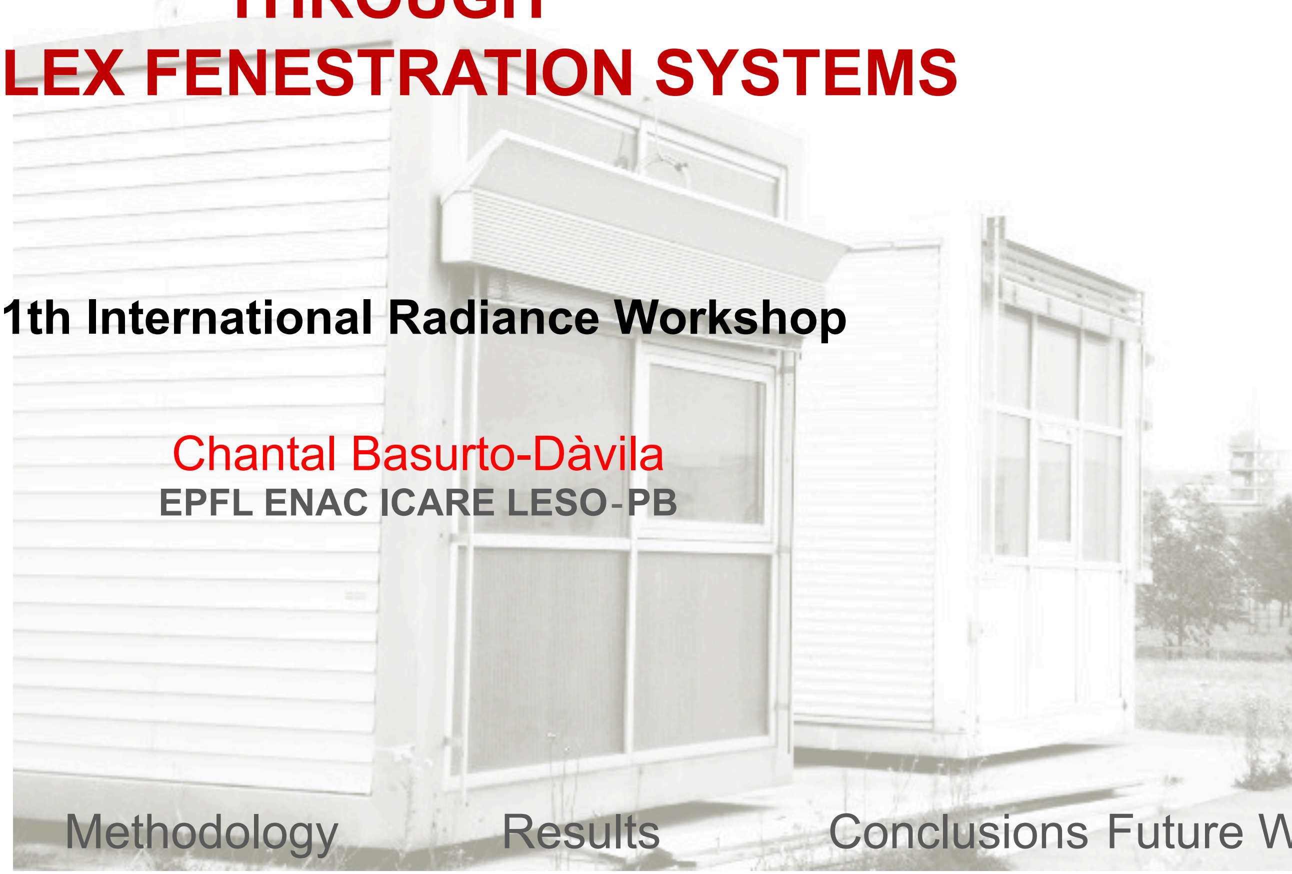
VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS



11th International Radiance Workshop

Chantal Basurto-Dàvila
EPFL ENAC ICARE LESO-PB

Introduction

1. Buildings located at low latitudes
2. Possible Solution: use of CFS
3. Applying CFS by the use of computer simulations

Methodology

1. Case Study: DEMONA

Results

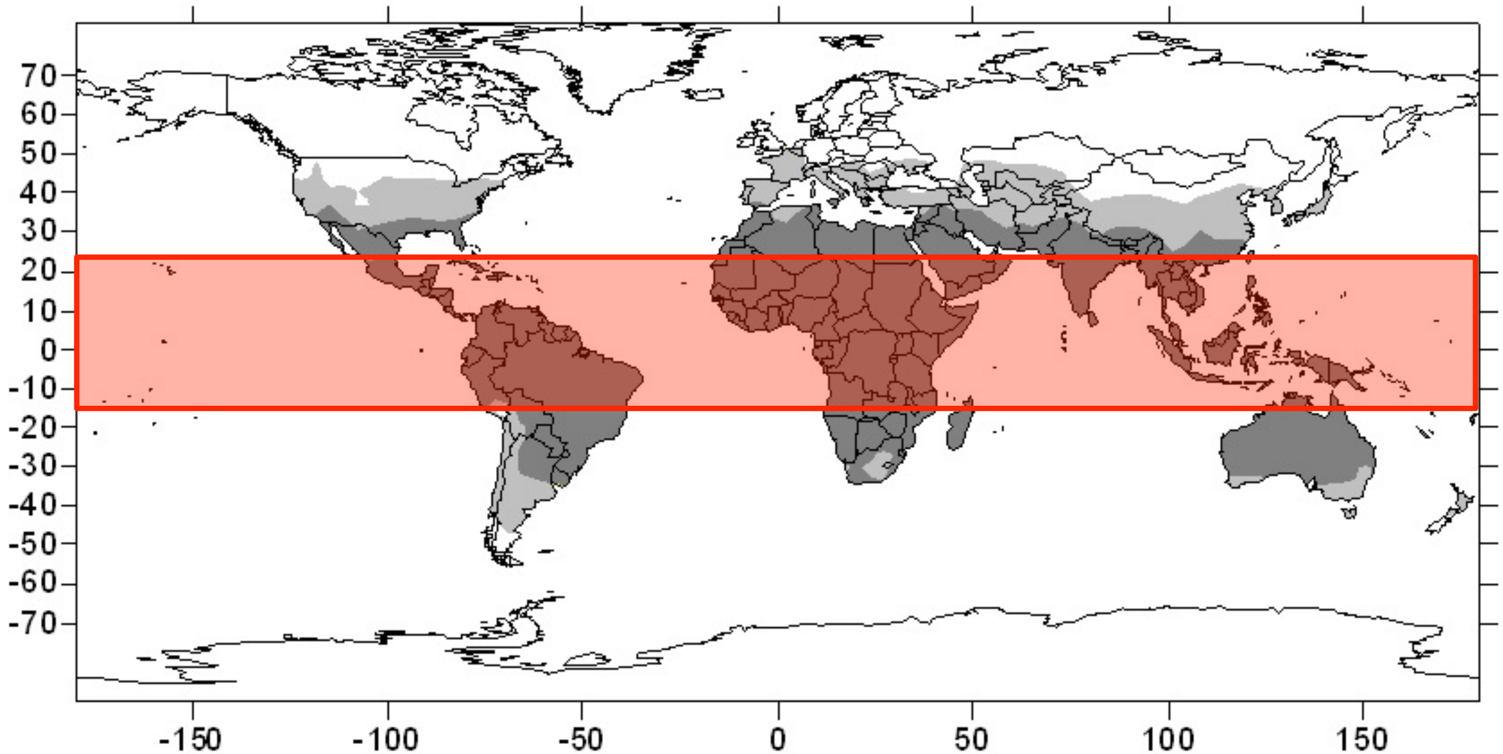
1. Double glazing window
2. CFS: Prismatic Film 3M
3. CFS: Lasercut Panel

Conclusions

Future Wor

1. Tec de Monterrey
2. UAZ

1. Daylight optimization for buildings located at low latitudes



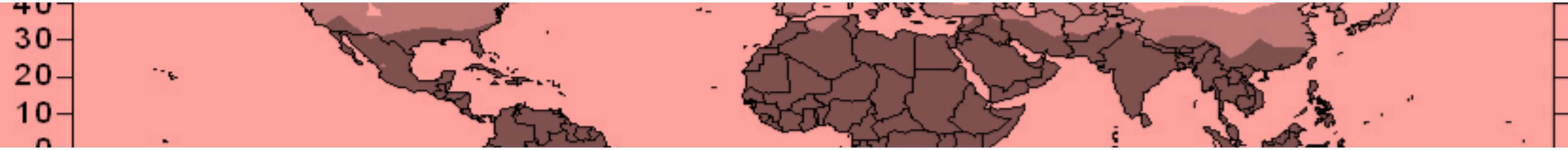
Daylight:

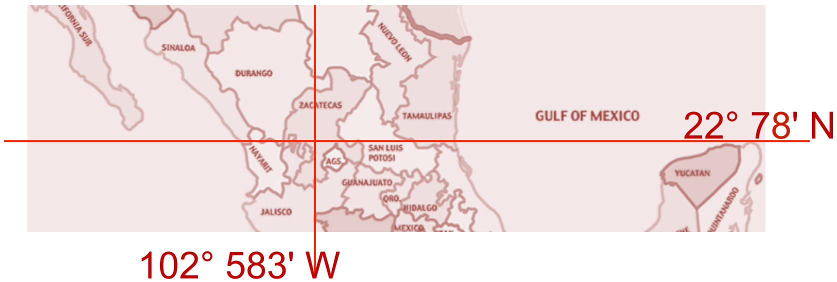
- Admission of heat that increases the cooling loads
- Sun rays which alter the visual comfort and perception of the indoor environment

Local standard strategies:

- Tinted glazing,
- Reduced window size,
- Window protection: venetial blinds.

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS



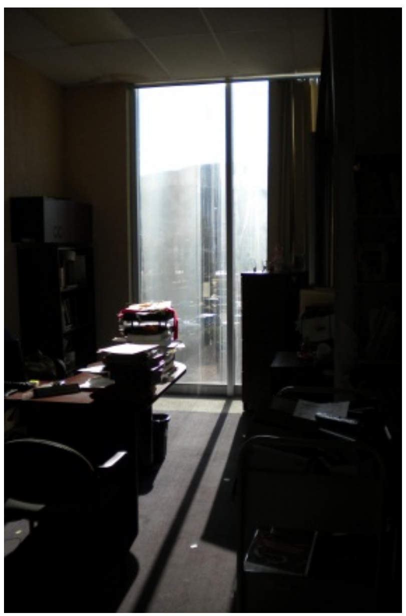


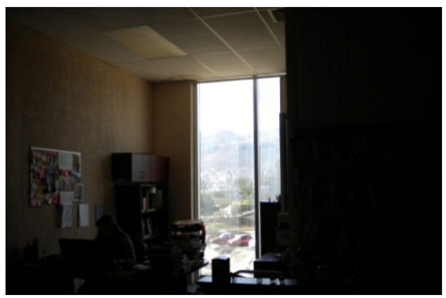
Building Location:
Zacatecas, México
Latitude: 22° 783' N.,
Longitude: 102° 583' W
Altitude: 2450m

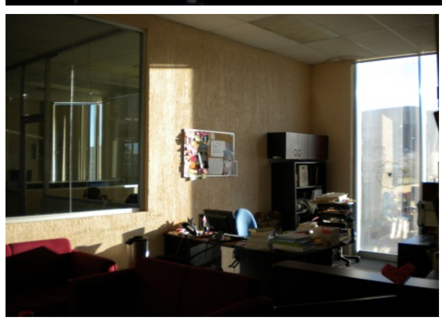
Warmest Temperature: 32°C may/june
Annual Sunshine Hours : 2676 (7.3/day)
Annual Daylight Hours: 4599 (12.6/ day)

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

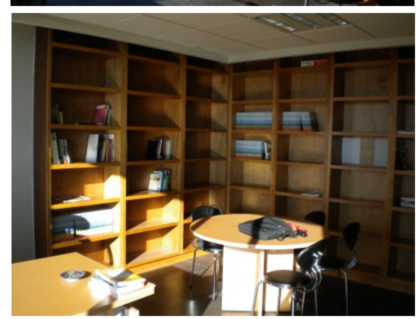
a) Tec de Monterrey -Private University

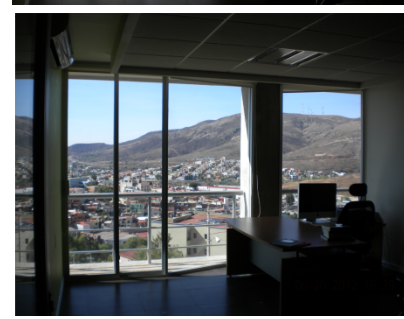






b)-Centro de Estudios del Desarrollo (UAZ) –R





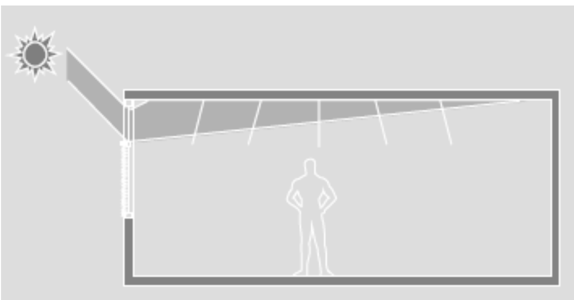
1.1 Possible Solution: Complex Fenestration Systems (CFS)

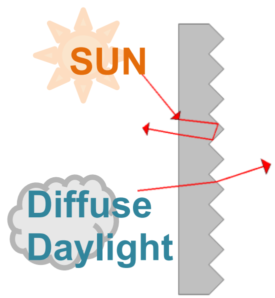
a) Solar shading: control direct sun rays

b) Improve daylight interior environment

-lighting redirection: increase daylight levels deep within rooms

-reduce the risk of glare



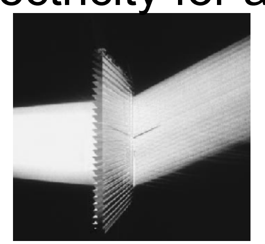


a) Reduction in the interior cooling loads in summer

b) Reduction in electricity for artificial lighting

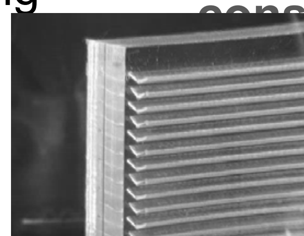
→ Reduction in the final energy consumption

Lasercut panel



Prismatic Panel

Okasolar



Light Channelling Panels

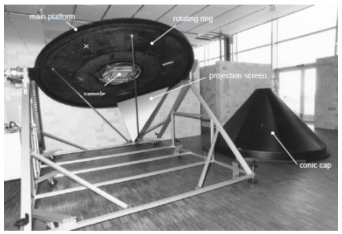
…testings on-site → diffi

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

1.2 Simulating CFS with RADIANCE

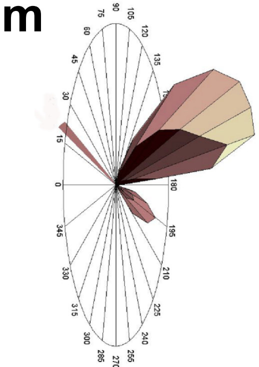
Luminous transmission properties of CFS

Bi-directional photogoniometer



IEA 21 file format
Bi-directional Transmission Distribution Function (BTDF)
International standard for BTDF data

Photometric properties of CFS characterized in diagram



btdf2radiance

Window 6 XML format
Multiple lighting redirections

1) BTDF data as matrix of size: 145 x 145 / 145 x 1297 adapted to be used with mkillum

Btdf2mkillum145x1297.xml

2) *bsdf* material
Without need of mkillum for lighting modelling through th

Prism2
Only two emerging lighting directions can be determined for each incident beam direction

Btdf2prism2→translate monitored BTDF into prism2

Applied for sharp redirecting CFS:
Lasercut panel, prismatic film, holographic film

2) Methodology

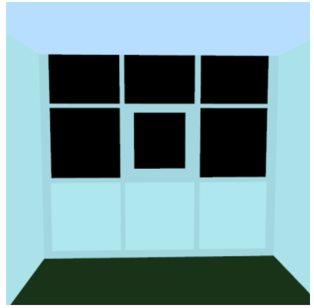
Case Study: DEMONA

Module Location: EPFL, Lausanne, Switzerland

Latitude: 46.5° N
Longitude: 6.6° E
Elevation: 396m
Orientation: South

Dimensions: 6.5m x 3.05m x 2.65m
Area: 32.7 m²
Window Area: 14.24 m²
Proportion window/area: 0.43
Fenestration details: double insulated glazing
ittance: 80.5%

2.1 Demona virtual model



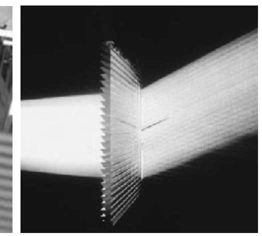
Double Glazing
28th august 11:17am
5099lx

Lasercut panel
5th april 9:13am
10765lx

Prismatic Film 3M (e
28th august 13:11am
19588lx

	Real Building	Virtual Model
Surface	**Measured Reflectance %**	
North Wall	82.6 ±	82.6
East Wall	81.5 ±	81.5
South Wall	72.1±	72.1
West Wall	82.3 ±	82.3
Ceiling	79.9 ±	79.9
Floor	16.1 ±	16.1
	Transmittance %	**Transmissivity**
Double Glazing Window	80.5 ±	0.8769

Lasercut panel
6mm single acrylic w/ 4mm parallel cuts



Prismatic Panel Exterior
3M Brand optical Lighting film

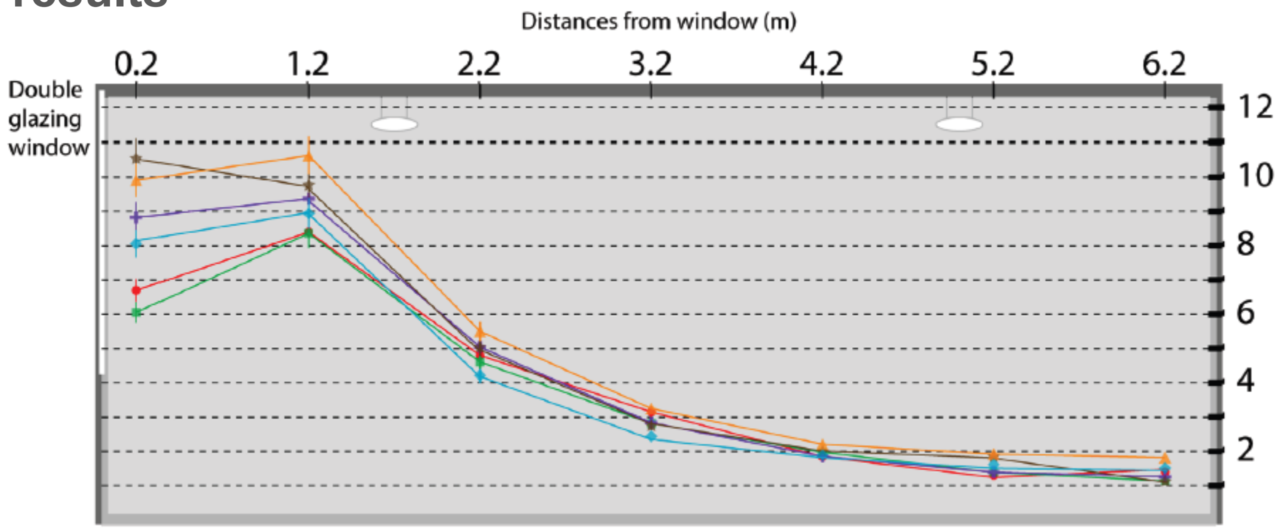
Radiance Simulation Paramètres	
-ab	9
-aa	0.1
-ad	26315
-ar	128

Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

2.2 Previous results

Daylight Factor %



Real Building, Real sky Conditions

Case A: Scaled Model 1:10, under real sky conditions

Case B: Scaled model 1:10, under sky simulator, for CIE standard ovescast sky (Type 1)

Case C: Scaled model 1:10, sky reproduced in sky-simulator. Sky luminance data obtained from sky scanner

Case D: Virtual model using Radiance Gensky, under CIE standard sky distribution

Case E: Virtual model, sky reproduction using the data from the sky scanner

Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

2.3 Comparing simulations of the daylight propagation through CFS using

A)Measurements of the Real building under real sky

A)Simulations:

1) Standard double glazing window

2)Using CFS:

a) Primitive *Prism2* → cfs.cal

Simulations:

1) Standard double glazing window

2) Using CFS:

a) *Prism2* → btdf2prism2_cfs.cal

Window 6 –XML file format

b) BTDF pre-process mkillum

c) *bsdf* material

d) *bsdf* material + mk

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

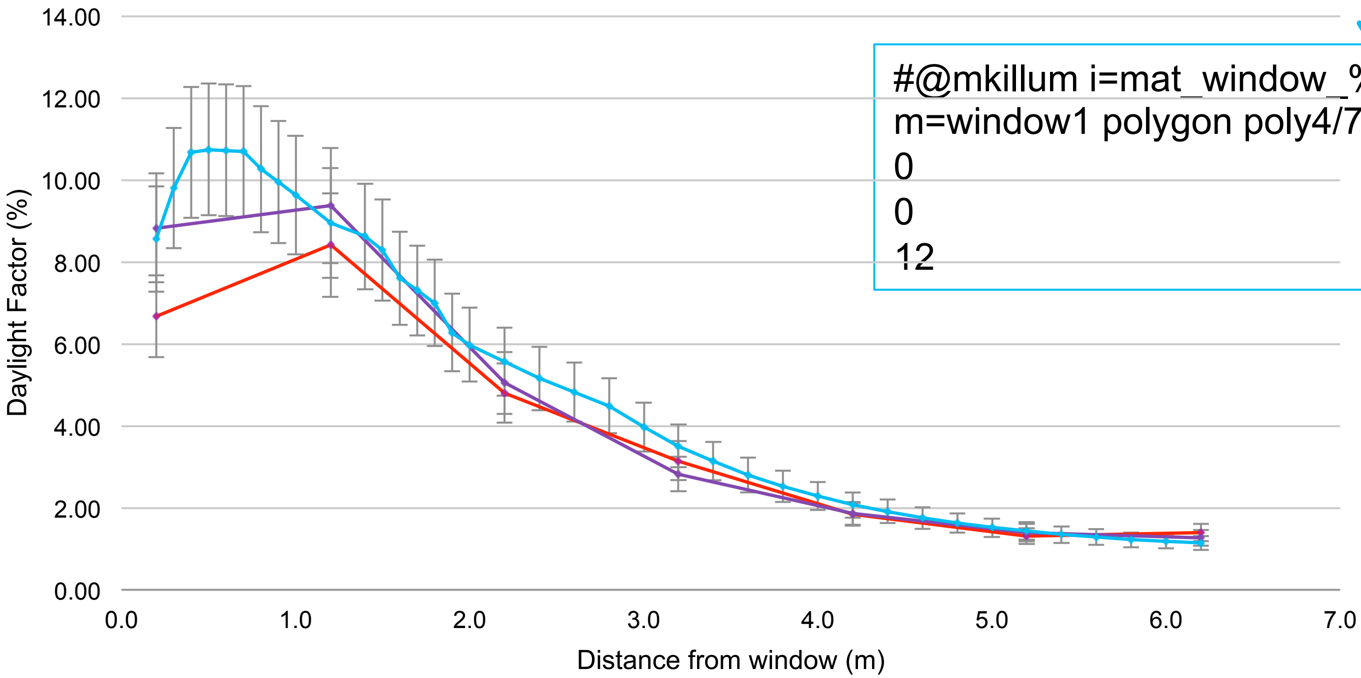
3) Results

Double glazing window

1. Standard Module: double glazing window

```
.\bin\oconv -f sim_ovc_cie_window_2012.rad material.rad model.rad window.rad > base_D_0.oct
```

```
#@mkillum i=mat_window_%t80.5 d=223 s=115
m=window1 polygon poly4/78
0
0
12
```



A) Real Building (real sky)

A) CASE D: simulated CIE standard sky

1b) Reference. window.rad @mkillum t=80.5% (0.8777)-double glazing-

Computing Time

1.5h

Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

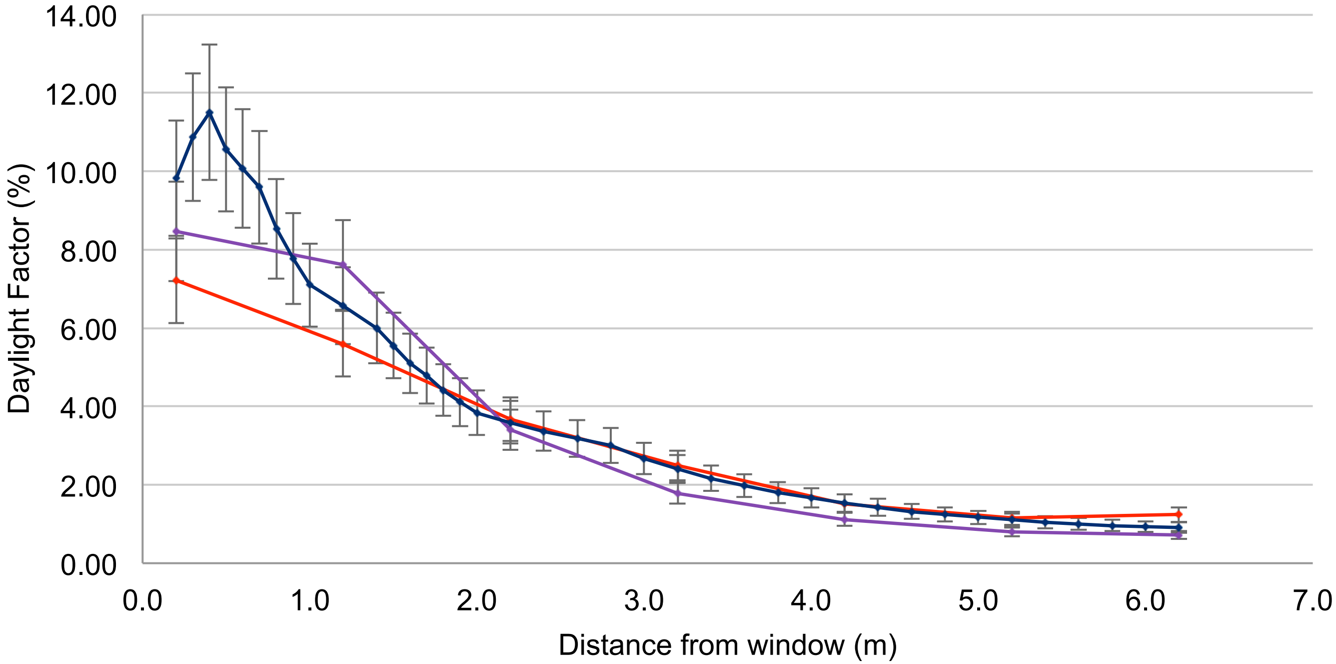
2. CFS: Lasercut panel

a) primitive *prism2*

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercut.rad > base_D_0.oct
```

a) Previous simulation 2007 — LaserCutPanel.cal

b) Present simulation 2012 — btdf2prism2_lcp.cal



A) Real Building (real sky)
A) Case D simulated st. Sky (lasercutpanel.cal)
2) ovc lasercut.rad prism2 (btdf2prism2_lcp.cal)

Case D: simulated st. Sky (lasercutpanel.cal)

Vs.

Ovc_lasercut.rad prism2 (btdf2prism2_lcp.cal)

Computin g Time

~72h

Work performed by: Anothai Thanachareonkit

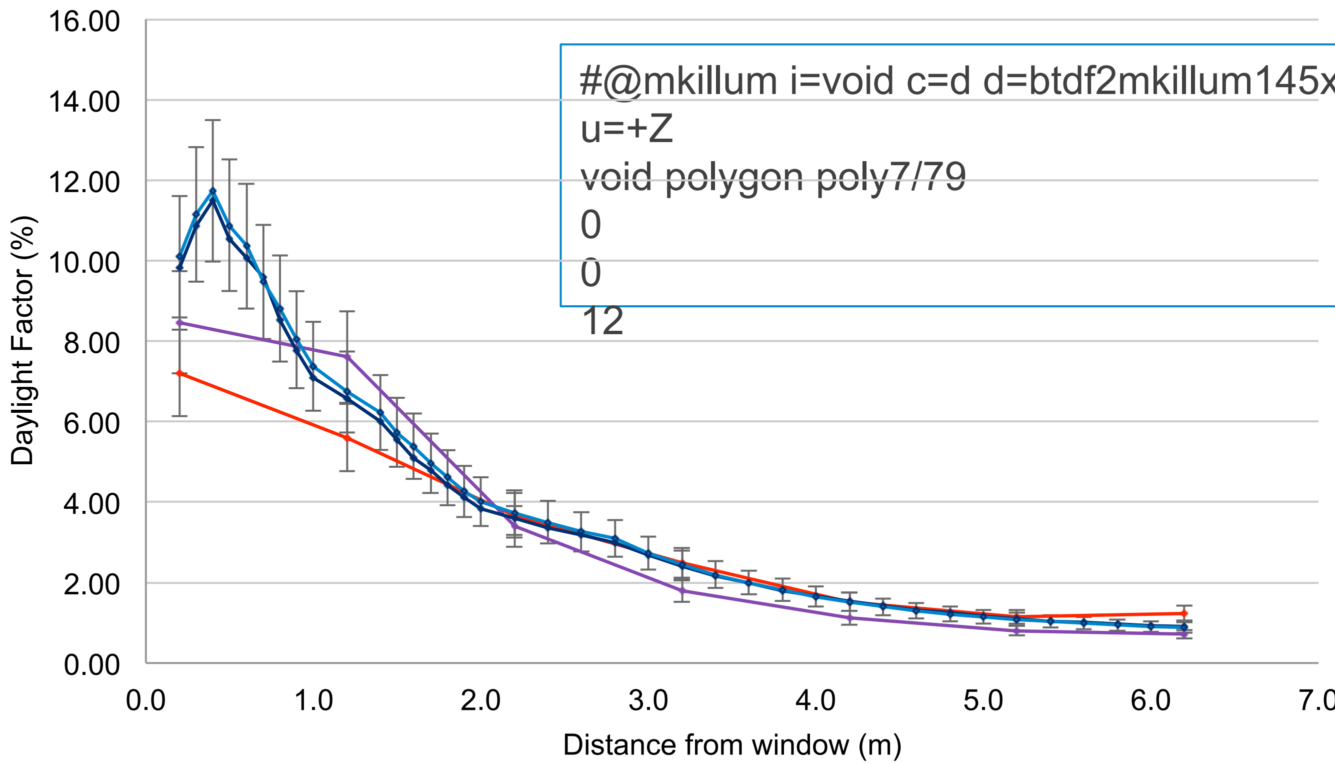
VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

Lasercut par

b) BTDF data

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBTDF_1297.rad > base_D_0.oct
```

```
#@mkillum i=void c=d d=btdf2mkillum145x1297_LCP.xml s=40000 l+ u=+Z
void polygon poly7/79
0
0
12
```



A) Real Building (real sky)

A) Case D simulated st. Sky (lasercutpanel.cal)

2) ovc lasercut.rad prism2 (btdf2prism2_lcp.cal)

3b) ovc LCP_BTDF.rad (btdf2mkillum145x1297_LCP.xml)

Computing Time

~64h

Case D: simulated st. Sky (LaserCutPanel.cal)

Vs.

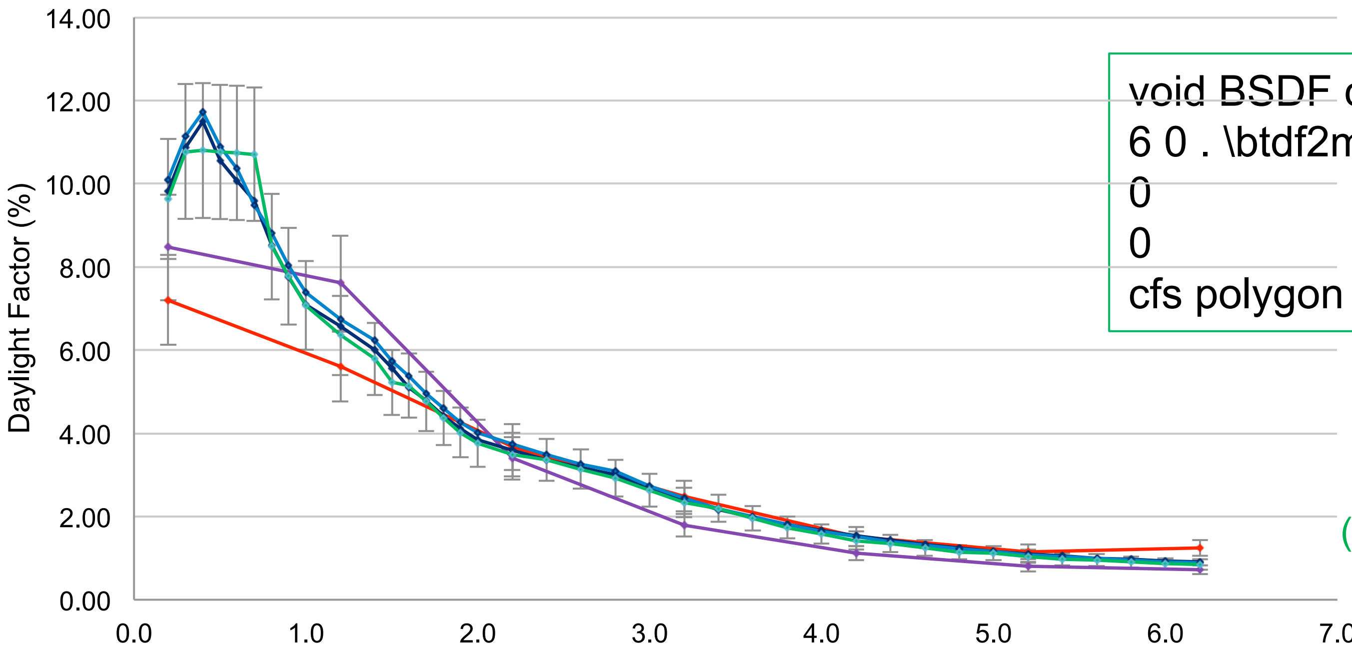
Ovc_LCP_BTDF.rad (btdf2mkillum145x1297_lcp.xml

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

c) *bsdf* material

Lasercut pa

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBSDF.rad > base_D_1.oct
```




```
void BSDF cfs
6 0 . \btdf2mkillum145x1297_LCP. xml 0
0
0
cfs polygon poly7/79
```

Case D: simulated st. Sky (lasercutpanel.cal

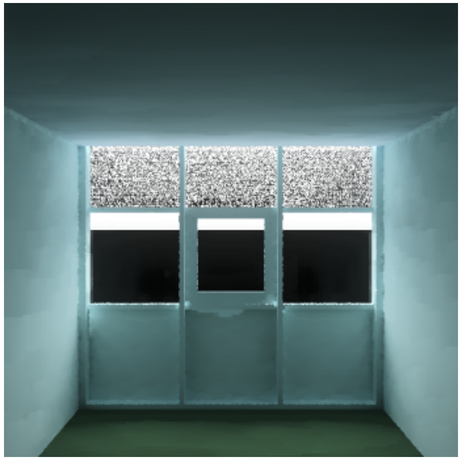
Vs.

Ovc_LCP_BSDF.rad (btdf2mkillum145x1297_lcp.xml)

- A) Real Building (real sky)
- A) Case D simulated st. Sky (lasercutpanel.cal)
- 2) ovc lasercut.rad prism2 (btdf2prism2_lcp.cal)
- 3b) ovc LCP_BTDF.rad (btdf2mkillum145x1297_LCP.xml)
- 4b) ovc LCP_BSDF (btdf2mkillum145x1297)

Computing Time

60h



VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

d) *bsdf* material + mkillum

Lasercut pa

```
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBSDF_MK.rad > base_D_0.oct
```

```
void BSDF cfs
6 0 . \btdf2mkillum145x1297_LCP.xml
0 0 1.
0
0

#@mkillum i=cfs d=223 s=115
m=window4
cfs polygon poly7/79
```

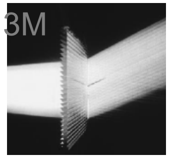
Case D: simulated st. Sky
(LaserCutPanel.cal)

Vs.

Ovc_LCP_BSDF_MK.rad
(btdf2mkillum145x1297_lcp.xml)

3. CFS: Prismatic Film 3M exterior

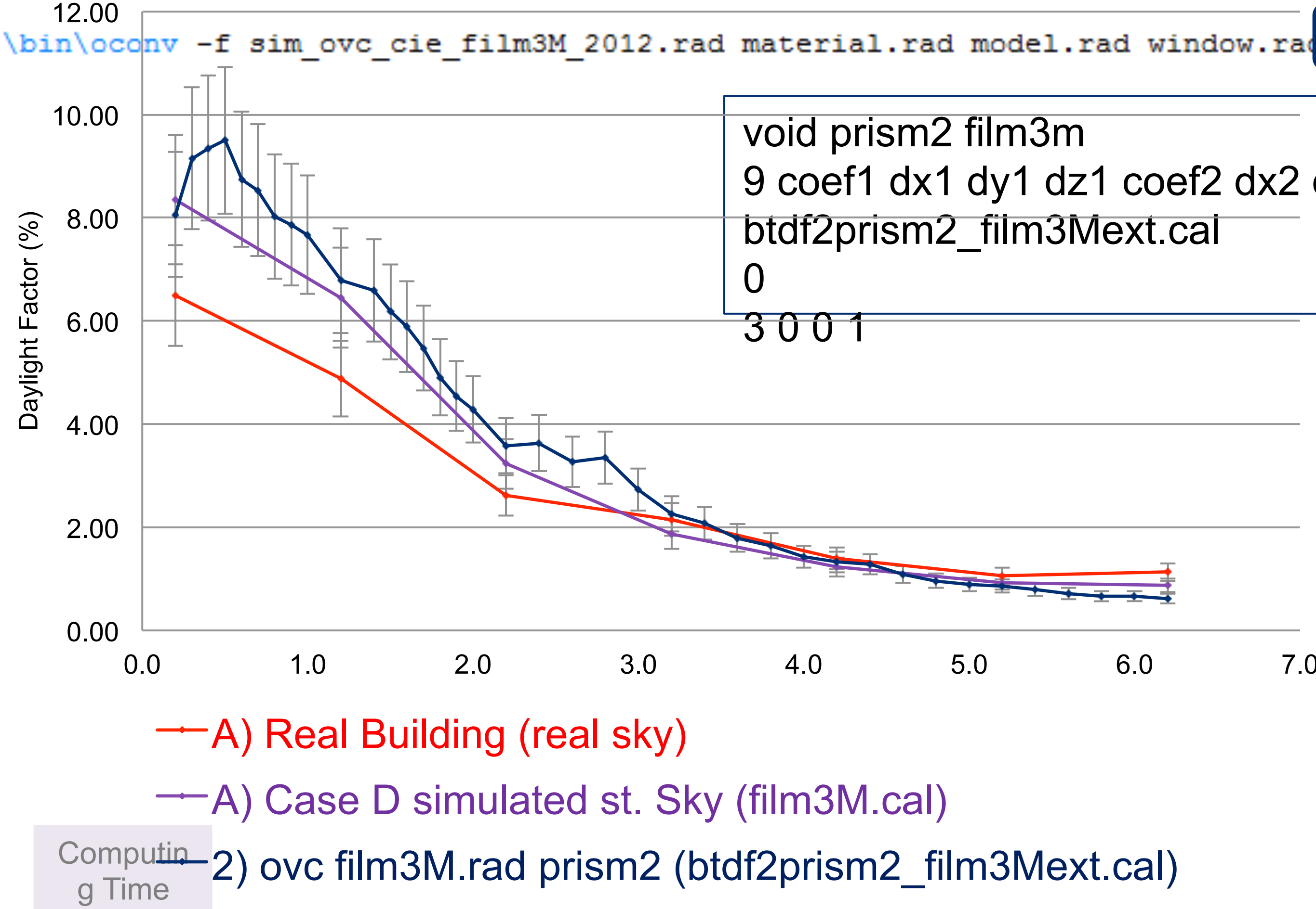
Prismatic Film 3M



a) primitive *prism2*

```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3M.rad > base_D_0.oct
```

```
void prism2 film3m
9 coef1 dx1 dy1 dz1 coef2 dx2 dy2 dz2
btdf2prism2_film3Mext.cal
0
3 0 0 1
```



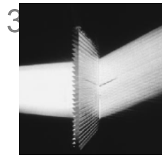
Case D: simulated st. Sky (Film3M_Int.cal)

Vs.

Ovc_lasercut.rad prism2 (btdf2prism2_film3Mext.cal

Computing Time
76h

Prismatic Film 3



b) BTDF data

```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3MBTDF_1297.rad > base_D_0.oct
```

```
#@mkillum i=void c=d d=btdf2mkillum145x1297_film3Mext.xml s=40000 l+ u=+Z

void polygon poly7/79
```

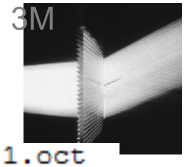
Case D: simulated st. Sky
(film3M_Int.cal)

Vs.

Ovc_film3M_BTDF.rad
(btdf2mkillum145x1297_film3Mext.x

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

Prismatic Film 3M



c) *bsdf* material

```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3MBSDF.rad > base_D_1.oct
```

```
void BSDF cfs
6  0 .\btdf2mkillum145x1297_film3Mext.xml
0 0 1 .
0
0
cfs polygon poly7/79
```

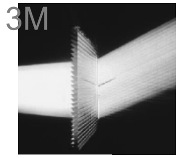
Case D: simulated st. Sky
(lasercutpanel.cal

Vs.

Ovc_film3M_BSDF.rad
(btdf2mkillum145x1297_film3Mext.x

d) *bsdf* material + mkillum

Prismatic Film 3M



```
.\bin\oconv -f sim_ovc_cie_film3M_2012.rad material.rad model.rad window.rad film3MBSDF_MK.rad > base_D_0.oct
```

```
void BSDF cfs
6 0 .\btdf2mkillum145x1297_film3Mext.xml
0 0 1.
0
0
#@mkillum i=cfs d=223 s=115 m=window4
cfs polygon poly7/79
```

Case D: simulated st. Sky
(Film3M_Int.cal)
Vs.
Ovc_film3M_BSDF_MK.rad
(btdf2mkillum145x1297_film3Mext.xm

4) Preliminar conclusions

1) The results obtained in this verification suggests that the use of the procedures available today **are reliable**.

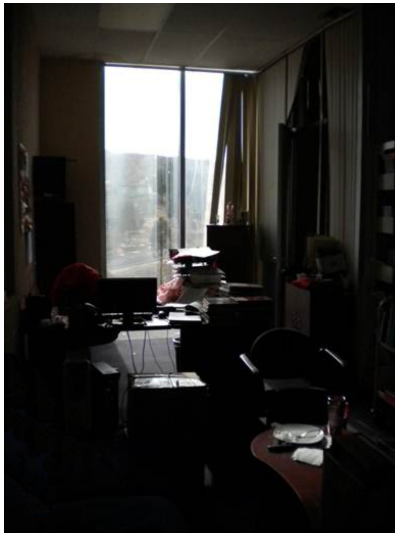
2) Results using the new procedures were slightly closer to those using the primitive ***prism2*** when simulating sharp redirecting CFS than when simulating less sharp redirecting CFS.

3) **Computing time** doesn't increase when applying Window 6 XML file, and in some cases its even reduced.

4) The use of the new available procedures gives the possibility of testing more CFS as allows the use of not only sharp redirecting CFS.

5) Future Work

a) Tec de Monterrey -Private University-




b) Centro de Estudios del Desarrollo (UAZ) –Research Center-


PRESENT WORK

*Illuminance and Luminance measurements were already taken
on-site during winter and summer solstice (clear and overcast sky conditions)

*Calibration of the virtual model: ongoing process

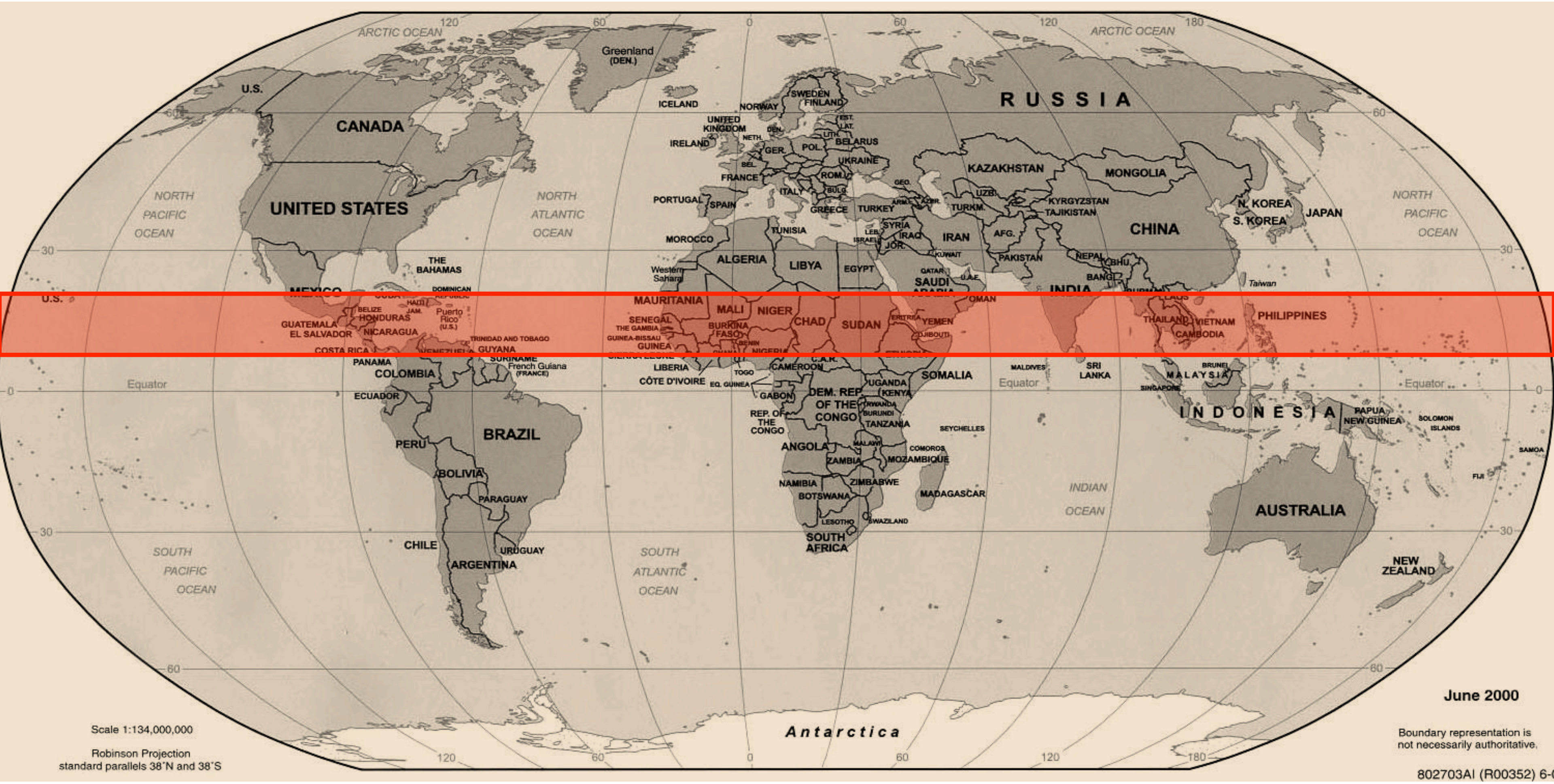
NEXT:

*Testing of different CFS on both virtual models:

-LCP
-Prismatic Film 3M interior and exterior
-Light channeling panel
-Sun directing Glass (lumitop)
-Others

Thank you!

VERIFICATION OF THE COMPUTER MODELLED DAYLIGHT PROPAGATION THROUGH COMPLEX FENESTRATION SYSTEMS

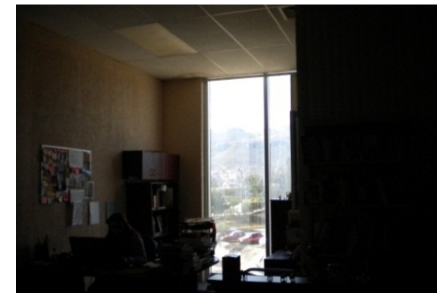


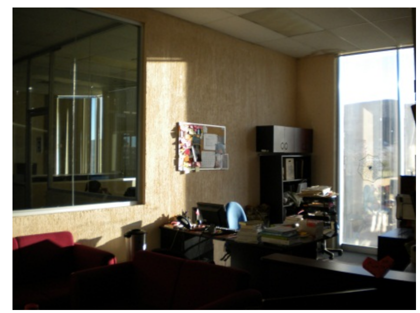
1) Daylight optimization of buildings located at low latitudes

1.1 Tec de Monterrey

Orientation: 53° SW
Typology: Educational-Private University
Function: Library Office
Dimensions: 5.2m x 7.3m x 3.02m
Area: 32.7 m²
Occupation Time: 9am to 2pm / 4pm to 8pm

Window Area: 14.24 m²
Proportion window/area: 0.43
Fenestration details: double glazing
Sun shading: none



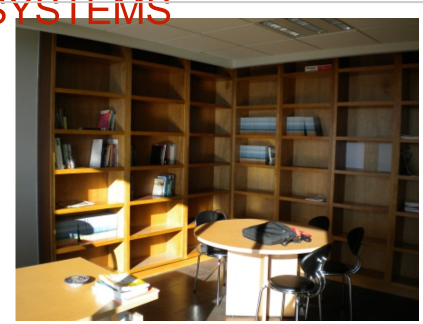


2) Universidad Autonoma de Zacatecas (UAZ)

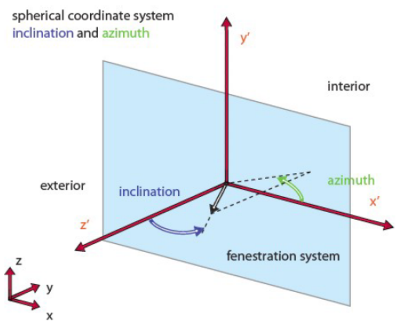
Orientation: 35° SE
Typology: Educational-Public Research Center
Function: Private Office
Dimensions: 4.2 m x 5.2m x 2.7m

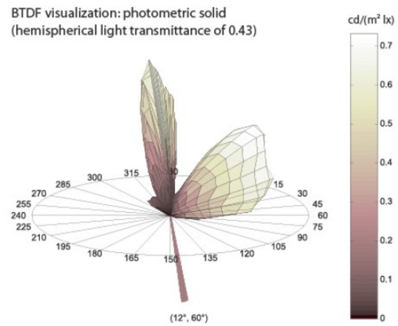
Area: 21.84 m²
Occupation Time: 9am to 2pm / 4pm

Window Area: 10.75 m²
Proportion window/area: 0.52
Fenestration details: single glazing
Sun shading: 0.45m exterior overhang



Conversion from IEA21 to the XML format

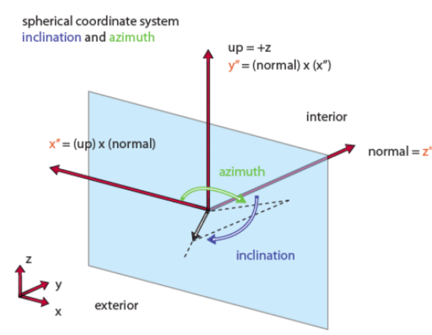


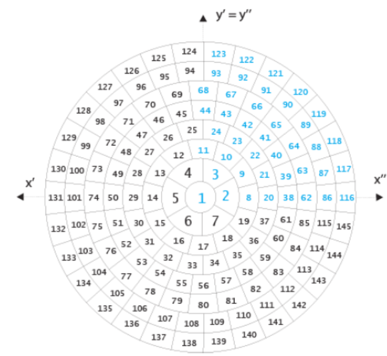


Reference frame attached to the sample:
- z' pointing outside, y' vertical, x' horizontal

BTDF2RADIANCE: BTDFs and Radiance
Introduction | Method | Examples | Conclusion

Conversion from IEA21 to the XML format





Reference frame attached to the sample (with up=+Z or direction 0 0 1):
- z" pointing inside, y" vertical, x" horizontal

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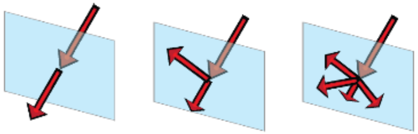
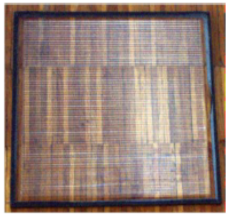
Presentation at the Radiance 10th International Workshop
Jérôme Kämpf by Carsten Bauer
Berkeley Laboratory, LA, 2011

BTDF2RADIANCE: BTDFs and Radiance

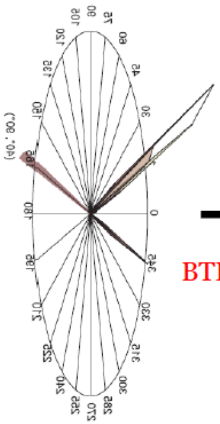


New attempt to use BTDF data with Radiance (2010)

Laser Cut Panel



IEA21



BTDF2RADIANCE

2010: mkillum pre-process
2011: bsdf material

Using an XML file format to describe the BTDF

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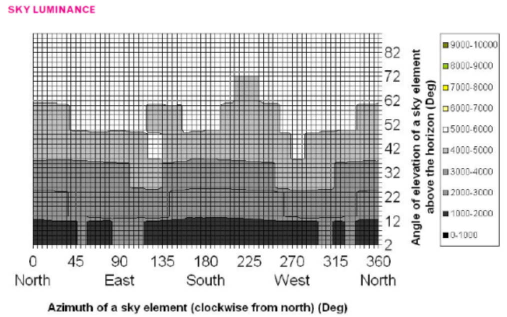
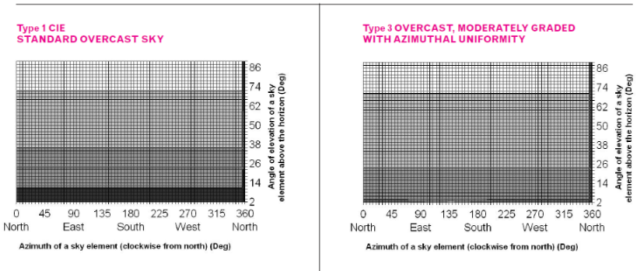
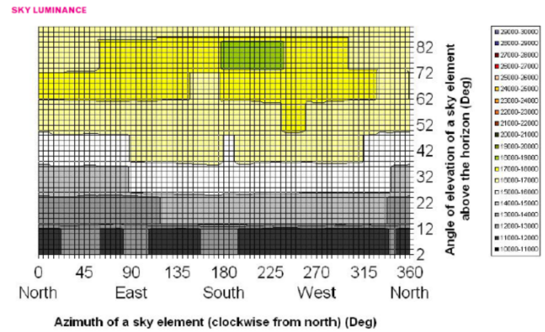
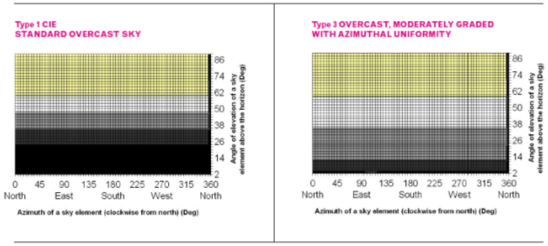
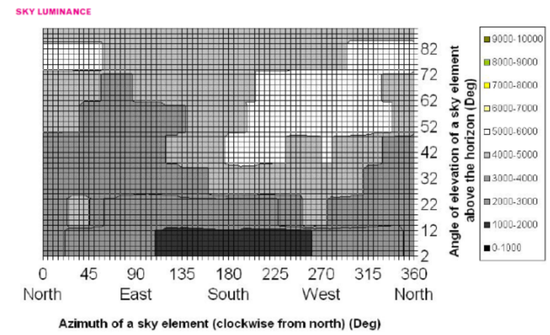


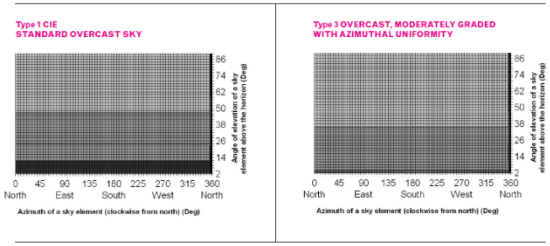
Fig. 4.11
Graphic comparison of real sky luminance observed for the double glazing with CIE standard skies

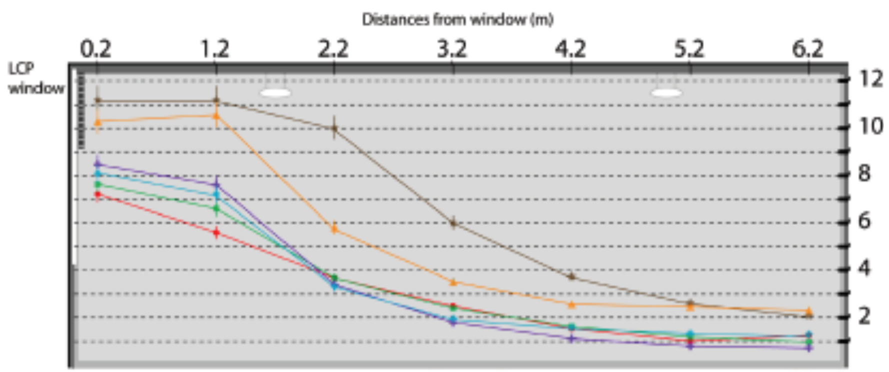


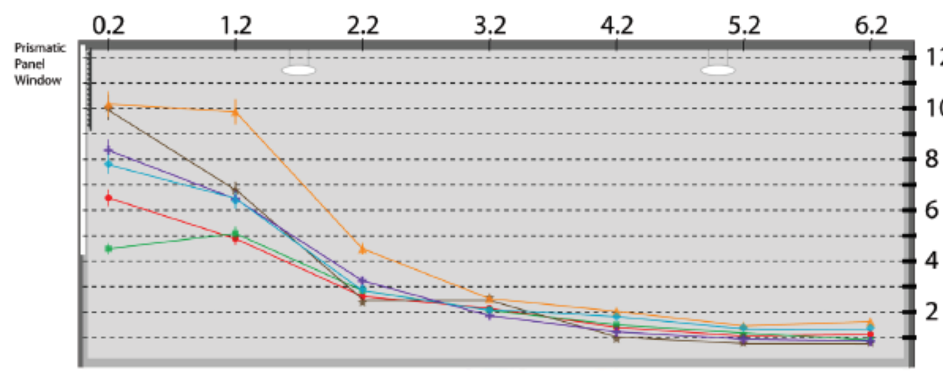












Work performed by: Anothai Thanachareonkit
EPFL LESO-PB 2008

C:\Users\basurto\Desktop\Nikon\PROJECT\SIMULATIONS\SWISS\NewGeronimov1.1_DEMONA\batch_DEMONA_ovc_LCP_prism2.bat - Notepad++

```
@echo off
echo "First octree"
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercut.rad > base_D_0.oct
echo "Mkillum"
.\bin\mkillum -u+ -av 0 0 0 -ab 9 -ds 0.01 -dj 0.9 -dt 0.05 -dc 0.17 -dr 3 -dp 4096 -ar 64 -aa 0.2 -ad 4096 -as 2048 base_D_0.oct "<" lasercut.rad > illums_D.rad
echo "Second octree"
.\bin\oconv sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad illums_D.rad > base_D_1.oct
echo "Mesh-points calculation"
.\bin\rtrace -w -I -h -u+ -av 0 0 0 -ab 9 -ds 0.01 -dj 0.9 -dt 0.05 -dc 0.17 -dr 3 -dp 4096 -ar 64 -aa 0.2 -ad 2048 -as 1024 base_D_1.oct < mesh_D_p.inp |.\bin\rcalc -e "$1=(0.265*$1+0.67*$2+0.065*$3)*179" > mesh_D_p.out
echo "Picture window"
.\bin\rpict -t 10 -pa 1 -x 600 -y 600 -vtv -vp 1.53 5.5 1.8 -vd 0 -5 0 -vu 0 0 1 -ab 11 -av 0 0 0 -ad 256 -as 128 -aa .2 -ar 32 -dp 4096 base_D_1.oct >.\LCP\ovc\base_D_1.hdr
.\bin\pcond -h .\LCP\ovc\base_D_1.hdr >.\LCP\ovc\base_D_1_H.hdr
.\bin\ra_bmp .\LCP\ovc\base_D_1_H.hdr .\LCP\ovc\base_D_1_H.bmp
echo "Picture wall"
```

C:\Users\basurto\Desktop\Nikon\PROJECT\SIMULATIONS\SWISS\NewGeronimov1.1_DEMONA\batch_DEMONA_ovc_LCP_BTDF.bat - Notepad++

```
@echo off
echo "First octree"
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBTDF_145.rad > base_D_0.oct
echo "Mkillum"
.\bin\mkillum -u+ -av 0 0 0 -ab 9 -ds 0.01 -dj 0.9 -dt 0.05 -dc 0.17 -dr 3 -dp 4096 -ar 128 -aa 0.1 -ad 26315 -as 10240 base_D_0.oct "<" lasercutBTDF_145.rad > illums_D.rad
echo "Second octree"
.\bin\oconv sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad illums_D.rad > base_D_1.oct
echo "Mesh-points calculation"
.\bin\rtrace -w -I -h -u+ -av 0 0 0 -ab 9 -ds 0.01 -dj 0.9 -dt 0.05 -dc 0.17 -dr 3 -dp 4096 -ar 128 -aa 0.1 -ad 26315 -as 10240 base_D_1.oct < mesh_D_p.inp |.\bin\rcalc -e "$1=(0.265*$1+0.67*$2+0.065*$3)*179" > mesh_D_p.out
echo "Picture window"
```

C:\Users\basurto\Desktop\Nikon\PROJECT\SIMULATIONS\SWISS\NewGeronimov1.1_DEMONA\batch_DEMONA_ovc_LCP_BSDF.bat - Notepad++

```
@echo off
echo "First octree"
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBSDF.rad > base_D_1.oct
echo "Mesh-points calculation"
.\bin\rtrace -w -I -h -u+ -av 0 0 0 -ab 9 -ds 0.05 -dj 0.9 -dt 0.05 -dc 0.5 -dr 3 -dp 4096 -ar 128 -aa 0.1 -ad 26315 -as 10240 base_D_1.oct < mesh_D_p.inp |.\bin\rcalc -e "$1=(0.265*$1+0.67*$2+0.065*$3)*179" > mesh_D_p.out
echo "Picture window"
.\bin\rpict -t 10 -pa 1 -x 600 -y 600 -vtv -vp 1.53 5.5 1.8 -vd 0 -1 0 -vu 0 0 1 -ab 9 -av 0 0 0 -ad 512 -as 256 -aa 0.2 -ar 32 -dp 4096 base_D_1.oct >.\_LCP\BSDF\ovc\base_D_1.hdr
.\bin\pcond -h .\_LCP\BSDF\ovc\base_D_1.hdr > .\_LCP\BSDF\ovc\base_D_1_H.hdr
.\bin\ra_bmp .\_LCP\BSDF\ovc\base_D_1_H.hdr .\_LCP\BSDF\ovc\base_D_1_H.bmp
```

C:\Users\basurto\Desktop\Nikon\PROJECT\SIMULATIONS\SWISS\NewGeronimov1.1_DEMONA\batch_DEMONA_ovc_LCP_BSDF_MKILLUM.bat - Notepad++

```
@echo off
echo "First octree"
.\bin\oconv -f sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad lasercutBSDF_MK.rad > base_D_0.oct
echo "Mkillum"
.\bin\mkillum -u+ -av 0 0 0 -ab 9 -ds 0.01 -dj 0.9 -dt 0.05 -dc 0.5 -dr 3 -dp 4096 -ar 128 -aa 0.1 -ad 26315 -as 10240 base_D_0.oct "<" lasercutBSDF_MK.rad > illums_D.rad
echo "Second octree"
.\bin\oconv sim_ovc_cie_lcp_2012.rad material.rad model.rad window.rad illums_D.rad > base_D_1.oct
echo "Mesh-points calculation"
.\bin\rtrace -w -I -h -u+ -av 0 0 0 -ab 9 -ds 0.05 -dj 0.9 -dt 0.03 -dc 0.5 -dr 3 -dp 4096 -ar 128 -aa 0.1 -ad 26315 -as 10240 base_D_1.oct < mesh_D_p.inp |.\bin\rcalc -e "$1=(0.265*$1+0.67*$2+0.065*$3)*179" > mesh_D_p.out
```