Assignment 3

- Some of your are amazingly close!
- For the results near the window I believe that the single pane glazing has a lower falloff for higher angles than the Radiance model.
- Desktop height 85cm; falls within measurement uncertainty.
Goals for This Week

- Where is the sun?
- Designing Static Shading Systems

Sky Radiance Distribution
Sky Models

- The solar radiation coming from different parts of the sky is defined by the sky radiance distribution function.

Sky Models

- Sky radiance distribution functions. Are defined using a different coordinate system than azimuth and altitude.
- \( \psi(\chi) \) is called the radiance gradation function. It defines the changes of luminance from horizon to zenith. For a uniform sky this function corresponds to unity (\( a=0 \)).
- \( f(\chi) \) is called the scattering indicatrix. It relates the changes of luminance of a sky segment to its angular distance from the sun (circumsolar region).
Sky Models - April 2nd at noon

Visual Comparison: Perez & Real Sky
Radiation Maps

How to calculate Solar Radiation in an Urban Setting?
Radiation Maps using Ecotect (not recommended)

Ecotect solar access calculation for Boston, MA

DIVA for RHino

Rhino Model

Radiation Map
How does the calculation work?

- Step (2): Generate Perez sky radiance distribution for each hour of the year of interest.
How does the calculation work?

- Step (2): Generate Perez sky radiance distribution for each hour of the year/of interest.
- Step (3): Add up sky conditions for hours of interest and store the values in 145 bins.

Cumulative Sky proposed by several authors including Mardaljevic, Compagnon, Robinson & Stone. We are using Robinson & Stone's approach. Reading 2.3 on the course web site.

How does the calculation work?

- Step (2): Generate Perez sky radiance distribution for each hour of the year/of interest.
- Step (3): Add up sky conditions for hours of interest and store the values in 145 bins.
- Step (4): Run a simulation under cumulative sky.

We are using Radiance for the simulation (global illumination calculation).
Annual Radiation Study

Radiation Map Analysis

Table 1

<table>
<thead>
<tr>
<th>Solar technique</th>
<th>Threshold for systems mounted on facades</th>
<th>Threshold for systems mounted on roofs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Passive thermal heating</td>
<td>216 kJ/m²·yr solar radiation during the heating season</td>
<td>Same as for facades</td>
</tr>
<tr>
<td>Photovoltaic systems</td>
<td>600 kJ/m²·yr annual solar radiation</td>
<td>1000 kJ/m²·yr annual solar radiation</td>
</tr>
<tr>
<td>Daylighting systems</td>
<td>10 kJ/m²·day daylight illumination during office hours (8–18h)</td>
<td>Same as for facades</td>
</tr>
<tr>
<td>Solar thermal collectors</td>
<td>400 kJ/m²·yr annual solar radiation</td>
<td>600 kJ/m²·yr annual solar radiation</td>
</tr>
</tbody>
</table>

Appendix A explains how these values were chosen.

Shading

Why Shading?
- Avoidance of visual discomfort (glare).
- Avoidance of thermal discomfort (overheating).
- Avoidance of cooling loads (energy)

Why not Shading?
- Solar gains needed to reduce heating loads.
- Maintain a view to the outside.
General Guidelines

Combined Fins and Overhangs
Patterned Louvers

Image of patterned louvers in Santiago de Chile removed due to copyright restrictions.

Santiago de Chile (Photo M Soden)

Iconic Louvers

New York Times, Architecture R Piano
When designing a static shading device for a window, the task can be divided into two steps:

1. When is it desirable to have direct solar radiation incident on a window?
   (a) Find a start and end date
   (b) Find a start and end time of day

2. What form should a shading device have to fulfill the requirements from step (1)?
(1) When is it desirable to have direct solar radiation incident on a window?

Find a start and end date for the shading period:

- Option 1: The cooling period lasts from March 21 to September 21.

- Option 2: Crossover between heating and cooling degree hours.

- Option 3: Crossover between heating and cooling loads.

Heating Degree Days (HDD)

- The number of heating degrees in a day is defined as the difference between a reference value of 65°F (18°C) and the average outside temperature for that day.

- Rule of thumb: If a site has
  - >5000 °F HDD (~2800 °C HDD): long cold winters
  - < 2000 °F HDD (~1100 °C HDD): mild winters

- Fixed base temperature allows to compare different climates but 65°F is not representative for buildings.
Cooling Degree Days (CDD)

- The number of cooling degrees in a day is defined as the difference between a reference value of 65°F (20°C) and the average outside temperature for that day.

- Rule of thumb: If a site has
  - >1500 °F CDD (~800 °C CDD): long hot summers
  - < 500 °F CDD (~ 300 °C CDD): mild summers

Heating and Cooling Degree Hours

- Heating Degree Hours based on 18 C; Cooling Hours based on 20 C.
- Measure for the severity of a climate.
- Related to annual energy use.
Heating and Cooling Degree Hours

Shaded period has to be symmetrical around the summer solstice.

(1) When is it desirable to have direct solar radiation incident on a window?

Find a start and end date for the shading period:

- Option 1: The cooling period lasts from March 21 to September 21.
- Option 2: Crossover between heating and cooling degree hours.
- Option 3: Crossover between heating and cooling loads.
Option 3. One Zone Thermal Simulation

DesignBuilder/E+ Analysis
Office Building

Residential

Airport Terminal
Option 3. One Zone Thermal Simulation

Heating Season: ~ October 15 to April 30
Cooling Season: ~ June 1 to Sep 15

(1) When is it desirable to have direct solar radiation incident on a window?

Find a start and end time of day e.g.:
- 9AM to 3PM
- 10Am to 2PM
- at noon
Sensitivity Analysis Using Radiation Maps
Radiation during cooling period: June 1 to September 15:

111/192~60% of unwanted radiation are incident on the South façade from 10 AM to 2 PM

Extending the shading period by two hours only increases percentage by 7%.

Conclusion 10 AM to 2 PM interval suffices.

(2) What form should a shading device have to fulfill the requirements from step (1)?

Option 1: 2d for method for a simple overhang.
(2) What form should a shading device have to fulfill the requirements form step (1)?

Option 2: 3d for method for a simple overhang.

June 1st, 10AM no shading

June 1st, 10AM with shading
(2) What form should a shading device have to fulfill the requirements from step (1)?

Option 2: 3d using Ecotect Shading Wizard

Diagrams of horizontal shade and surround shade removed due to copyright restrictions.

Uses bottom nodes of the window as reference points.
(Marsh 2003)

Sun track diagrams using Ecotect removed due to copyright restrictions.

Uses bottom nodes of the window as reference points.
(Marsh 2003)
What are the limitations of existing methods?

Limitations:
- June
  - Shade has conflicting thermal value at different times of year. Most existing methods have no way of weighing the good vs. the bad.

Hybrid Facades

Renderings of Hotel Tower by Lang Hugger Ramp and ASCER Project removed due to copyright restrictions.
Aqua Building in Chicago

The sizing of the overhangs is guided by formal aspects rather than by environmental performance.

Shaderade – A new Approach
Static Exterior Shading: SHADERADE

New Approach: Break shading volumes / surfaces into small pixels, and assess the thermal value of one pixel at a time.

For speed, we run one thermal simulation of the space without shading, and then cast solar rays to find all hours during which a pixel casts direct shade on a window. Based on loads and transmitted solar gains at those hours, the pixel is given credit for reducing cooling or punished for increasing heating.

Static Exterior Shading: SHADERADE

Once the volume has been assessed, any surface within its bounds can be visualized:

Trimming away regions with negative value (cutoff = 0)
**Static Exterior Shading: SHADERADE**

Increasing cutoff produces more ‘efficient’ shade.

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**Static Exterior Shading: SHADERADE**

Horizontal and surround shades
Load optimized, 85% value trim:

- Anchorage
- Boston
- Phoenix
**Static Exterior Shading: SHADERADE**

Horizontal and surround shades,
Carbon optimized, 85% value trim:

(COP of 1.67, 0.83 for cooling, heating; carbon equivalent factors of 0.232, 0.758 kg/kWh for gas, electricity)

Anchorage  Boston  Phoenix

*How does Shaderade compare to conventional methods?*
SHADERADE is consistently in the top range.