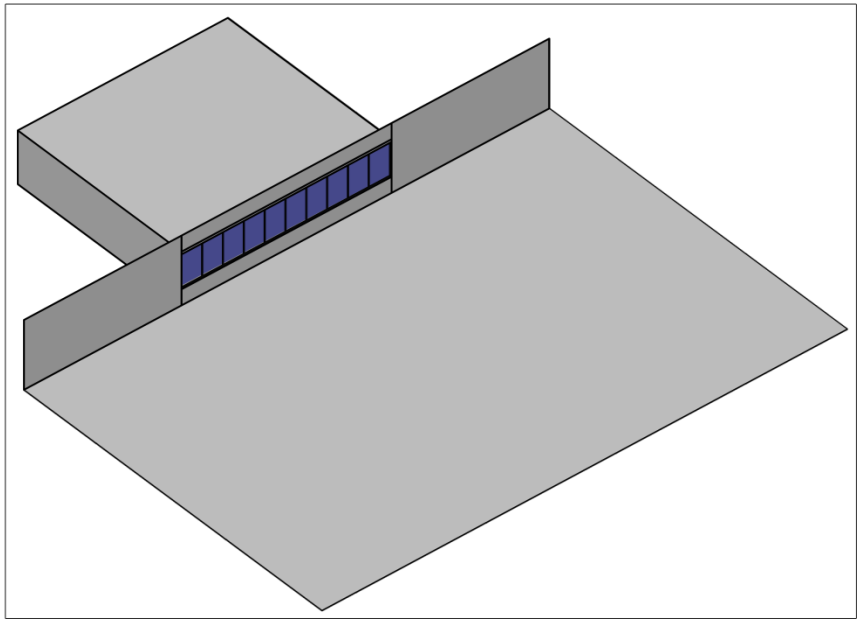
2015 International Radiance Workshop
Wednesday August 19th, 2015

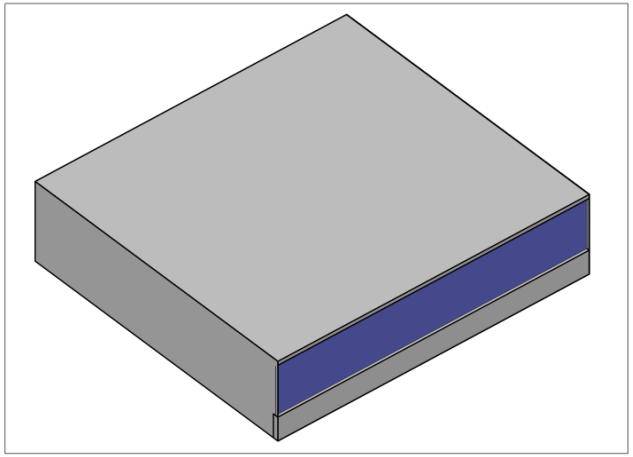
MODELING THE EXTERIOR SURROUND - HOW MUCH DETAIL IS NECESSARY?

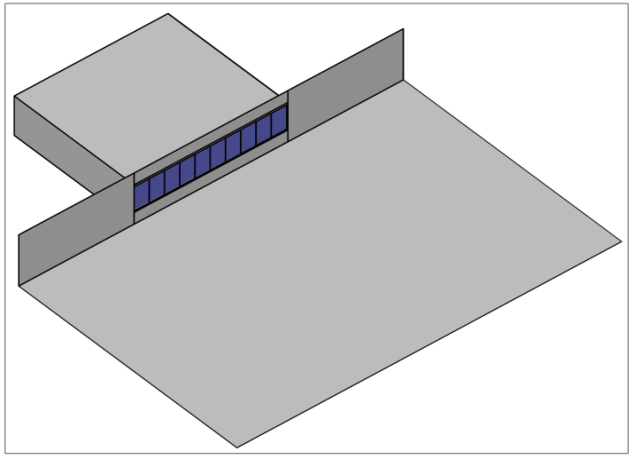
Reza Sadeghi, Richard Mistrick
Penn State University
Department of Architectural Engineering



Introduction:
The Problem

- Daylighting is affected by the surrounding exterior
- The exterior surround both reflects and blocks daylight
- Occupants are more tolerant of glare when the view is appealing to them
- Current daylight modeling practice considers minimal or no exterior elements
- Very little information is available on modeling the exterior daylighting environment





Introduction:
LM83: Exterior Surround Modeling Instructions

- Buildings and opaque structures are to be modeled within at least 100’ (with resolution of at least a 10’ increment)
- Actual reflectance is to be used (or 30% if unknown)
- Exterior surround of equal height and setback of space under study(if unknown)
- Ground reflectance of 10% (if the actual value is unknown)
- Trees are modeled as cones, spheres or cylinders with a 20% reflectance

Methodology

- Part 1: Case study
  - HDR images of actual buildings in a real life setting (HDR of the window view)
- Part2: Radiance simulations
  - Modeling of the environment conditions in part 1 using common practice methods and tools

Methodology
Data Collection : Selected location

		
Loc-A-01	Loc-A-02	Loc-A-03
		
Loc-A-04	Loc-A-05	Loc-A-06

Methodology
Data Collection : Selected location

		
Loc-B-01	Loc-B-02	Loc-B-03
		
Loc-B-04	Loc-B-05	Loc-C-01

Methodology
Data Collection : Selected location

Loc-C-02

Methodology
Data Collection : Seasonal Variations

Summer

Fall

Winter

Methodology
Data Collection : Sky conditions

10:00 AM

12:00 AM

3:00 PM

Overcast

Methodology
Data Collection

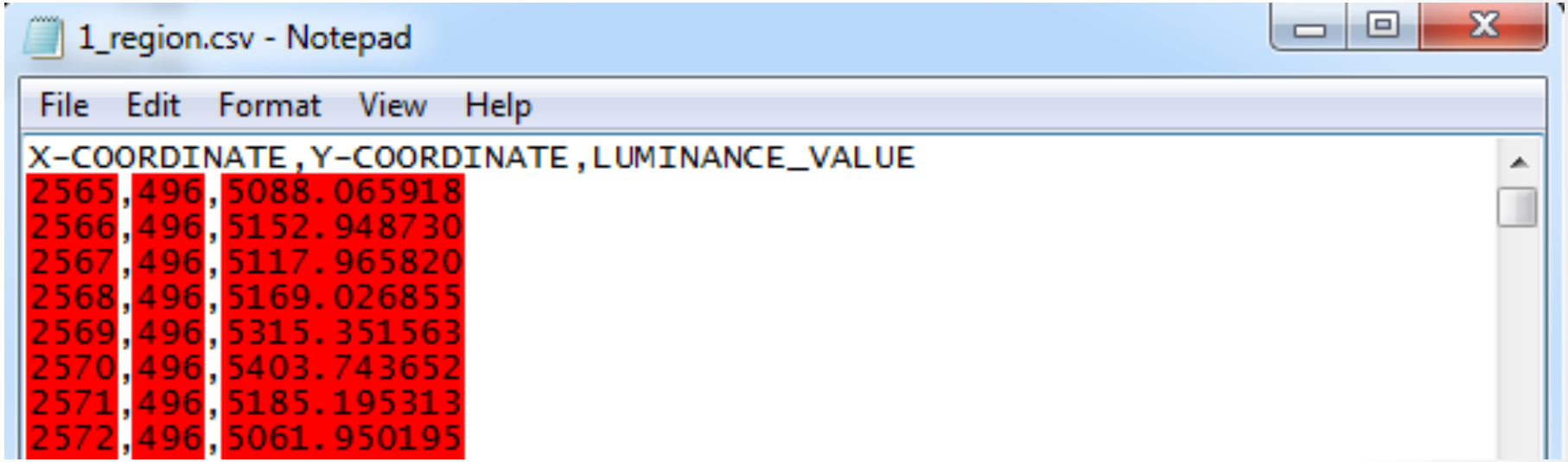
- Sky: Irradiance (Direct & Diffuse) and Horizontal Illuminance (Direct & Diffuse). These values are used in the simulations.
- 9 LDR images are fused to create the HDR of the window view)
- Vertical Illuminance at the camera lens (To verify E_v as computed from the HDR)
- Luminance measured at few points in the view (for calibration)
- Date, Time (saved automatically by camera and Pyranometer system)

Methodology
Data analysis: Luminance map

- Photosphere (HDR)
- Calibration process (Luminance, Vignetting effect)
- HDR: RGB plus luminance information

Methodology
Data analysis: Luminance map

- Data: x-y pixel coordinate, Luminance



Methodology
Exterior luminous environment

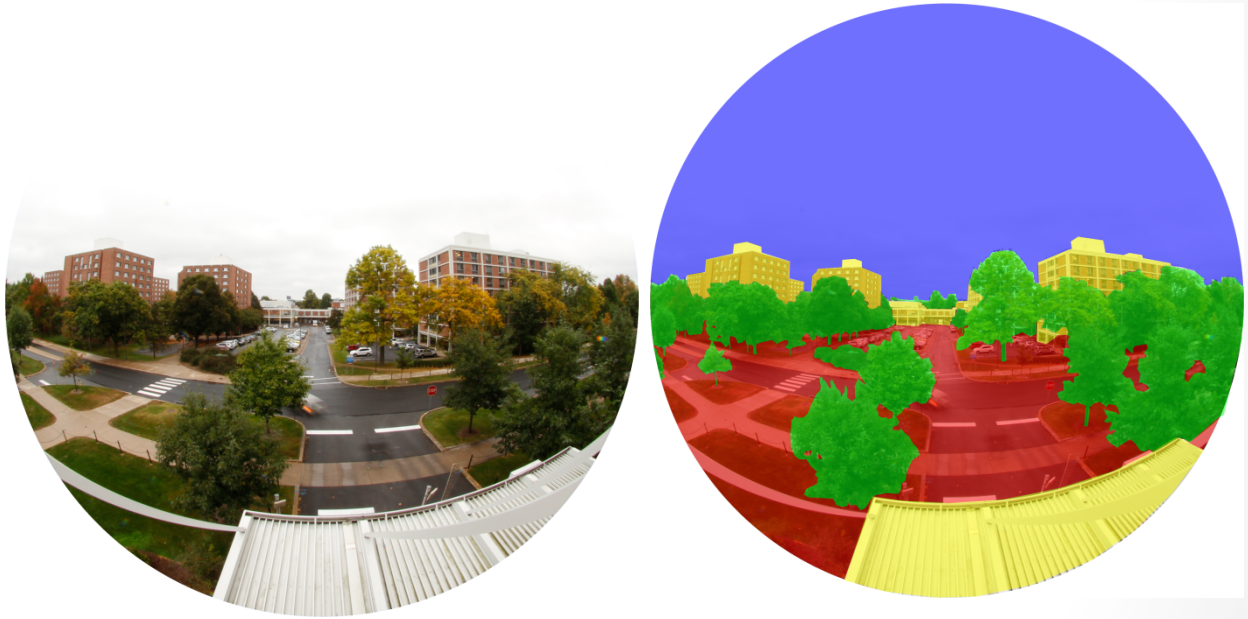
- Contribution to architectural opening:

1- Sky

2- Architectural Elements

3- Vegetation (3D)

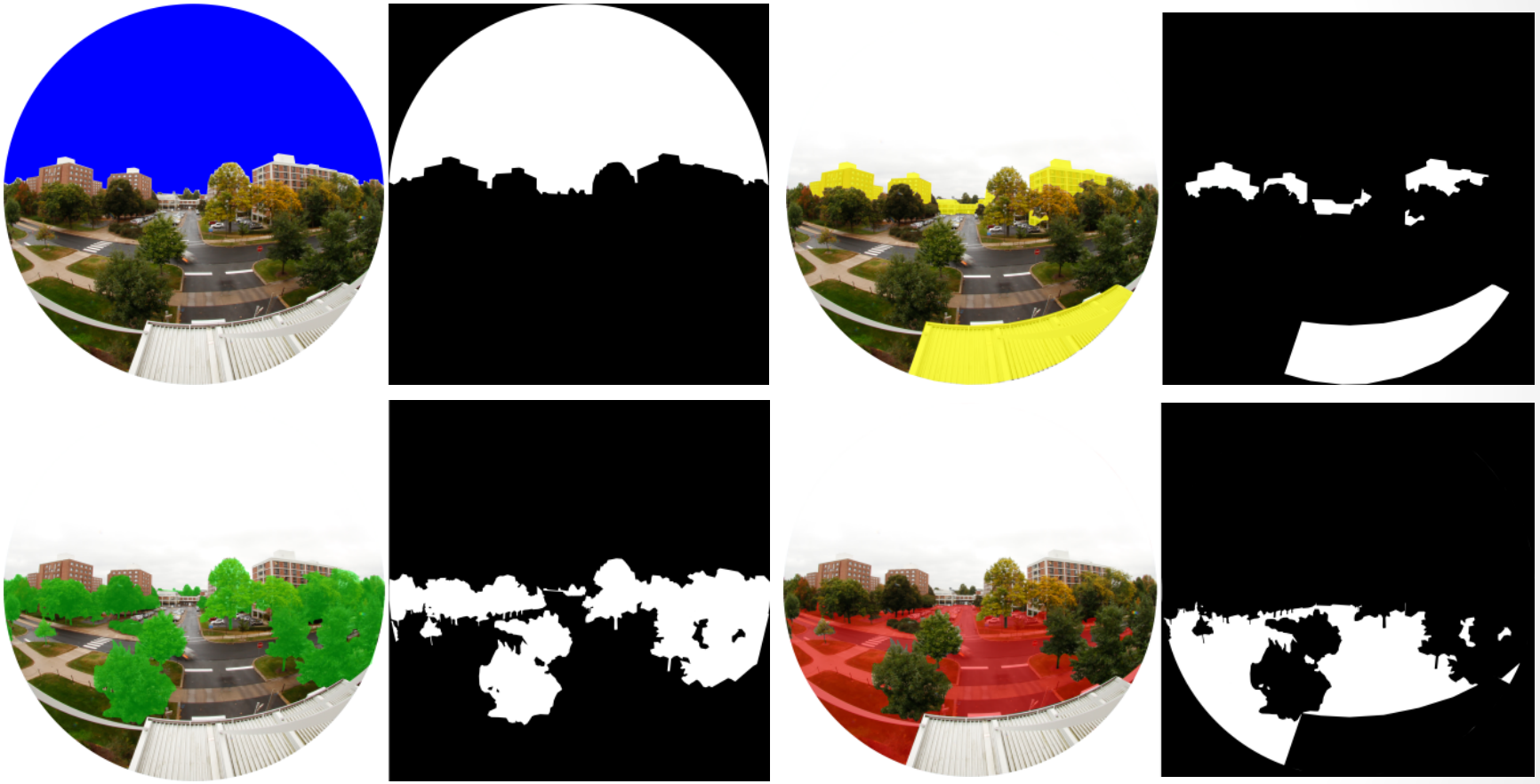
4- Ground



Methodology
Data analysis: Luminance map

- An appropriate mask is applied

Methodology
Data analysis: Luminance map



Methodology
Data analysis: Vertical illuminance

- Fish eye lens: equidistance projection (Miyamoto, 1964)
- Solid angle computation from pixel's xy coordinates

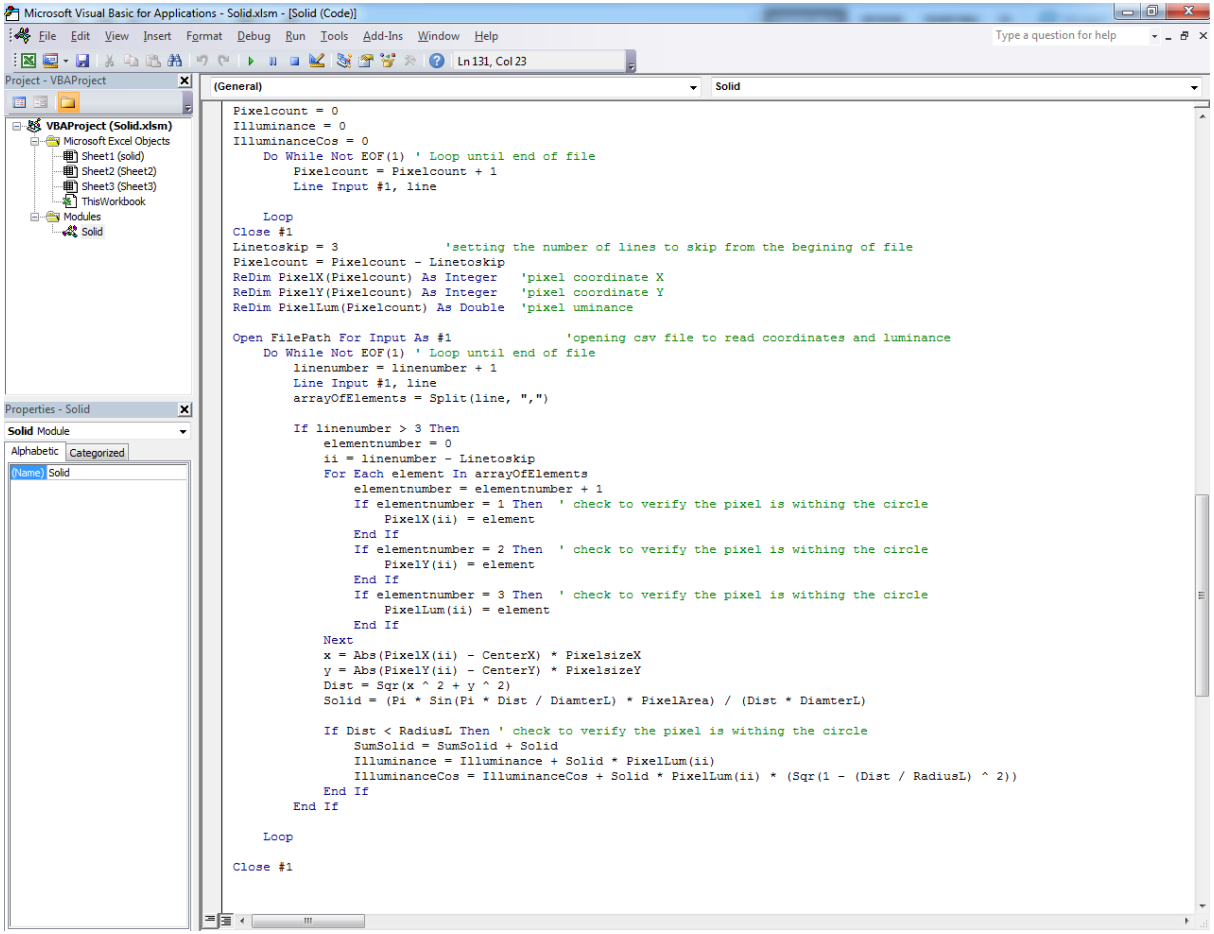
$$d\Omega(i,j)=\Pi/l\downarrow ij \ D \cdot \sin(\Pi.l\downarrow ij /D_{\cdot}).dA$$

(Wei, Van Dommelen, Lewis, McLean, & Voss, 2012)

(Ω = Solid angle in steradian, $l\downarrow ij$ =distance of pixel from the center of image, D=diameter of image, i & j=pixel row and column, dA=pixel area)

Methodology
Data analysis: Vertical illuminance

- VBA code was developed (Vertical illuminance)



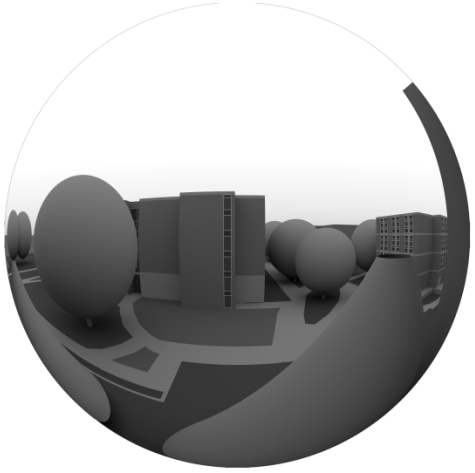
Hypothesis
Data analysis: Luminance map

Descriptive Statistics: Building, Ground, Sky, Vegetation (Ratio)

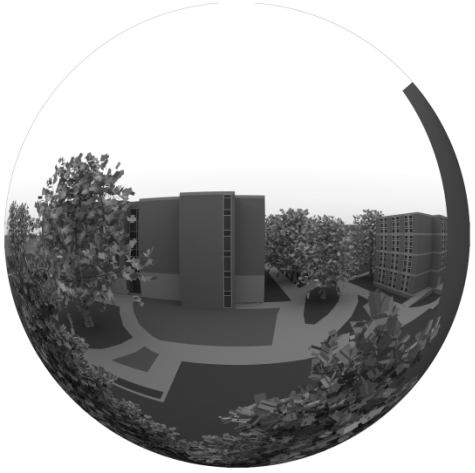
Variable	Mean	SE Mean	StDev	Minimum	Maximum
Building	13.70	8.09	16.18	3.52	37.65
Ground	11.97	4.39	8.78	4.49	22.65
Sky	62.69	9.05	18.09	46.38	87.62
Vegetation	12.01	2.74	5.48	4.53	16.74

Methodology
Modeling : Level of Details

Methodology
Modeling : Level of Details

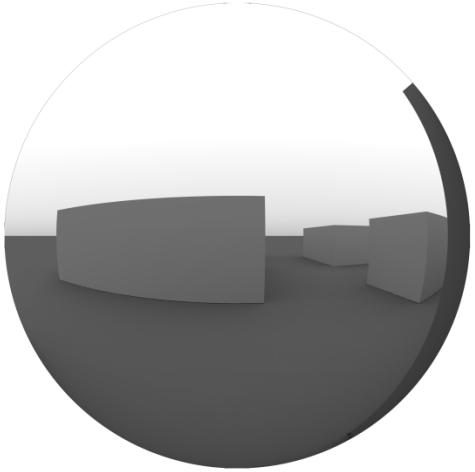


LM-83

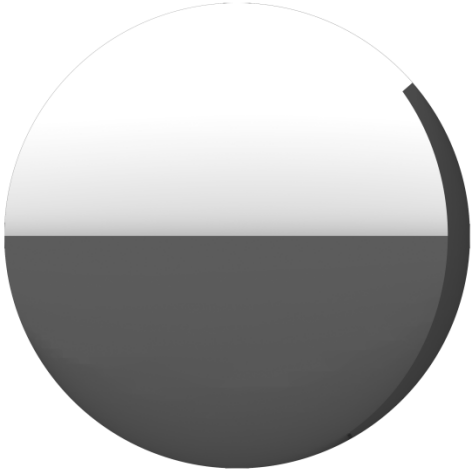


High Detailed Surround + Trees

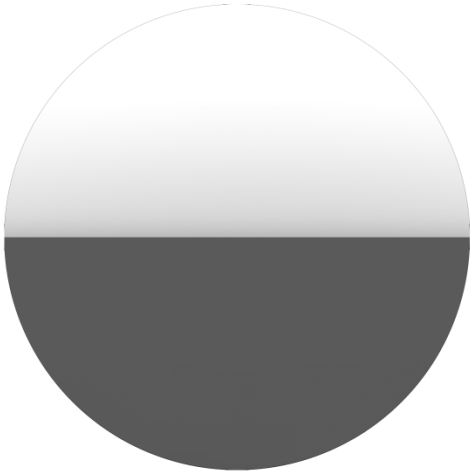
High Detailed Surround



Low Detailed Surround



Building itself

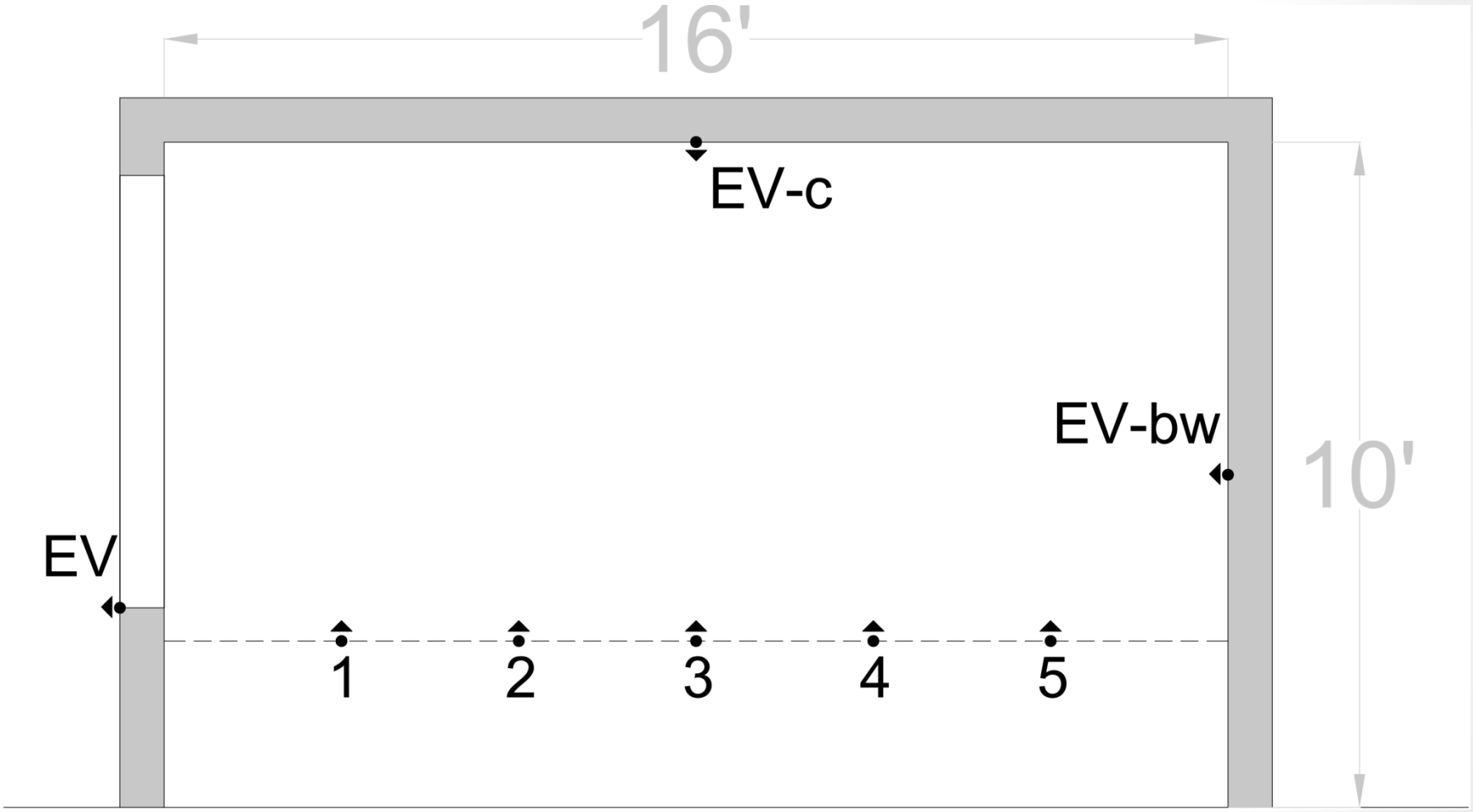


No Surround

Methodology
Modeling

- Small office (10’ x 16’ x 10’)
- Reflectance (Floor=0.2, Walls=0.6 , Ceiling=0.9)
- Workplane at 2.5 ft.

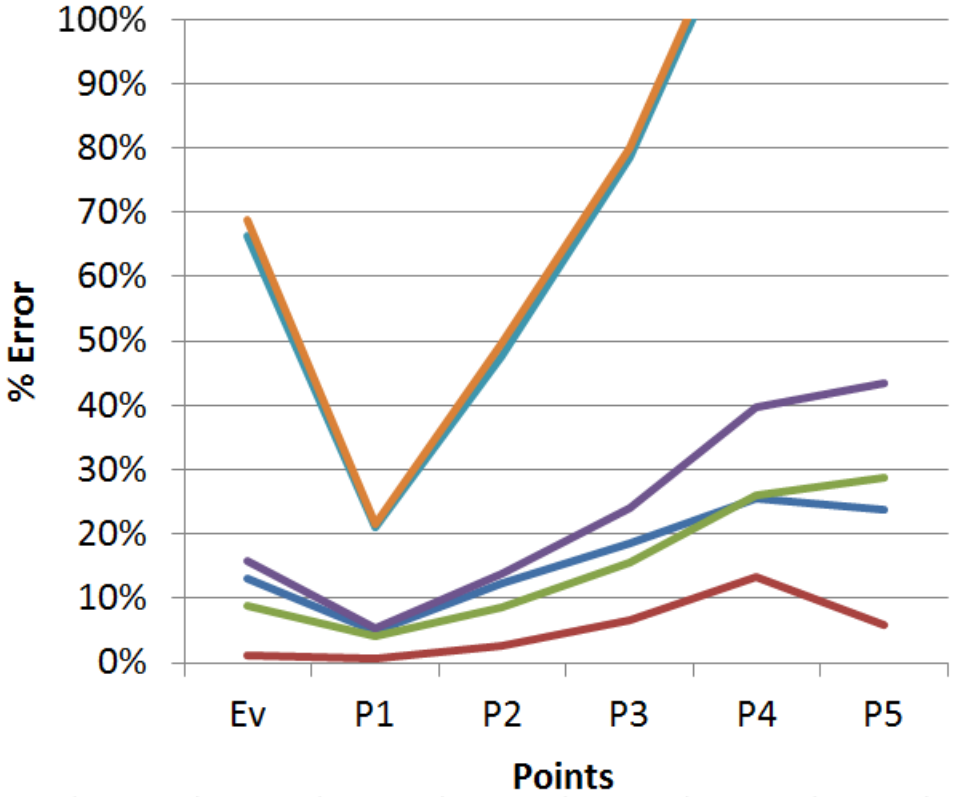
Methodology
Modeling



Methodology
Simulation

- Radiance (dxf2rad, oconv, rpict, rtrace)
- Image-based lighting was used in Radiance to compute illuminance in the interior from the HDR image
- 6 levels of detail were modeled using irradiance values as input to Perez sky to models

Results
Summer



No Surround

Building itself

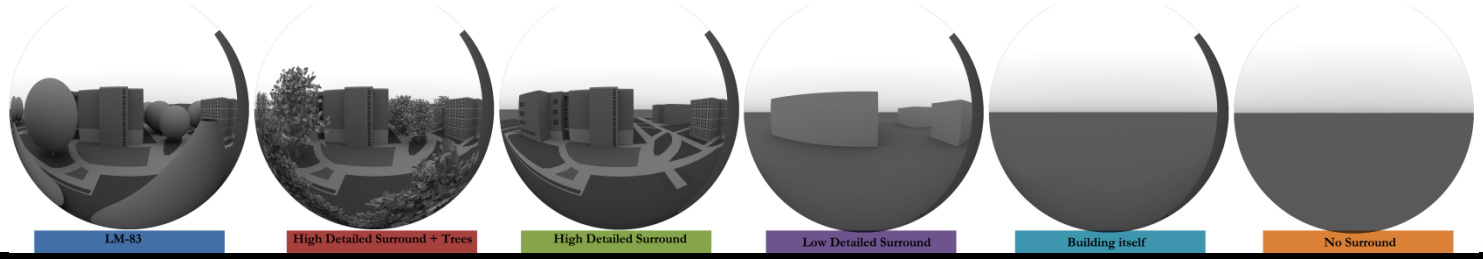
Low Detailed Surround

LM-83

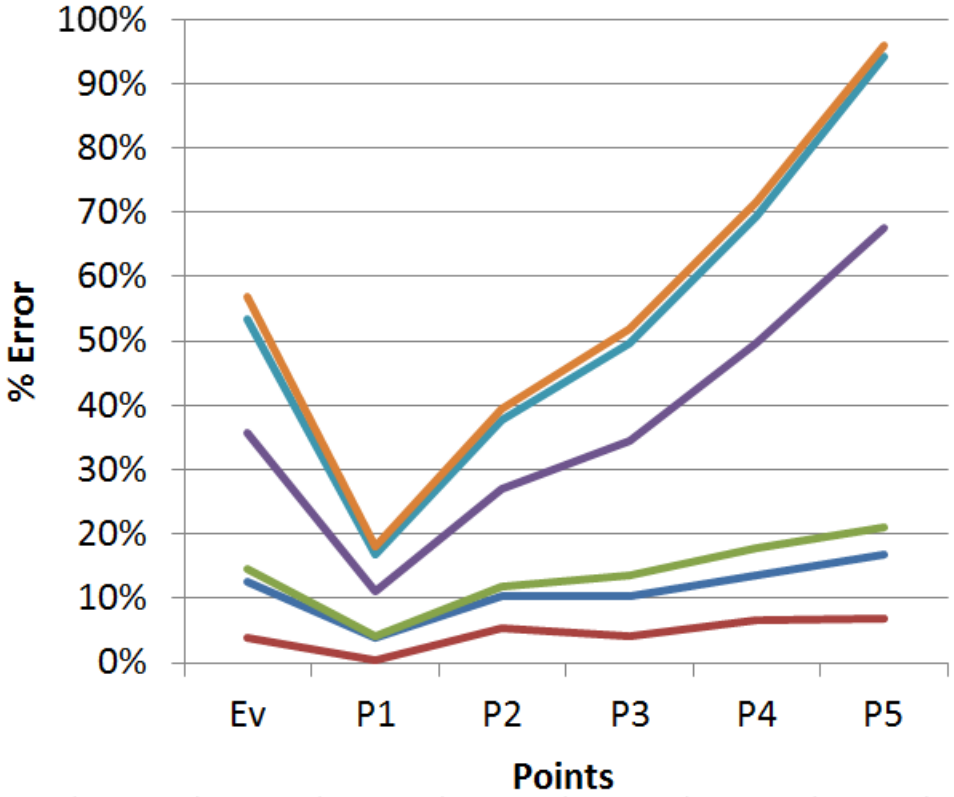
High Detailed Surround

High Detailed Surround & Trees

Season: Summer
Sky: Clear
Time: Morning



Results
Summer



No Surround

Building itself

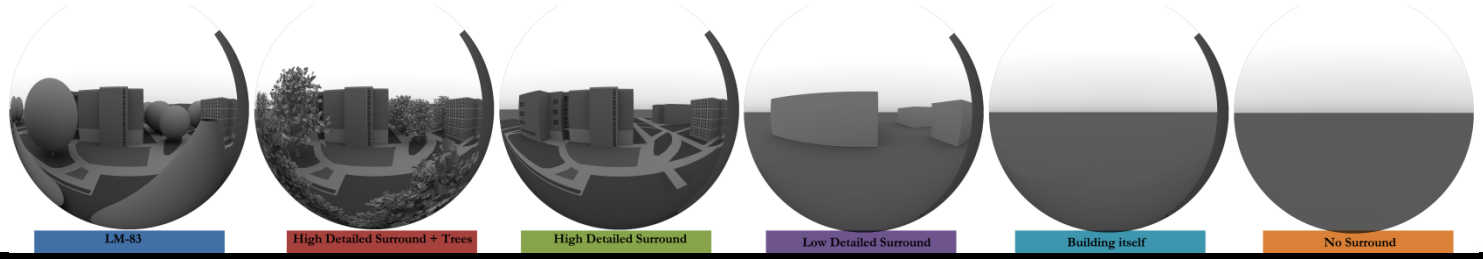
Low Detailed Surround

High Detailed Surround

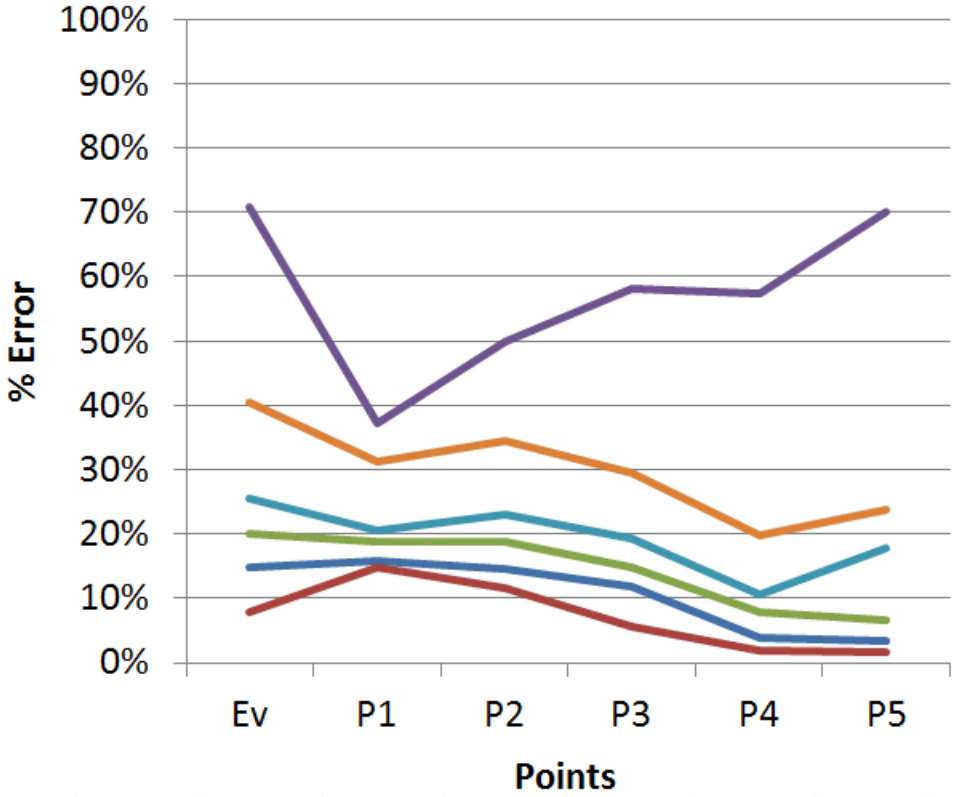
LM-83

High Detailed Surround & Trees

Season: Summer
Sky: Clear
Time: Noon



Results
Summer



Low Detailed Surround

No Surround

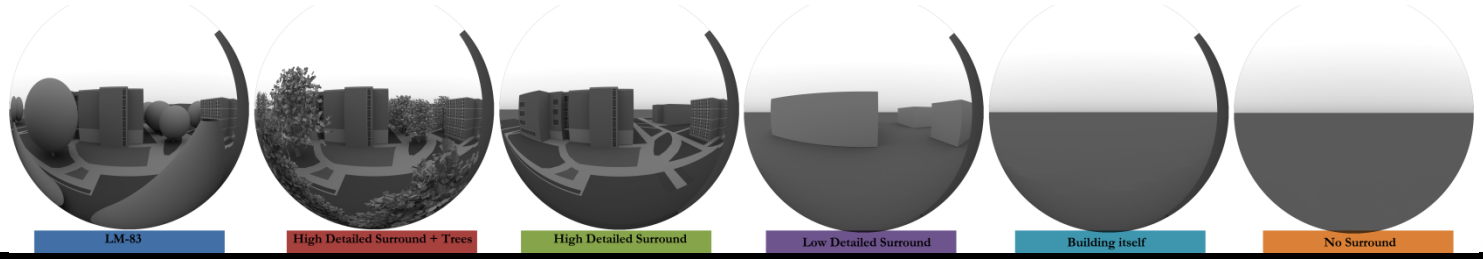
Building itself

High Detailed Surround

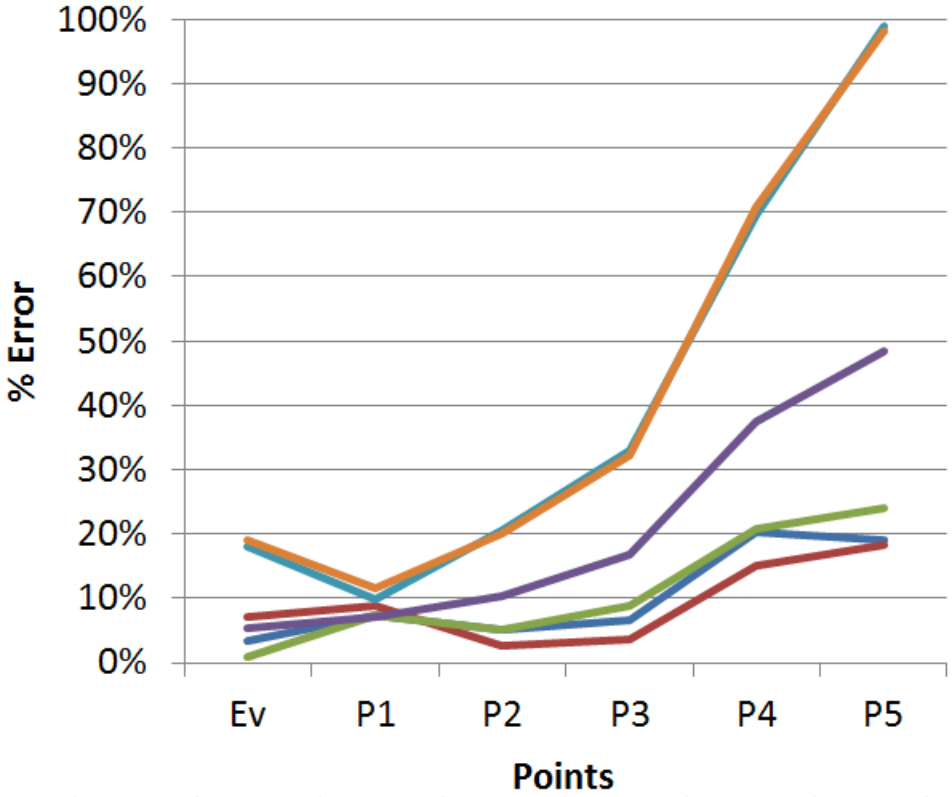
LM-83

High Detailed Surround & Trees

Season: Summer
Sky: Clear
Time: Afternoon



Results
Summer



No Surround

Building itself

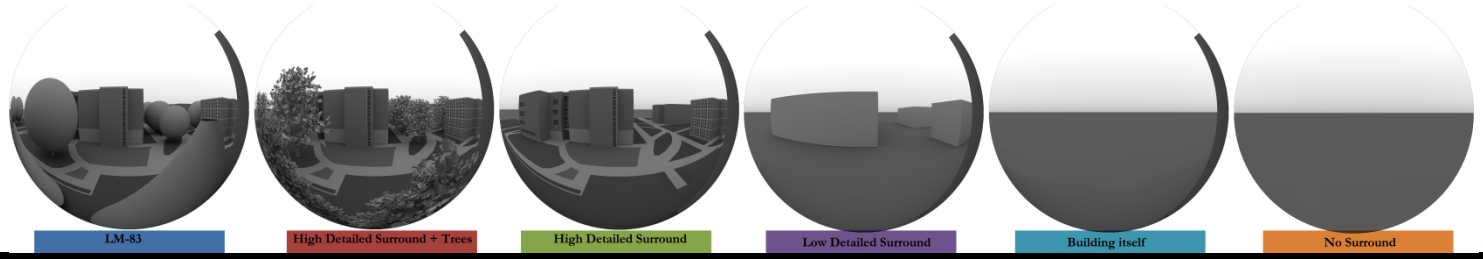
Low Detailed Surround

High Detailed Surround

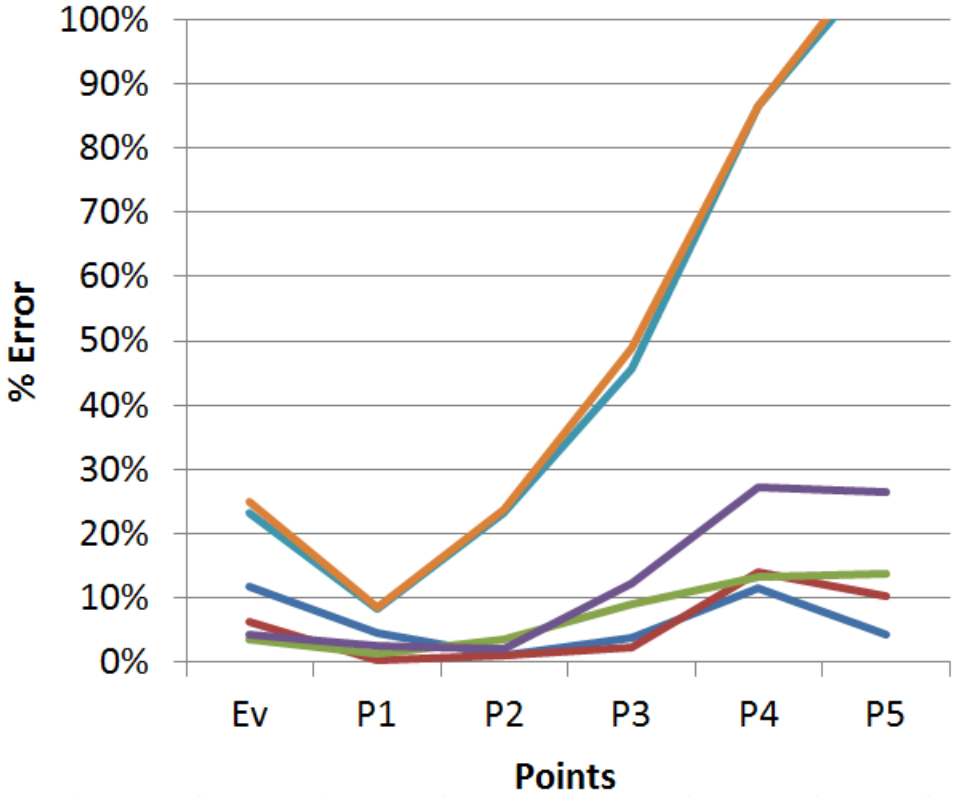
LM-83

High Detailed Surround & Trees

Season: Summer
Sky: Overcast
Time: -



Results
Fall



No Surround

Building itself

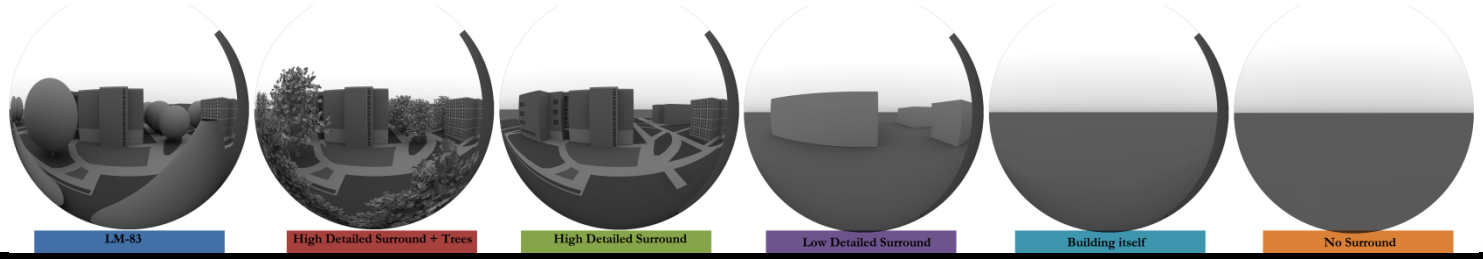
Low Detailed Surround

High Detailed Surround

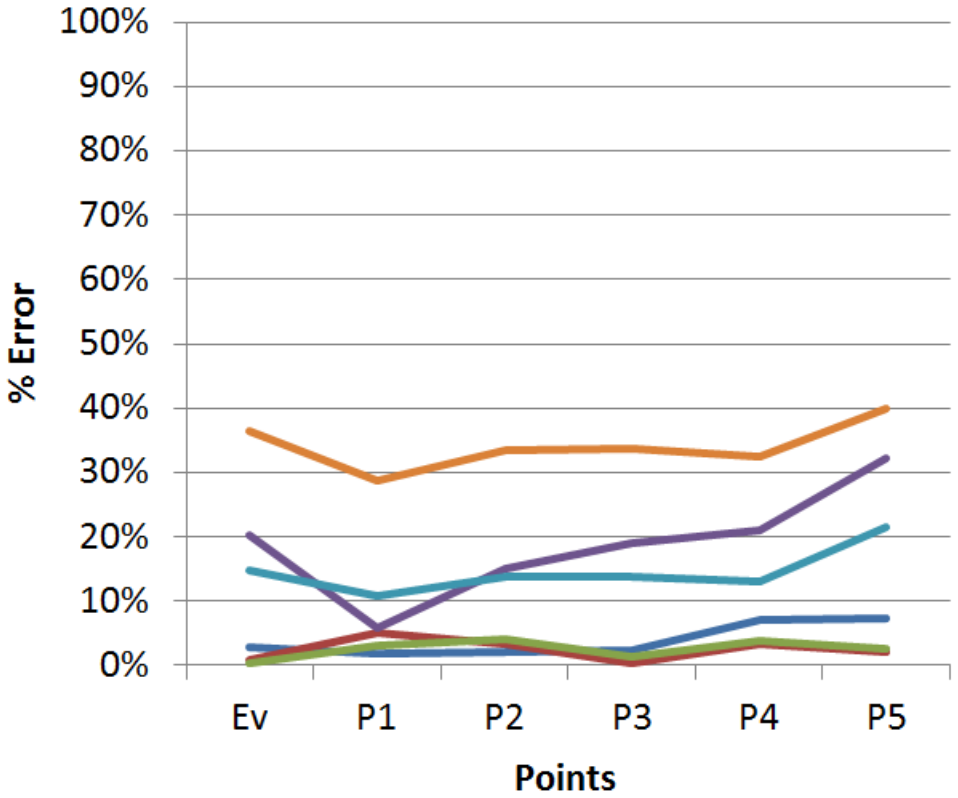
LM-83

High Detailed Surround & Trees

Season: Fall
Sky: Clear
Time: Morning



Results
Fall



No Surround

Low Detailed Surround

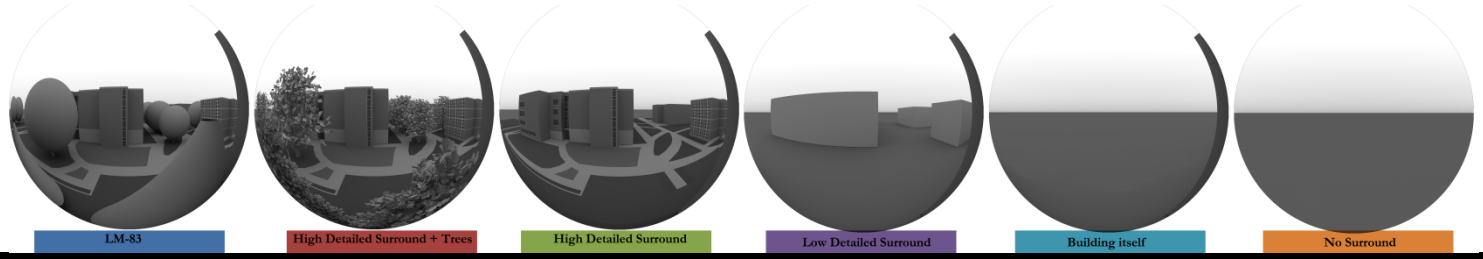
Building itself

High Detailed Surround

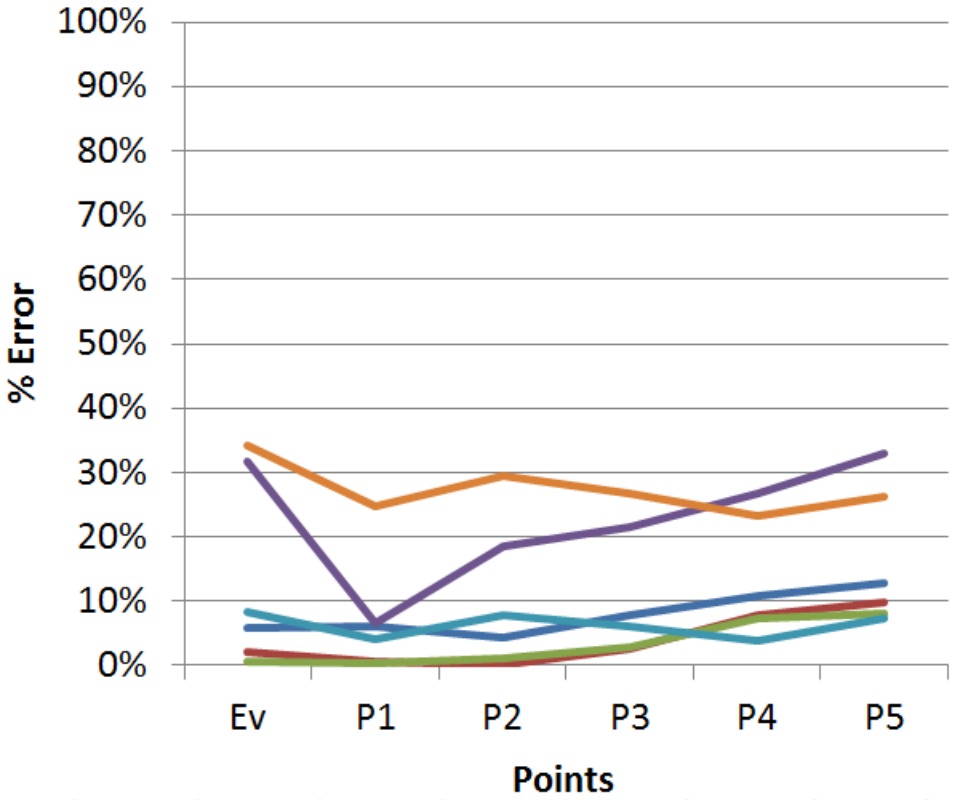
LM-83

High Detailed Surround & Trees

Season: Fall
Sky: Clear
Time: Noon



Results
Fall



No Surround

Low Detailed Surround

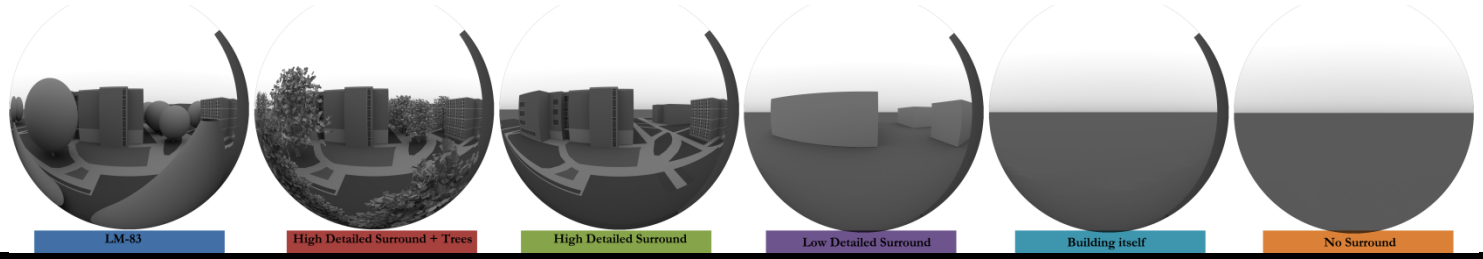
Building itself

LM-83

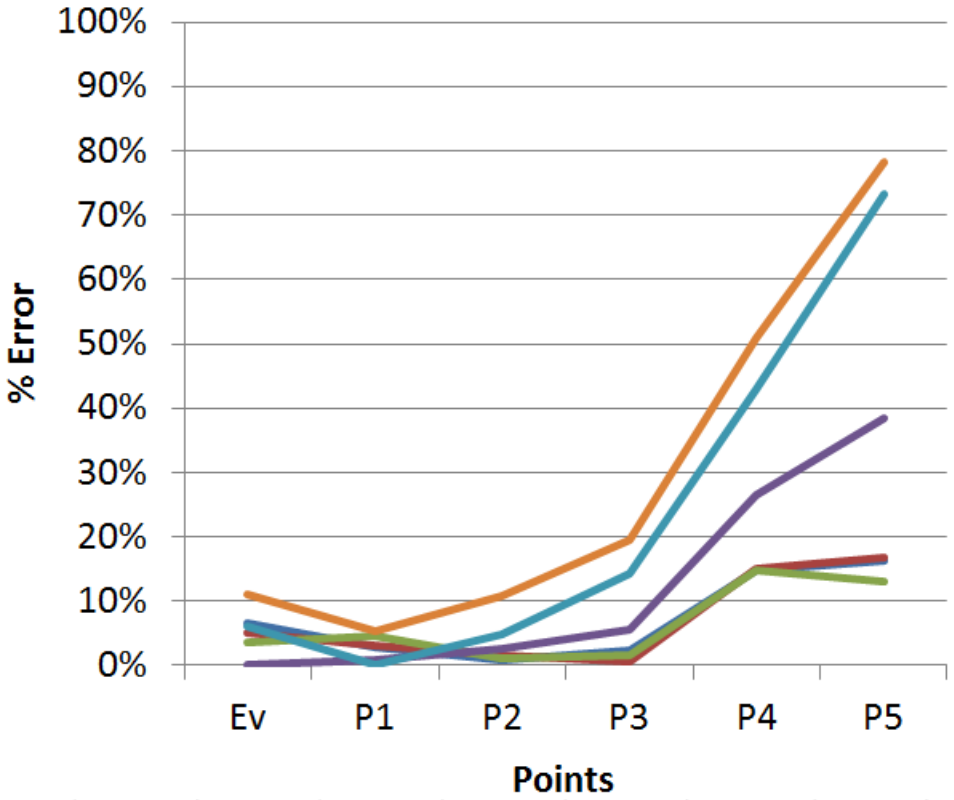
High Detailed Surround

High Detailed Surround & Trees

Season: Fall
Sky: Clear
Time: Afternoon



Results
Fall



No Surround

Building itself

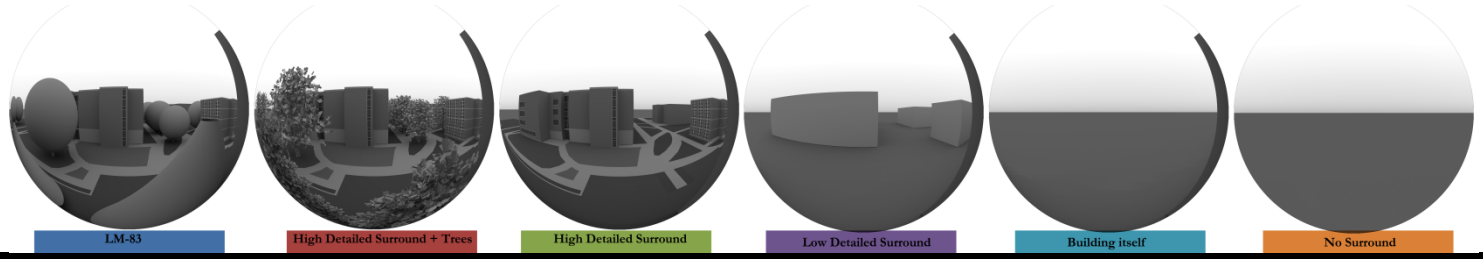
Low Detailed Surround

LM-83

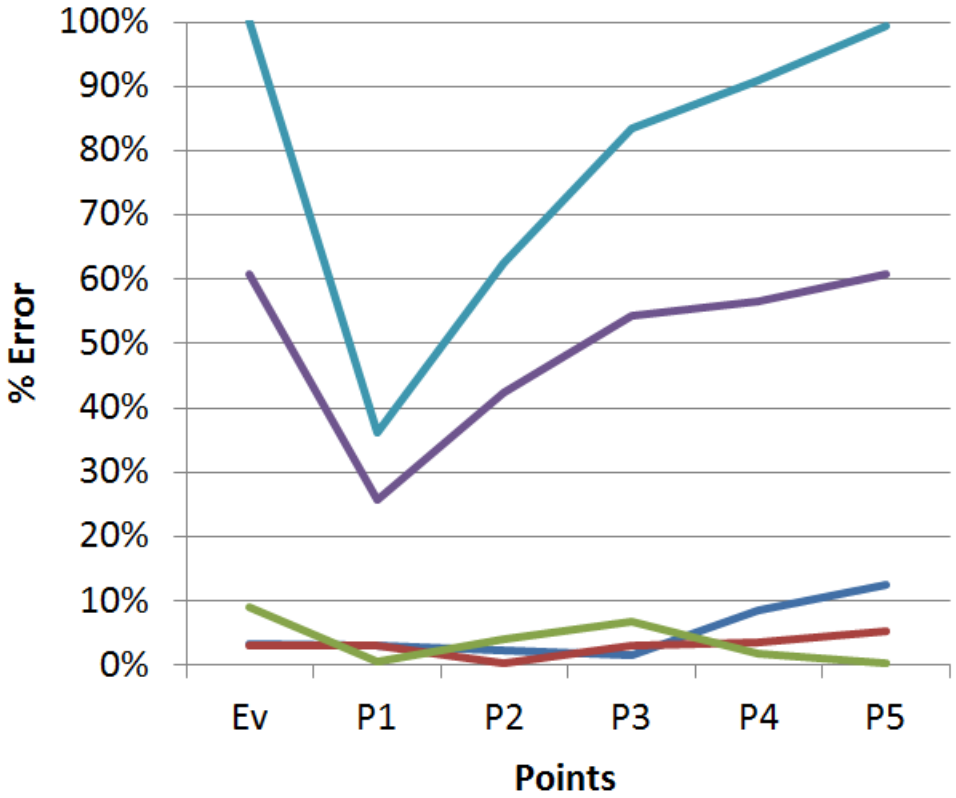
High Detailed Surround

High Detailed Surround & Trees

Season: Fall
Sky: Overcast
Time: -



Results
Winter



No Surround

Building itself

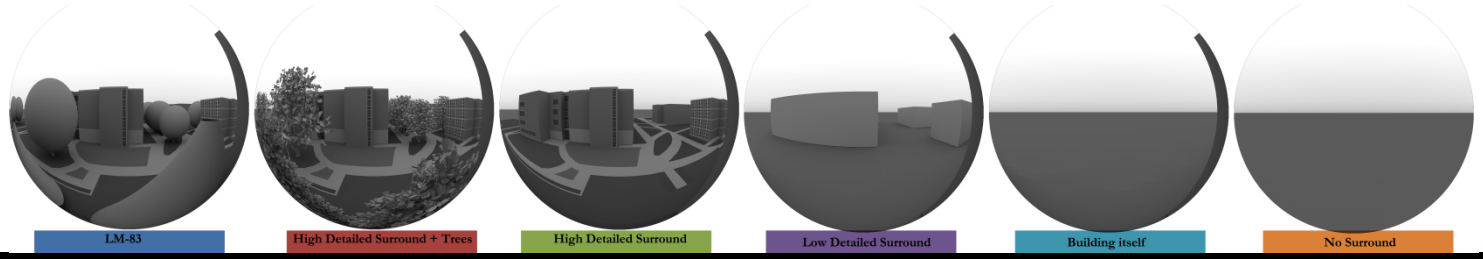
Low Detailed Surround

High Detailed Surround

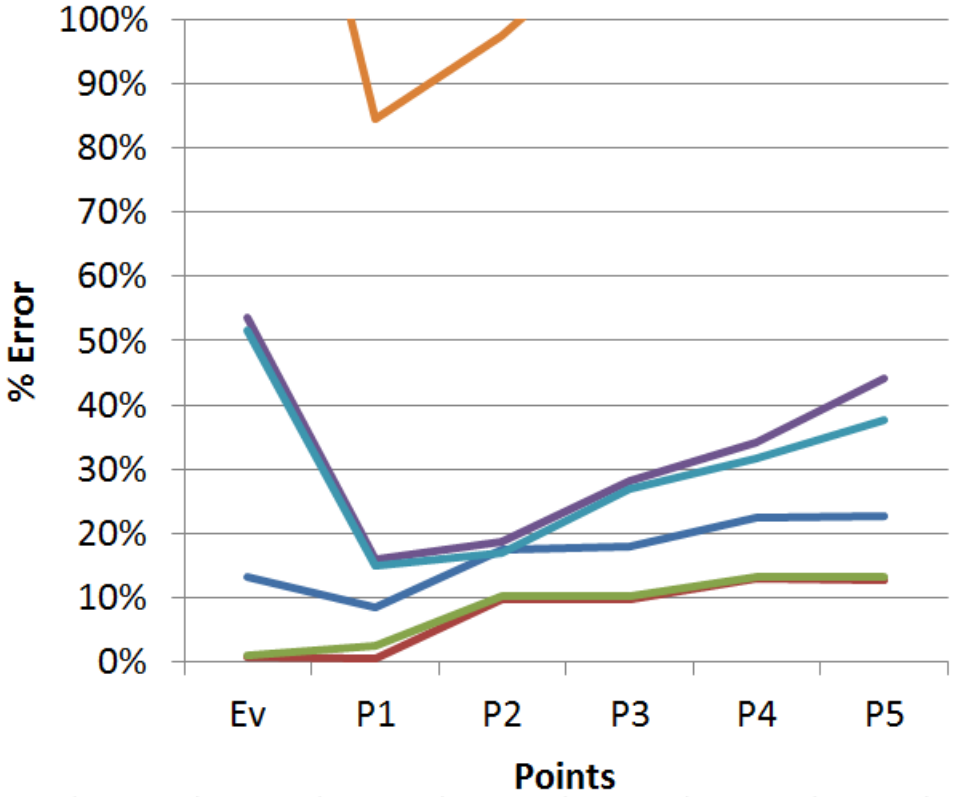
LM-83

High Detailed Surround & Trees

Season: Winter
Sky: Clear
Time: Noon



Results
Winter



No Surround

Building itself

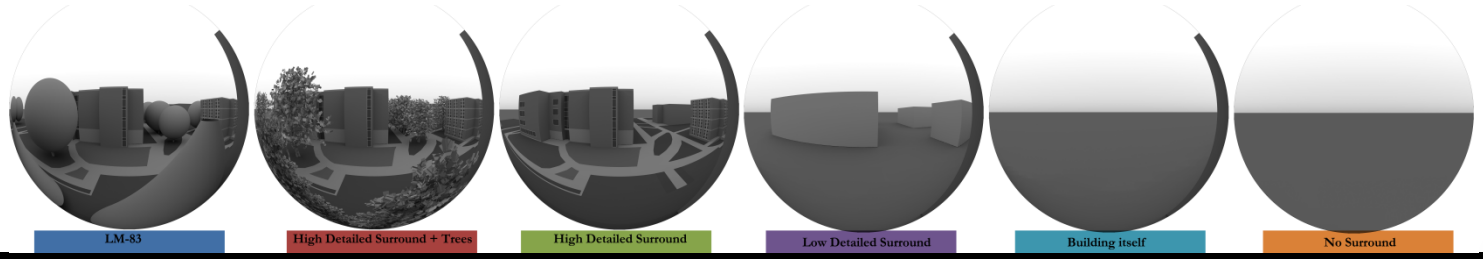
Low Detailed Surround

LM-83

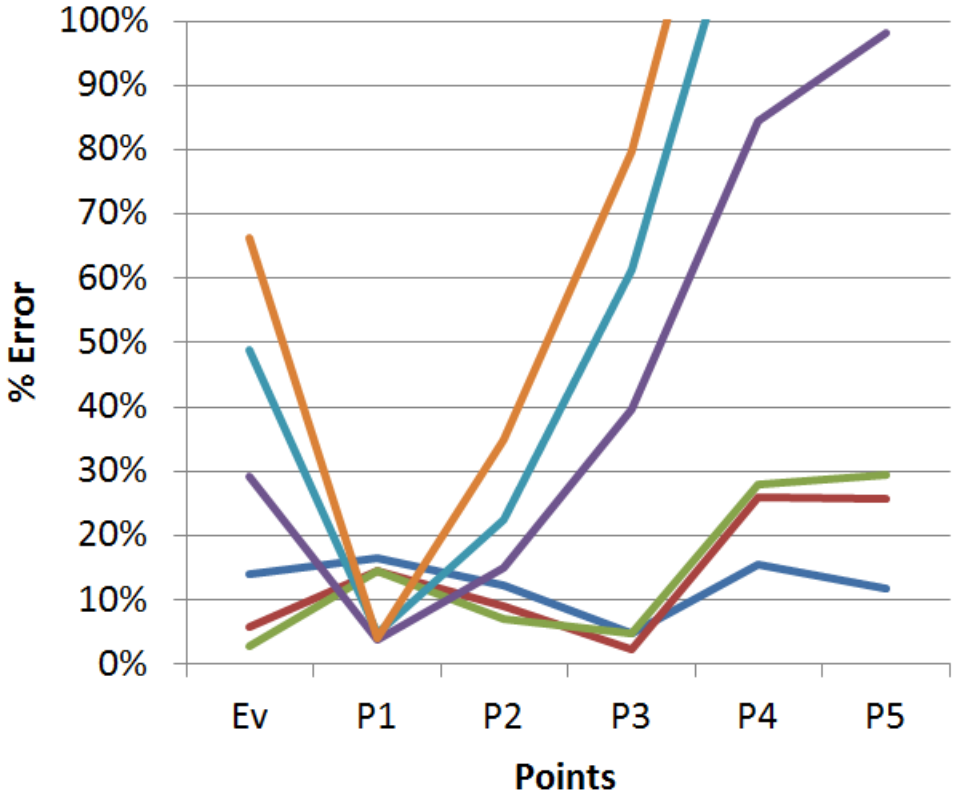
High Detailed Surround

High Detailed Surround & Trees

Season: Winter
Sky: Clear
Time: Afternoon



Results
Winter



No Surround

Building itself

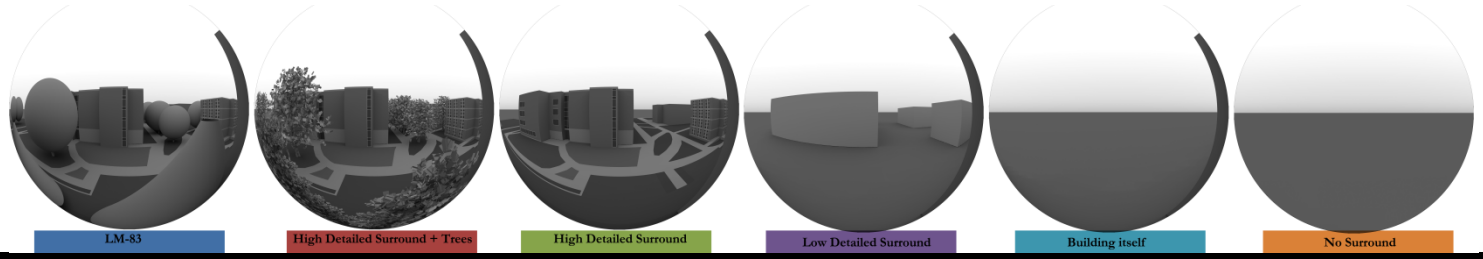
Low Detailed Surround

LM-83

High Detailed Surround

High Detailed Surround & Trees

Season: Winter
Sky: Overcast
Time: -



Conclusion

- Not including exterior elements results in significant error (overestimating the available daylight)
- A high level of detail, including detailed trees, generated the lowest error
- The level of error of LM-83 model was generally acceptable
- Seasonal effects need to be considered

Comments/Questions