Daylight Factor, Irradiation or Illuminance value. To derive that result, a factor is placed on each component and the weighted values are summed.

For the Daylight Factor and Radiation Maps metrics, this equation is: $R*0.265 + G*0.67 + B*0.065$, where R, G and B are the R, G, B values from the last three columns of the results file. For the Illuminance metrics, the equation remains the same, but the entire sum is multiplied by 179: $(R*0.265 + G*0.67 + B*0.065)*179$. For the .da files, there is just



The screenshot shows the Microsoft Excel interface. The 'Clipboard' taskbar includes icons for Cut, Copy, Paste, and Format Painter. The 'Font' taskbar shows the font set to Calibri, size 11, with options for Bold, Italic, Underline, and text color. The spreadsheet has a grid with columns A through E and rows 1 through 11. The formula bar at the top shows the active cell A1 contains the text '#'. The spreadsheet data is as follows:

	A	B	C	D	E
1	#	Daylight	Autonomy	(300	lux)
2	#	sensor	file	info	
3	-613.949	816.0325	30	88	
4	-615.893	801.9393	30	61	
5	-617.837	787.8462	30	46	
6	-619.781	773.7531	30	31	
7	-621.725	759.6599	30	19	
8	-623.668	745.5668	30	15	
9	-625.612	731.4737	30	3	
10	-627.556	717.3806	30	1	
11	-629.5	703.2874	30	1	

one number after the sensor node coordinates which is the DA value. No additional steps are necessary to derive a final answer.

Once you have your values in place, you can Excel's functions and graphing capability to analyze your results in hundreds of ways.

CHAPTER 25

References

Want to know more about Radiance, Daysim, Grasshopper, etc.? Here are some places to start:

[Radiance References Page](#)

CHAPTER 26

Indices and tables

- `genindex`
- `modindex`
- `search`