# Radiance workshop 2012

## Complex facades in sunny climates, microclimates, reflection caustics

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# Overview

Daylight, sunlight and solar gains – approximate methods

More complex thermal analysis – Radiance assisted

Reflection caustics and solar heat

# Daylight, sunlight and solar gains

- Fast to implement method of estimation
- Handle large, unstructured CAD models (e.g. 300MB Rhino model)
- Give estimates of daylight/sunlight and solar gains
- First order estimates are acceptable – they'll be refined at later stages of design
- Time series of cooling load estimates are needed for all hours of a year

# Motivation – highly complex facades

Picture of a really complicated building, all curves, lots of different facade types

Another picture of a really complicated building, all curves, lots of different facade types

# Main components of calculation

**Daylight and sunlight**

- Weather data at 1 hour intervals (e.g. EnergyPlus)
- Direct solar irradiance – use sampling scheme
- Diffuse irradiance – reuse sampling data or calculate directly from Radiance
- Interreflected direct solar irradiance
- Interreflected diffuse irradiance

**Thermal**

- Direct solar and diffuse – needs g value for glazing
- Conducted – needs assumption of interior set point temperature and U values for facade elements.



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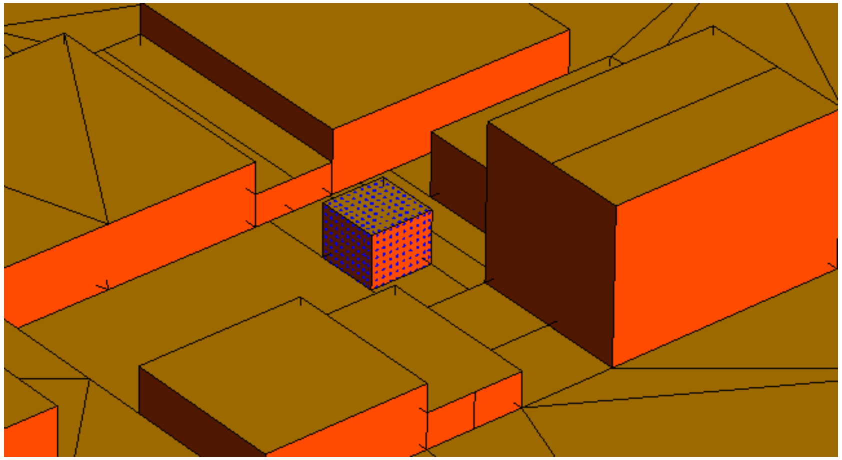
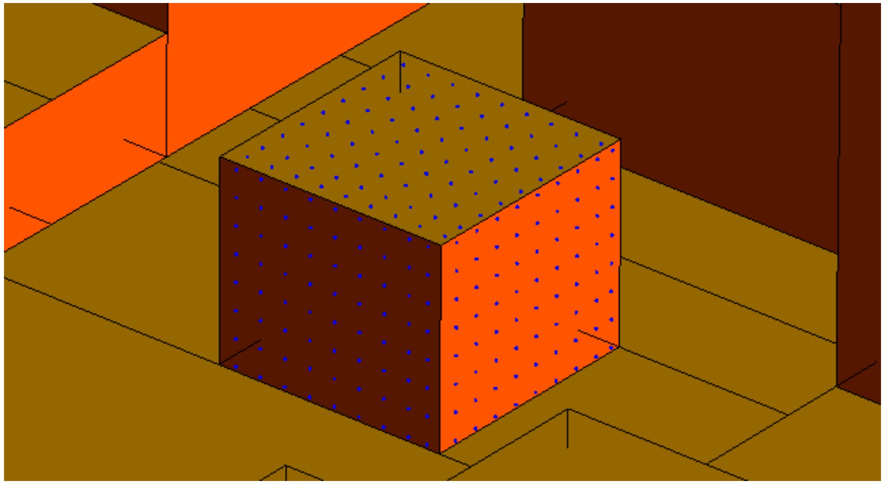
# External shading obstructions





- Set up grid points over the areas of interest



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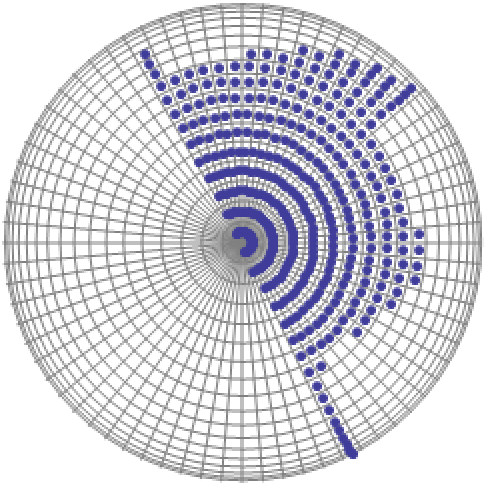
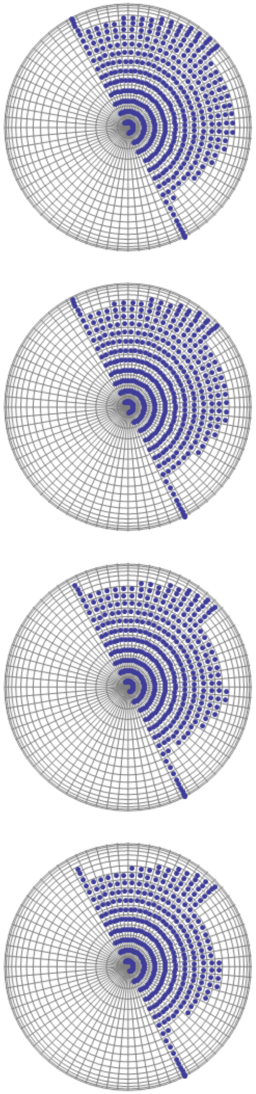
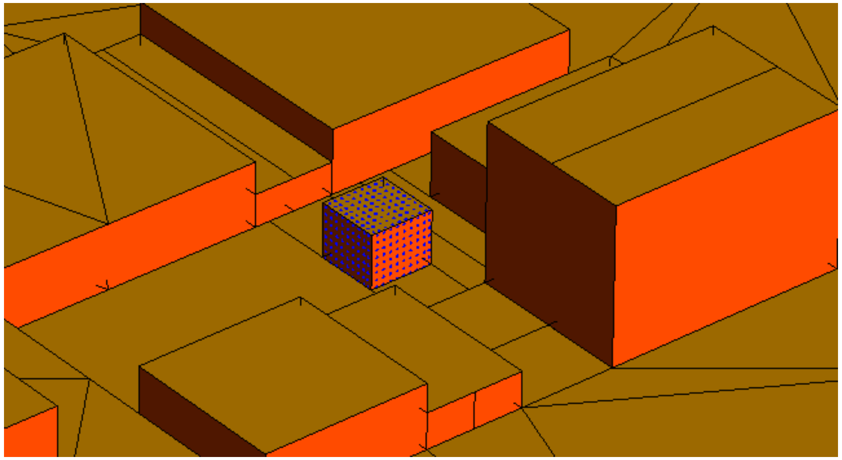
# External shading obstructions

- Sample the scene with a hemispherical distribution of rays and store the result for each grid point









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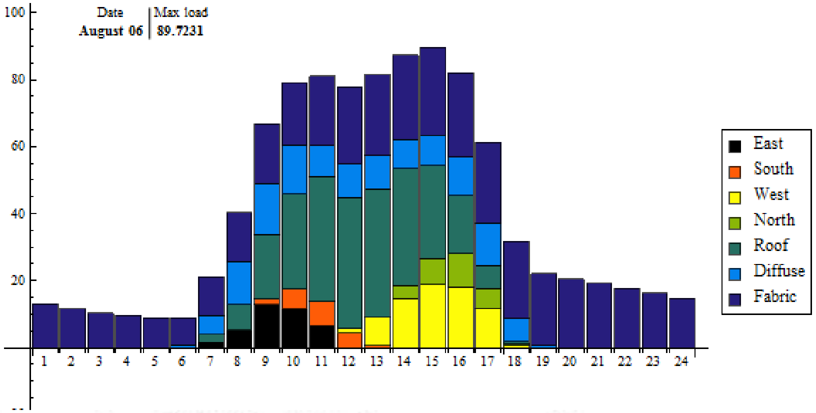
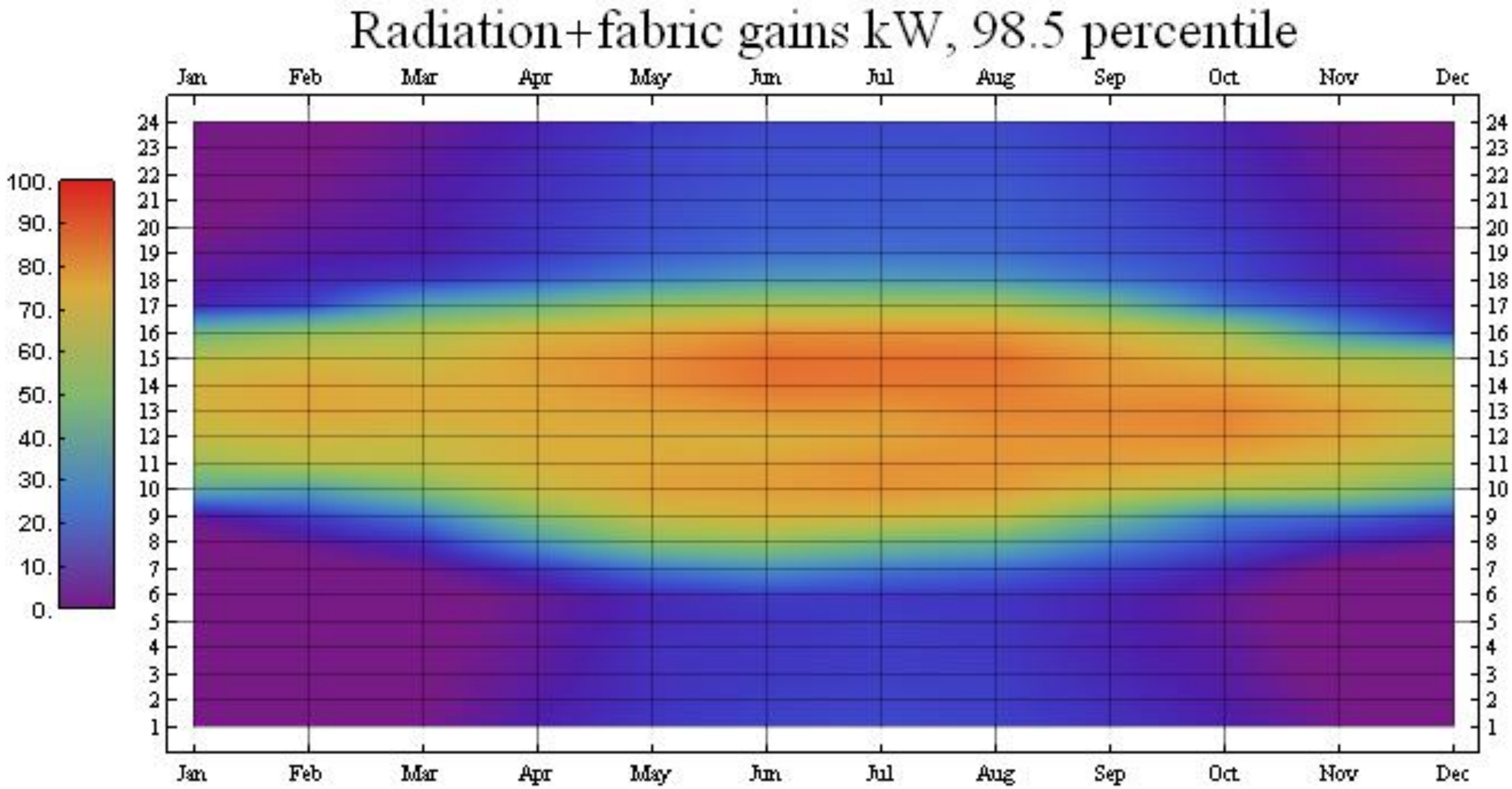
# Overall picture

- Several sets of data to combine and present



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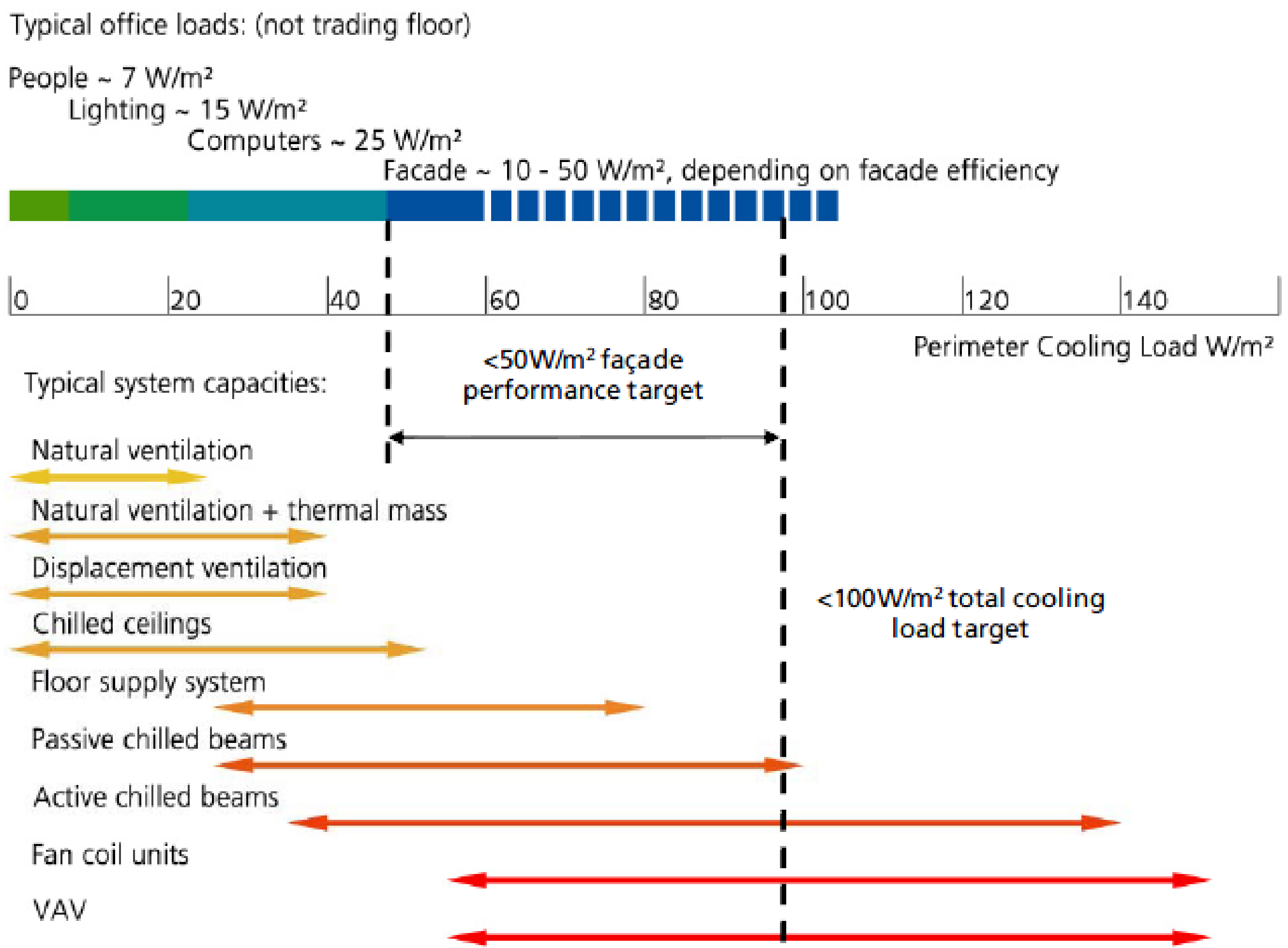
# Overall picture



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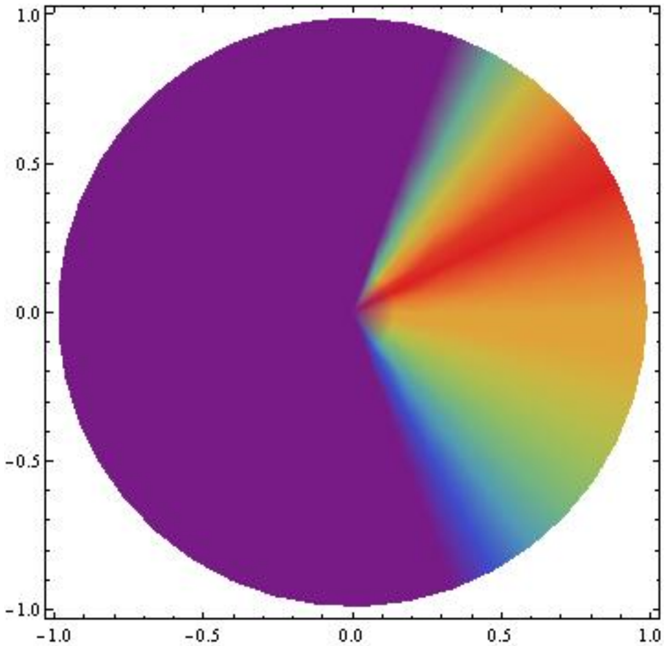
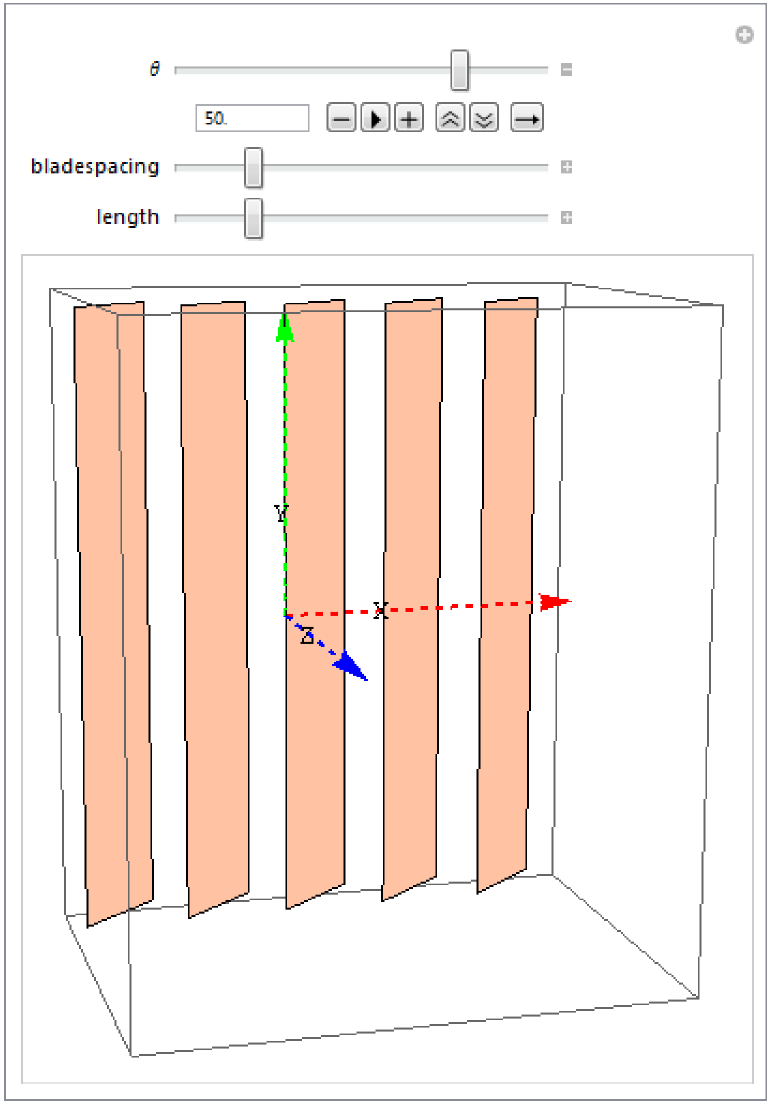
# More complex facade elements

The transmission of some shading elements are amenable to functional approximation. E.g. louvers or slats.

Uses an approximation to interreflected sunlight.



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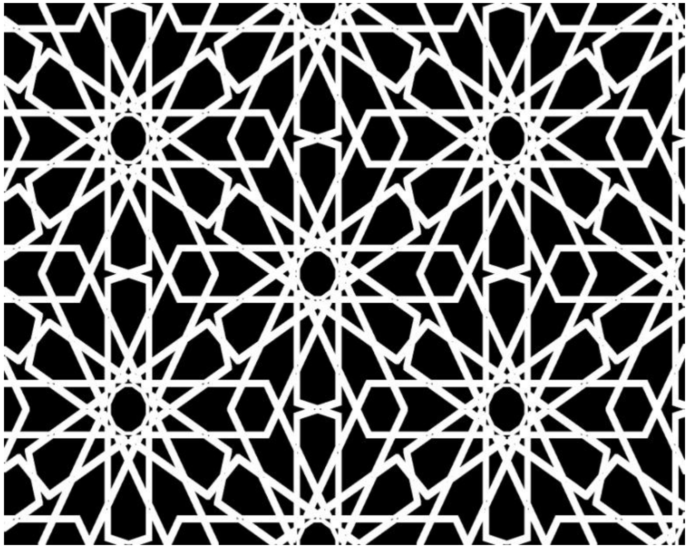
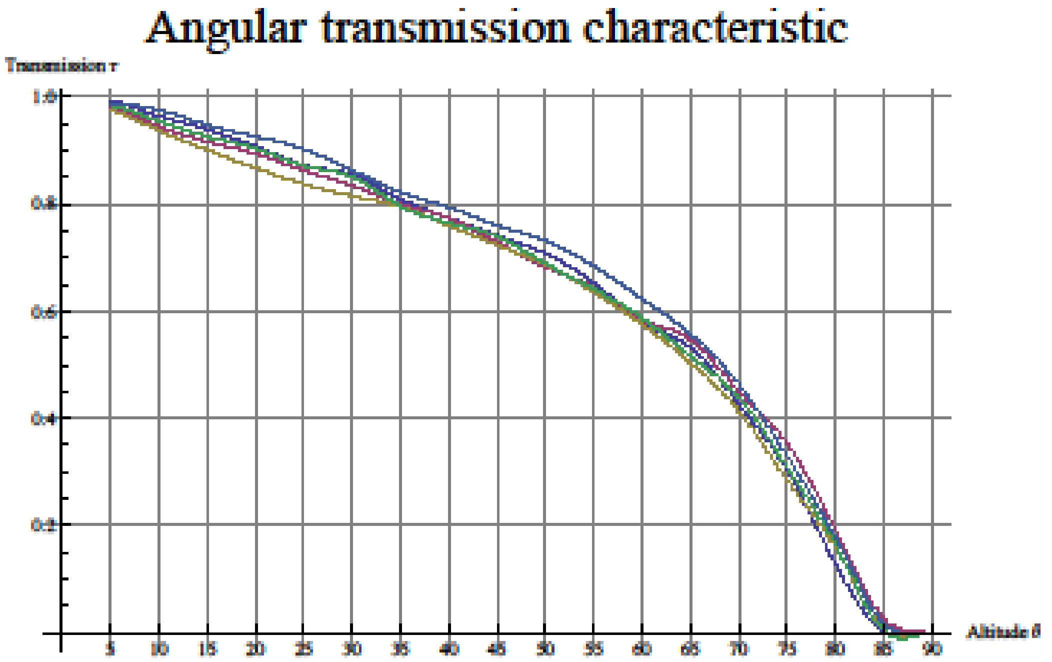
# More complex facade elements

Others can be pre-processed with a similar sampling scheme to that used for external shading.





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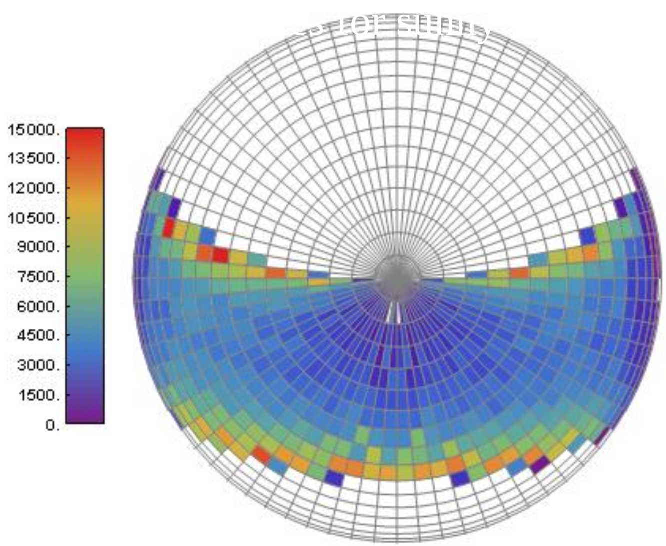
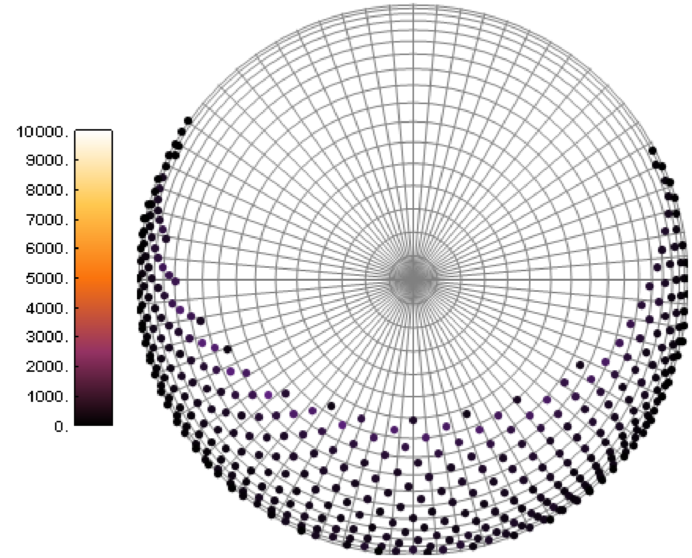
# Cumulative skies for sunny climates

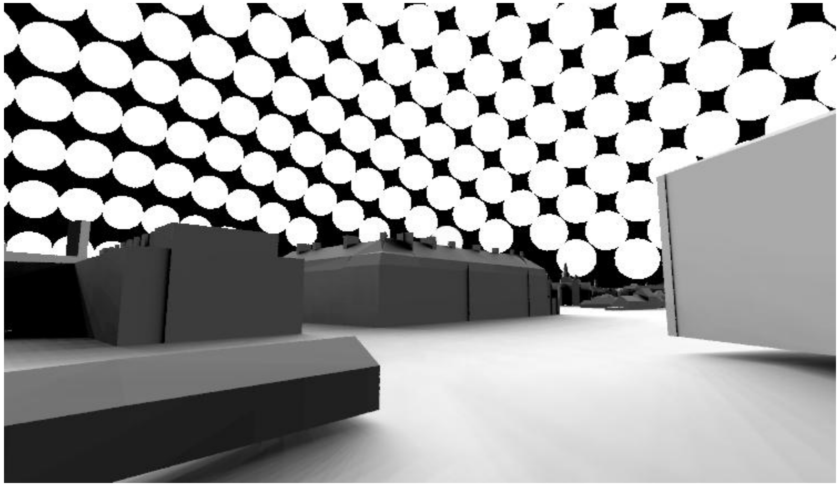
- In the Middle East for example, sunny conditions dominate over all others.
- Cumulative skies can be a very useful tool for estimating longer term averages from direct and interreflected sunlight
- Cumulative skies representing specific hours and season can be helpful where shading components are fixed (i.e. automatically or manually controlled blinds are not very compatible with this approach).



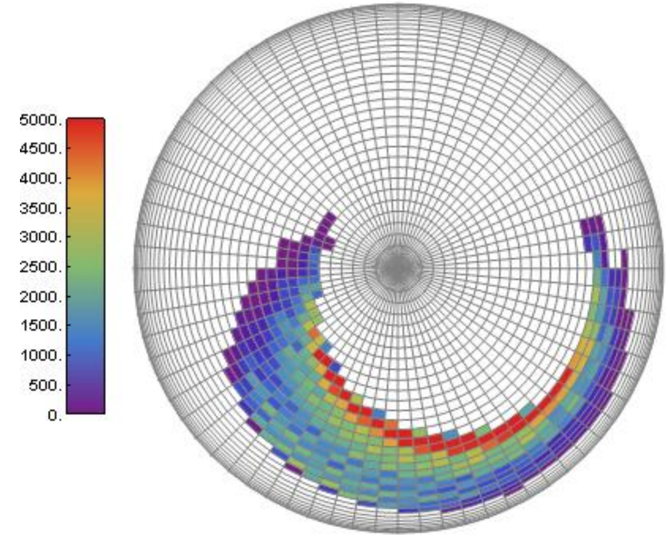

Cumulative irradiance




Coordinate transformed sky

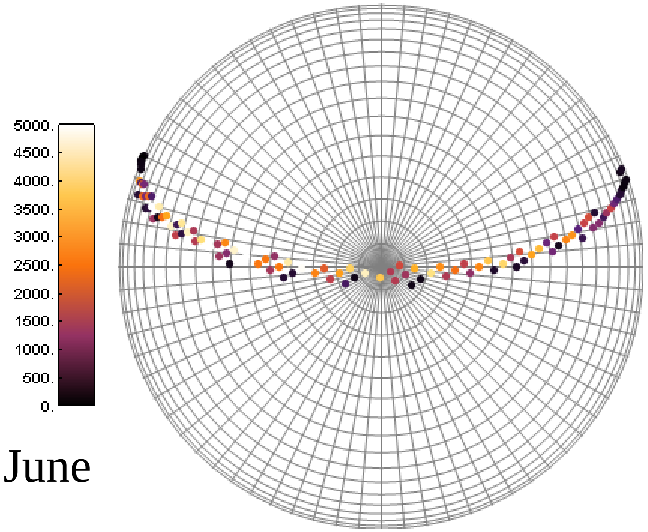


cumulative sky with maximal solar disk sizes

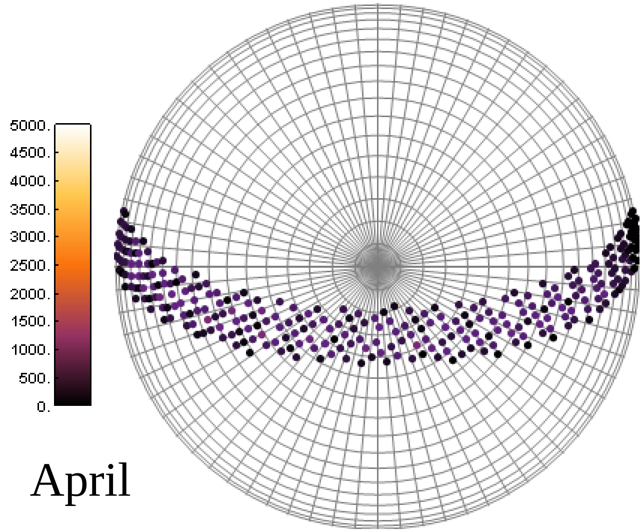



360 view, two rotations (rx, ry) applied

# Cumulative skies – hour and season ranges

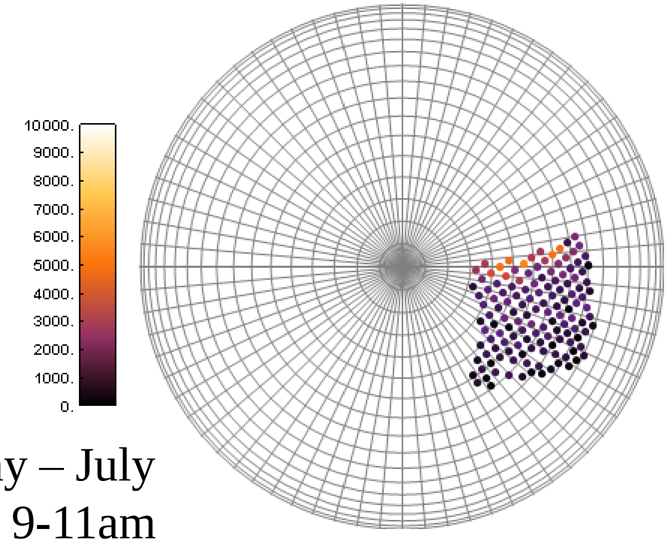



June




April

- Creating cumulative solar skies for specific periods and times can useful for investigating direct sunlight.




May – July
9-11am



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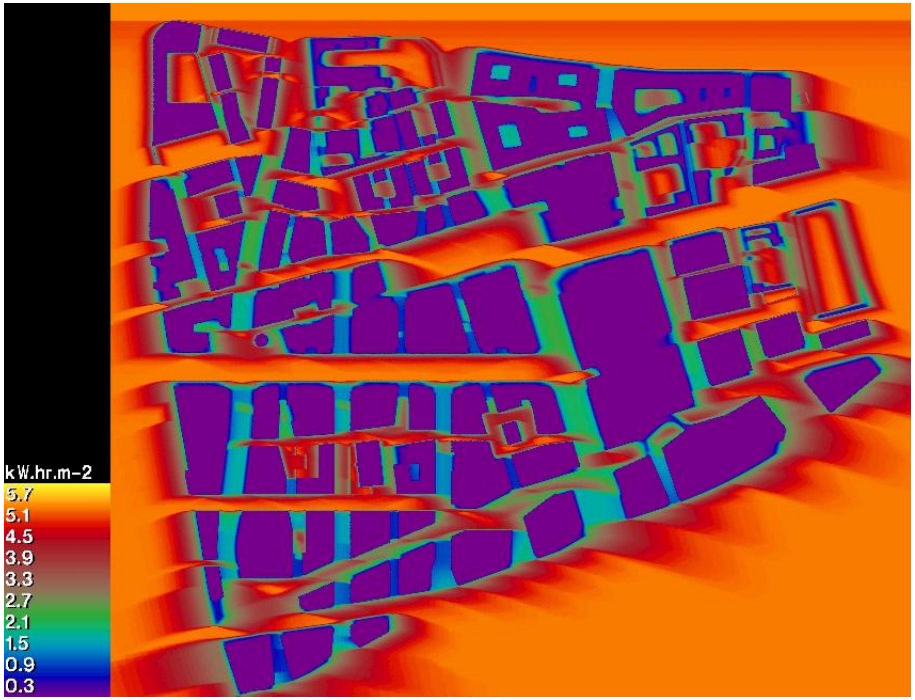
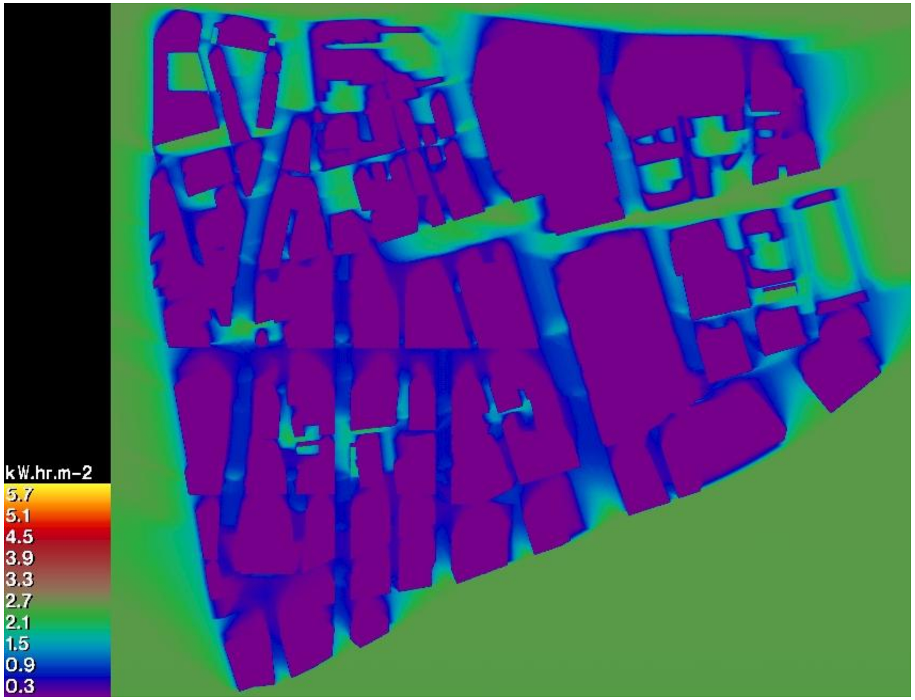
# Cumulative skies




June




December



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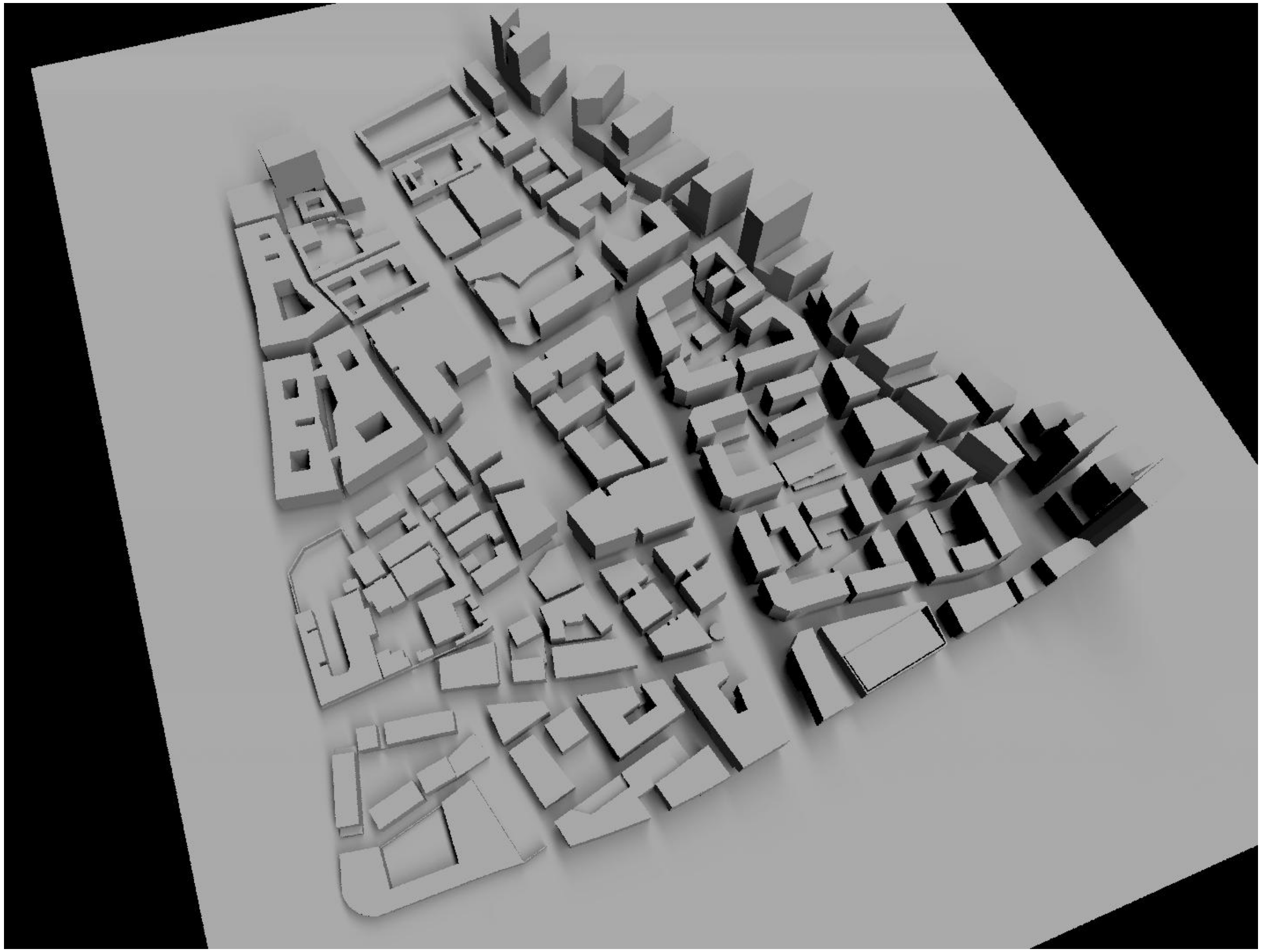
# Microclimates – thermal environment





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# Microclimates

**Main heat transfer mechanisms**:

Short wave radiation (0.3 - 3μm): direct, diffuse and reflected

Long wave radiation: ground, sky, building surfaces (hr, ε)

Convection: air velocity (hc)

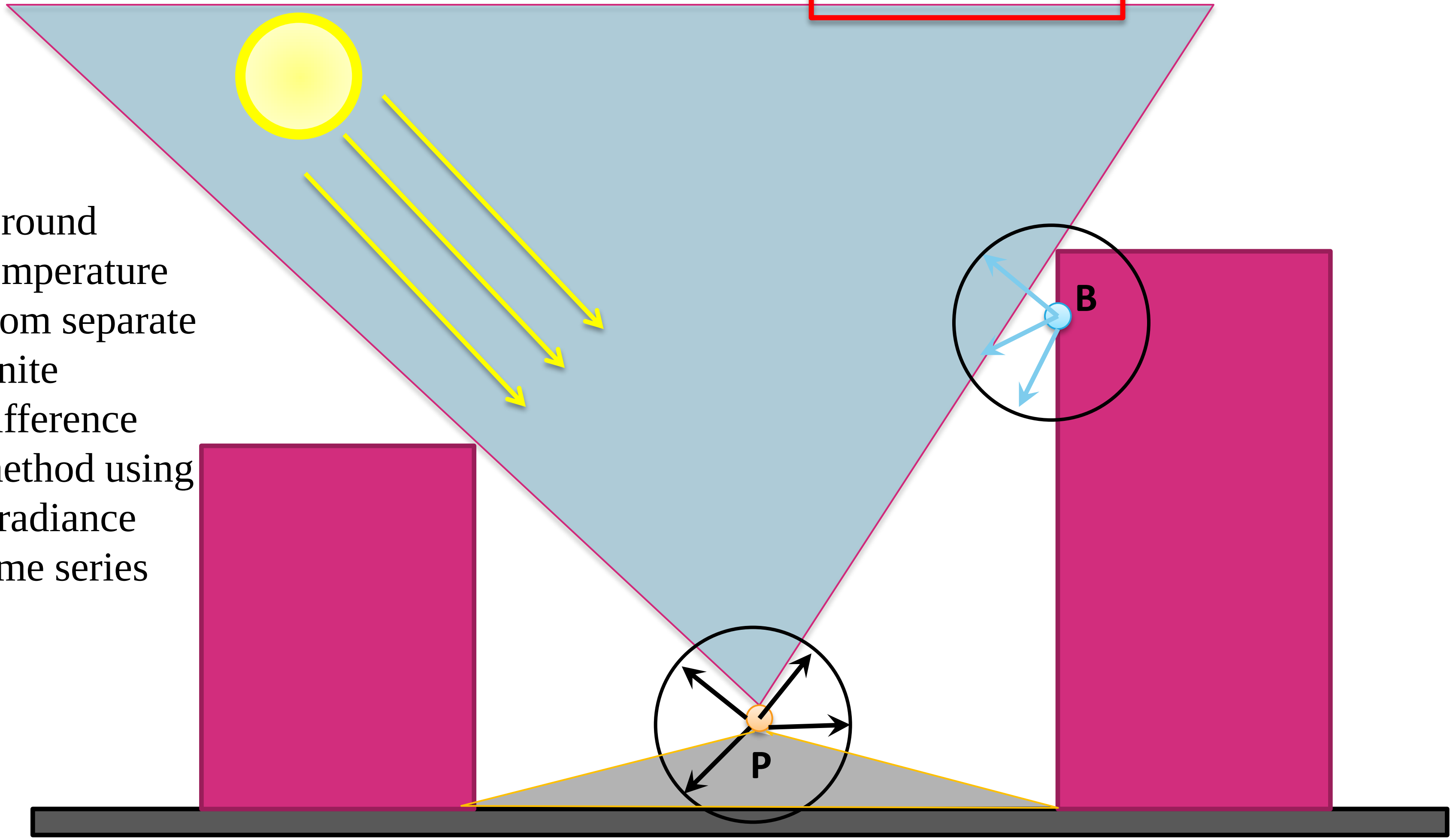
**Human thermal comfort**:

Air temperature, mean radiant temperature, humidity, air velocity

# Microclimates – MRT and sol-air temperatures

$$T_{sol} \approx \frac{\alpha}{h_c+h_r} Q_s + \frac{h_c}{h_c+h_r} T_{air} + \boxed{\frac{h_r}{h_c+h_r} \sum_{i=1}^{n} F_i T_i}$$

Ground temperature from separate finite difference method using irradiance time series



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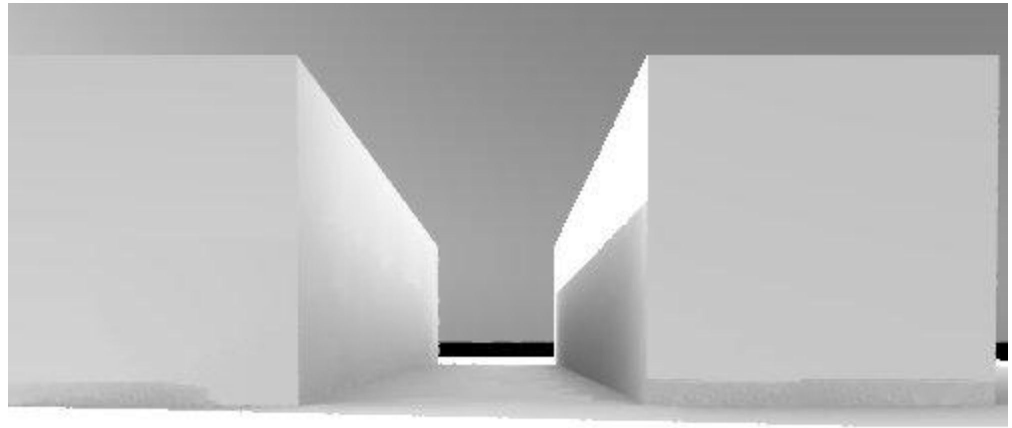
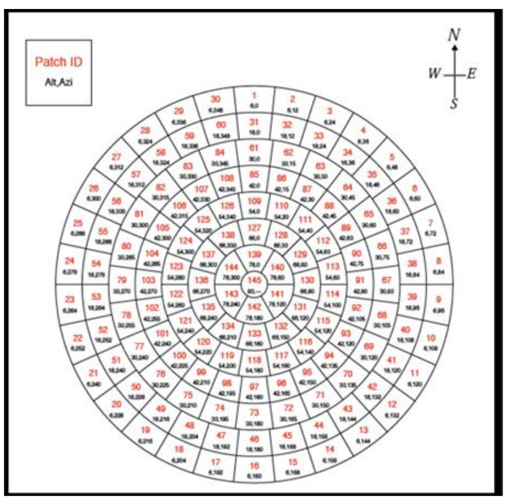
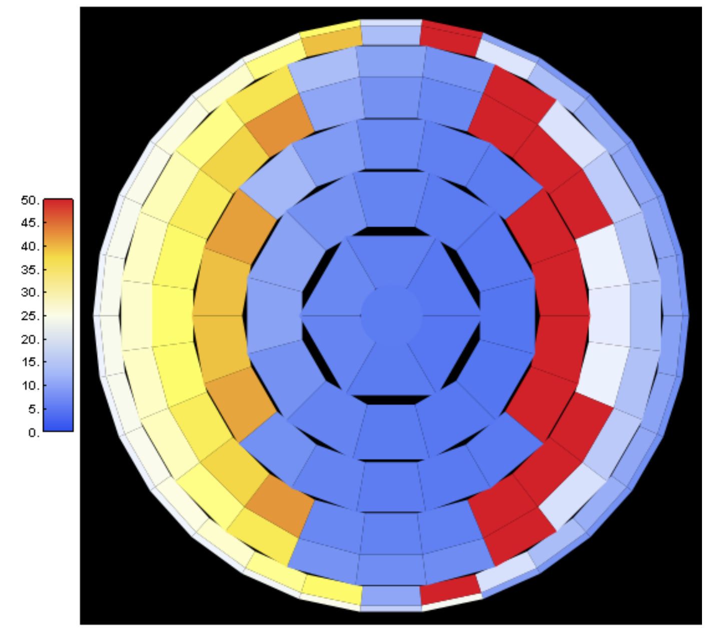
# Microclimate – mean radiant temperature

Long wave radiation at pedestrian location "p"





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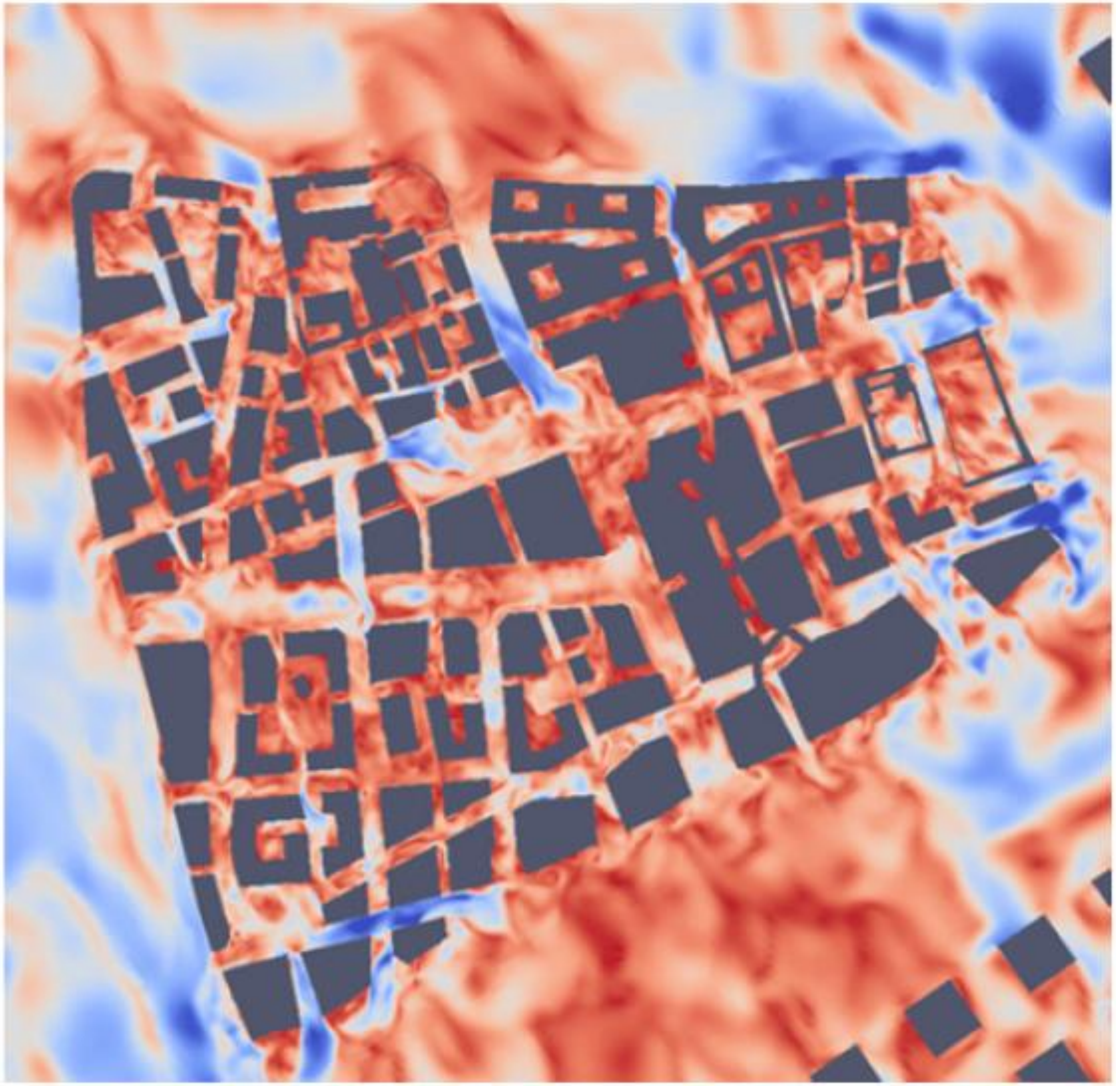
# Microclimate – wind simulation



Wind CFD:
Large eddy simulation with a synthetic atmospheric boundary layer

# Microclimate – SET* human thermal comfort

# Microclimate – shading added


# Cool building surfaces, water, exhaust air and active systems


# Reflection caustics

Double curved, free form, specular buildings are becoming increasingly common.

There are several well known cases of specular facades causing severe problems through intensely focused solar heat.

There are several ways by which Radiance can be used to simulate this type of phenomena (photon map, rtcontrib). The method presented here is simple to implement using rtrace.

# Reflection caustics

Picture of a smoking building hit by a reflected heat death ray

# Reflection caustics

- **Procedure**:
- Send an array of parallel rays along the solar direction vector towards a point of interest;
- Set target surfaces with appropriate material modifiers or identifiers;
- Use rtrace –ot... to expose the ray tree (there need be no light sources in the scene);
- Filter the resulting output (e.g. grep);
- Make a 2D histogram of the intersections with the target surfaces;
- Convert this data to a visualisation format e.g. VTK.

# Reflection caustics

```
vwrays -ff -vf vf/03-21-09.vf -x 2500 -y 2500 \

| rtrace -h -ffa -oodm -lr 2 oct/FullModel_New.oct \

| grep "NewFacade\|M-nor" \

| awk '{print $1,$2,$3,$4,$5,$6}' \

| rtrace -h -faa -otpm -lr 2 oct/FullModel_New.oct \

| grep target_mat1 \

| awk '{print $$1,$$2,$$3}' > dat/03-21-09-points1-n.dat
```



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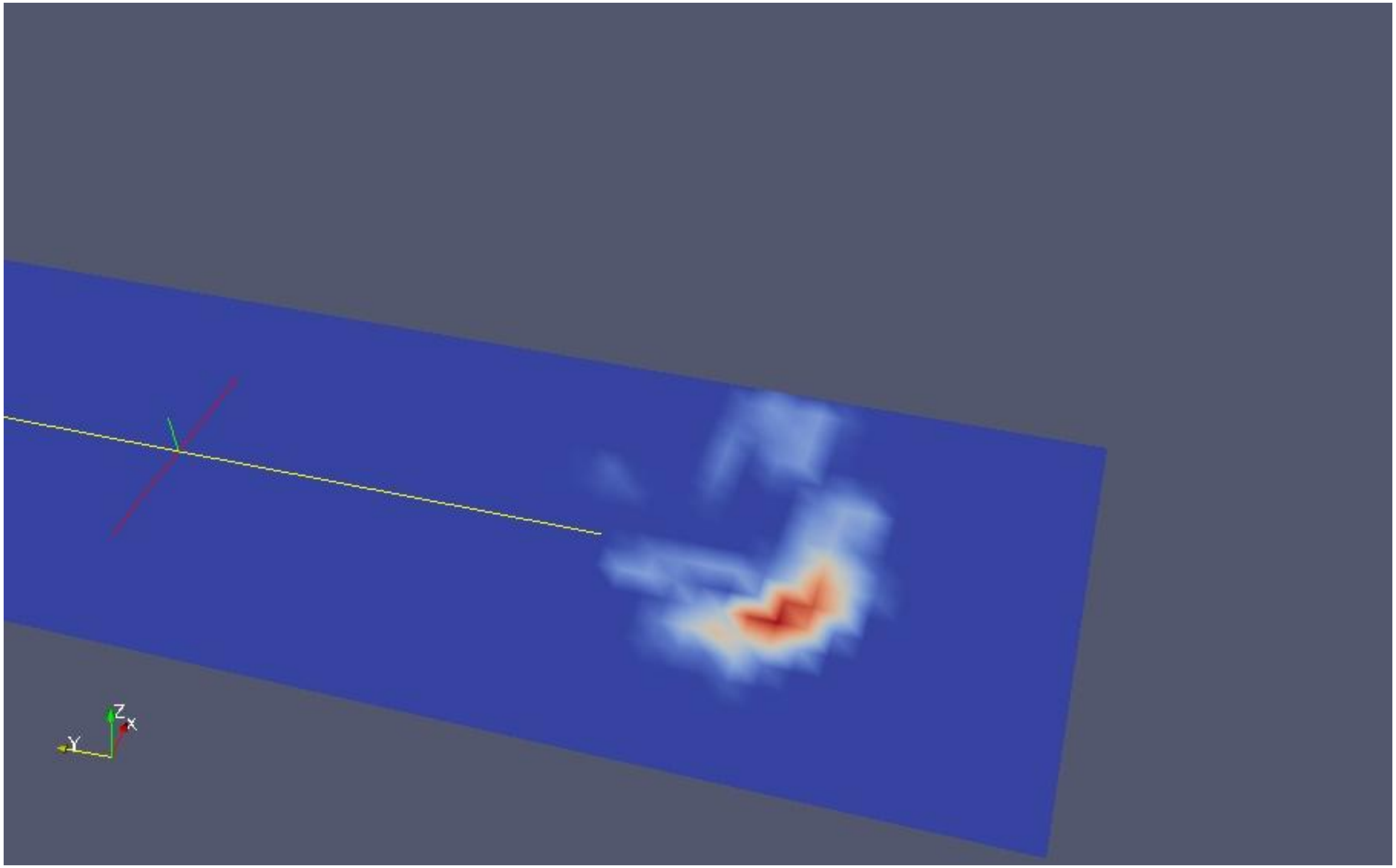
# Reflection caustics



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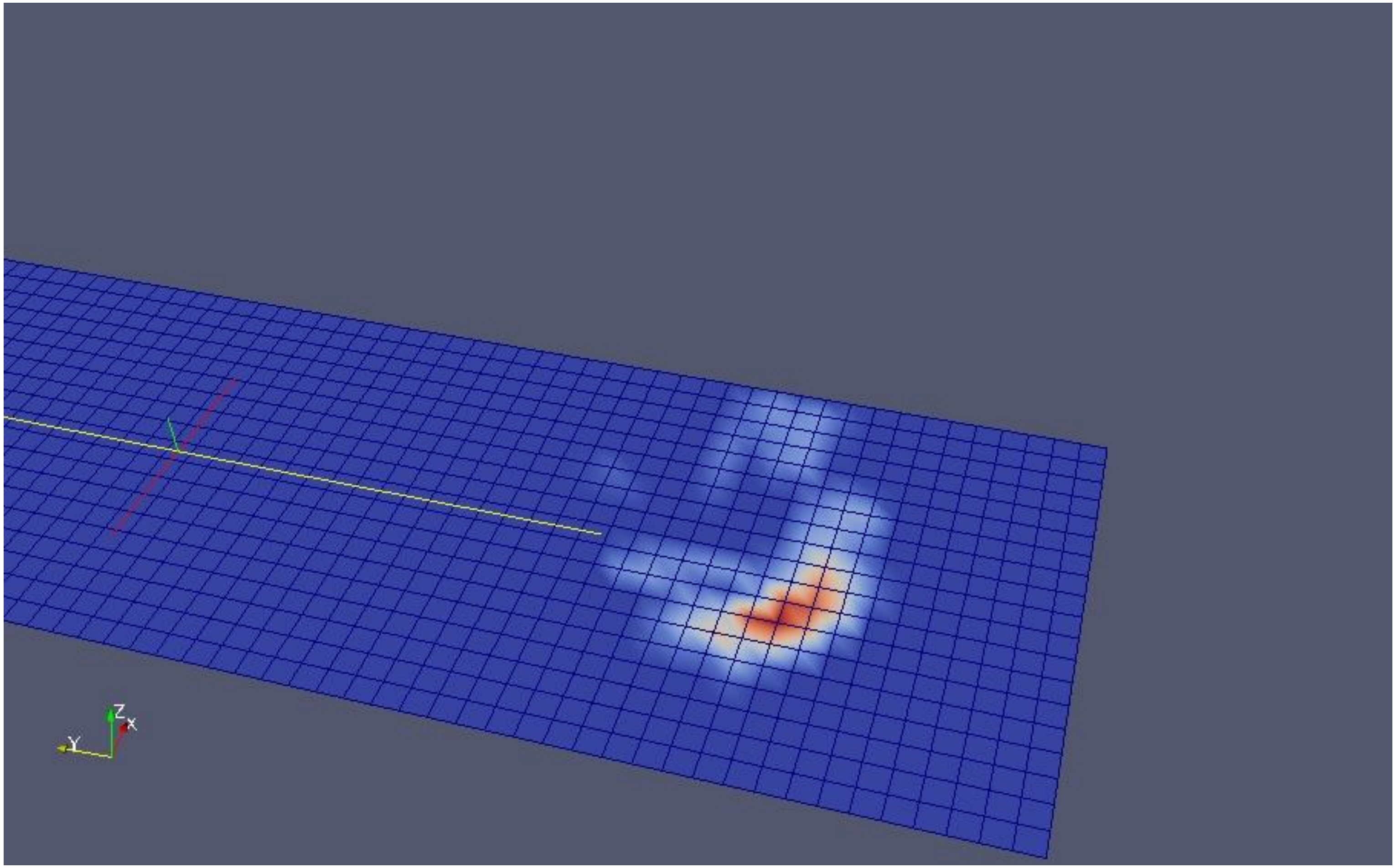
# Reflection caustics



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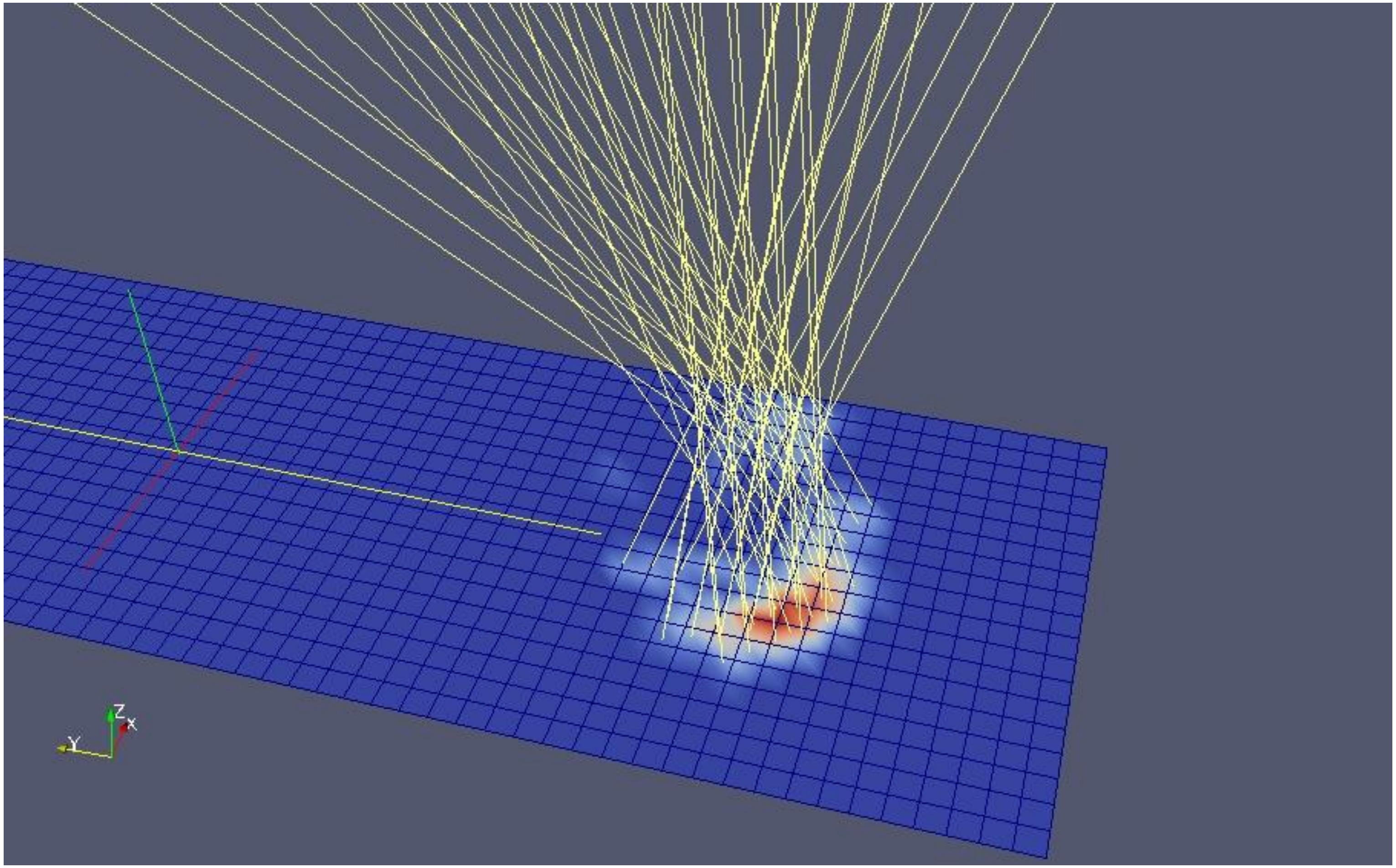




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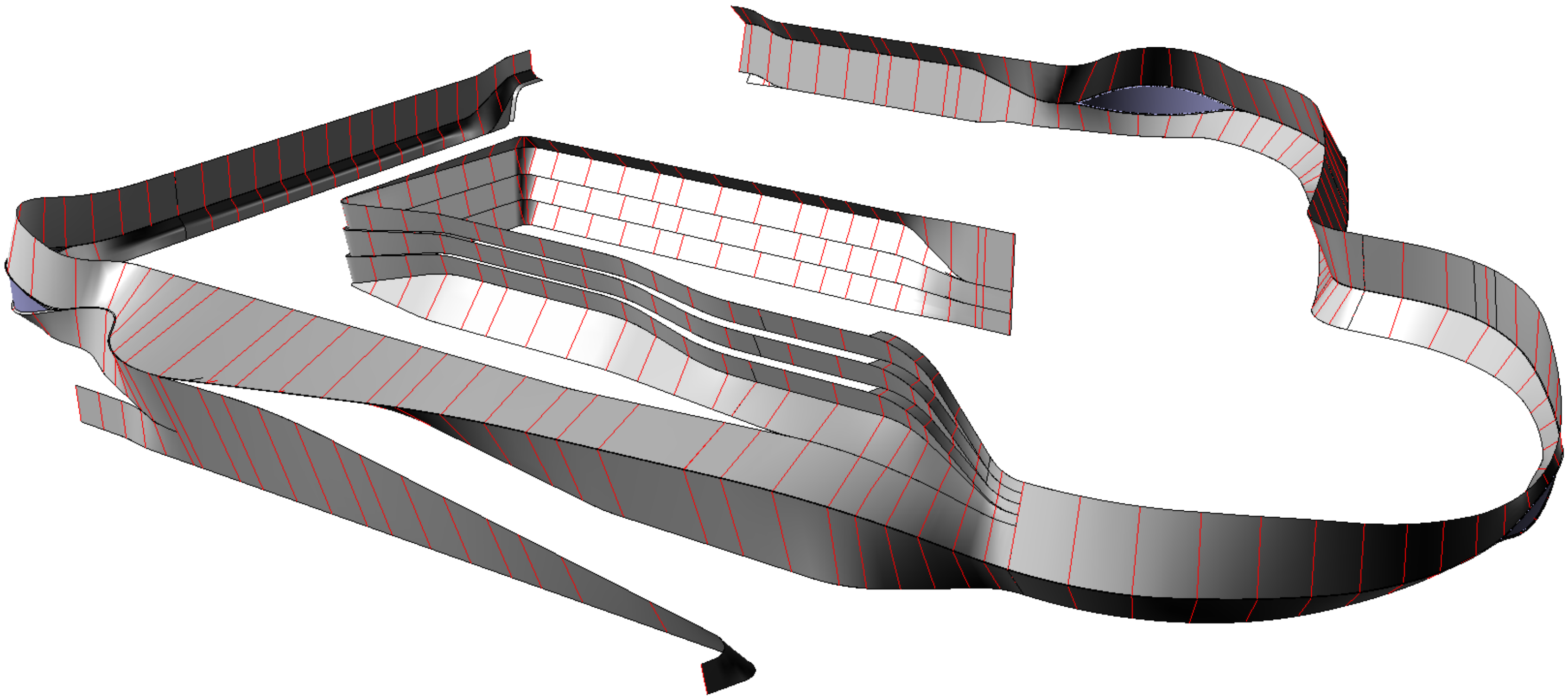
# Reflection caustics





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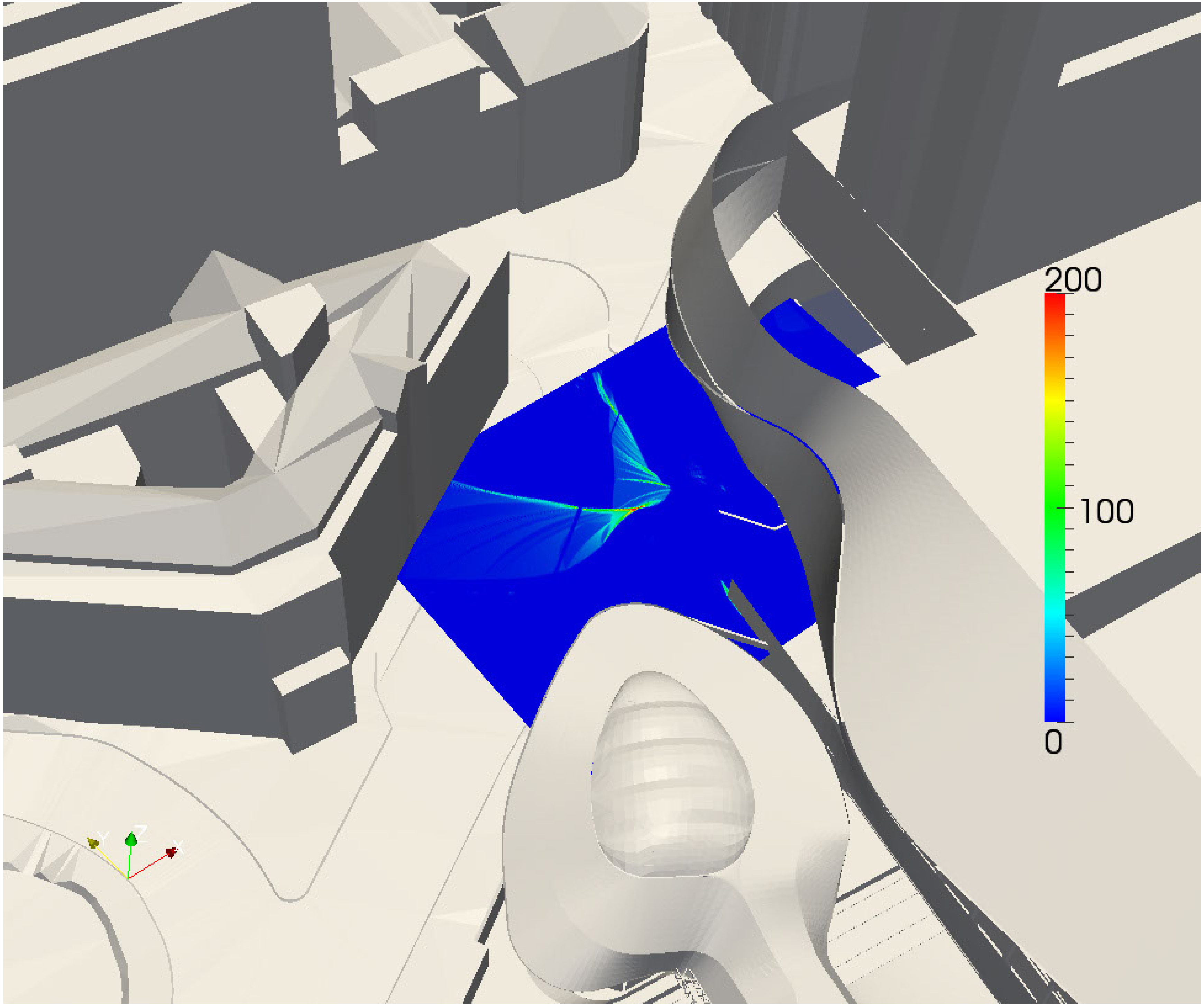
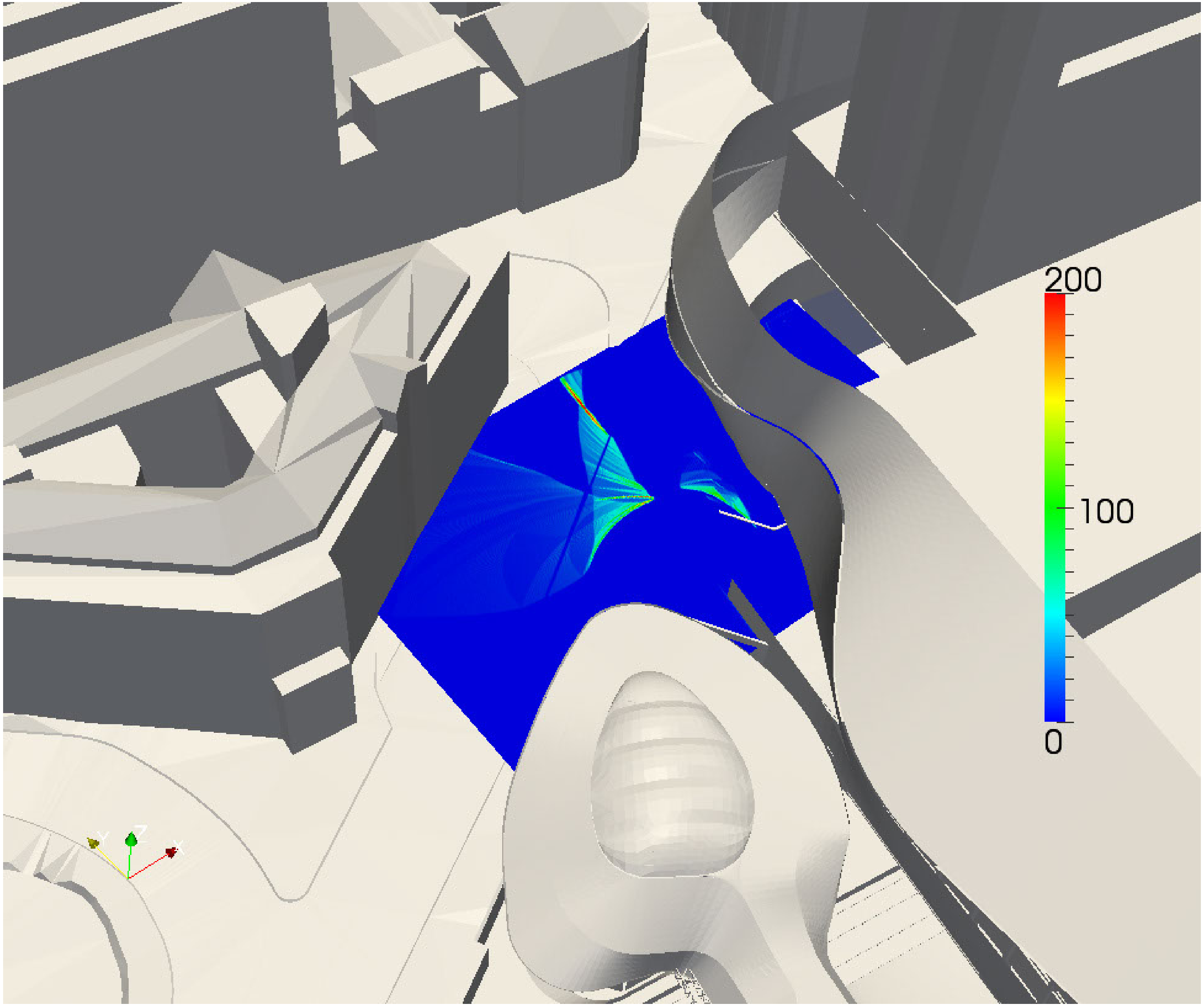
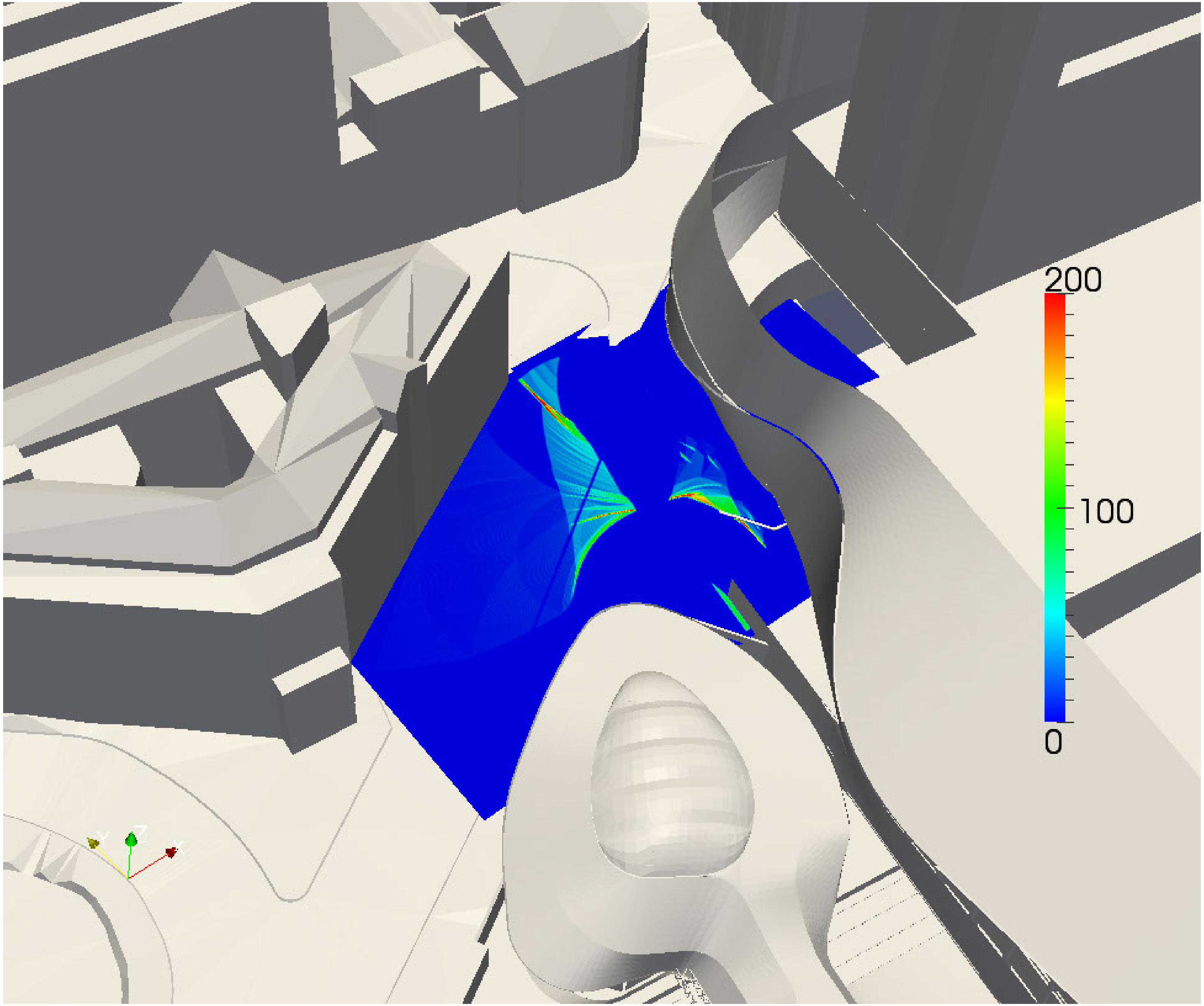


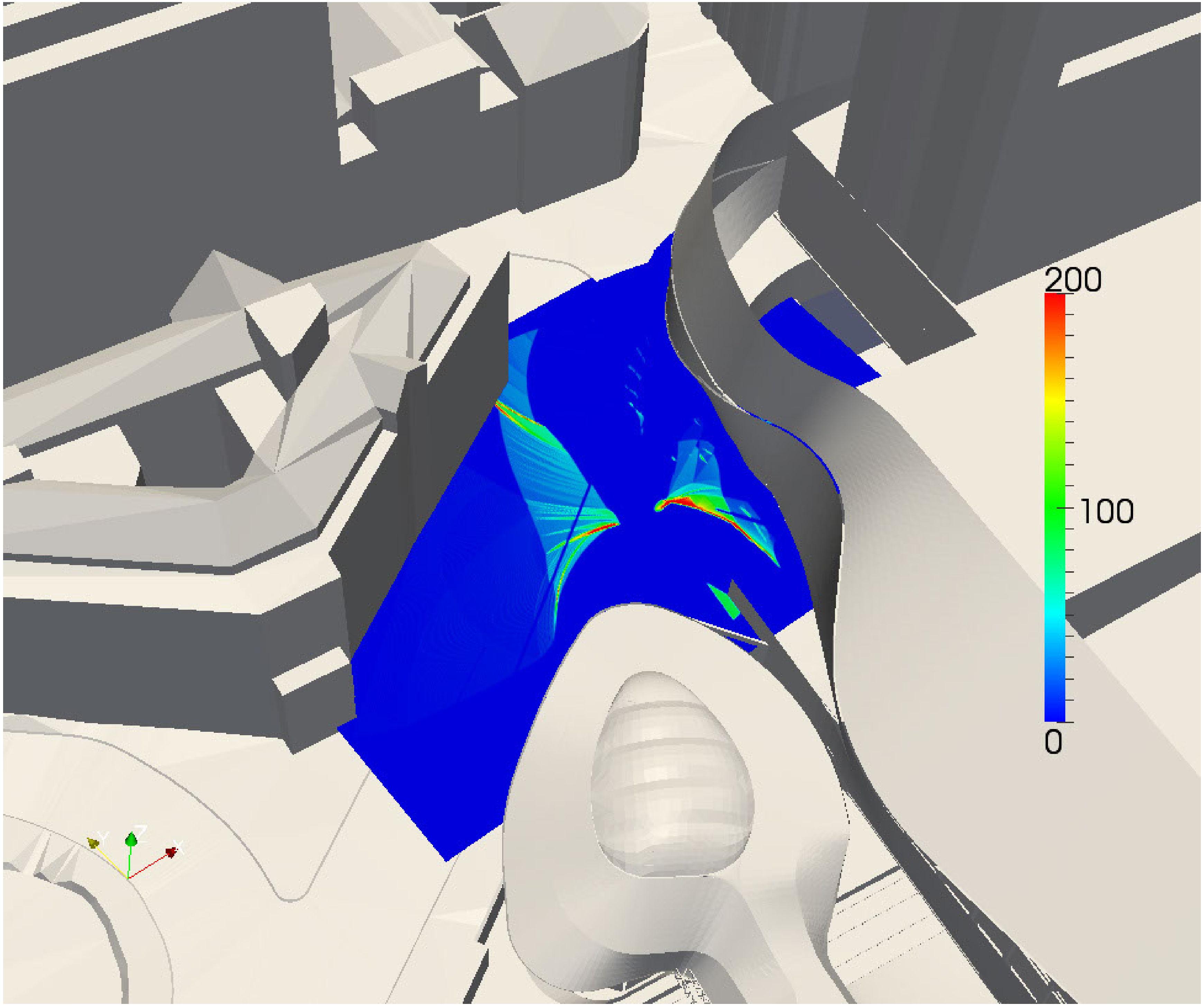

06-21-12-Points.png



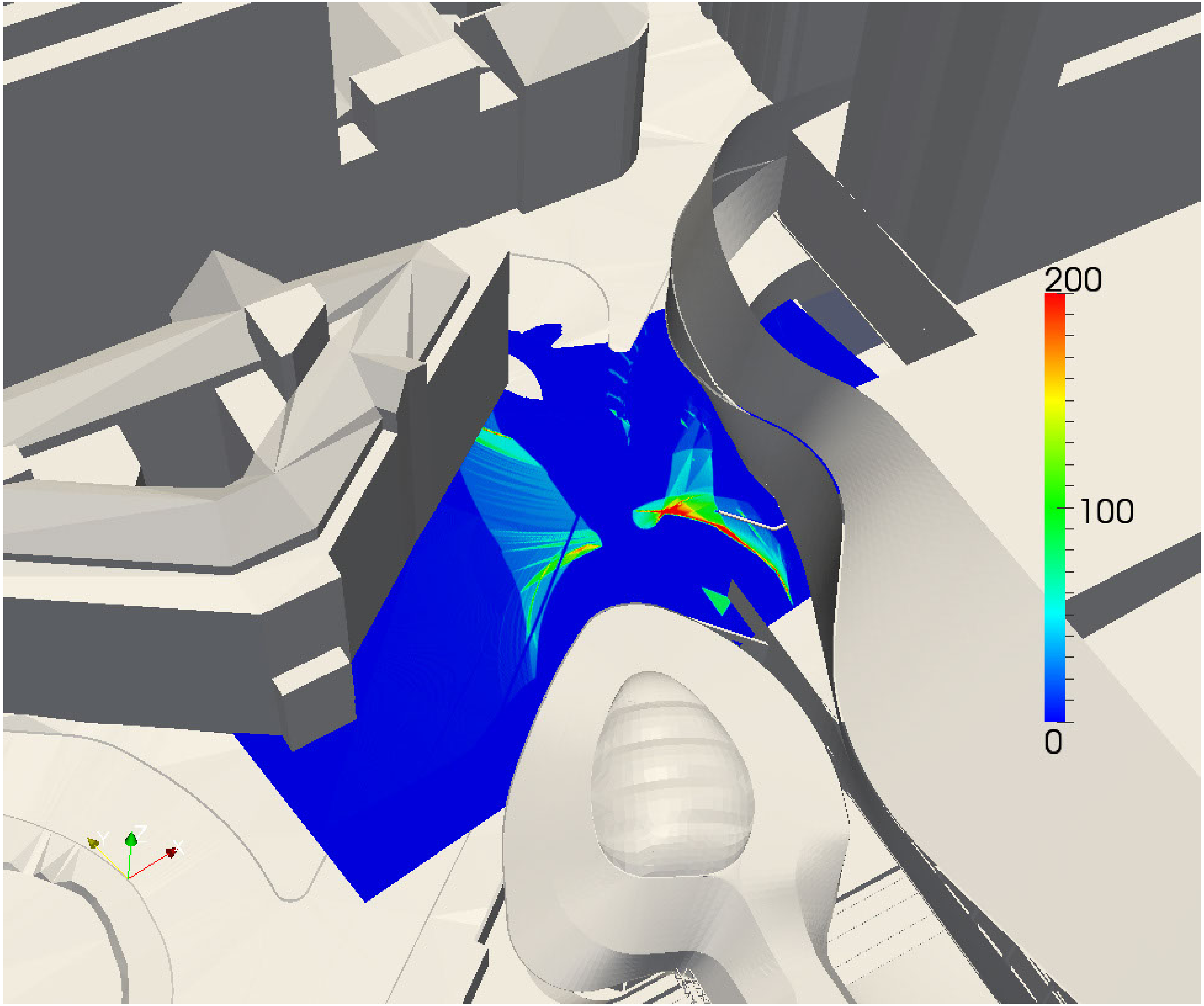

06-21-12thirty-Points.png



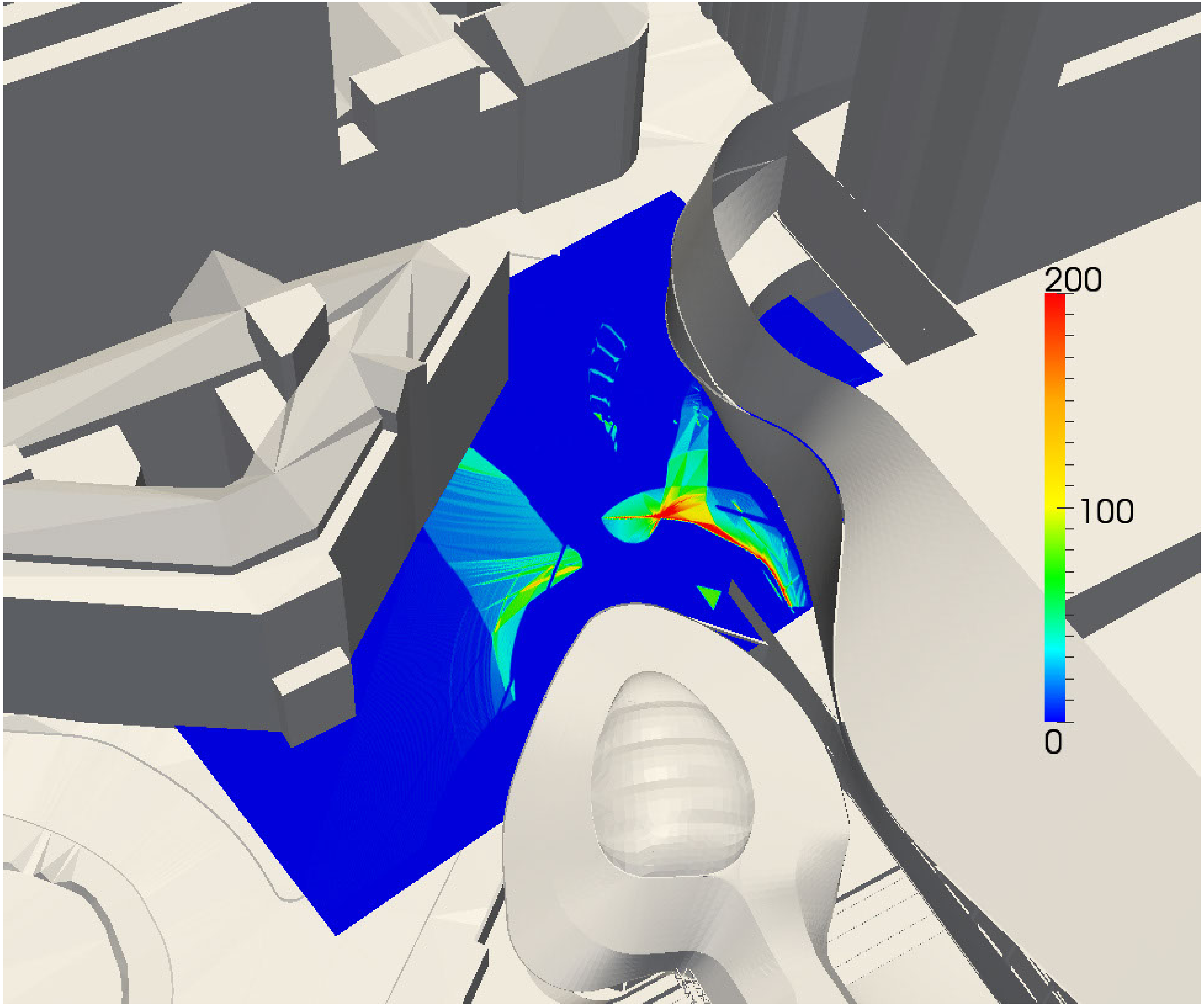

06-21-13-Points.png



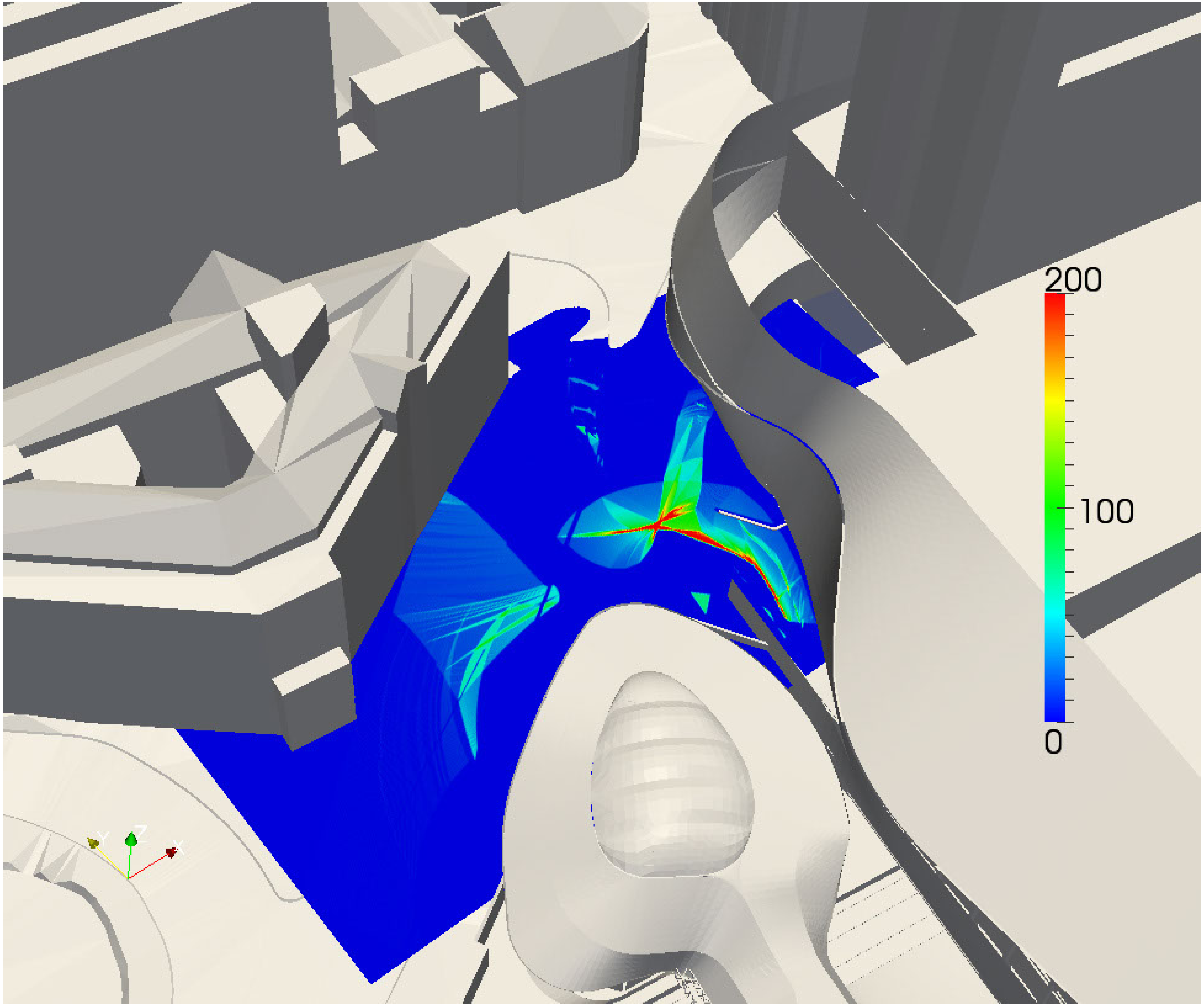

06-21-13thirty-Points.png




06-21-14-Points.png




06-21-14thirty-Points.png

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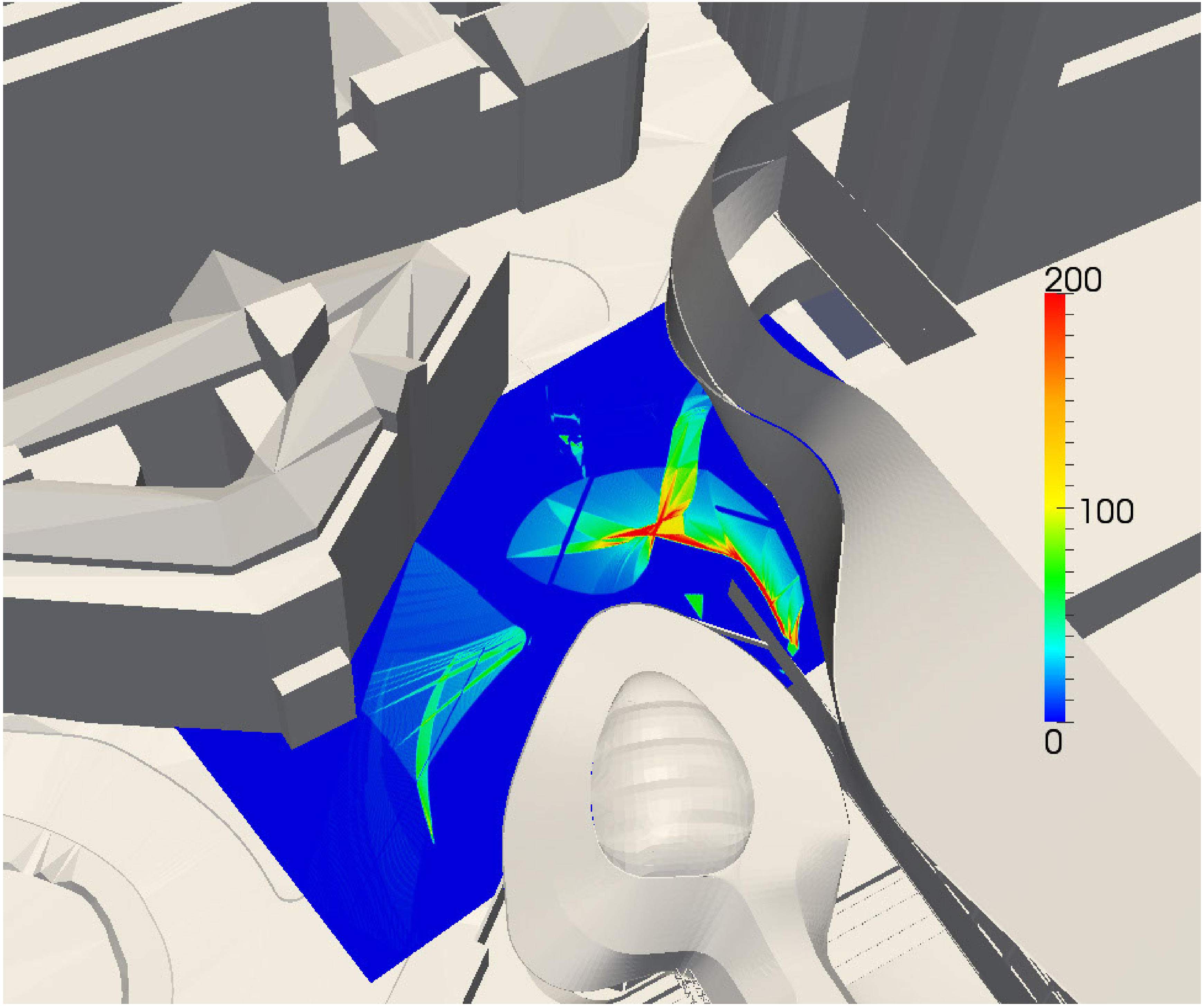
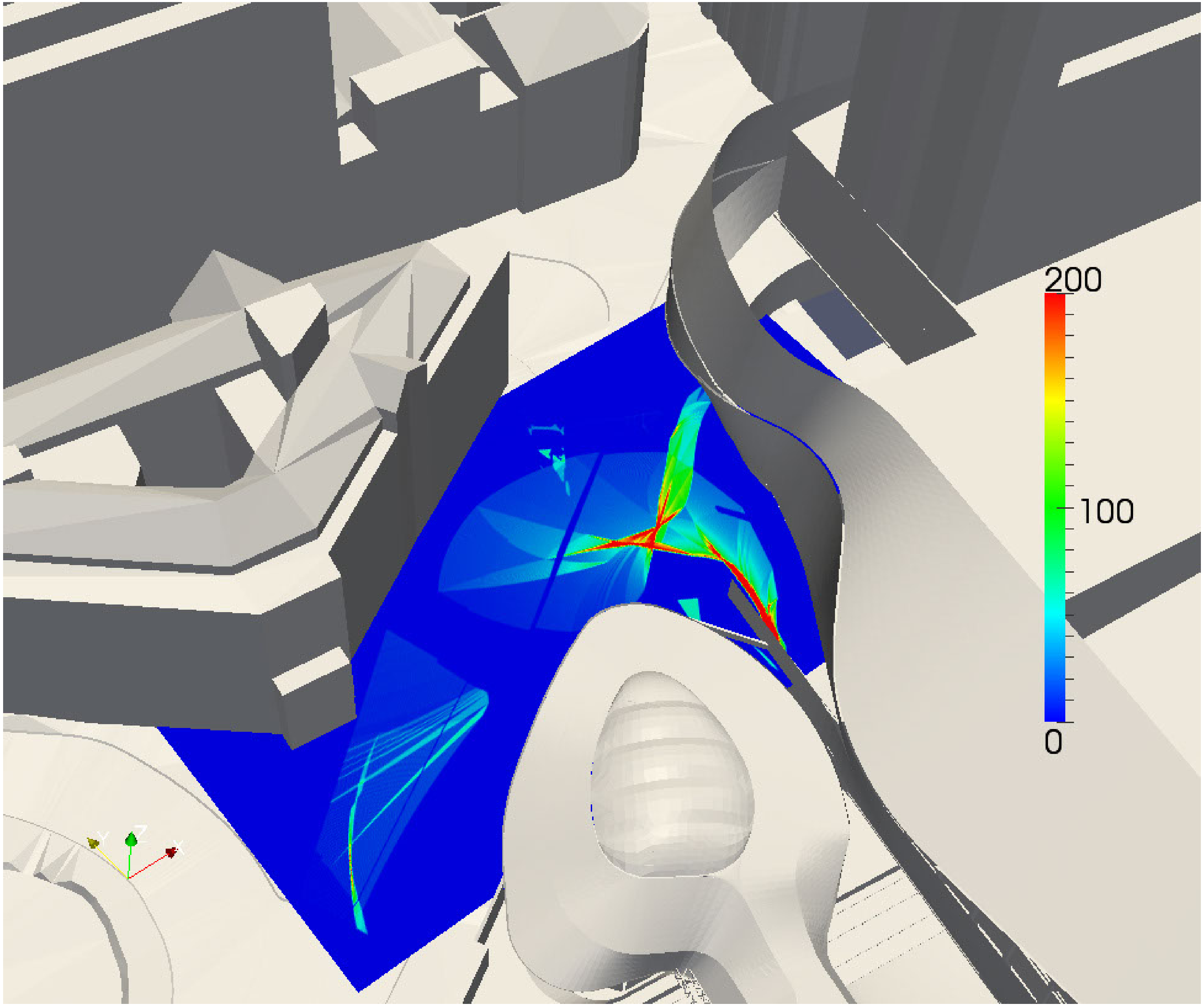



06-21-15thirty-PointsNew.png




06-21-16-Points.png

# Reflection caustics

- Some notes on the methodology:
- It’s fast but a little wasteful;
- Setting up complex target surfaces is involved, we limited ourselves to arbitrarily orientated planar targets;
- The method results in a magnification factor, the methodology could be extended to include a surface dot product with incidence angle if it were necessary (carry through ray direction data with rtrace –otopd into the binning process...);
- Analysing where hot spots originate from is also possible in a post process (compare maximum bin indices with corresponding ray indices);
- Volume rendering as an alternative to specifying targets explicitly was of inconclusive effectiveness.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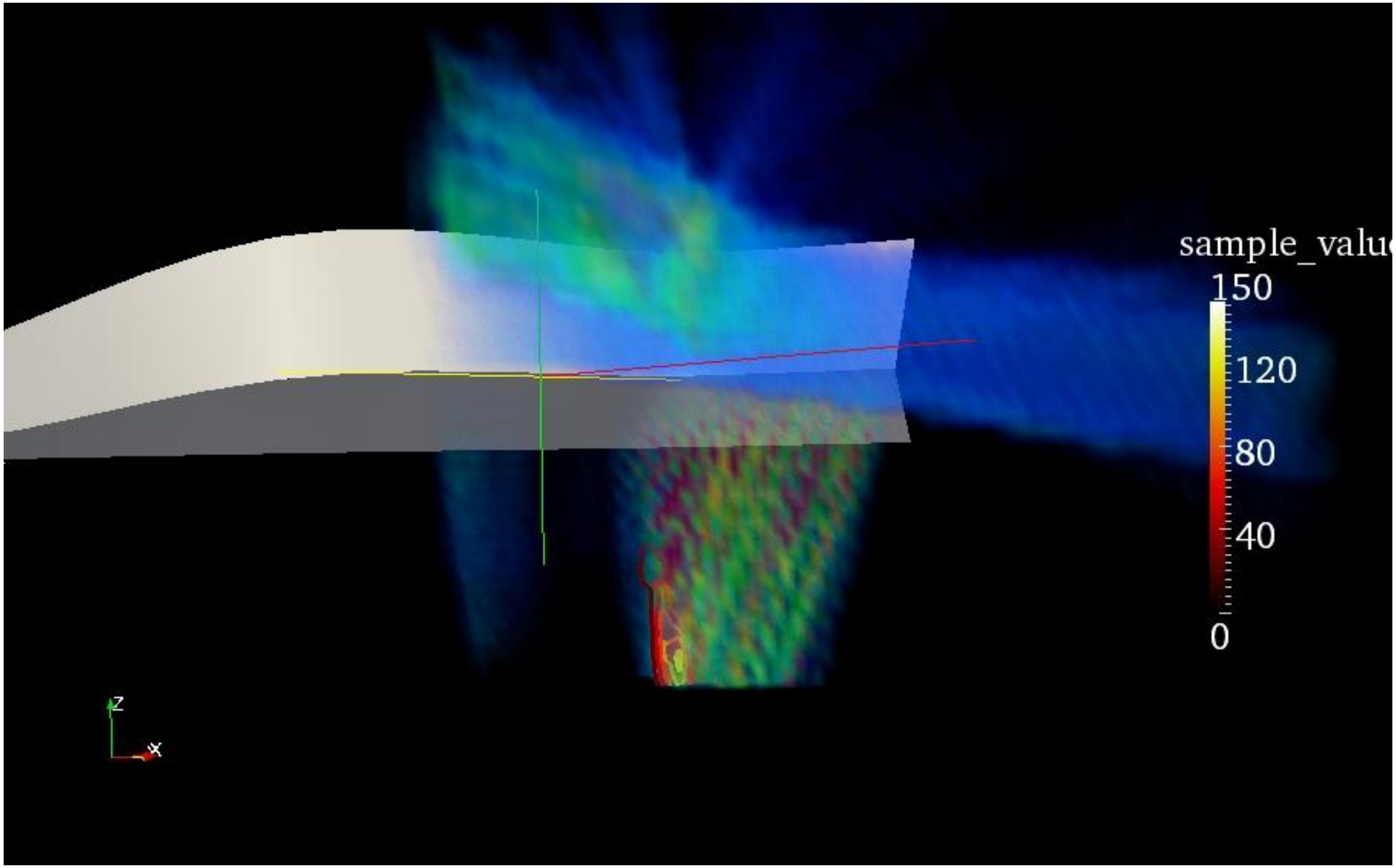
# Reflection caustics





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