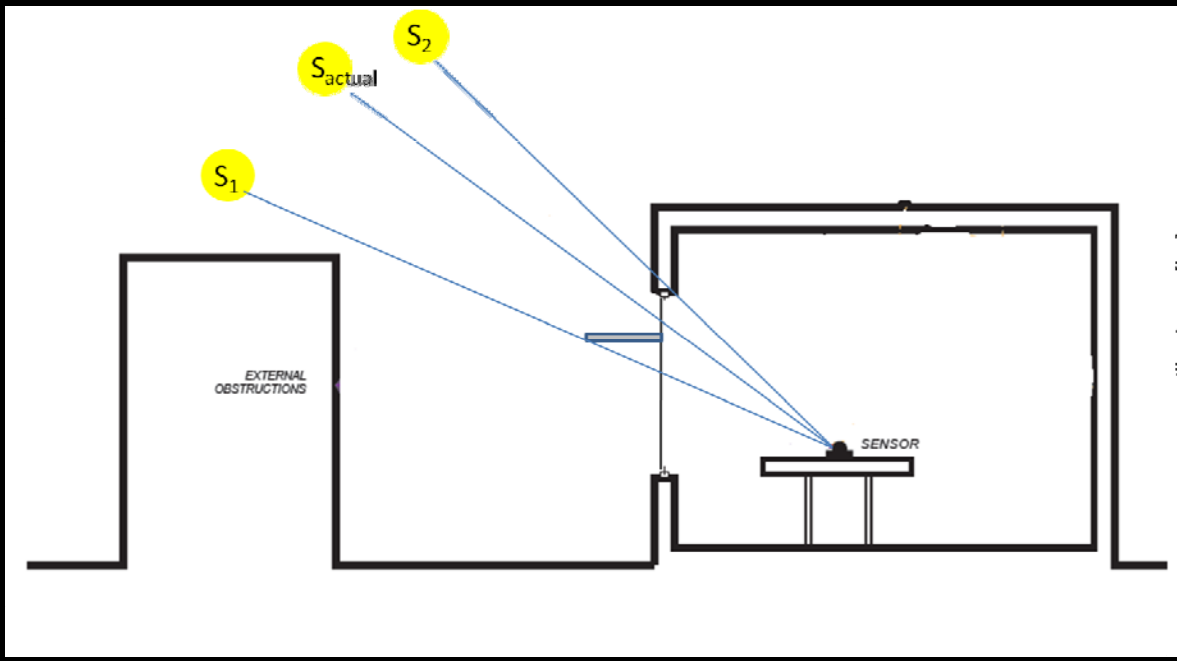
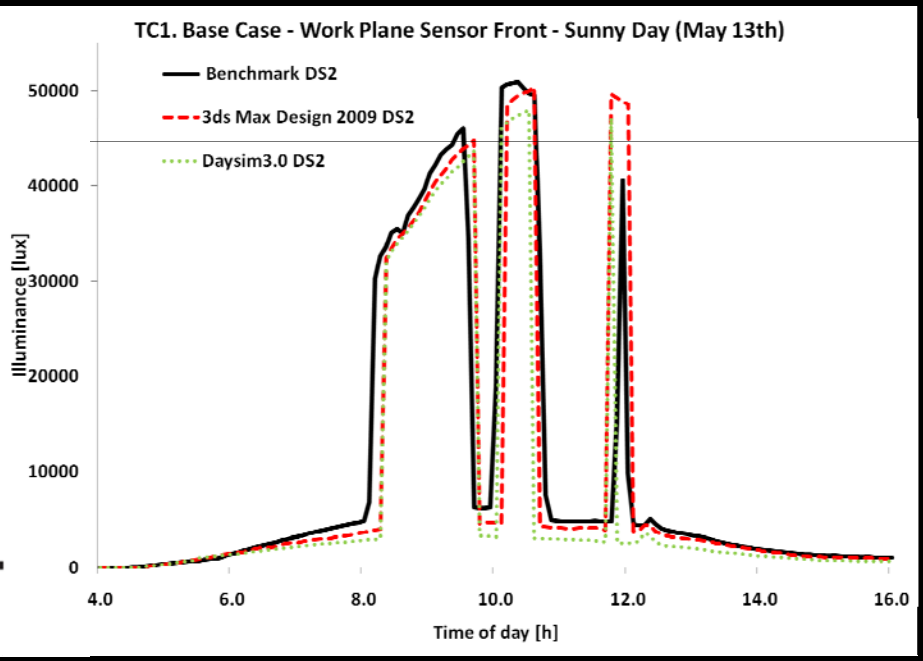
Daysim 3.0 – DDS, New Validation Study and Annual Daylight Glare Probability Schedules (Part 1)



New DC file format for Daysim 3.0



Daysim 3.0/3ds Max Design 2009 Validation

Christoph Reinhart and Jan Wienold

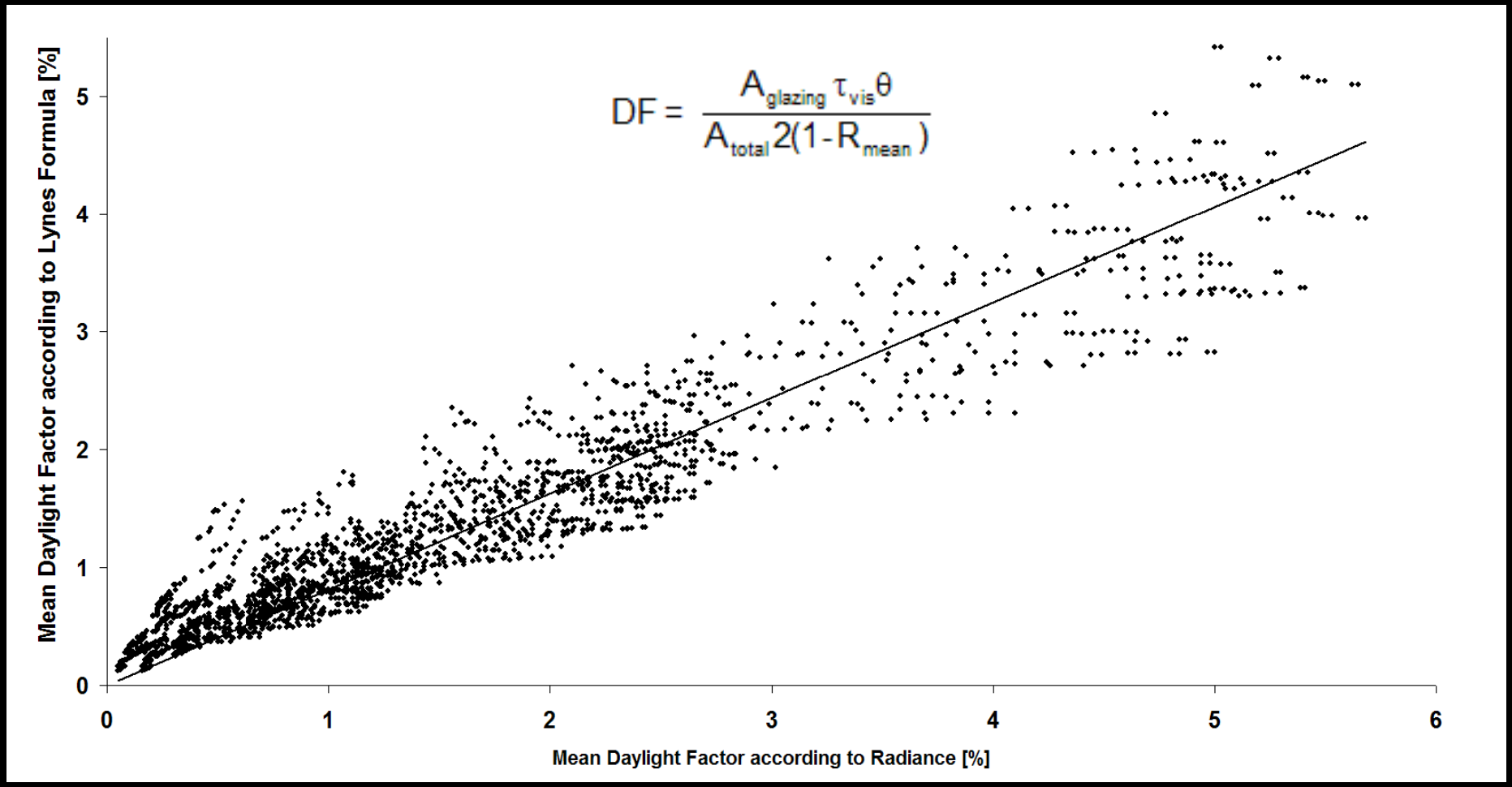
8th International Radiance Workshop

Oct 23 2009

Fraunhofer ISE

Harvard Design School

‘Validation’ of Daylight Factor Formula

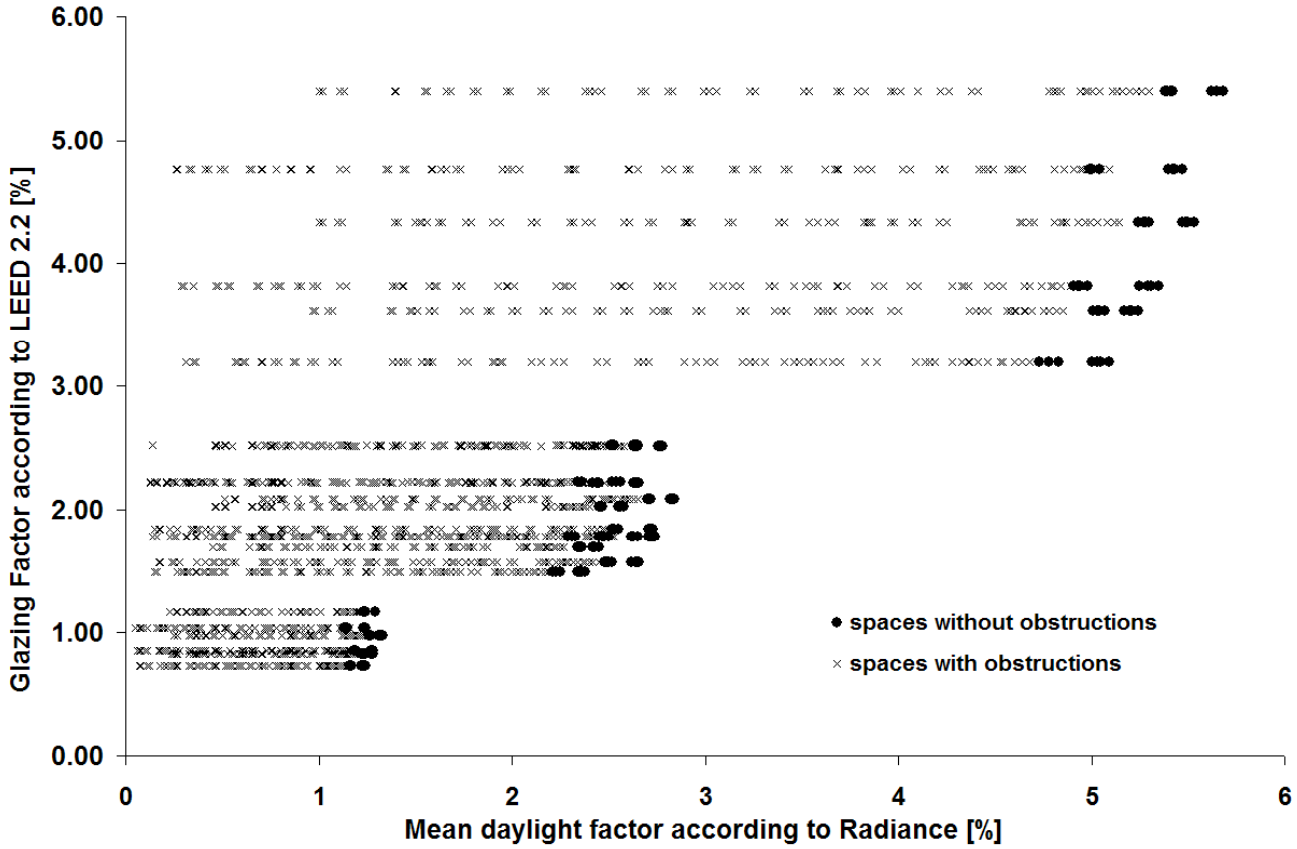


- Comparison to Radiance simulations for 2304 spaces.
- Quality control for simulation.s

Paper: www.gsd.harvard.edu/people/faculty/reinhart/documents/DiffuseDaylightingDesignSequenceInLRT.pdf

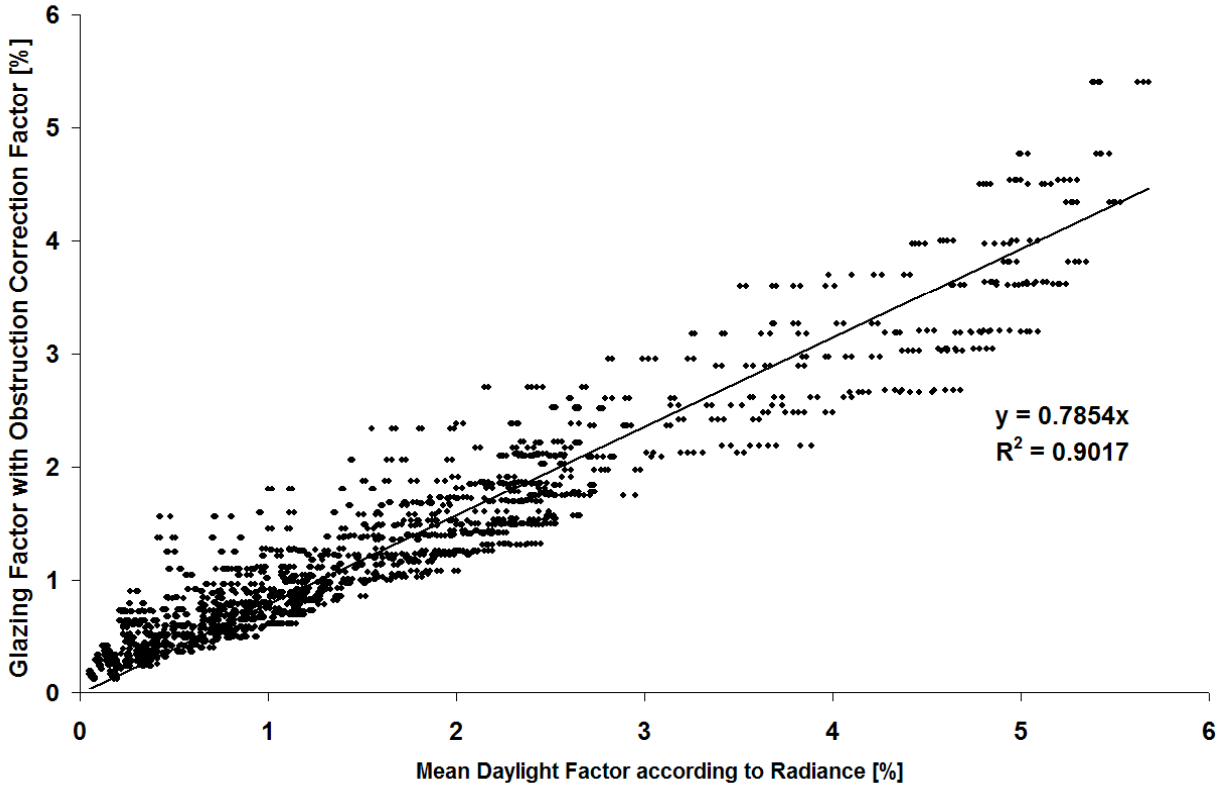
LEED 2.2 Glazing Factor Formula

$$\text{Glazing Factor} = \frac{A_{glazing}}{A_{floor}} \cdot \text{Window Geometry Factor} \cdot \frac{\tau_{vis\,actual}}{\tau_{vis\,reference}} \cdot \text{Window Height Factor}$$



LEED 2.2 Glazing Factor Formula (enhanced)

$$\text{Glazing Factor} = \frac{A_{glazing}}{A_{floor}} \cdot \text{Window Geometry Factor} \cdot \frac{\tau_{vis\,actual}}{\tau_{vis\,reference}} \cdot \text{Window Height Factor} \cdot \frac{\theta}{90°}$$



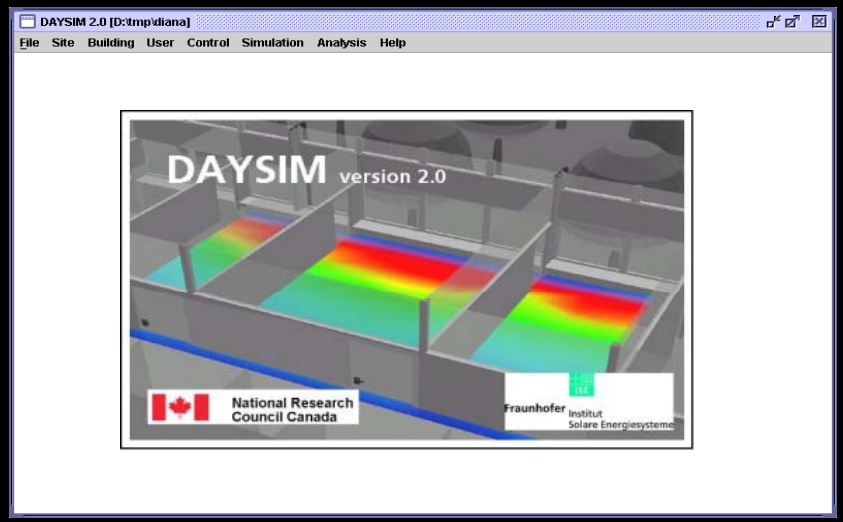
Daysim ...

- is a validated RADIANCE- based daylighting analysis software
- features a rudimentary JAVA graphical user interface with online help and a detailed tutorial
- calculates annual illuminance profiles and lighting energy use
- features an user behavior model that predicts occupant use of personal lighting and shading controls
- runs under Windows ™ and Linux OS
- can be coupled with thermal simulation ESP-r, TRNSYS

Simulation Input:

3dim CAD building model

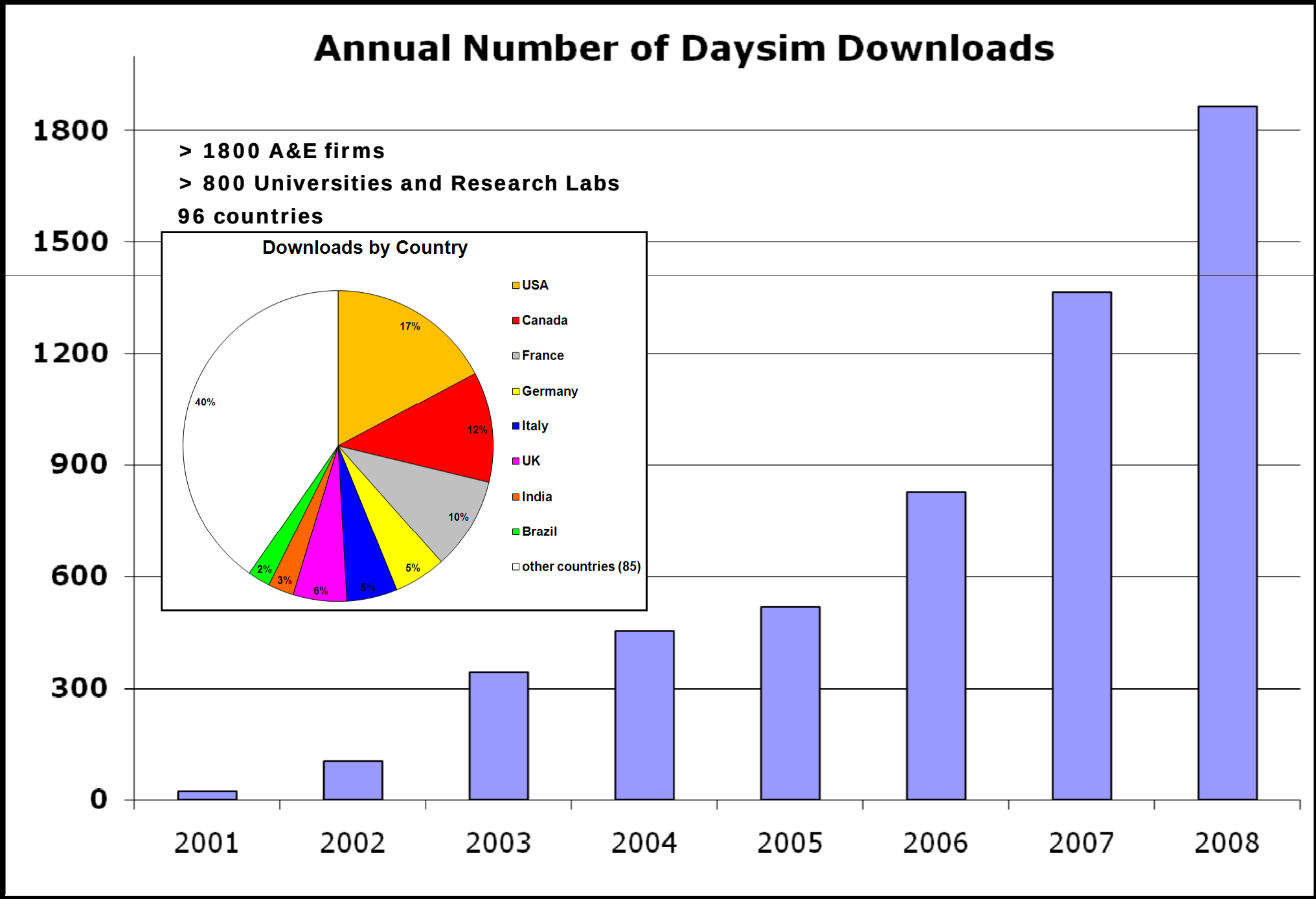
- **Rhino**
- **SketchUp**
- **AutoCAD**
- **Ecotect ...**



Simulation Output:

- **electric lighting energy use**
- **various daylighting metric distribution**
- **load profiles for thermal simulations**

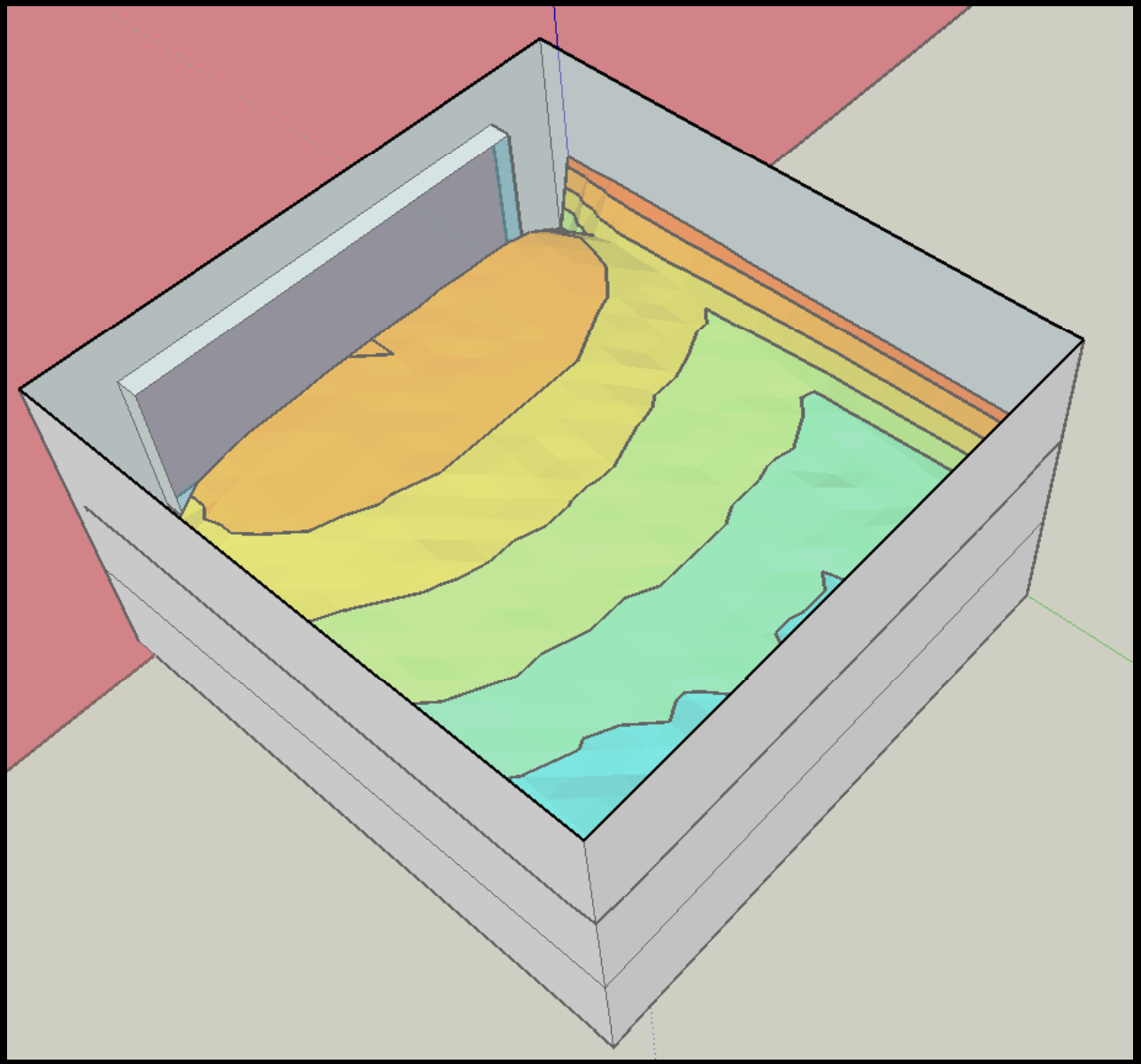
Daysim Stats (approximate)



Daysim ‘News’

- Release Date for Daysim 3.0 (beta): soon
- Sketchup to Daysim Export (T Bleicher)
- Improved Daylight Coefficient File Format (DDS): developed with D Bourgeois and G Ward
- Daysim 3.0/3ds Max Design 2009 validation (with P-F Breton)
- Annual Daylight Glare Probability Profiles (J Wienold)

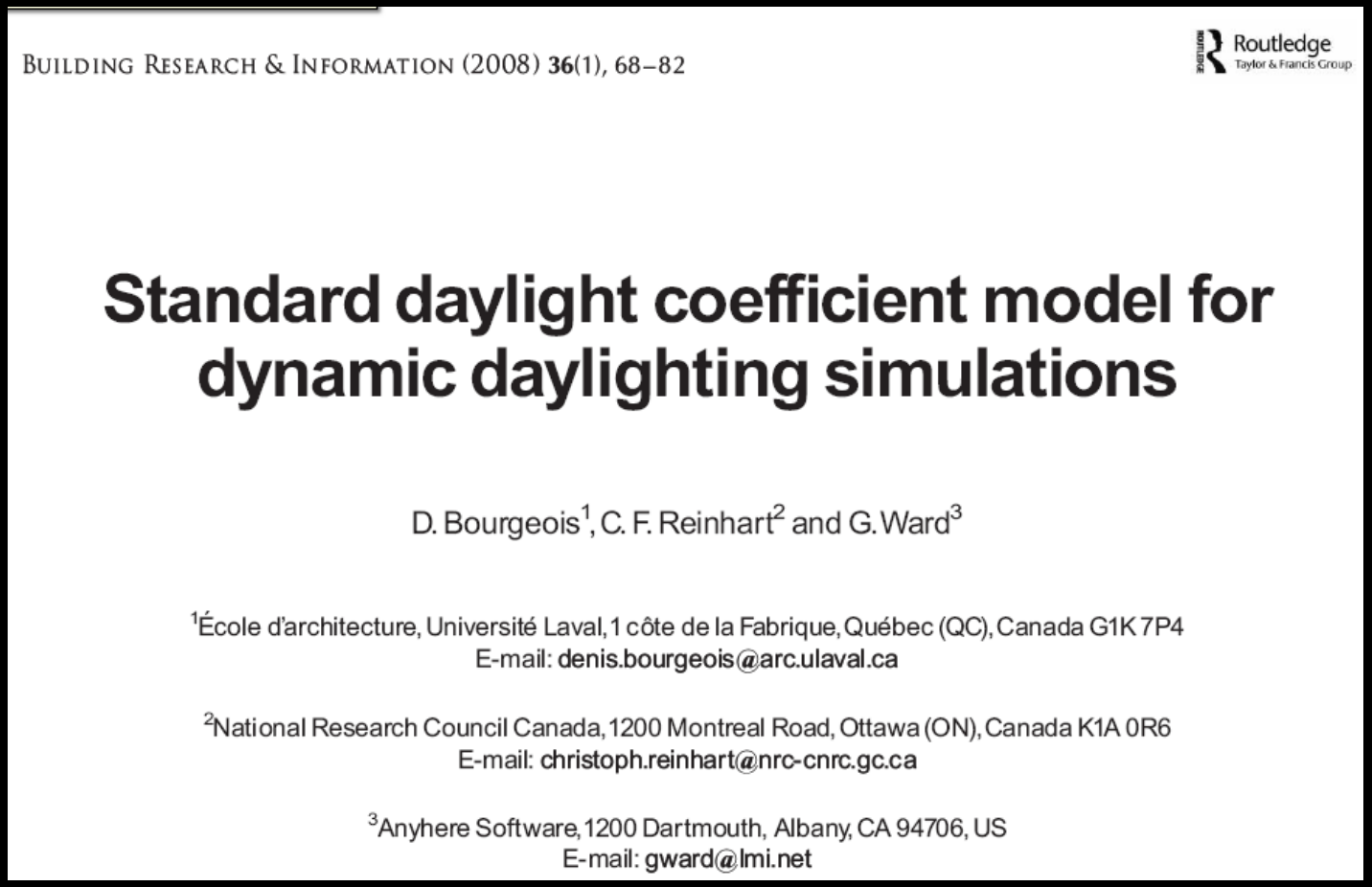
SketchUp to Daysim



su2rad (written by Thomas Bleicher)

Harvard Design School

Dynamic Daylight Simulation (DDS) File Format



BUILDING RESEARCH & INFORMATION (2008) 36(1), 68–82

Routledge
Taylor & Francis Group

Standard daylight coefficient model for dynamic daylighting simulations

D. Bourgeois[1], C. F. Reinhart[2] and G. Ward[3]

[1]École d'architecture, Université Laval, 1 côte de la Fabrique, Québec (QC), Canada G1K 7P4
E-mail: denis.bourgeois@arc.ulaval.ca

[2]National Research Council Canada, 1200 Montreal Road, Ottawa (ON), Canada K1A 0R6
E-mail: christoph.reinhart@nrc-cnrc.gc.ca

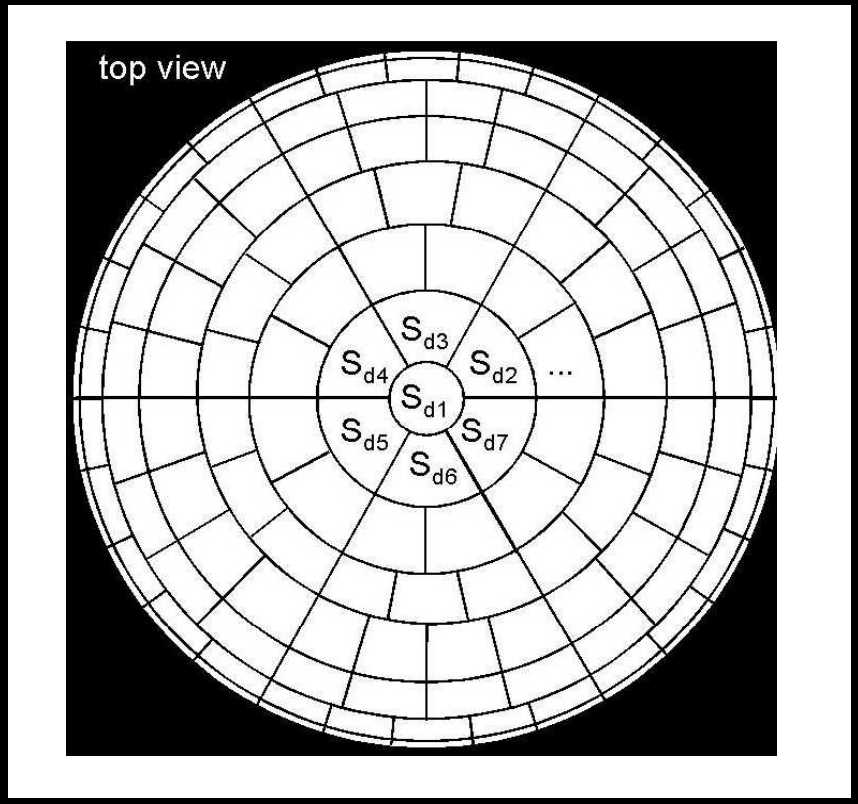
[3]Anyhere Software, 1200 Dartmouth, Albany, CA 94706, US
E-mail: gward@lmi.net

Plus several discussions with John Mardaljevic

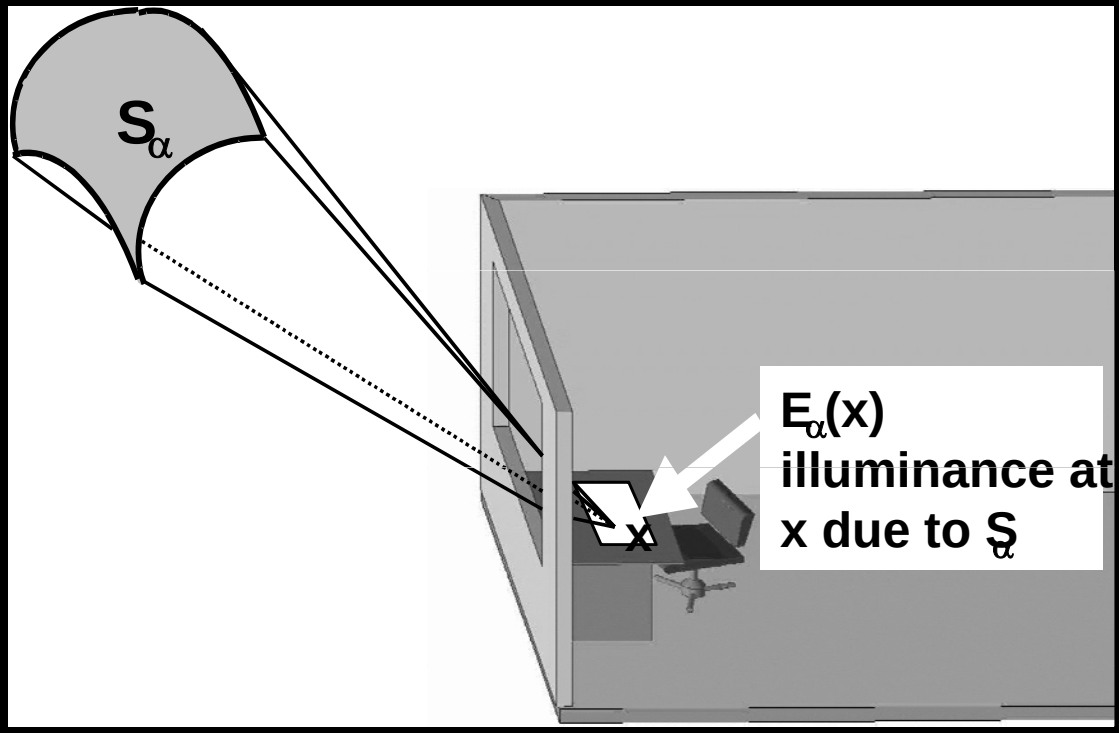
Paper: Bourgeois D, Reinhart CF, Ward G, "A Standard Daylight Coefficient Model for Dynamic Daylighting Simulations" Building Research & Information 36:1 pp. 68 – 82, 2008.

Daylight Coefficients

(1) Division of the Celestial Hemisphere



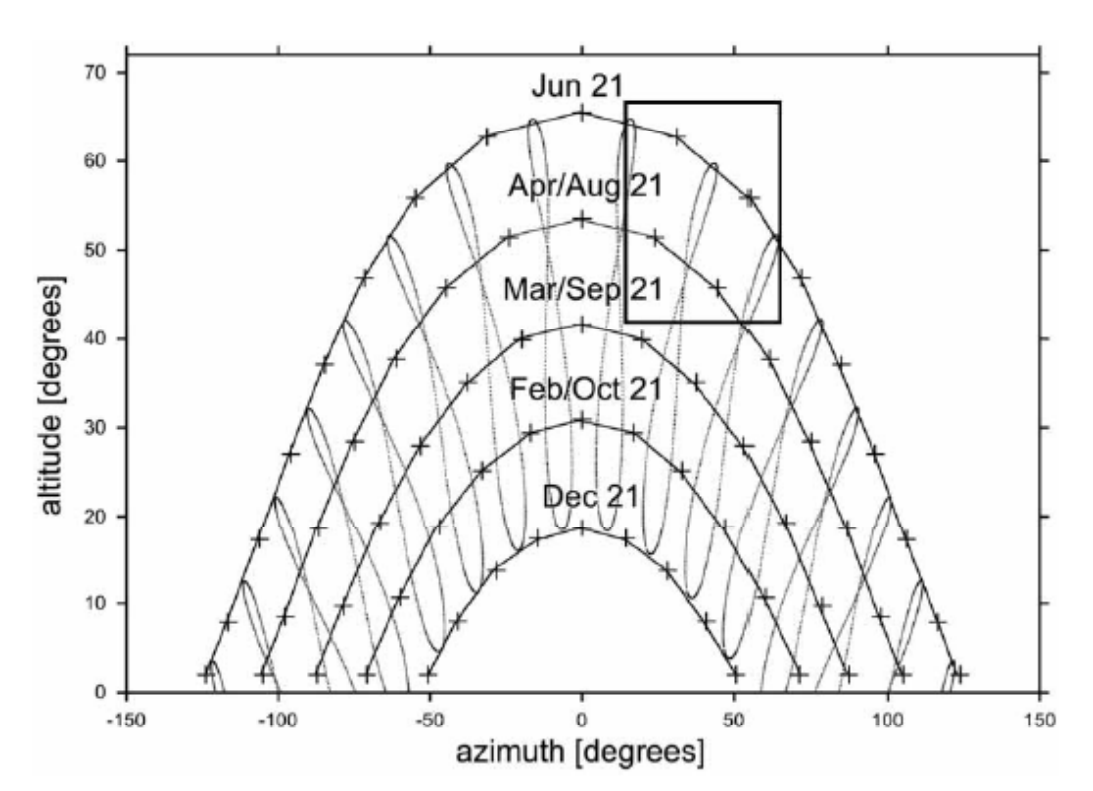
(2)Calculate Daylight Coefficients

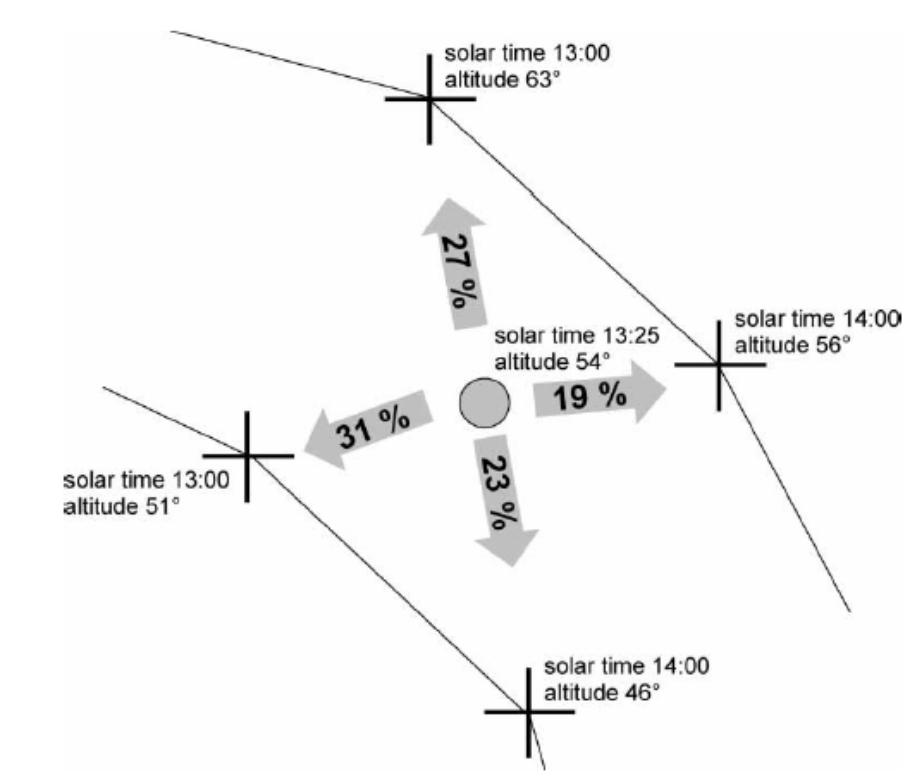


$$DC_\alpha(x) = \frac{E_\alpha(x)}{L_\alpha \Delta S_\alpha}$$

$$E(x) = \sum_{\alpha=1}^{N} DC_\alpha(x) L_\alpha \Delta S_\alpha$$

Direct Contribution

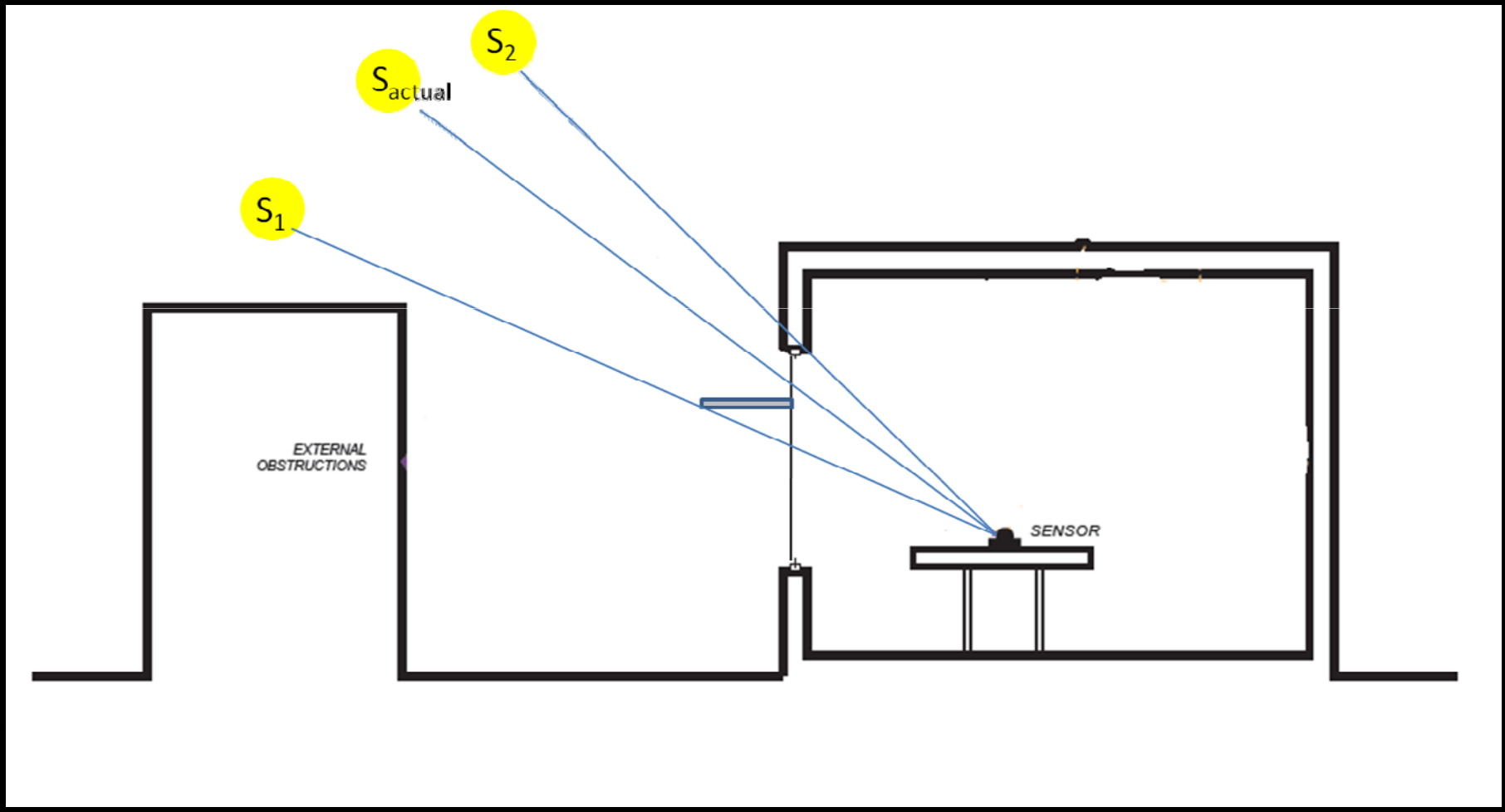




- Separation of daylight coefficients into ground, diffuse and direct contributions:
  - 3 ground
  - 145 diffuse patches
  - ~65 direct patches

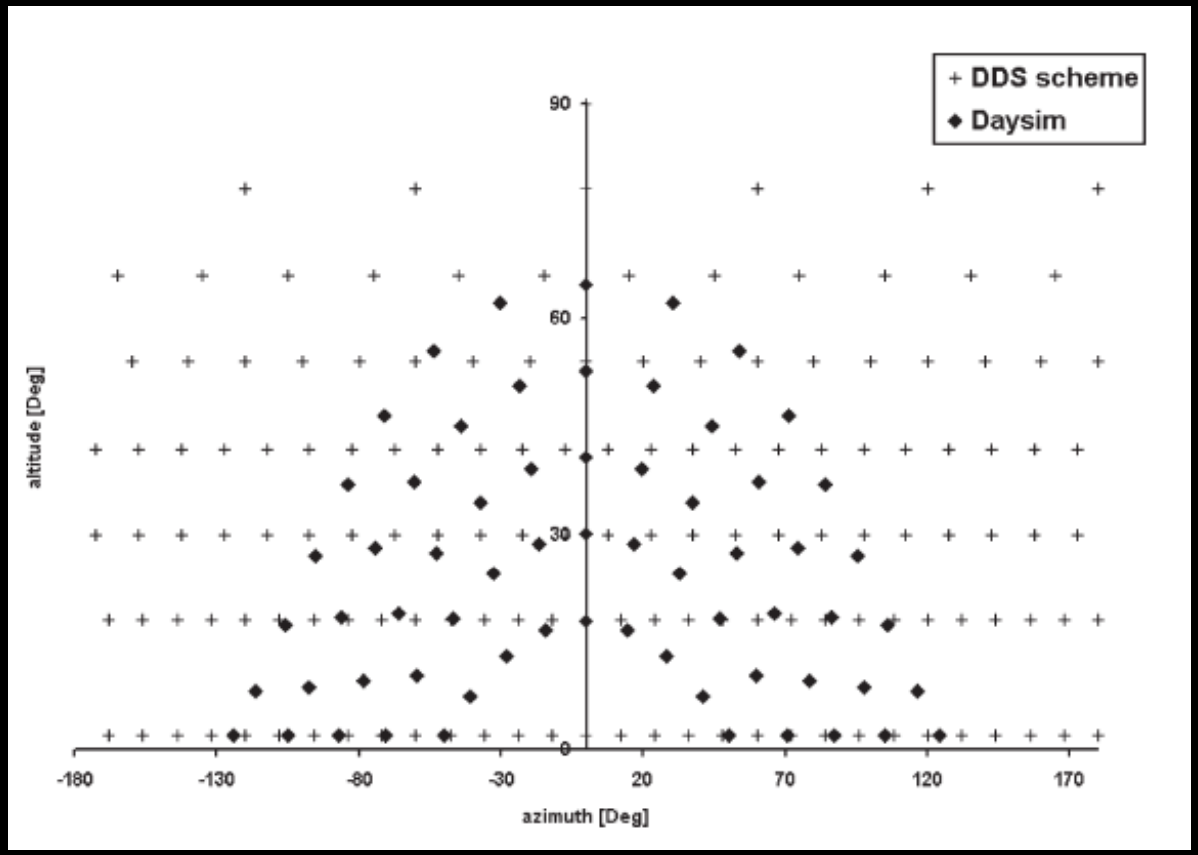
Plus several discussions with John Mardaljevic

Limitation of ‘old’ Daysim approach



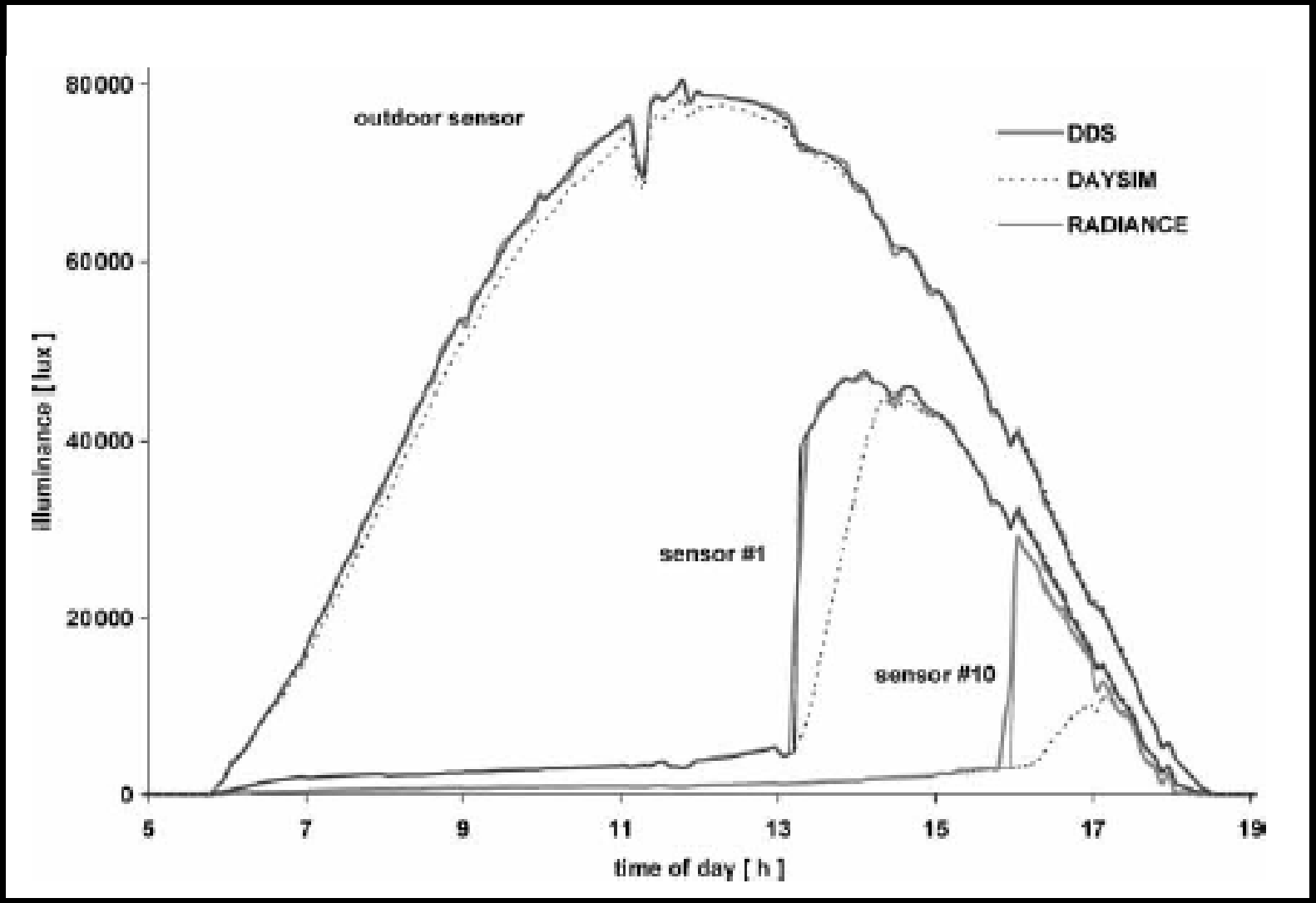
- The issues: pointed out by Ramana Koti: Direct sunlight contribution sometimes too coarse.

(DDS) File Format



- Separation of daylight coefficients into ground, diffuse, indirect-direct and direct-direct contributions:
  - 3 ground
  - 145 diffuse patches
  - 145 indirect-direct patches
  - 2305 direct-direct patches

Comparison old Daysim, DDS (Daysim >3.0) and Radiance



Implementation

```
gen_dc filename.hea -dds
ds_illum filename.hea -dds
```

- New option for gen_dc and ds_illum: '-dds'
- Calculates all four daylight coefficnet contrubuitions
- For indirect-direct regular direct daylight coefficients are calculated for 145 direct sun positions. Then the direct-direct contribution ('ab 0') is subtracted and the direct-direct contribution is repeated for 2305 direct sun positions.

New Direct Shadow Testing

```
ds_illum filename.hea -dds -s
```

- New option for ds_illum: '-s'
- Instead of relaying on the 2305 direct-direct sun positions the all actual direct sun positions that are taken from the climate file are used in order to further reduce interpolation errors.

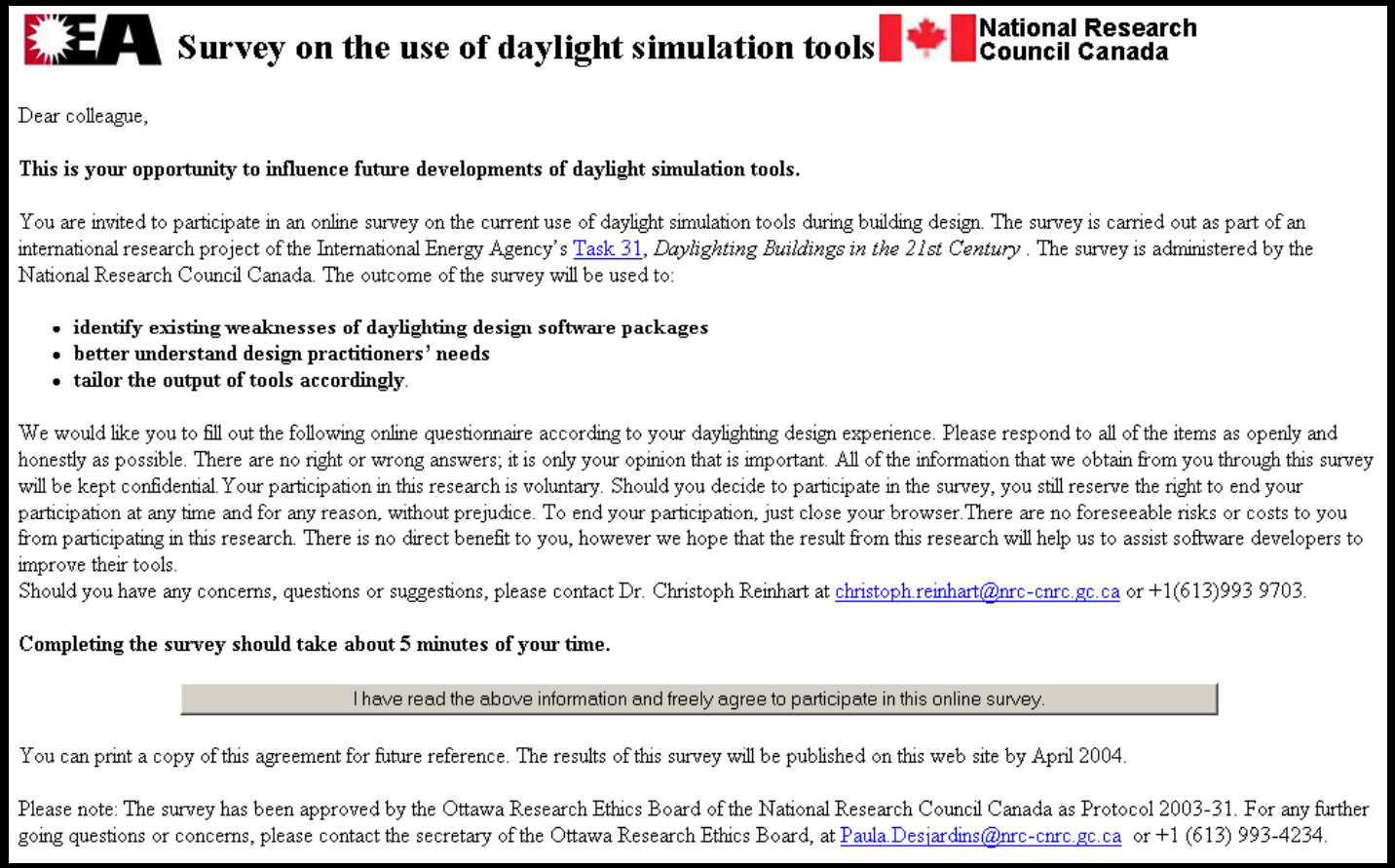
Software Validation

Collaboration with Pierre-Felix Breton

Harvard Design School

Survey on the Use of Daylight Simulations

Energy & Buildings, Reinhart & Fitz 2006



Survey on the use of daylight simulation tools

National Research Council Canada

Dear colleague,

This is your opportunity to influence future developments of daylight simulation tools.

You are invited to participate in an online survey on the current use of daylight simulation tools during building design. The survey is carried out as part of an international research project of the International Energy Agency's Task 31, *Daylighting Buildings in the 21st Century* . The survey is administered by the National Research Council Canada. The outcome of the survey will be used to:

- **identify existing weaknesses of daylighting design software packages**
- **better understand design practitioners' needs**
- **tailor the output of tools accordingly**.

We would like you to fill out the following online questionnaire according to your daylighting design experience. Please respond to all of the items as openly and honestly as possible. There are no right or wrong answers; it is only your opinion that is important. All of the information that we obtain from you through this survey will be kept confidential.Your participation in this research is voluntary. Should you decide to participate in the survey, you still reserve the right to end your participation at any time and for any reason, without prejudice. To end your participation, just close your browser.There are no foreseeable risks or costs to you from participating in this research. There is no direct benefit to you, however we hope that the result from this research will help us to assist software developers to improve their tools.
Should you have any concerns, questions or suggestions, please contact Dr. Christoph Reinhart at christoph.reinhart@nrc-cnrc.gc.ca or +1(613)993 9703.

Completing the survey should take about 5 minutes of your time.

I have read the above information and freely agree to participate in this online survey.

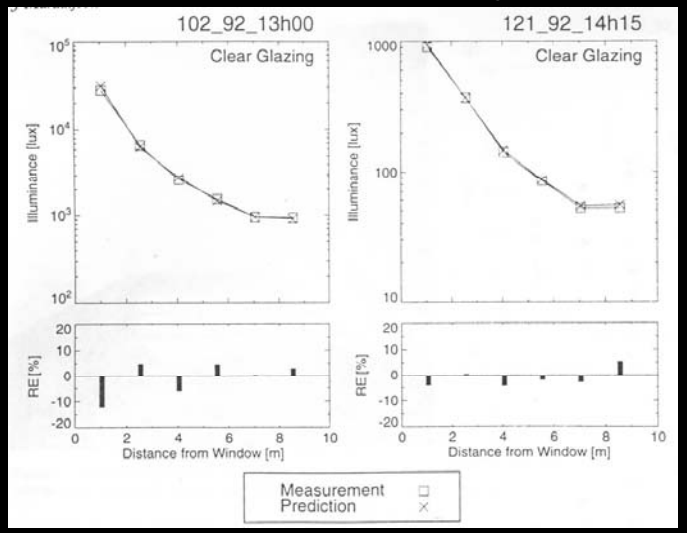
You can print a copy of this agreement for future reference. The results of this survey will be published on this web site by April 2004.

Please note: The survey has been approved by the Ottawa Research Ethics Board of the National Research Council Canada as Protocol 2003-31. For any further going questions or concerns, please contact the secretary of the Ottawa Research Ethics Board, at Paula.Desjardins@nrc-cnrc.gc.ca or +1 (613) 993-4234.

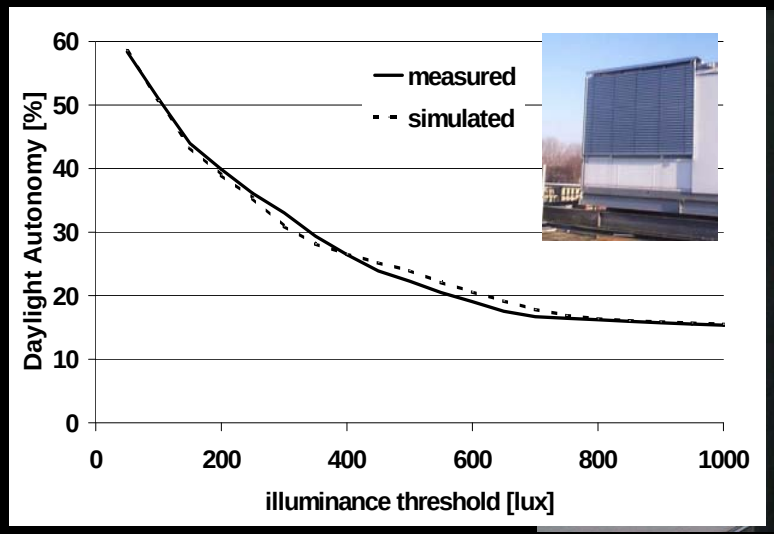
- 185 participants from 27 countries (40% Canada & US)
- validation seems less of an issue
- out of 40 tools mentioned, >50% of votes for RADIANCE based tools

Radiance Validation Studies

Light. Res. & Technology
Mardaljevic, 1995



Energy & Buildings
Reinhart, Walkenhorst 2001



Energy & Buildings
Reinhart, Andersen 2006

Conclusion: Radiance combined with daylight coefficients and Perez sky model can efficiently and reliably model annual illuminance time series with a mean relative error of around 25%.

Daylight Simulation Test Cases

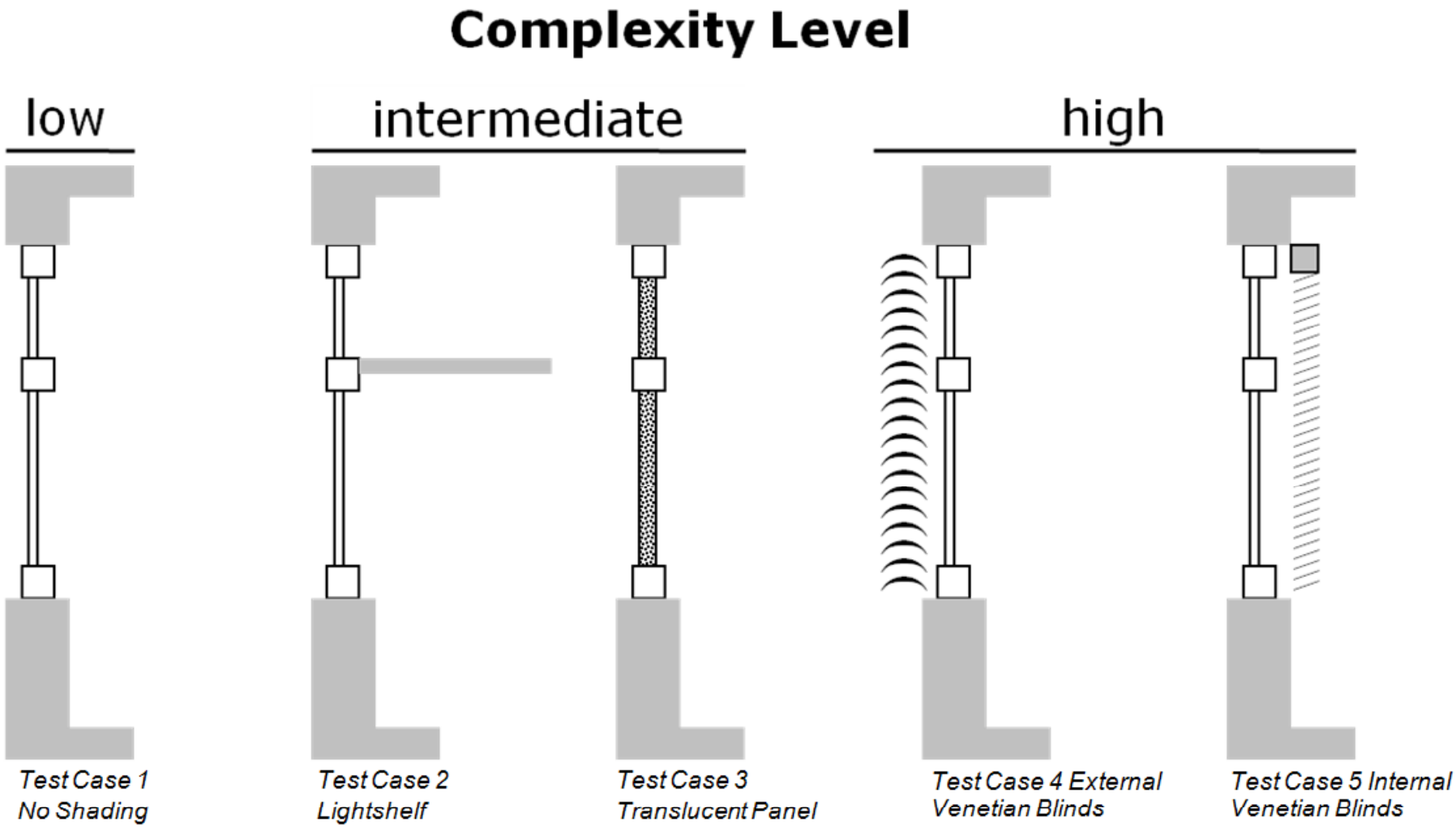


Figure 1: Façade sections of the five NRC daylighting test cases.

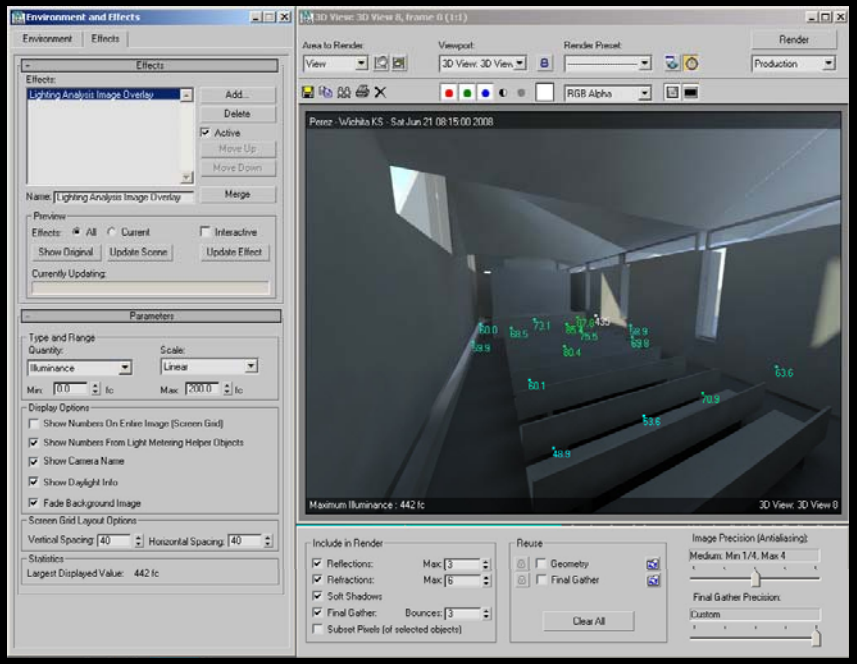
Paper: Reinhart C F, Breton PF, "Experimental Validation of 3ds Max® Design 2009 and Daysim 3.0", LEUKIOS 6:1 2009. (www.autodesk.com/us/3dsmaxdesign/B3241.MentalRayValidation_v3.pdf)

Daylight Simulation Test Cases

NRC Daylighting Laboratory

- development of a benchmarking procedure for daylight simulation programs
- comparison on simulation results with indoor illuminance measurements
- procedure has been applied to Radiance and 3ds Max Design 2009

3ds Max Design 2009

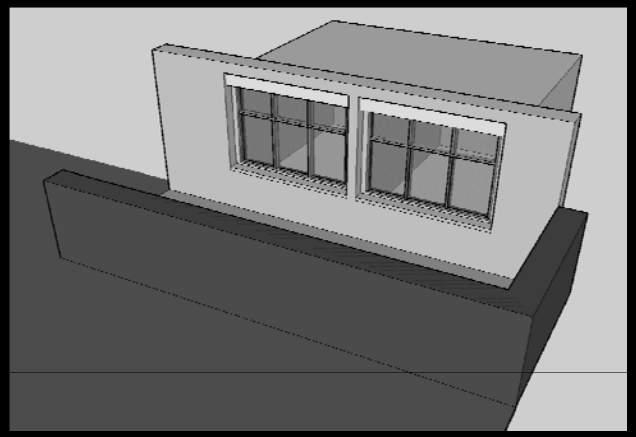


- Based on Exposure™ technology.
- Exposure™ includes a ‘shader’ of the Perez Sky Model (same model as Daysim).
- For the global illumination calculation Exposure uses the mental ray raytracer which supports forward (photon mapping) and backward raytracing (final gathering).
- Same as in Radiance final gather tracing in mental ray is performed only on discrete points (sensors).
- Light sensors in 3ds Max Design are specified using the Light Meter object.

For reliable results you have to use ‘Architectural’ materials!

Tutorial: http://images.autodesk.com/adsk/files/3dsmax_started.pdf

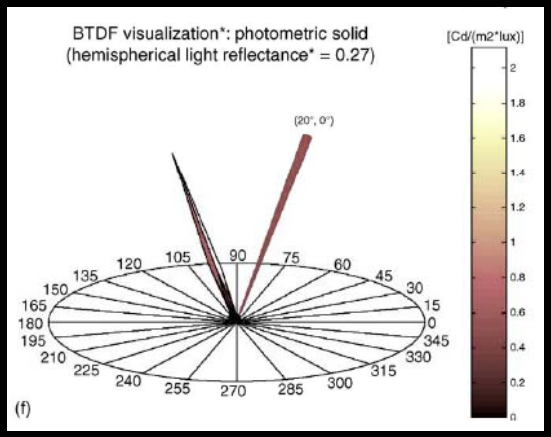
Validation Work Flow



SketchUp Model (geometry)

Outside Irradiances

Illuminances



Material Properties

Simulation Program:

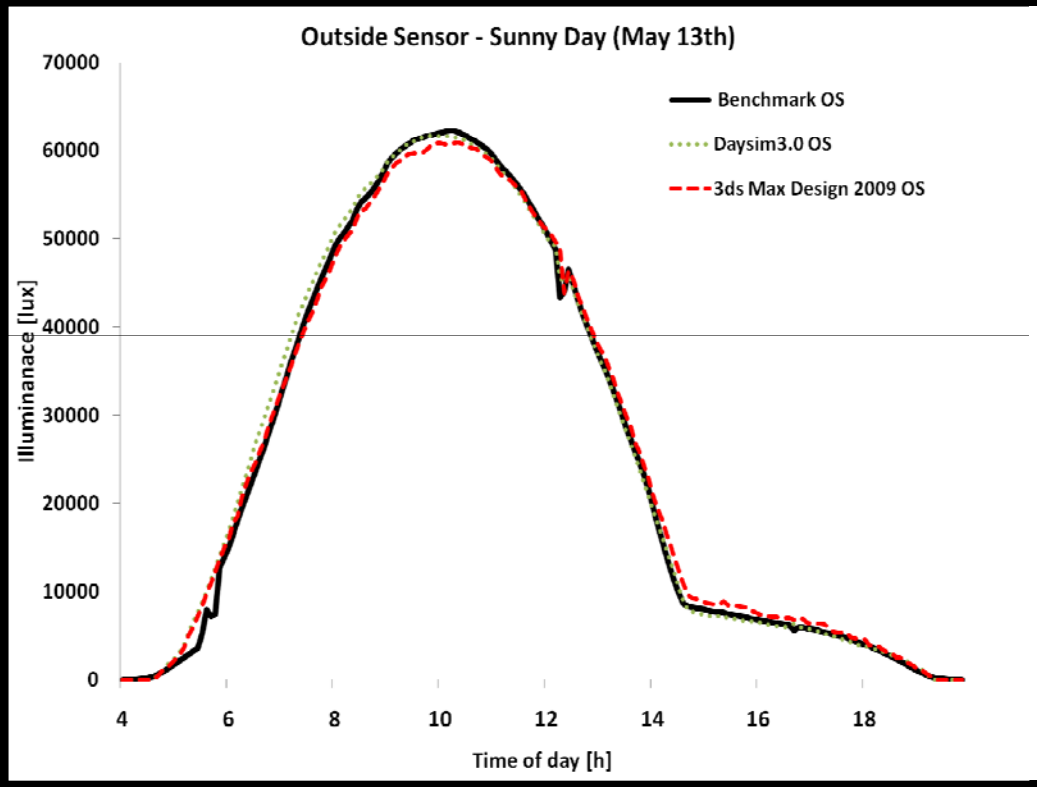
- 3ds Max Design 2009

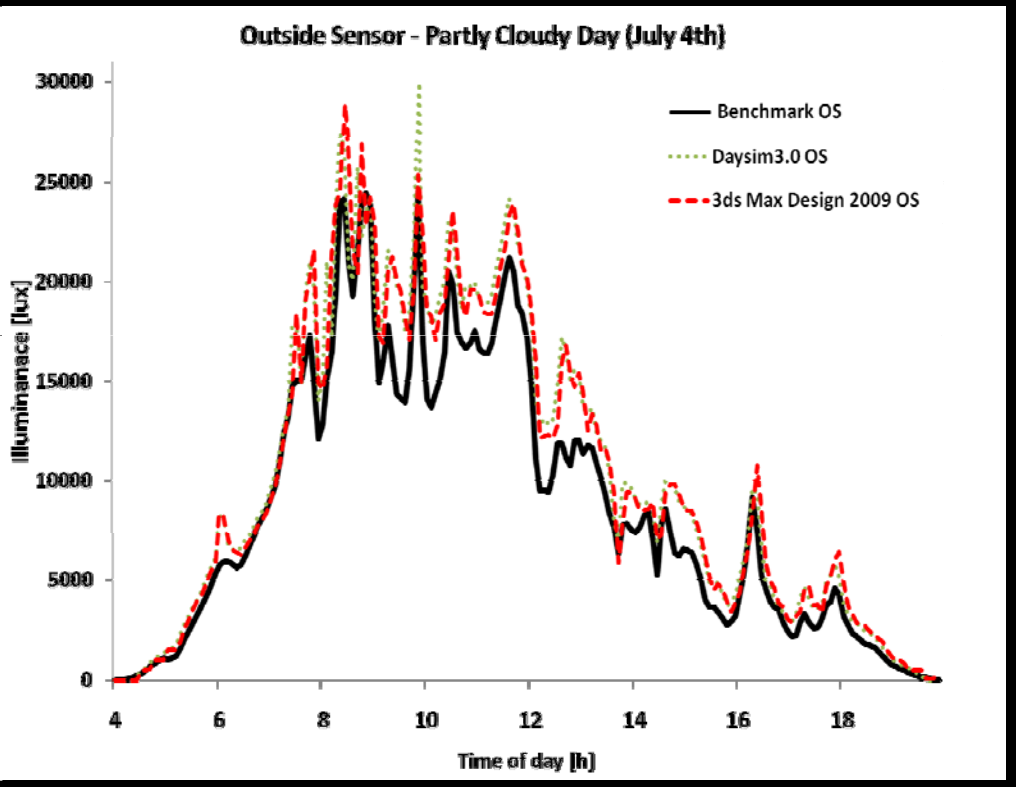
-Daysim3.0

- …

Simulated Illuminances

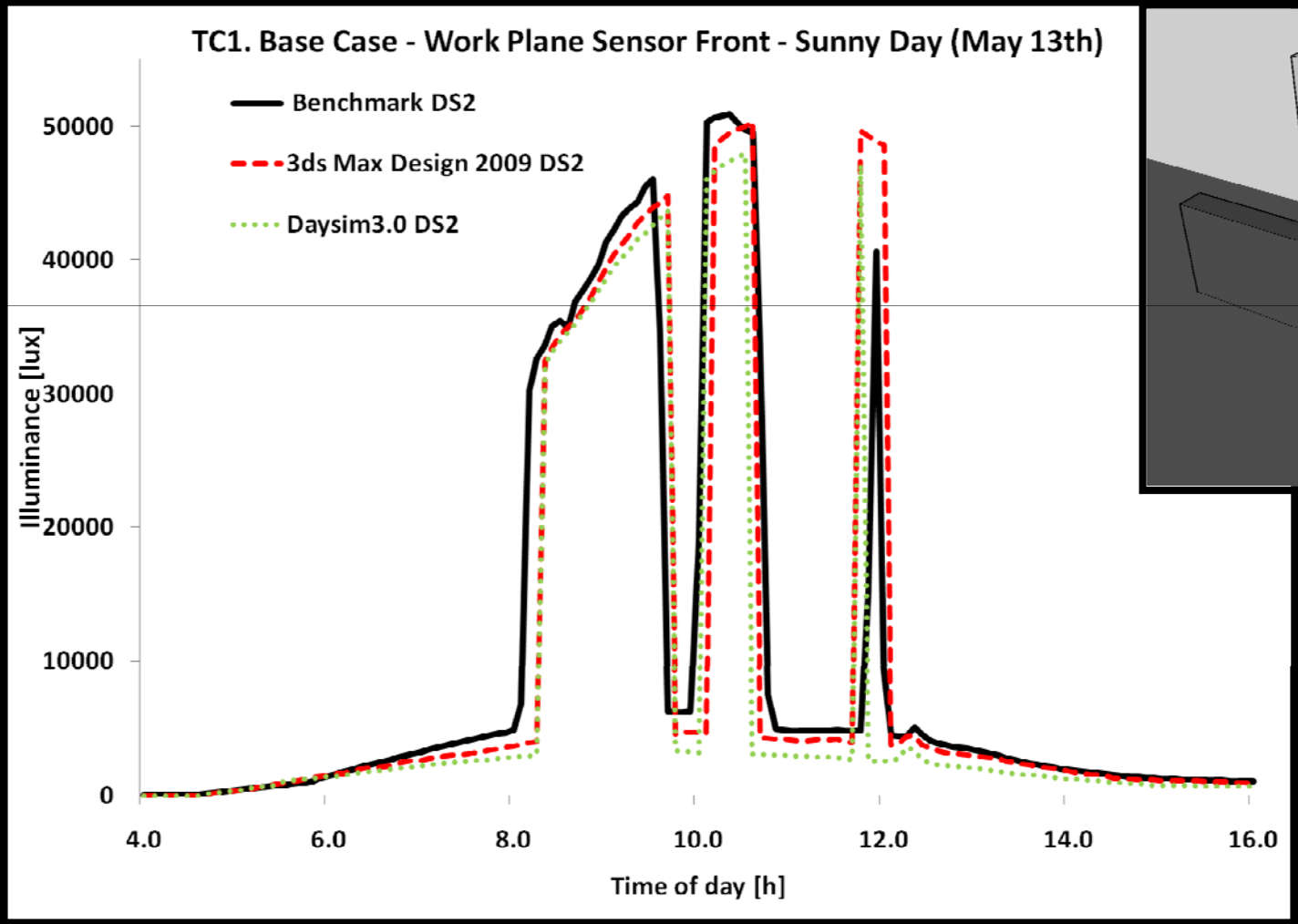
Outside Façade Illuminances

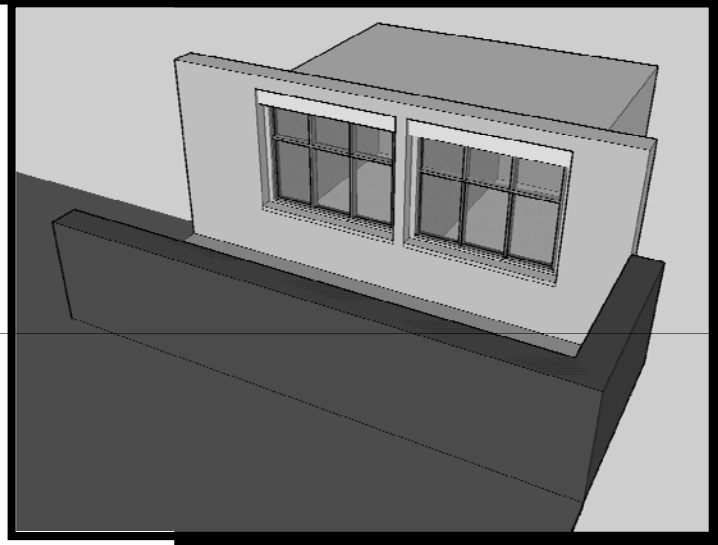




- Nearly identical simulation results for outside sensors.
- Differences mainly from how ground reflectances are being treated.

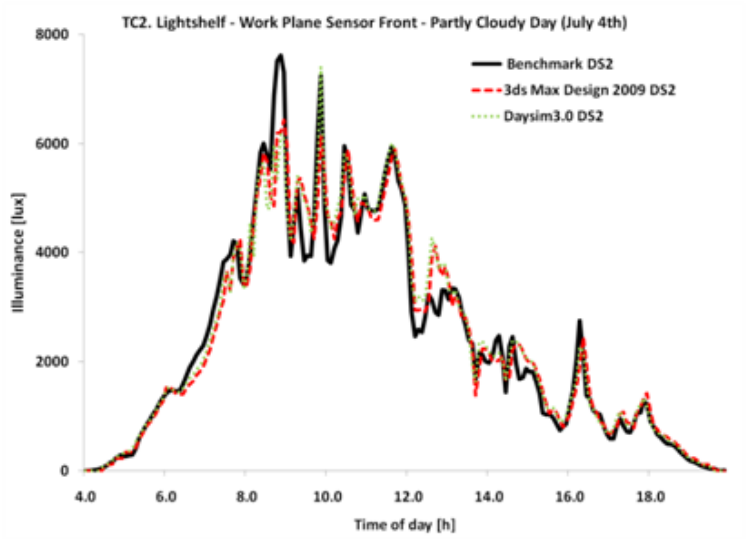
Test Case 1 – No Shading



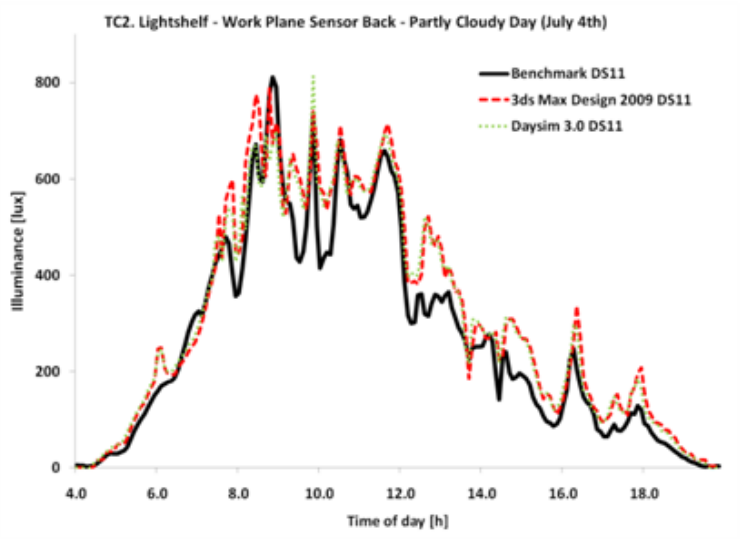


- Very close agreement over a large illuminance range.
- Slight offset probably due to geometry modeling errors and time lacks.

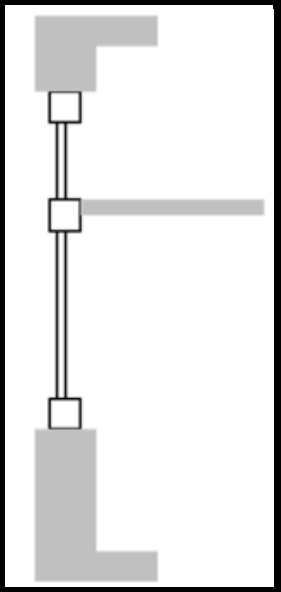
Test Case 2 – Lightshelf

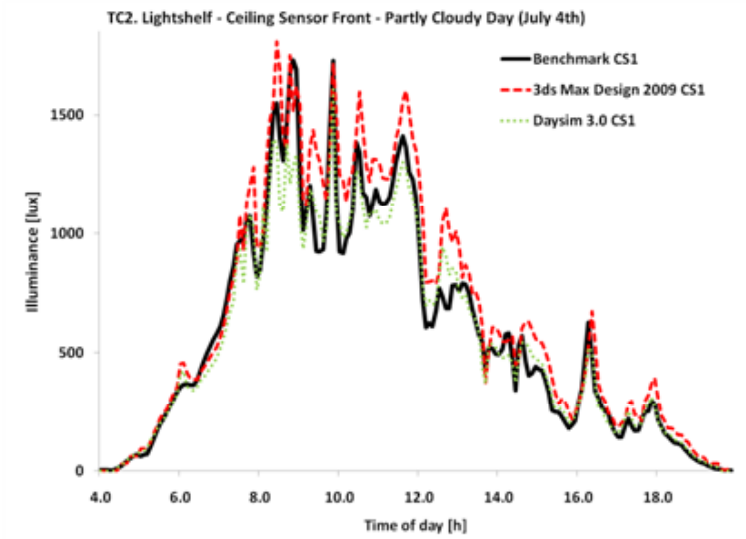


(a) Work plane sensor front

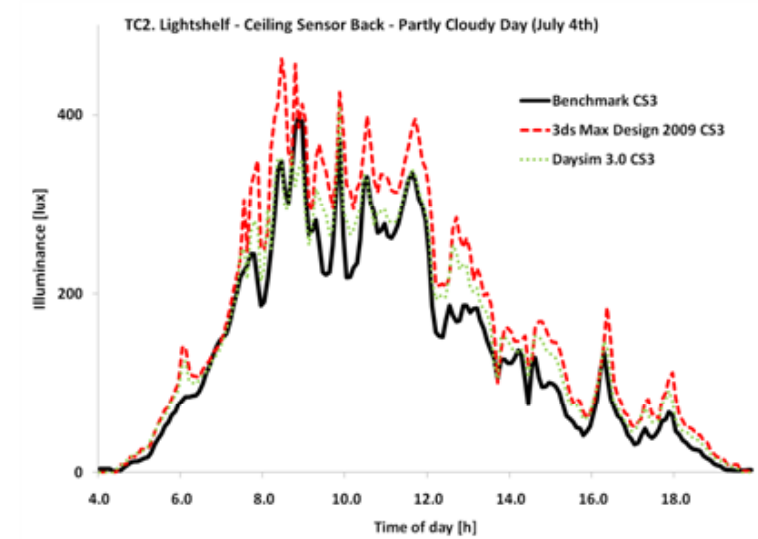


(b) Work plane sensor back





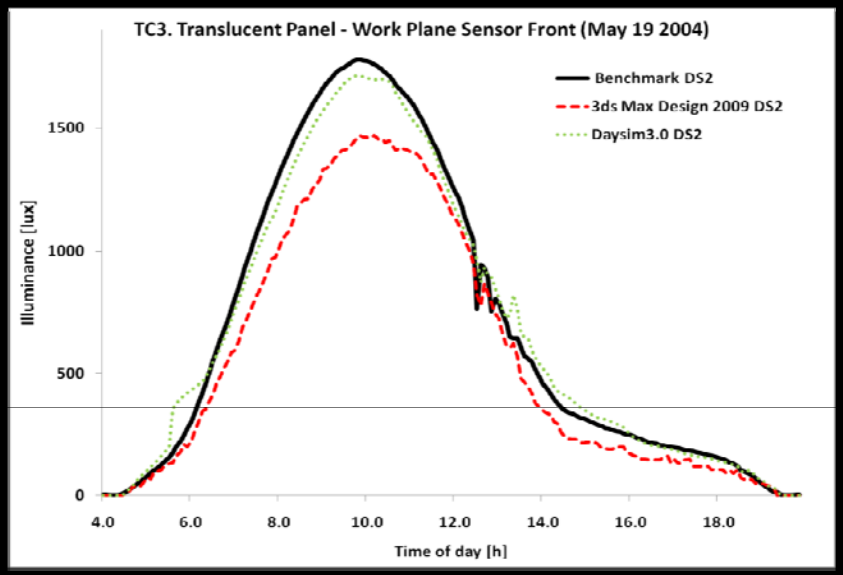
(c) Ceiling sensor front

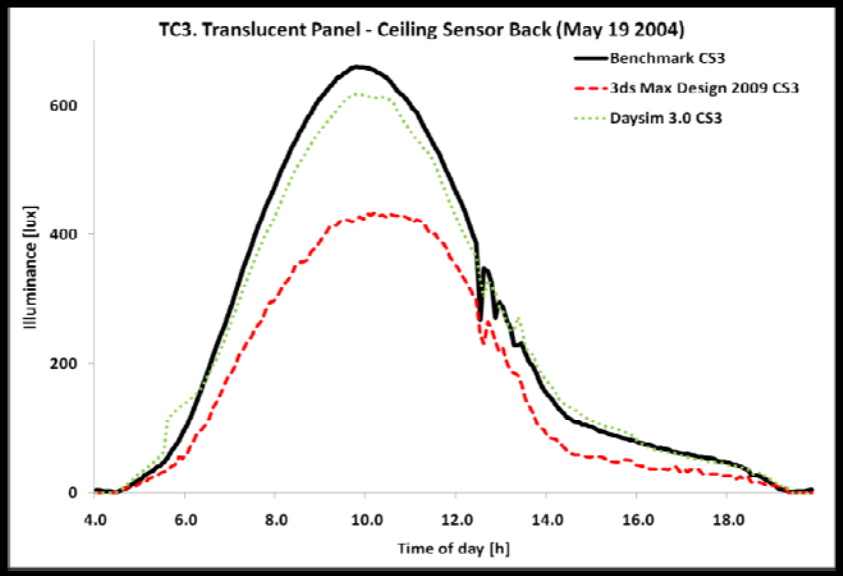


(d) Ceiling sensor back

- Close agreement from 50 lux to 8000lux (covers total illuminance range that is typically encountered in buildings.

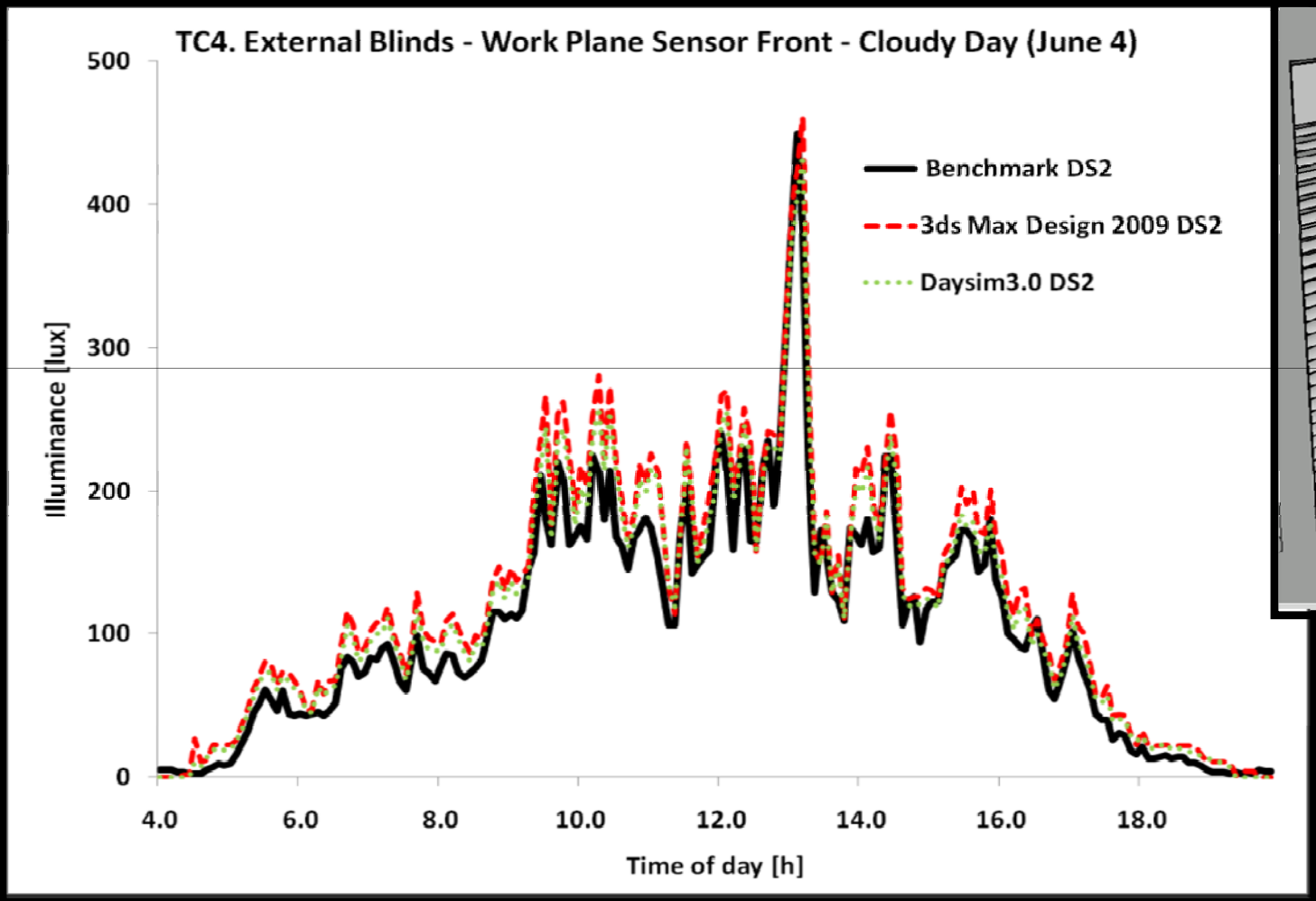
Test Case 3 – Translucent Panel

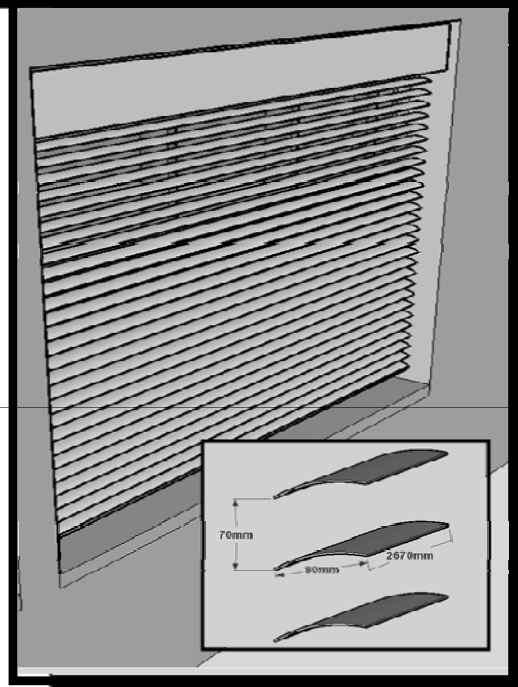




- Daysim very close; 3ds Max too low. Problem with translucent material modifier in 3ds Max Design was caused by a double layer of translucent glazing.
- This shows the value of daylighting test cases for developers.

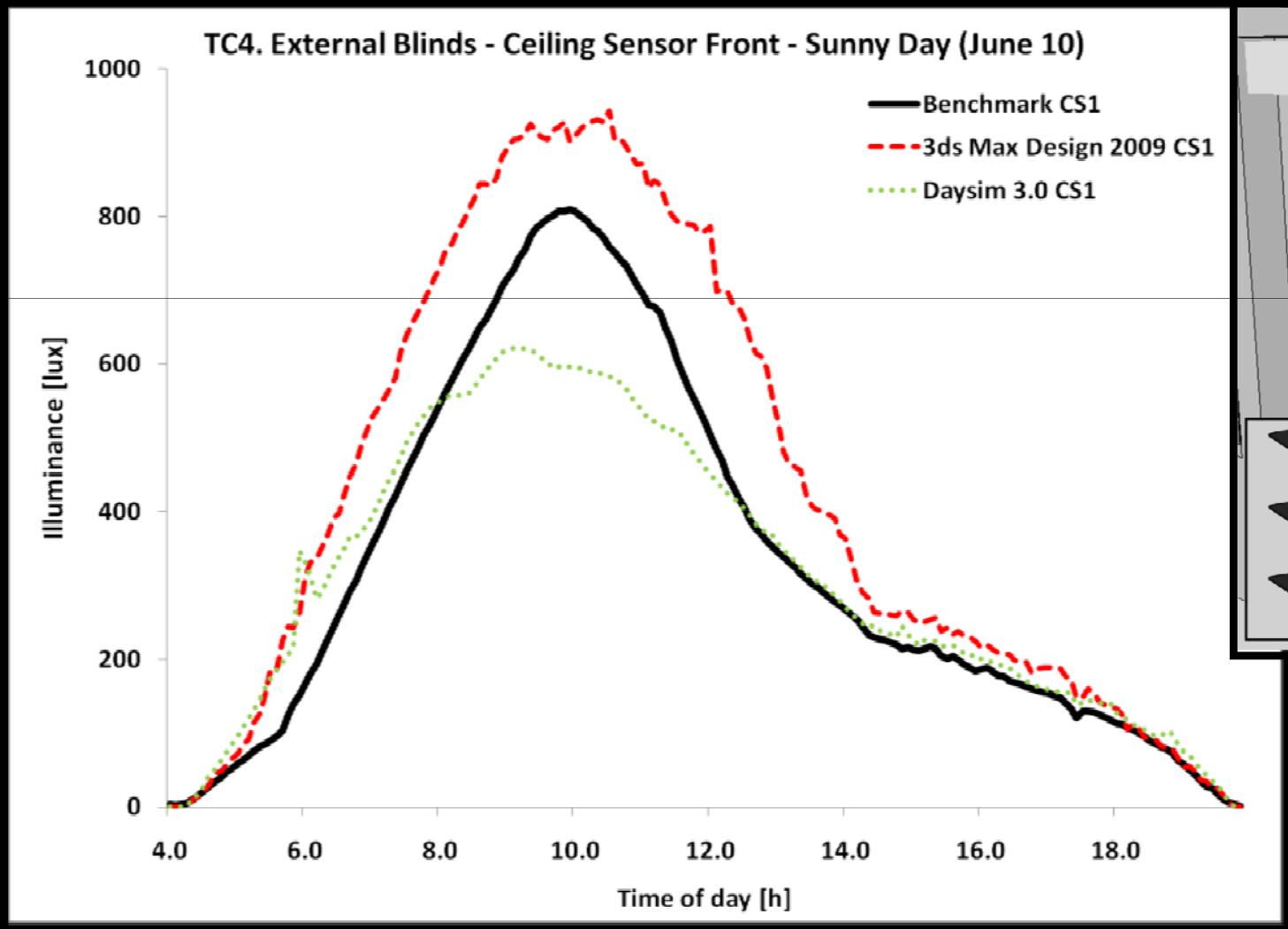
TC4 – External Venetian Blinds – Cloudy Day

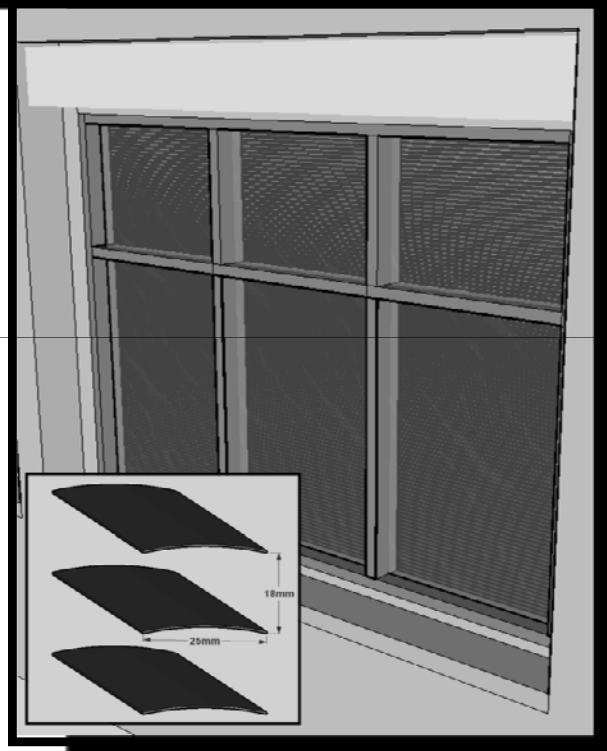




- Close results under overcast sky conditions.
- Similar results for the internal venetian blinds.

Test Case 5 – Internal Venetian Blinds – Sunny Day





- Systematic error under sunny sky conditions for both programs.
- Modeling challenges: Setting the slat angles evenly; measuring optical properties of blind slats (specular component); light spilling through cord holes.

Main Study Findings

- 3ds Max Design and Daysim can be used to support daylighting related design decisions in scenes of comparable complexity as the five daylighting test cases.

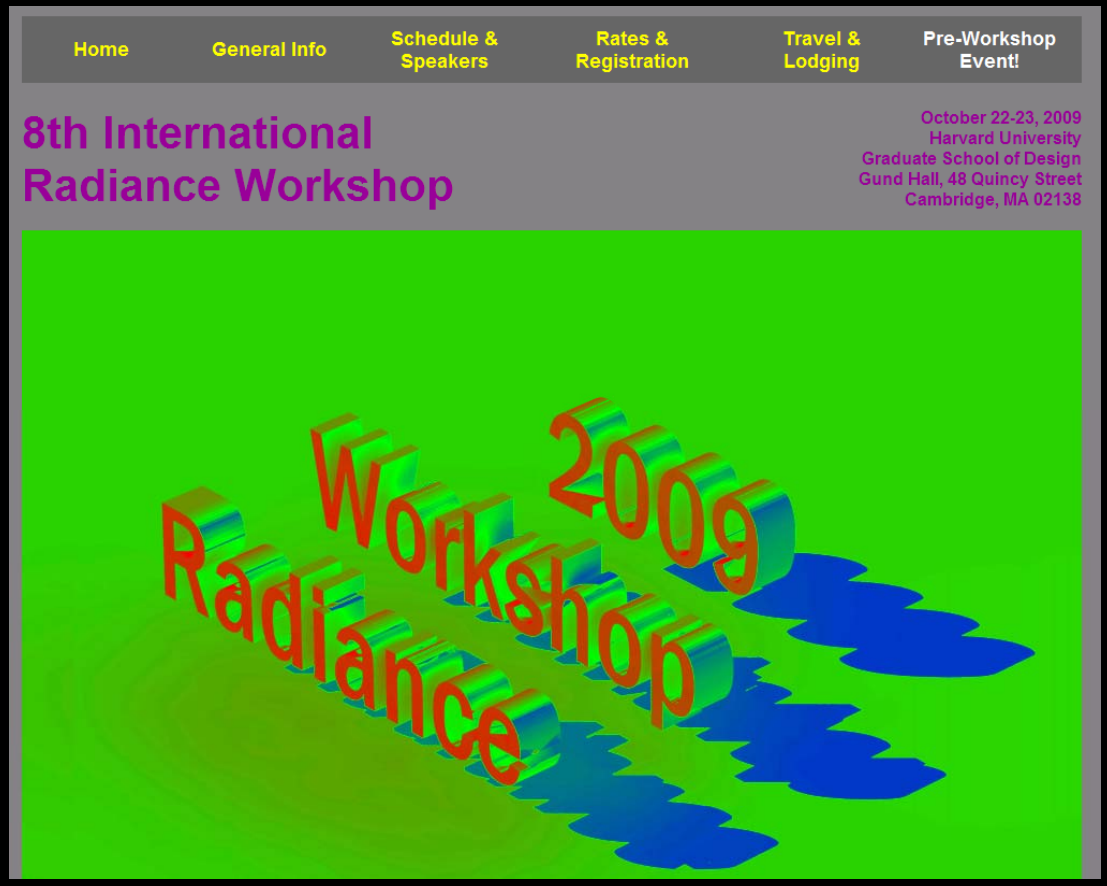
- This finding constitutes a certain paradigm shift as there are suddenly more than one lighting simulation engine that has been extensively validated based on physical measurements.

- It is expected that other programs will soon also undergo comparable simulation procedures.

Thank-you!

Contact:
Christoph Reinhart
Associate Professor
Harvard University
Graduate School of Design
Ottawa K1A 0R6, Canada

Tel.: (617) 384 7269
Email: reinhart@gsd.harvard.edu



October 21 to 23 @ the GSD