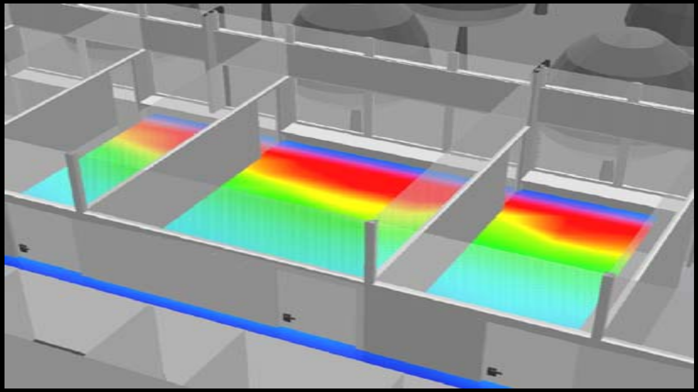
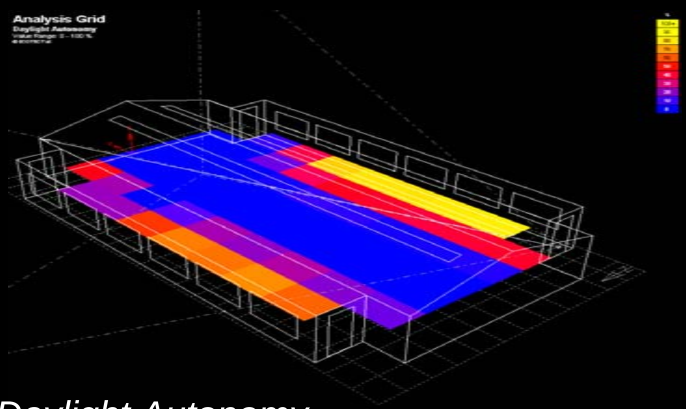
Natural Light in Design

Using simulation tools to explore realistic daylight-responsive solutions

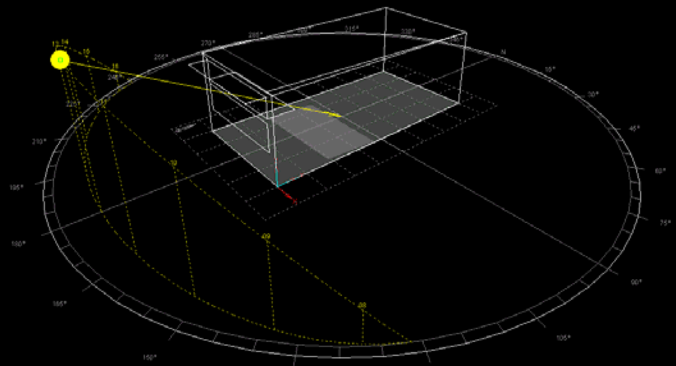


Daylight Factor

Visual Comfort



Daylight Autonomy



Avoidance of Direct Sunlight

Daysim

Christoph Reinhart, Ph.D.

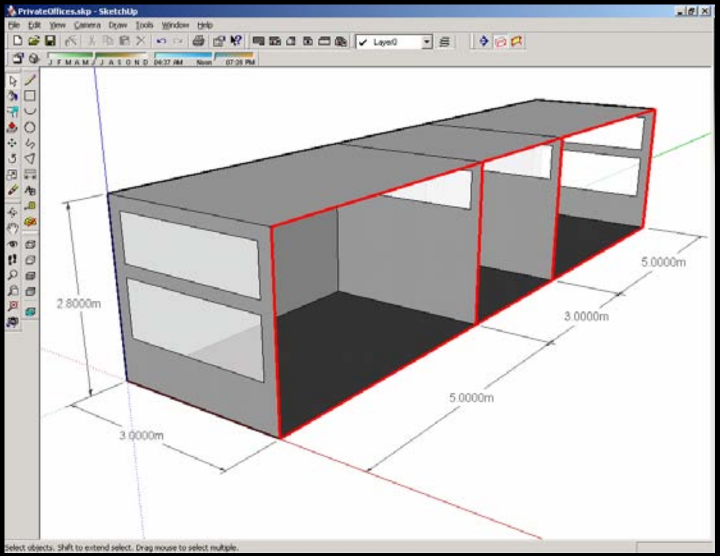
Overview – Daysim

Tuesday, Jan 24th 2006

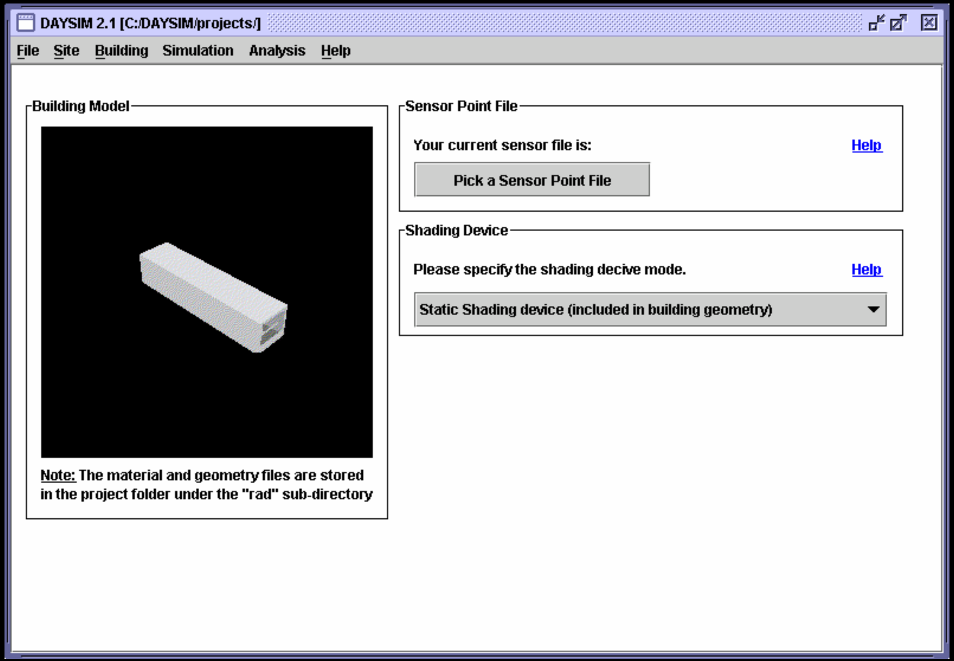
time slot	Content	instructor
Mon 9.30	Welcome, class introduction, design project (teams formed next morning)	MA, all
Mon 10.00	- General Introduction to daylighting (benefits, history, some case studies)	MA
Mon 10.30	- Introduction to Building Simulation (why simulations for architects, tools used in this course)	CR
Mon 11.00	coffee break	
Mon 11.15	- Photometry (definition, measurement, typical values, DF definition (MA) - Static Daylighting Metrics (context of LEED, selected results from NRC survey, DF & Solar Shading) (CR) - Daylight factor calculations: protractor method, LEED spreadsheet method, sky models CIE and Perez (MA) - Daylight factor simulation: design sky, split flux method in Ecotect (CR) ▪ Hands-on exercise: DF calculation in Ecotect (split flux) (CR) ▪ Hands-on exercise: solar shading module in Ecotect (CR) - Intro to Radiance (CR) ▪ Hands-on exercise: Radiance visualizations (CR) ▪ Hands-on exercise: DF calculation in Ecotect (Radiance) (CR)	MA, CR, all
Mon 13.00	lunch (on your own)	
Mon 14.00	- Climate Data (kind of data and measurement, weather files, E+ weather data directory) (MA) ▪ Hands-on exercise: weather tool in Ecotect (CR) - Overview on visual comfort (glare, contrast, requirements, health) (MA) - Dynamic Metrics & related tools (CR)	MA, CR, all
Mon 15.45	coffee break	
Mon 16.00	▪ Hands-on exercise: Daysim exercise from tutorial interrupted by discussions on: - Short time steps dynamics - Daylight Coefficients - User Behavior Model - Daylight Autonomy Results	all
Mon 17.00	▪ Hands-on exercise: students to repeat at DF, Solar Shading &DA analysis on their own	all
Mon 17.30	end of first day	

Required Work Flow

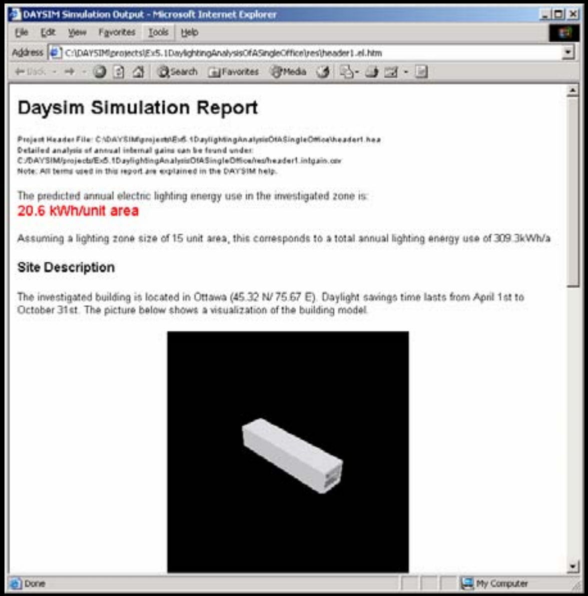
SketchUp/ AutoCAD/ Ecotect/ …



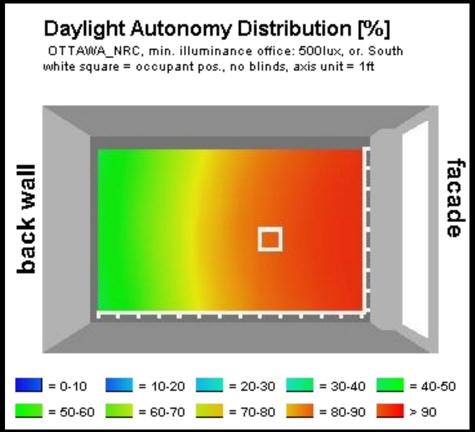
Daysim Analysis www.daysim.com



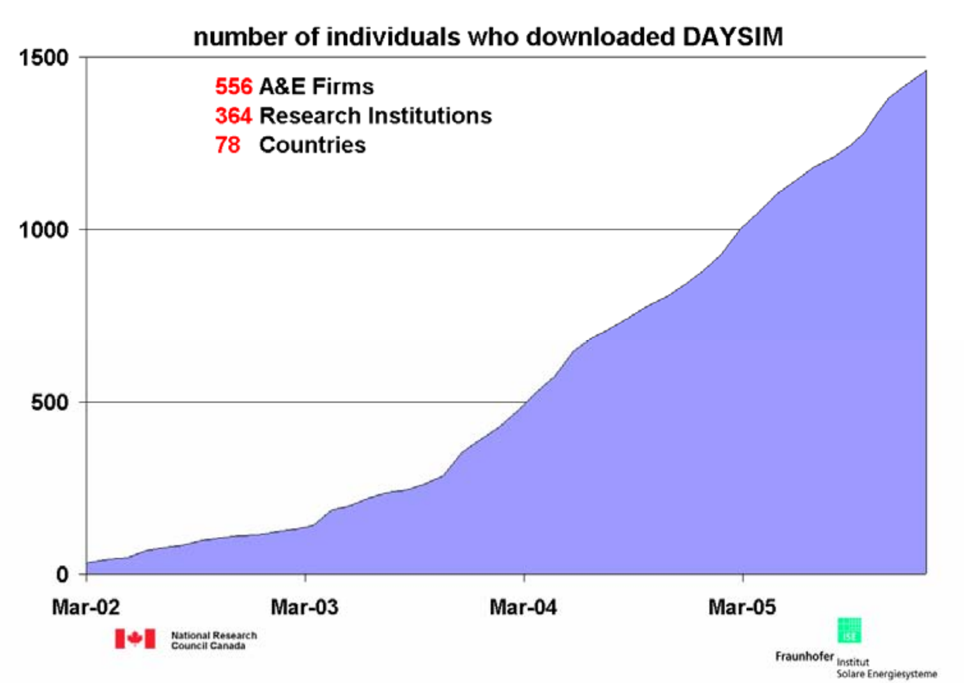
Daysim Simulation Report

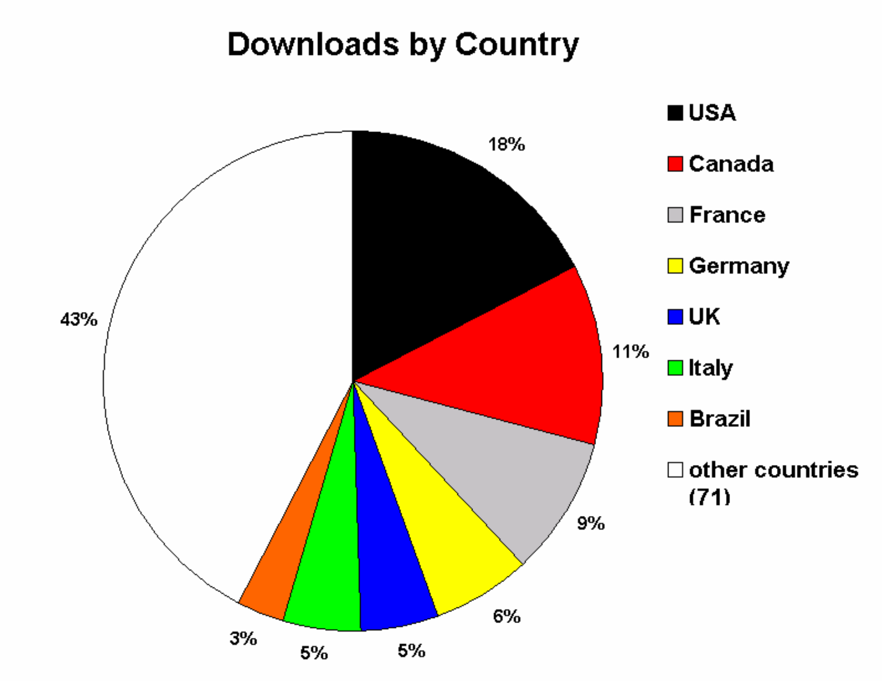


falsecolor maps



Daysim Statistics

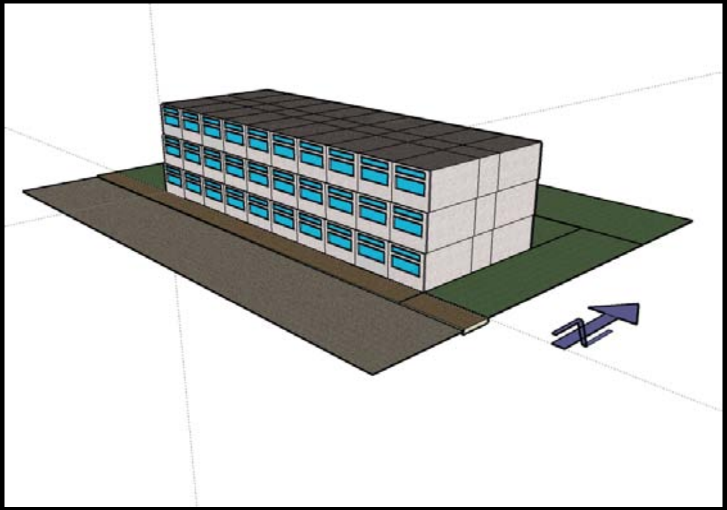




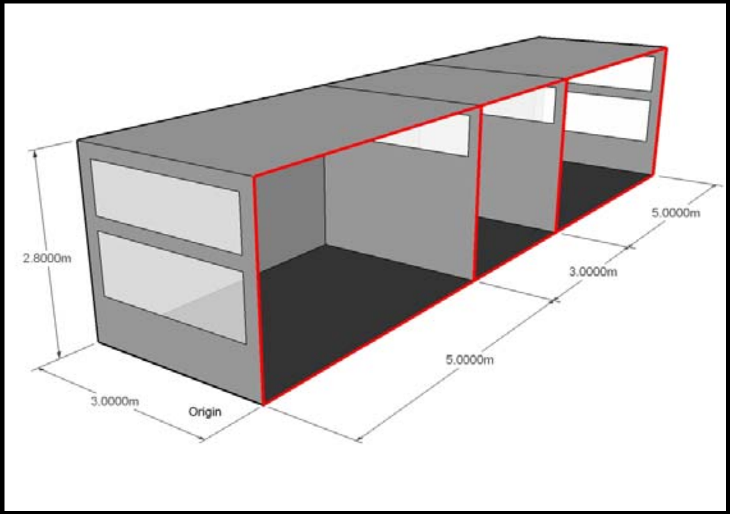
www.daysim.com

Example I – Single office

office building



three lighting zones

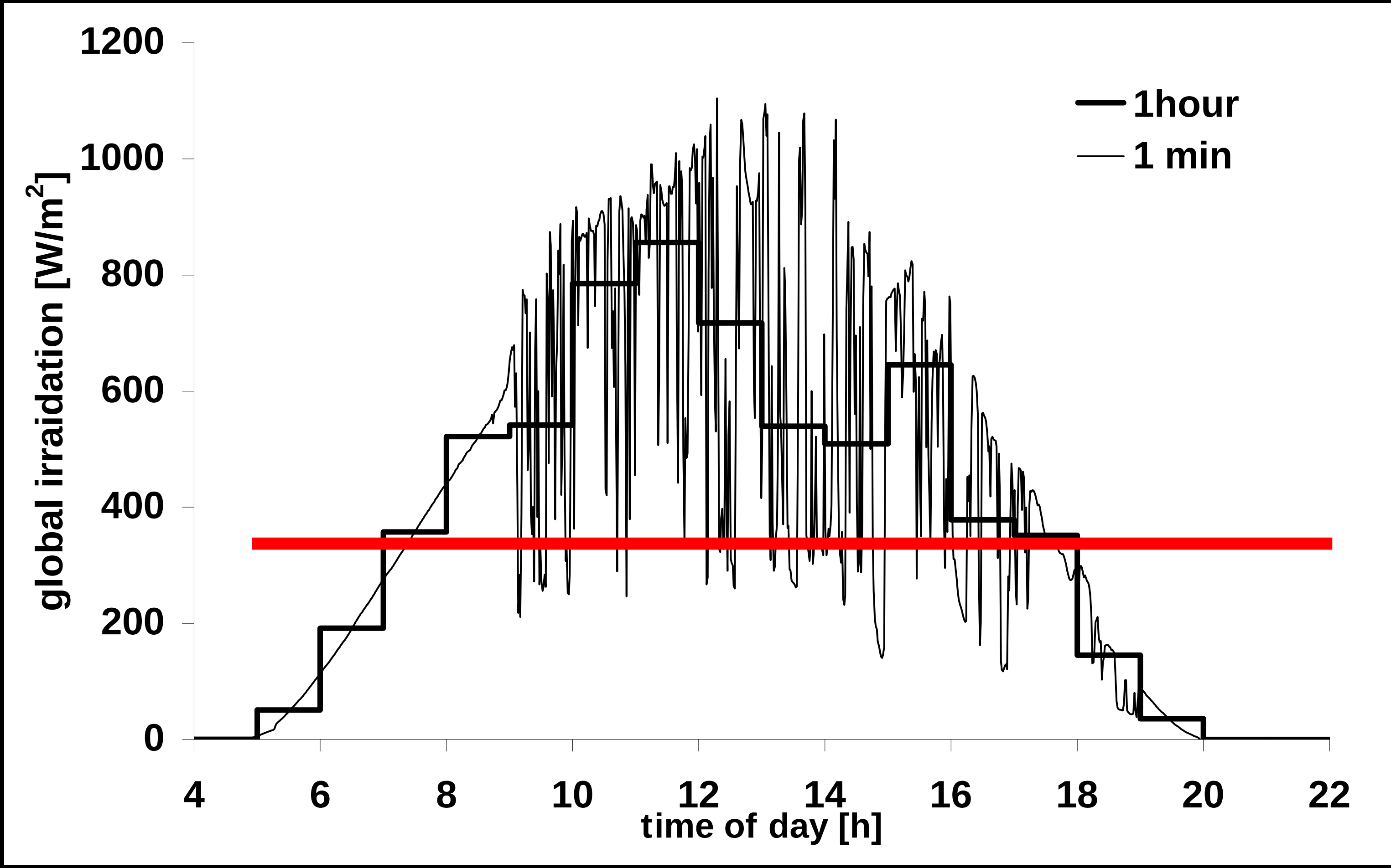


- Located in Ottawa Canada
- Taken from Daysim tutorial

Your Task: Use Daysim to:
- Calculate daylight autonomy and daylight factor in the offices
- Estimate the lighting energy savings from an occupancy sensor.

Short-Time-Step Dynamics of Daylight

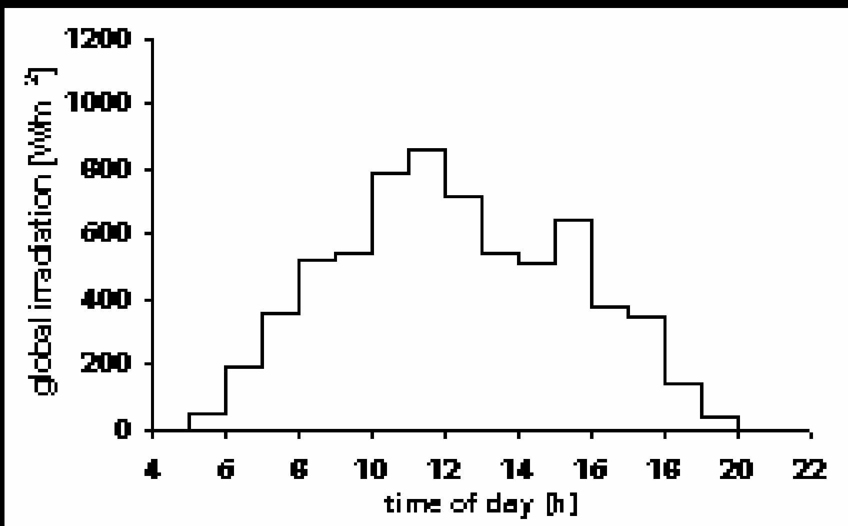
Solar Energy
Walkenhorst, Reinhart 2002

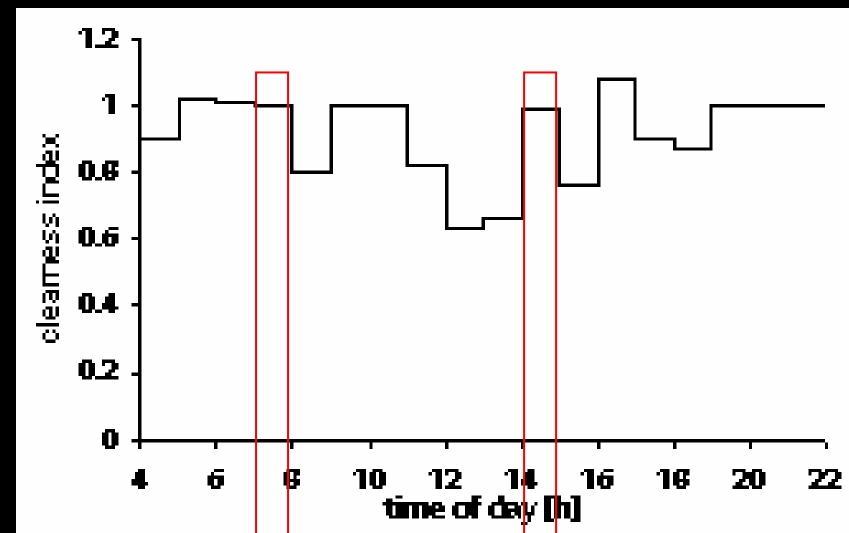


Development of a stochastic Model to calculate 1-min irradiances from 1 hour means

Short-Time-Step Dynamics of Daylight

Step 1: Normalization

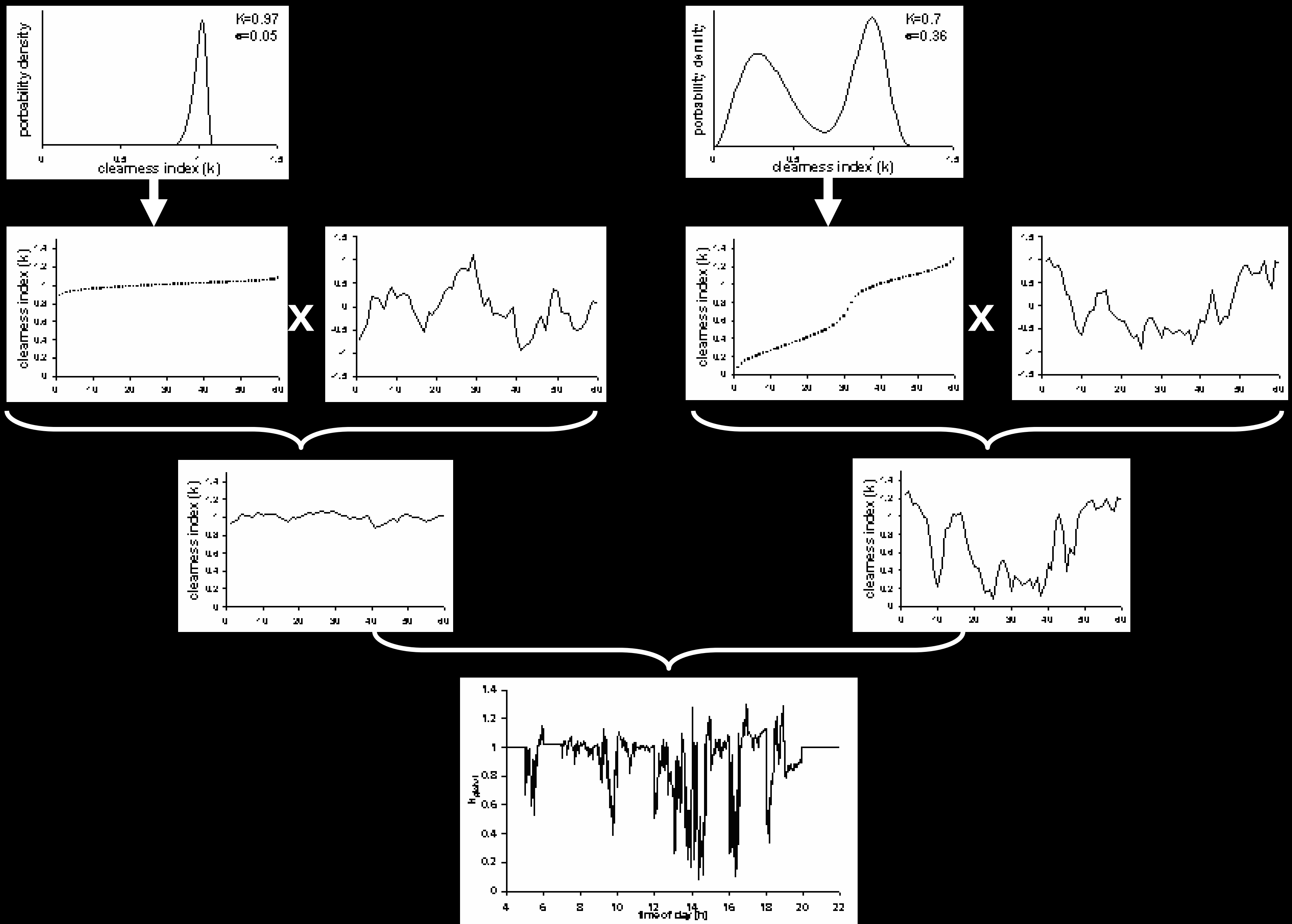




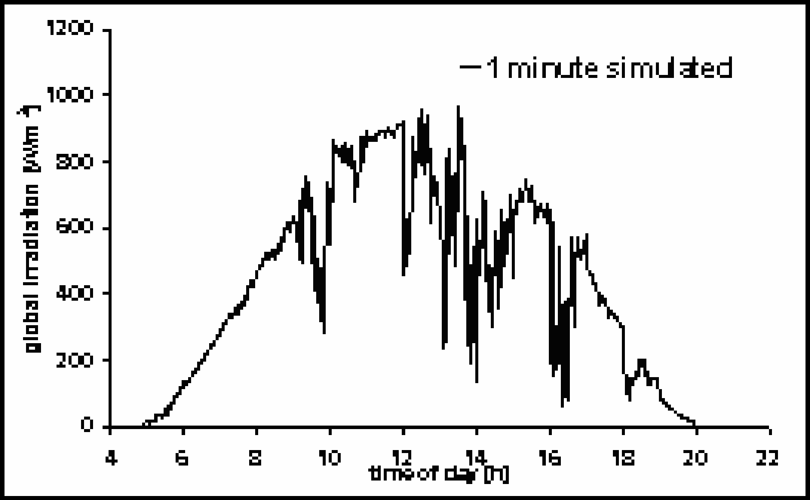
Interval 1 Interval 2

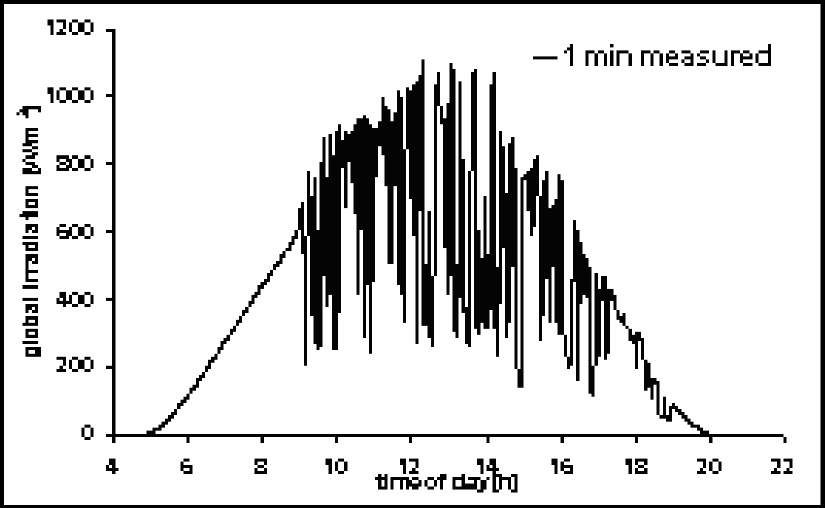
Short-Time-Step Dynamics of Daylight

7AM to 8 AM **2PM to 3PM**

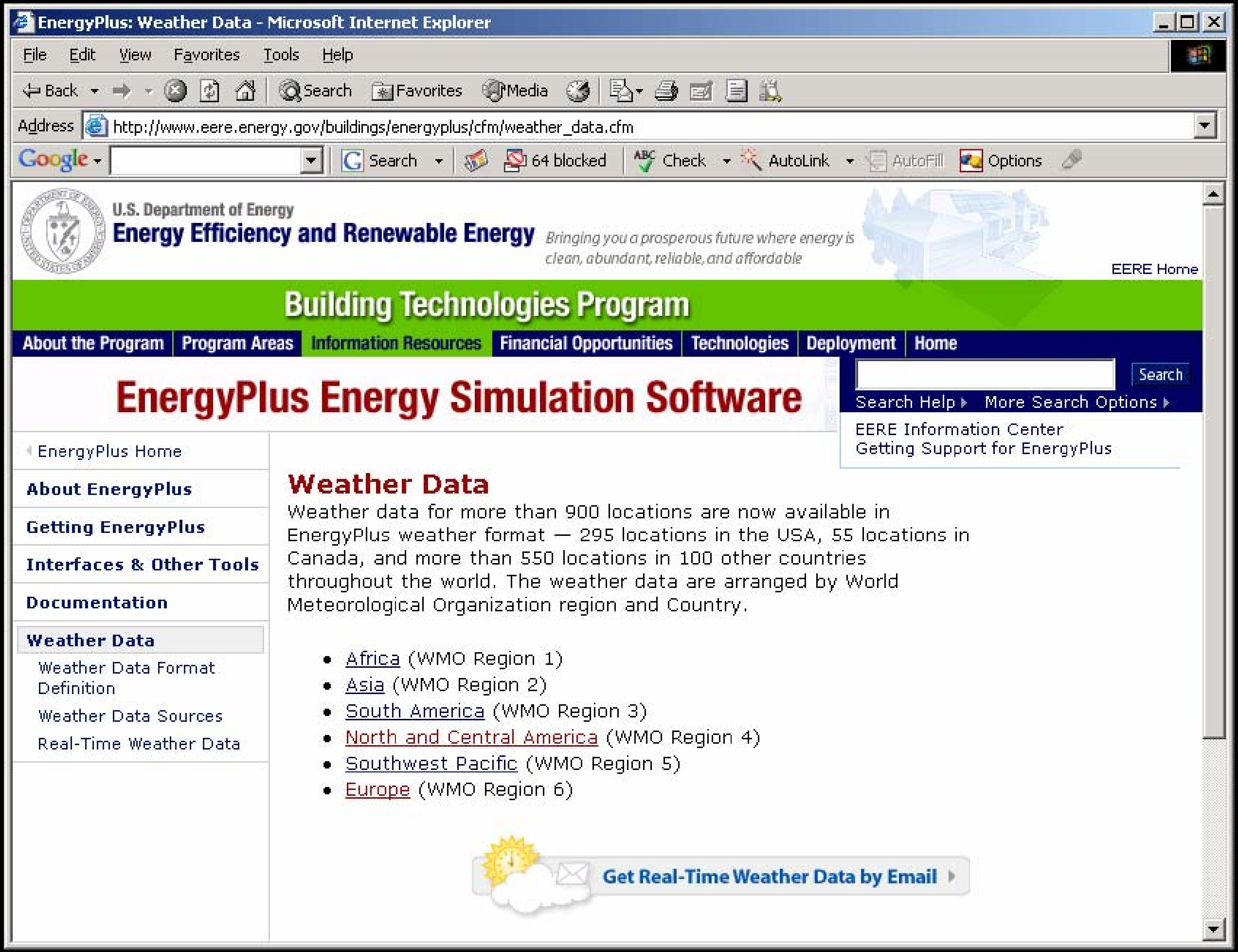


Short-Time-Step Dynamics of Daylight





Climate data – US DOE



http://www.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm

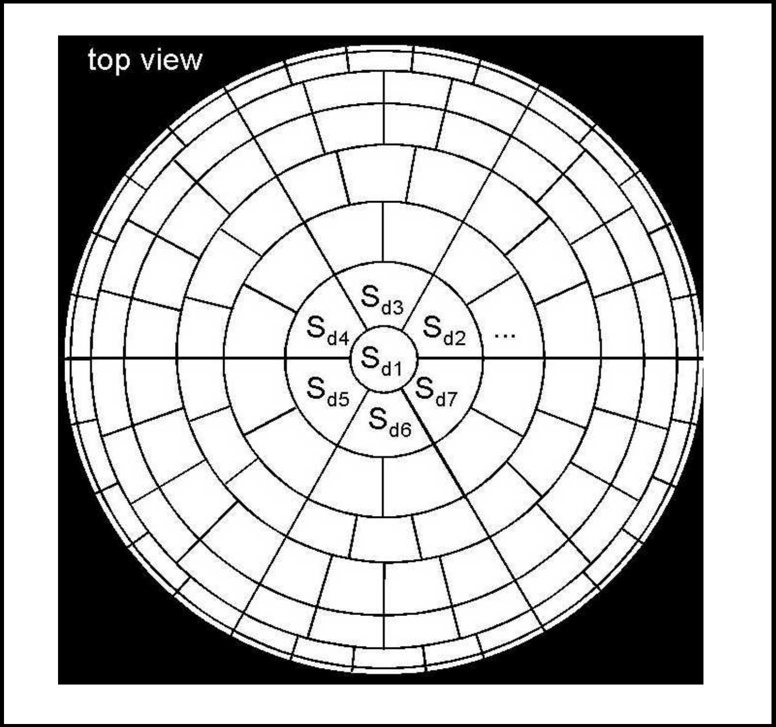
Dynamic Daylight Simulations (DDS)

- As opposed to static DL simulations that only consider one sky condition at a time, dynamic daylight simulations generate annual time series of interior illuminances and/or luminances.

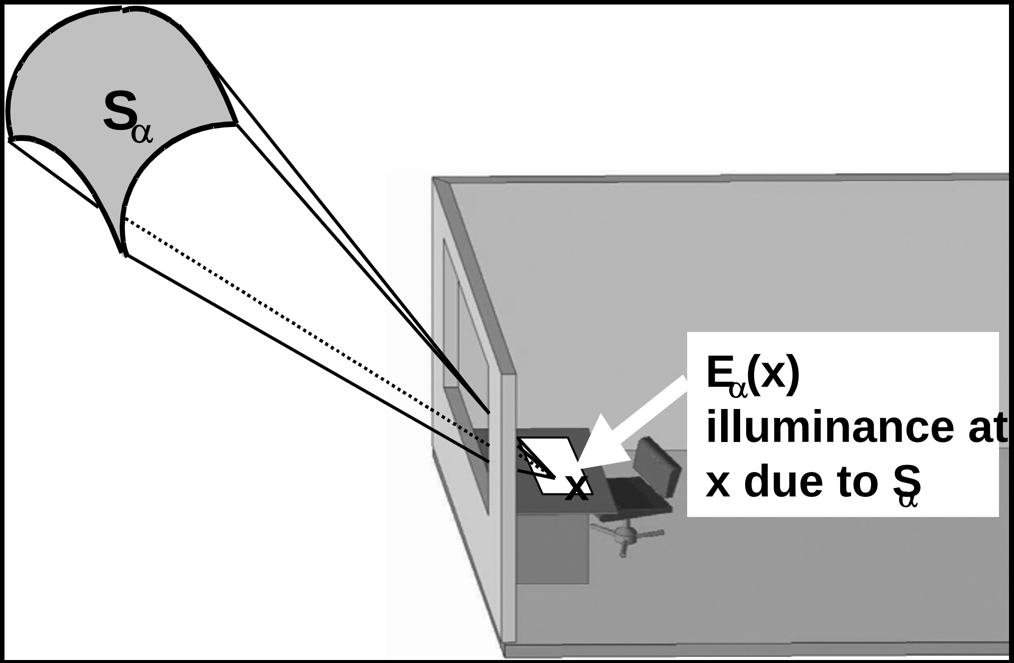
How?

Daylight Coefficients

(1) Division of the Celestial Hemisphere



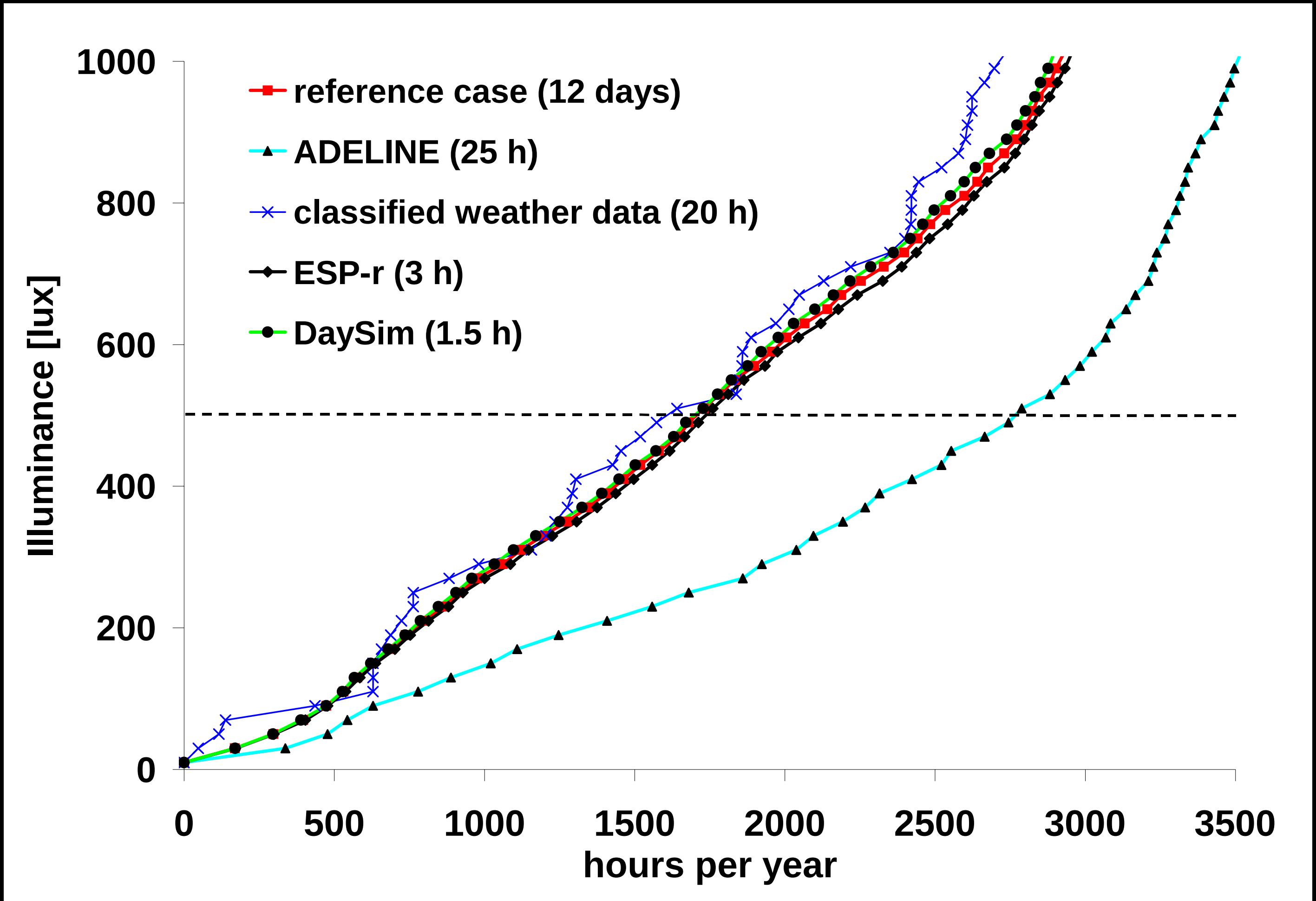
(2)Calculate Daylight Coefficients



Comparison of Dynamic Daylight Simulation Methods

Energy & Buildings

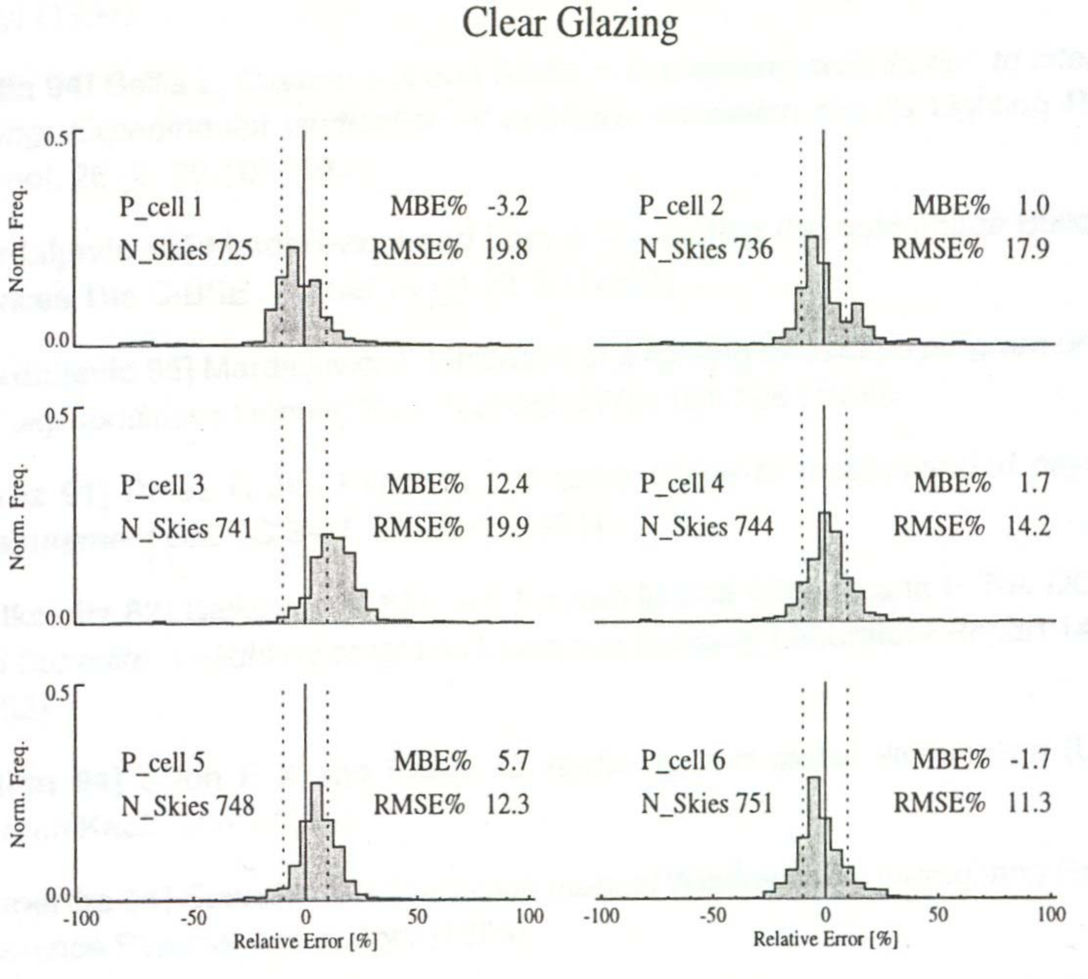
Reinhart & Herkel 2000



Daylight coefficients: "fastest method & most accurate dynamic method"

Validation II

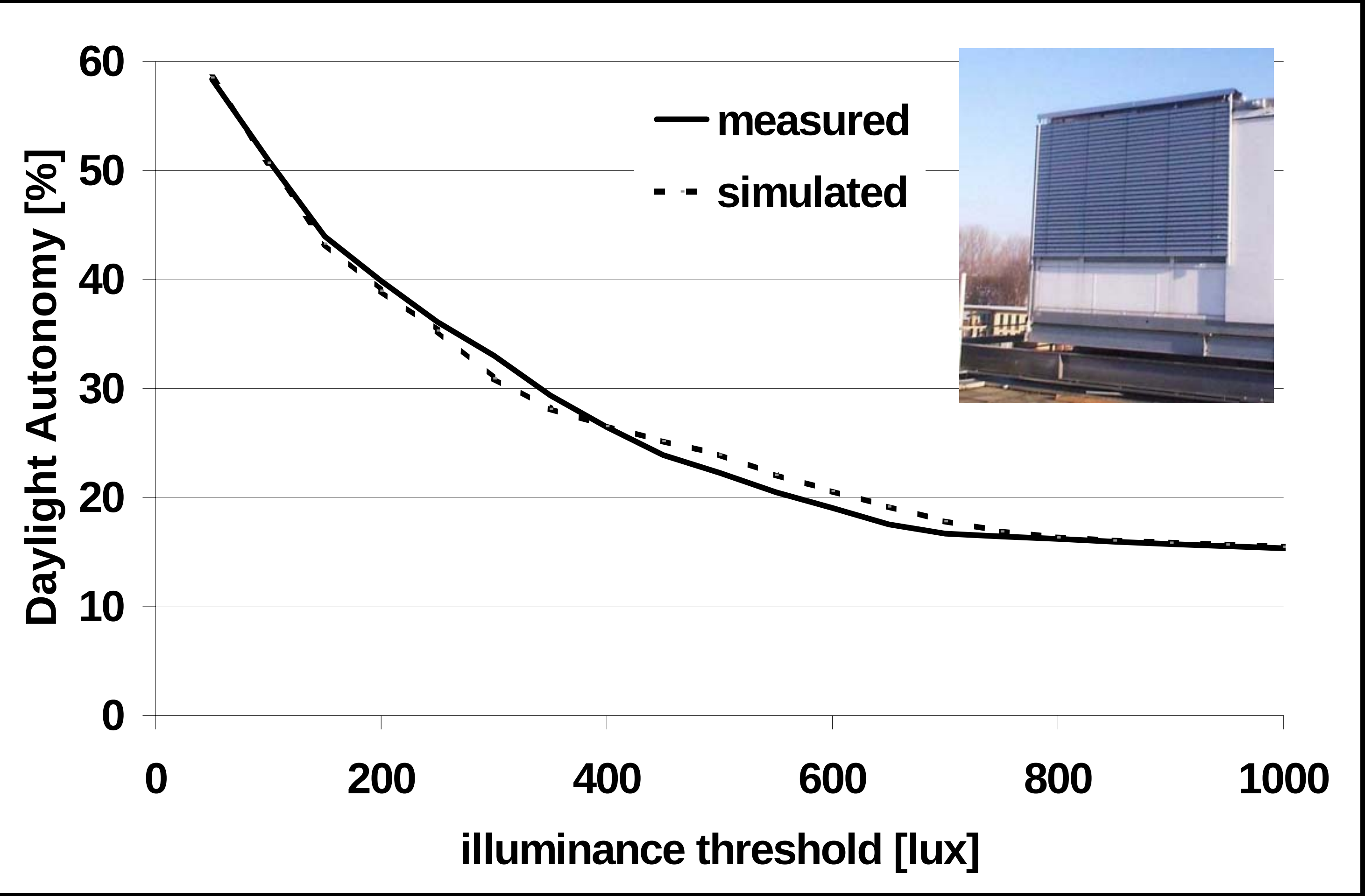
Light. Res. & Technology
Mardaljevic, 1997



Daylight Coefficients: “same accuracy as standard Radiance”

Validation III - Venetian Blinds

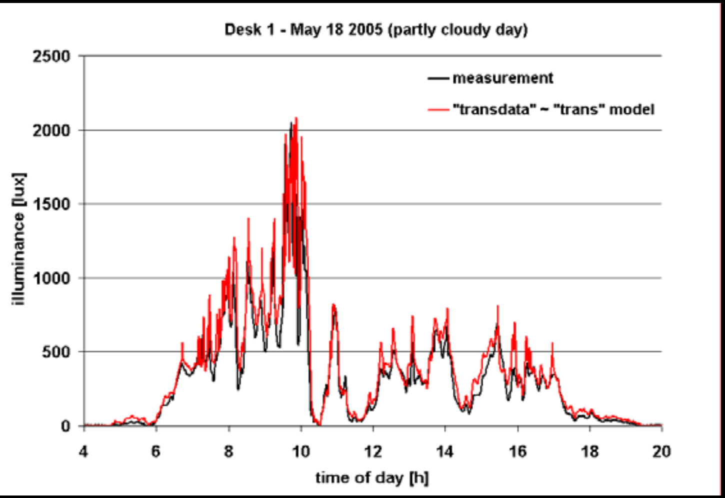
Energy & Buildings
Reinhart, Walkenhorst 2001

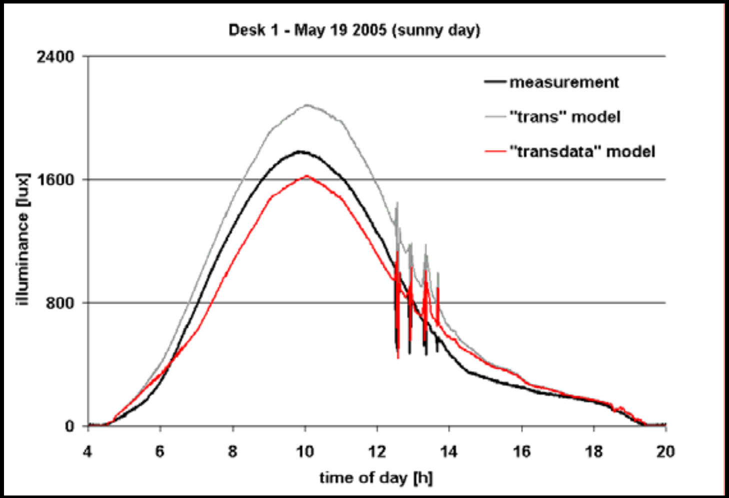


RADIANCE-based simulation approach

Validation IV - Translucent Panel

Energy & Buildings
Reinhart, Andersen 2005 (in review)





Need for a quality controlled material database.

Summary

- Radiance combined with daylight coefficients and Perez sky model can efficiently and reliable calculate DDS. (validated approach – several independent studies – resulting accuracy ~20% rel. error – comparable to static simulations)

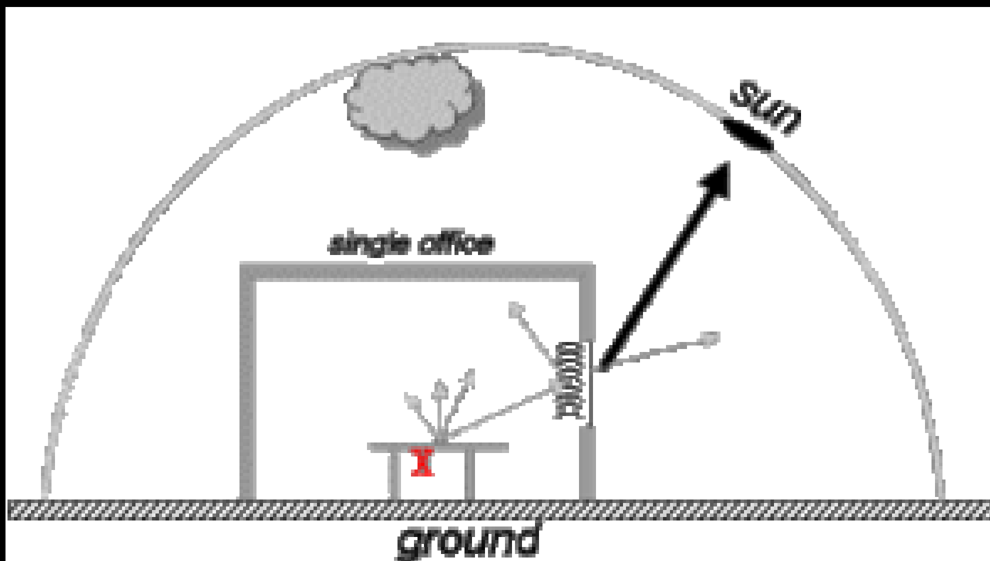
Radiance Simulation Parameters I

ambient bounces	ambient division	ambient sampling	ambient accuracy	ambient resolution	direct threshold	direct sampling
5	1000	20	0.1	300	0	0

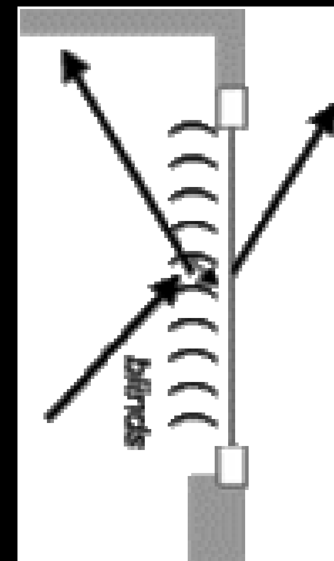
$$\text{simulation resolution} = \frac{\text{max scene dimensions x ambient accuracy}}{\text{ambient resolution}}$$

Example: $\frac{100\text{m} \times 0.1}{300}$ **~ 3cm (window mullion)**

Radiance Simulation Parameters II



Higher raytraing parameters for blinds



raytracing detail

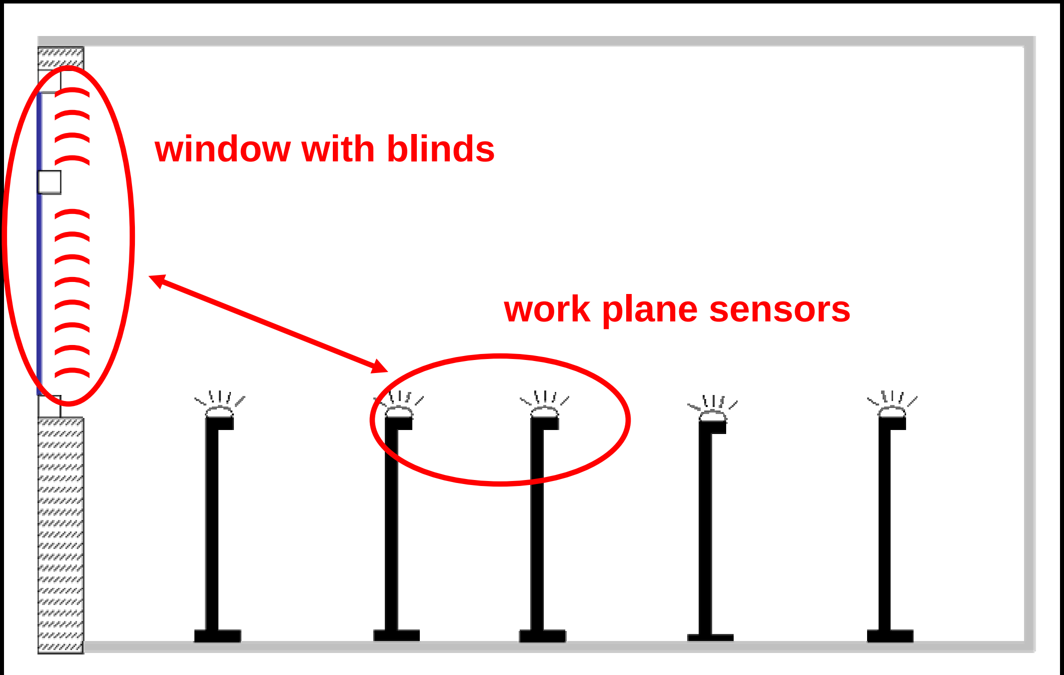
ambient bounces	ambient division	ambient sampling	ambient accuracy	ambient resolution	direct threshold	direct sampling
7	1500	100	0.1	300	0	0

aa and ar:

$$\frac{\max imum\ scene\ \dim ension\ x\ ambient\ accuracy}{ambient\ resolution}$$

10m x 0.1 /300~0.3cm (blind slat)

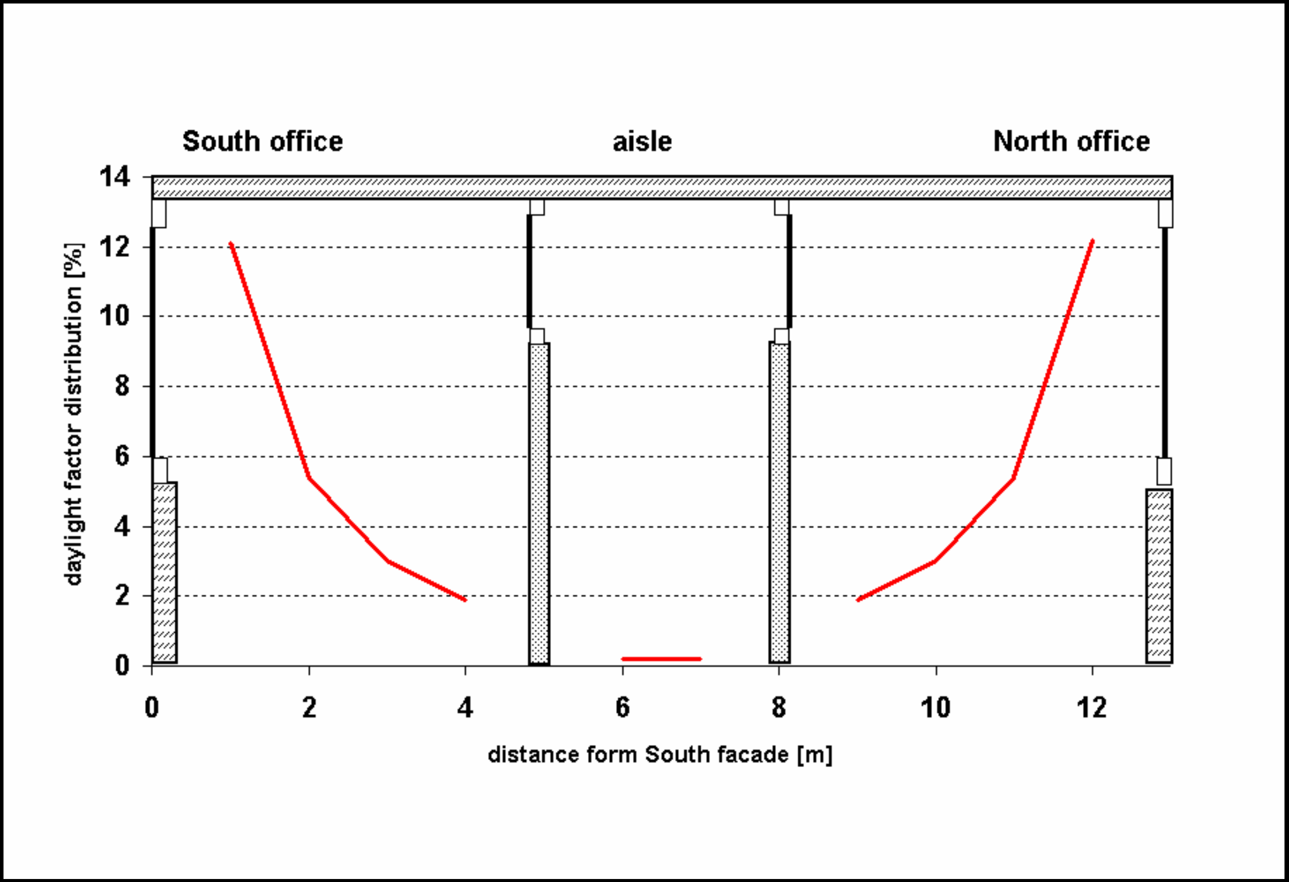
Manual blind control model



- Daysim: active (energy conscious) or passive user
- Associate work plan sensor with window
- Note: this step requires to couple individual sensors together.
- Benefit: Direct comparison between daylighting concepts with and without movable and/or fixed shading devices

Example I – Single office

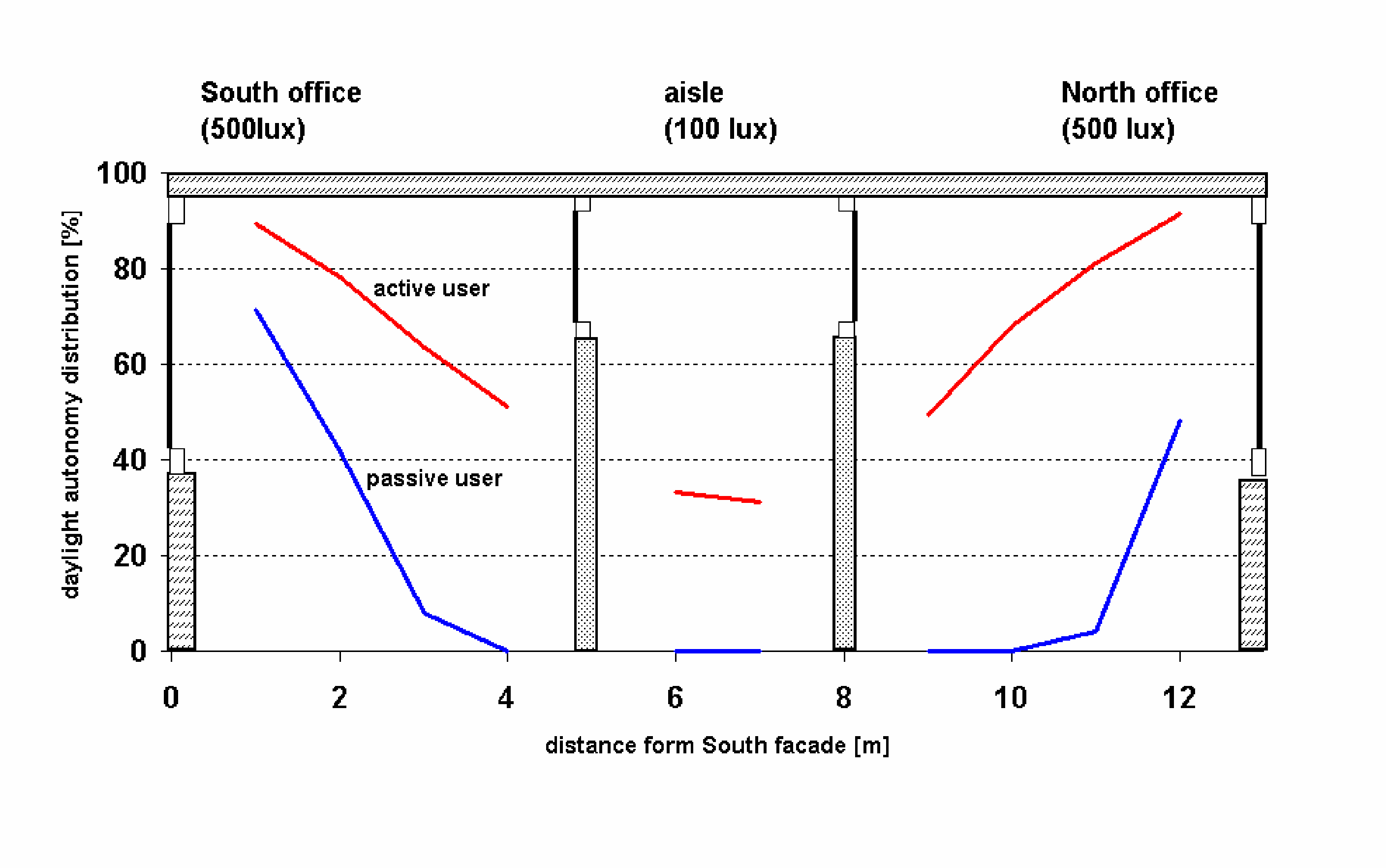
Daylight factor simulation



〈 same results for North and South offices
〈 no daylight on the central aisle

Example I – Single office

Daylight Autonomy simulation



- ample amount of daylight in both offices
- up to 30% DA on aisle => on/off switch with timer

Lighting Controls I

wall mounted

ceiling mounted

- Occupacy Sensors
  - IR: detect changing heat fields (work best when its cool inside)
  - UV: detects changing movements (cannot differentiate between a fax machine and a person)
  - wall, celing mounted, integrated in luminaire
  - stand alone, connected to BAS

Lighting Controls II

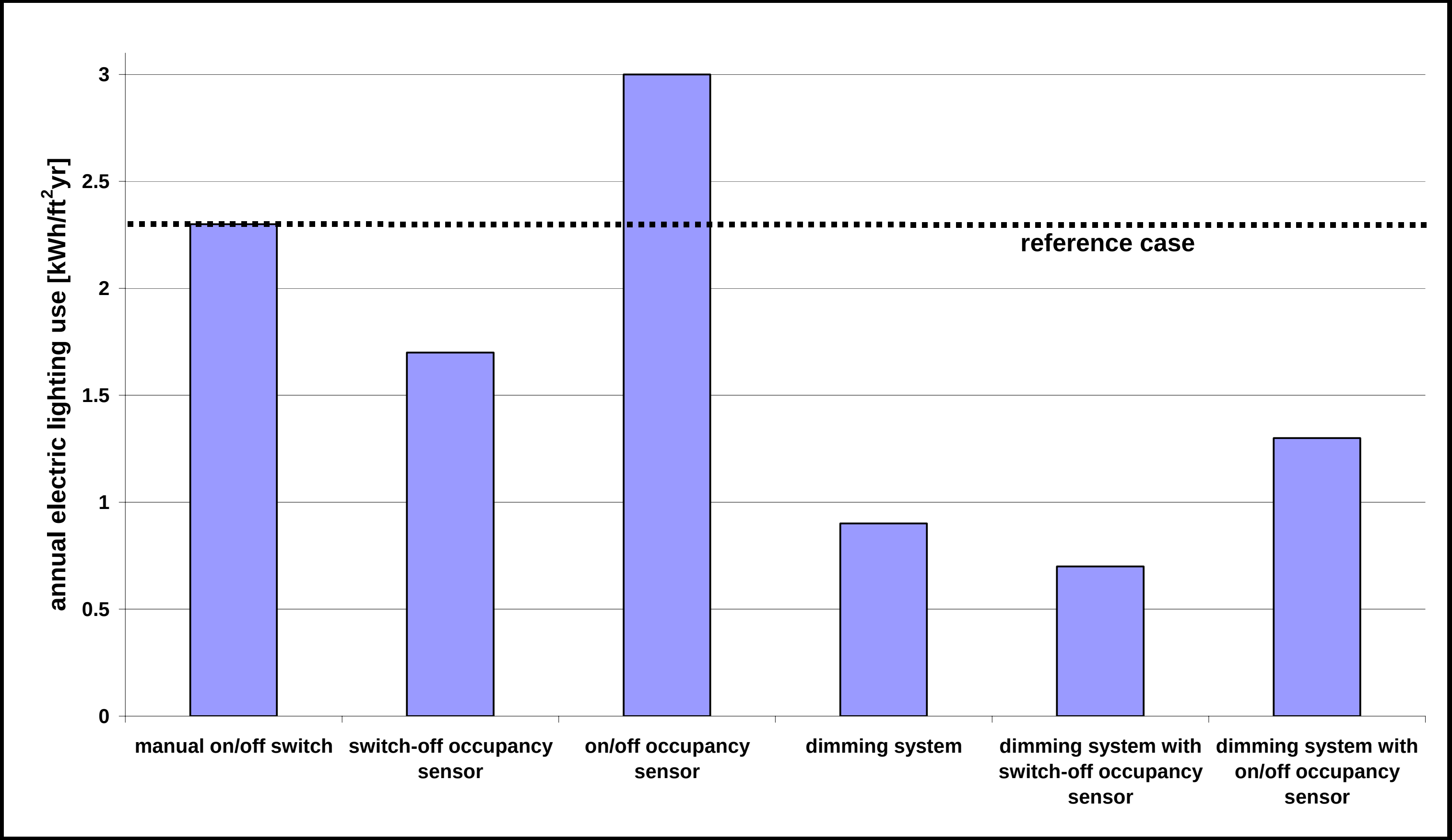
- **Photocell-controlled Dimming with Occupancy Sensor**

Photocell.

Occupancy sensor.

Example I – Single office

Electric Lighting Use in South facing Office



- absolute comparison of different control strategies
- reference case is manual on/off switch with venetian blinds

Example II - Museum Lighting

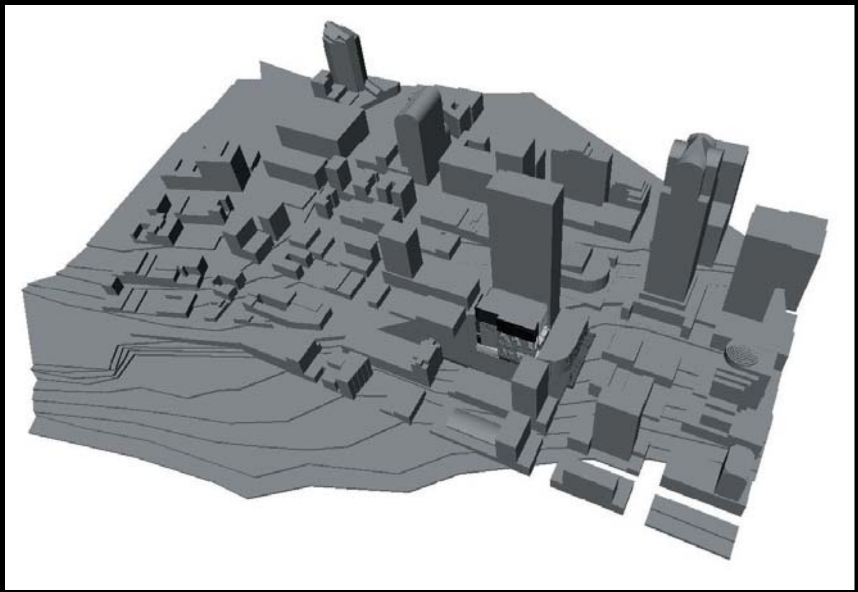
CIE TC3-22 ‘Museum lighting and protection against radiation damage’

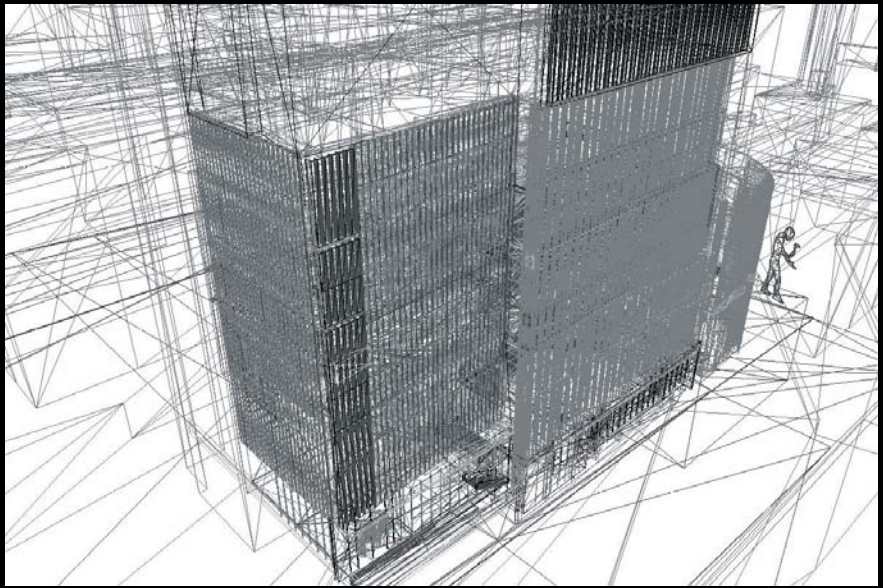
category	material classification	example of materials	lighting illuminance	limiting annual exposure
I	insensitive	metal, stone, glass, ceramic	no limit	no limit
II	low sensitivity	canvases, frescos, wood, leather	200 lux	600 000 lux h /yr
III	medium sensitivity	watercolor, pastel, various paper	50 lux	150 000 lux h/yr
IV	high sensitivity	silk, newspaper, sensitive pigments	50 lux	15 000 lux h/yr

Example II: Seattle Art Museum - Arup Lighting using Daysim

3D model of site and building

ARUP Lighting





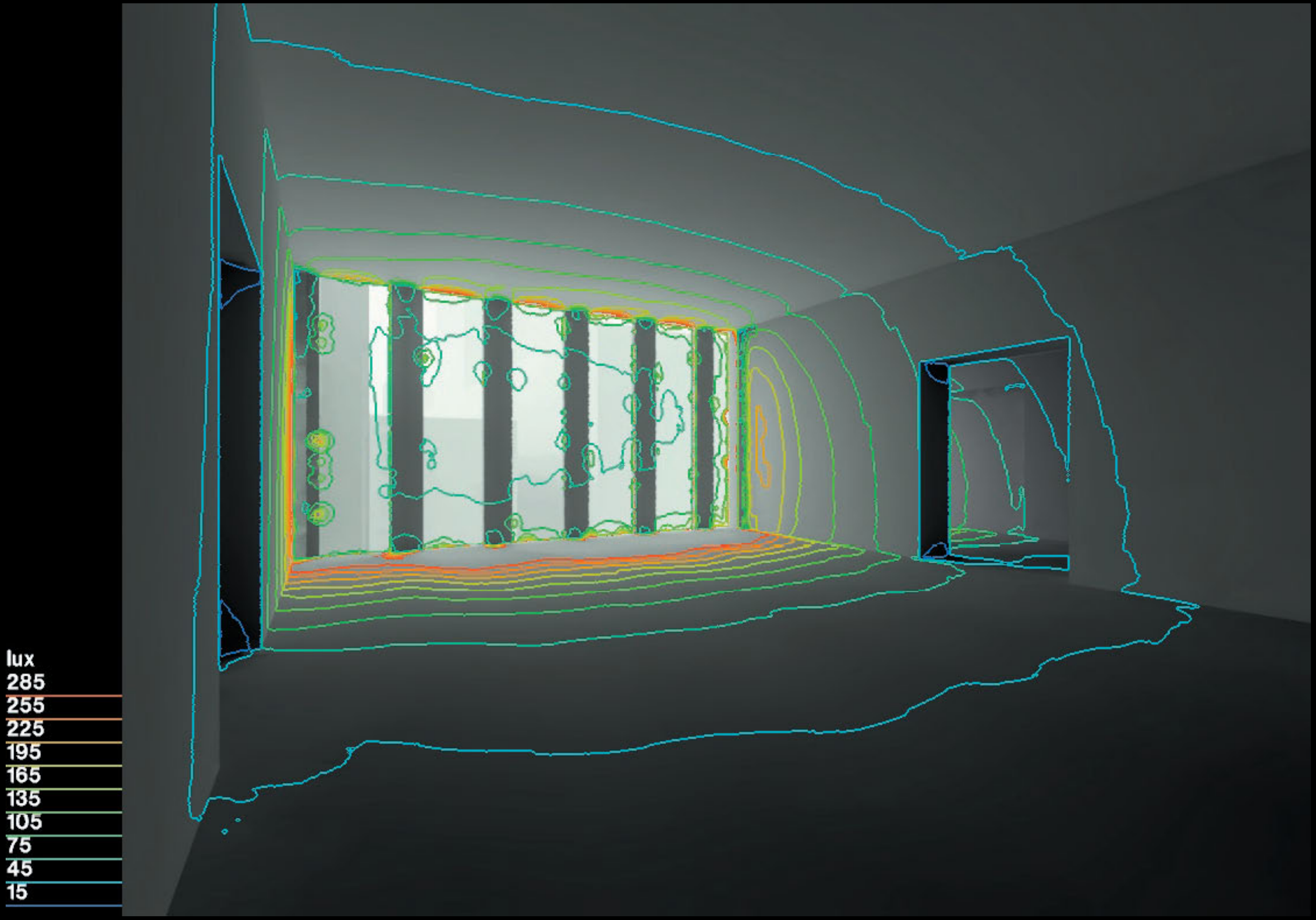
Source: Matt Franks 'Daylighting in Museum's

http://irc.nrc-cnrc.gc.ca/ie/light/RadianceWorkshop2005/PDF/Franks_ArupCaseStudies.pdf

Example II - Seattle Art Museum - Arup Lighting using Daysim

Sidelit Gallery

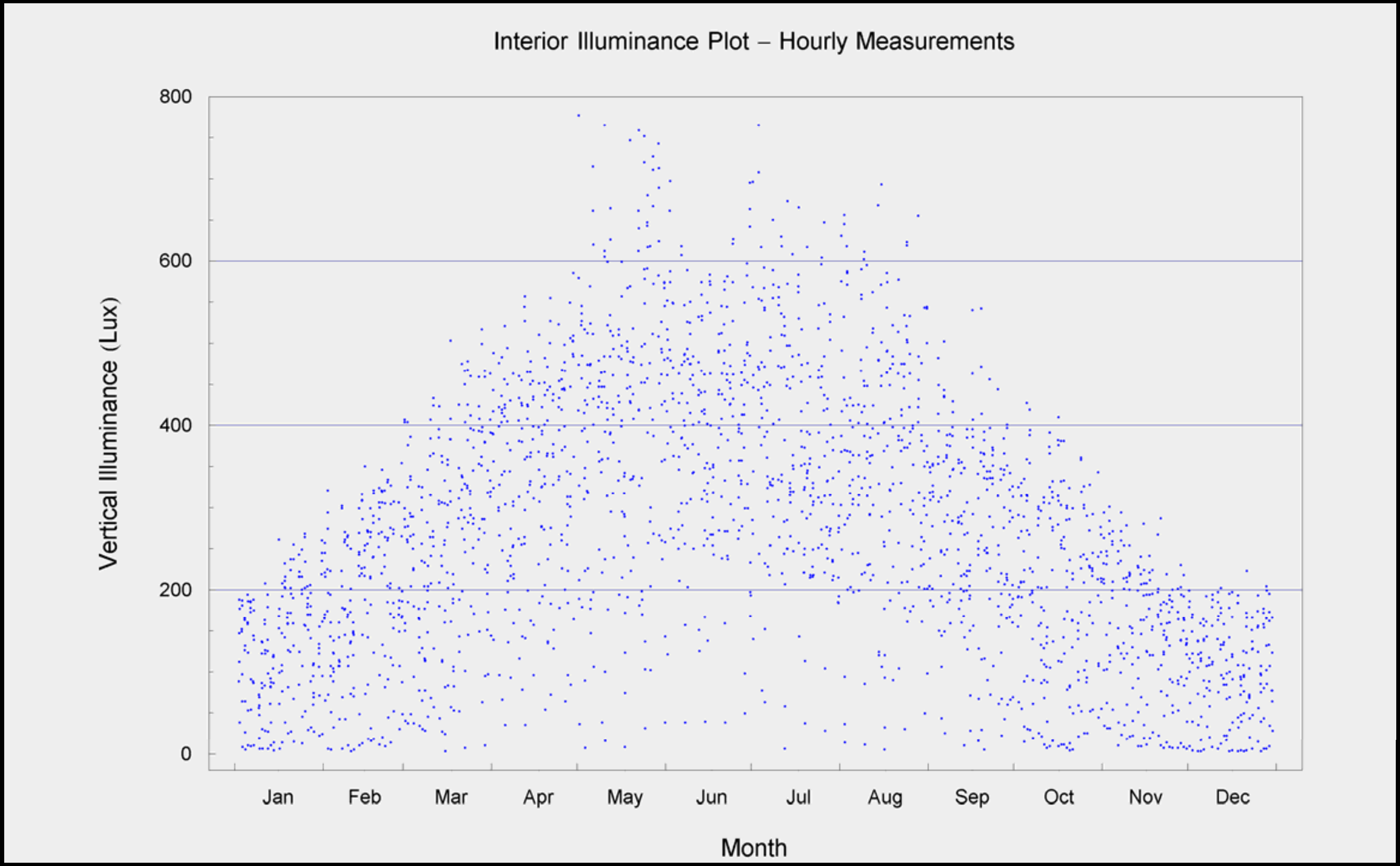
ARUP Lighting



Example II - Seattle Art Museum - Arup Lighting using Daysim

Museum Open Hours - 1,500,000+ lux-hours

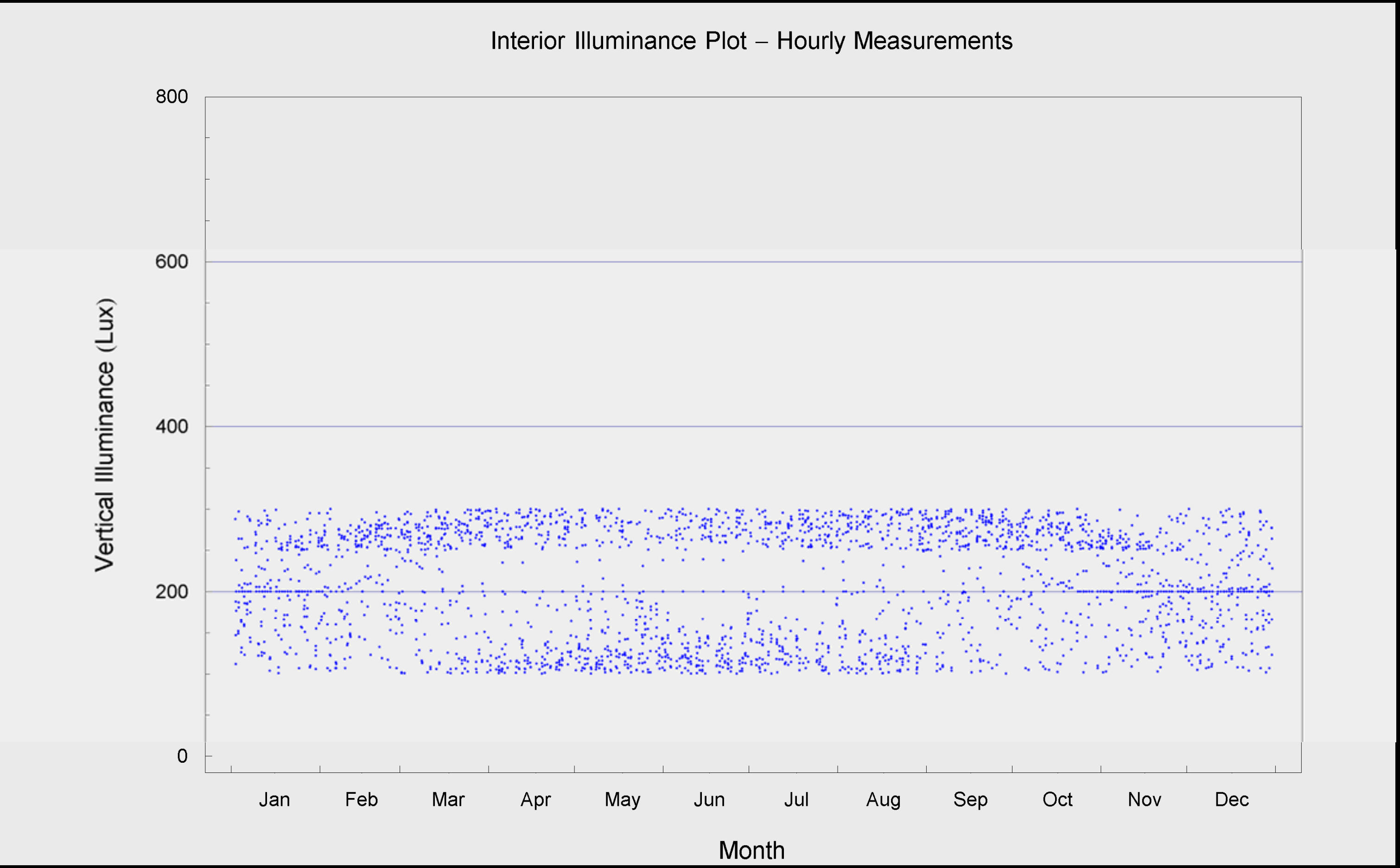
ARUP Lighting



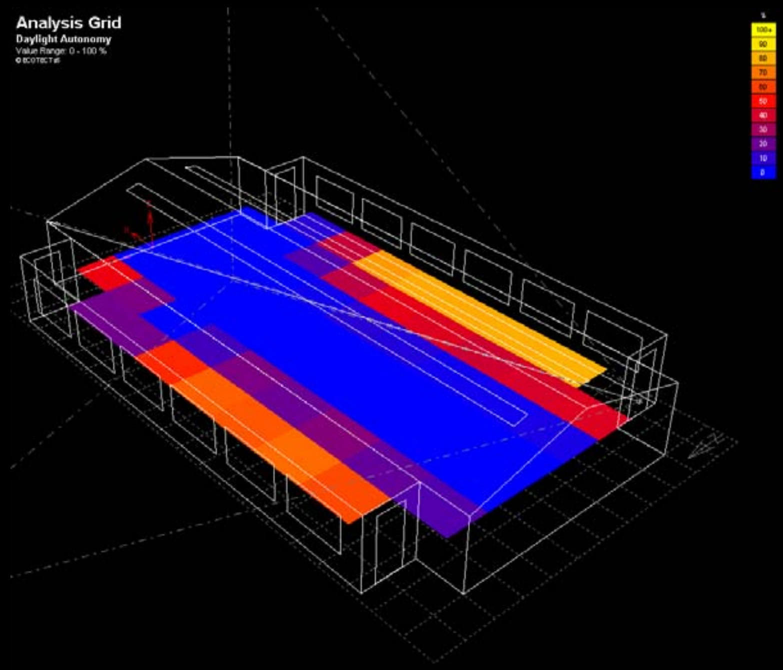
Example II - Seattle Art Museum - Arup Lighting using Daysim

Automatic Shading + Switching - 555,000 lh

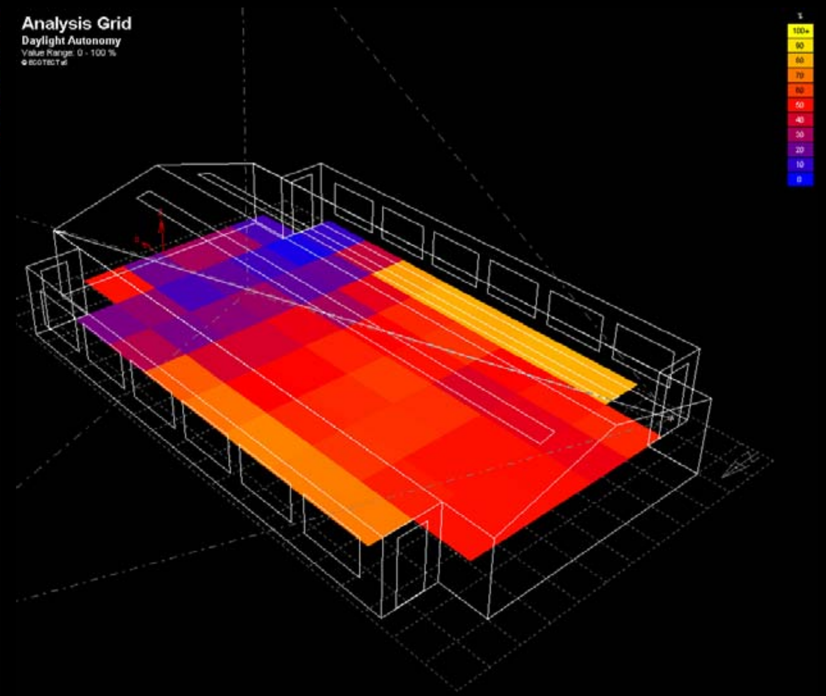
ARUP Lighting



Example III - Classroom



No skylights.



Skylights.