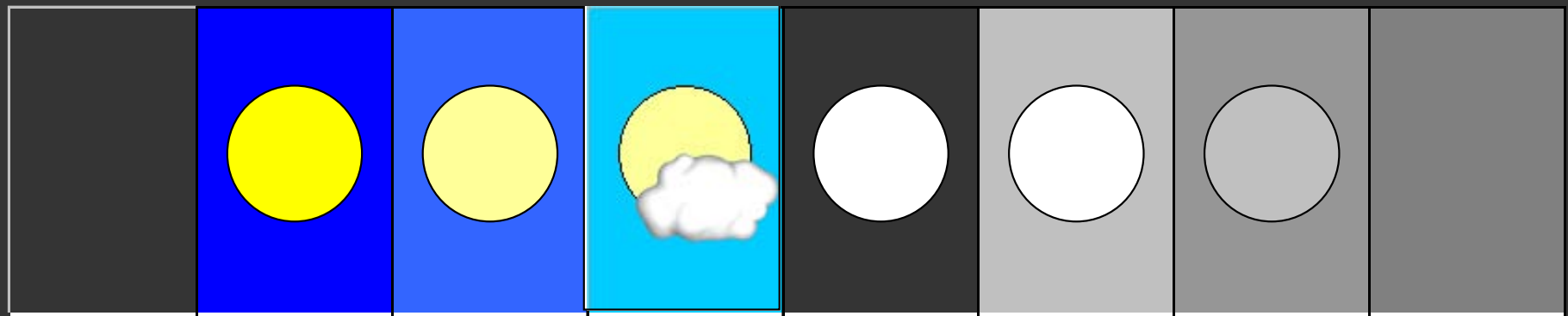
# Direct and diffuse components of daylight



| Sky type | Clear | Milky-white | Partly cloudy | Whitish | Light grey | Dark grey | Dark |
|---|---|---|---|---|---|---|---|
| Sun | Shiny | Clear | Partly veiled | Veiled | Still visible | Barely visible | Invisible |
| Global radiation [W/m$^2$] | 800 to 900 | 600 to 800 | 300 to 700 | 250 to 400 | 200 to 300 | 100 to 200 | 20 to 100 |
| Diffuse component | 10 to 20% | 20 to 40% | 20 to 50% | 40 to 80% | 50 to 100% | 75 to 100% | 100% |

# Direct and diffuse components of daylight

- Sky models for diffuse component

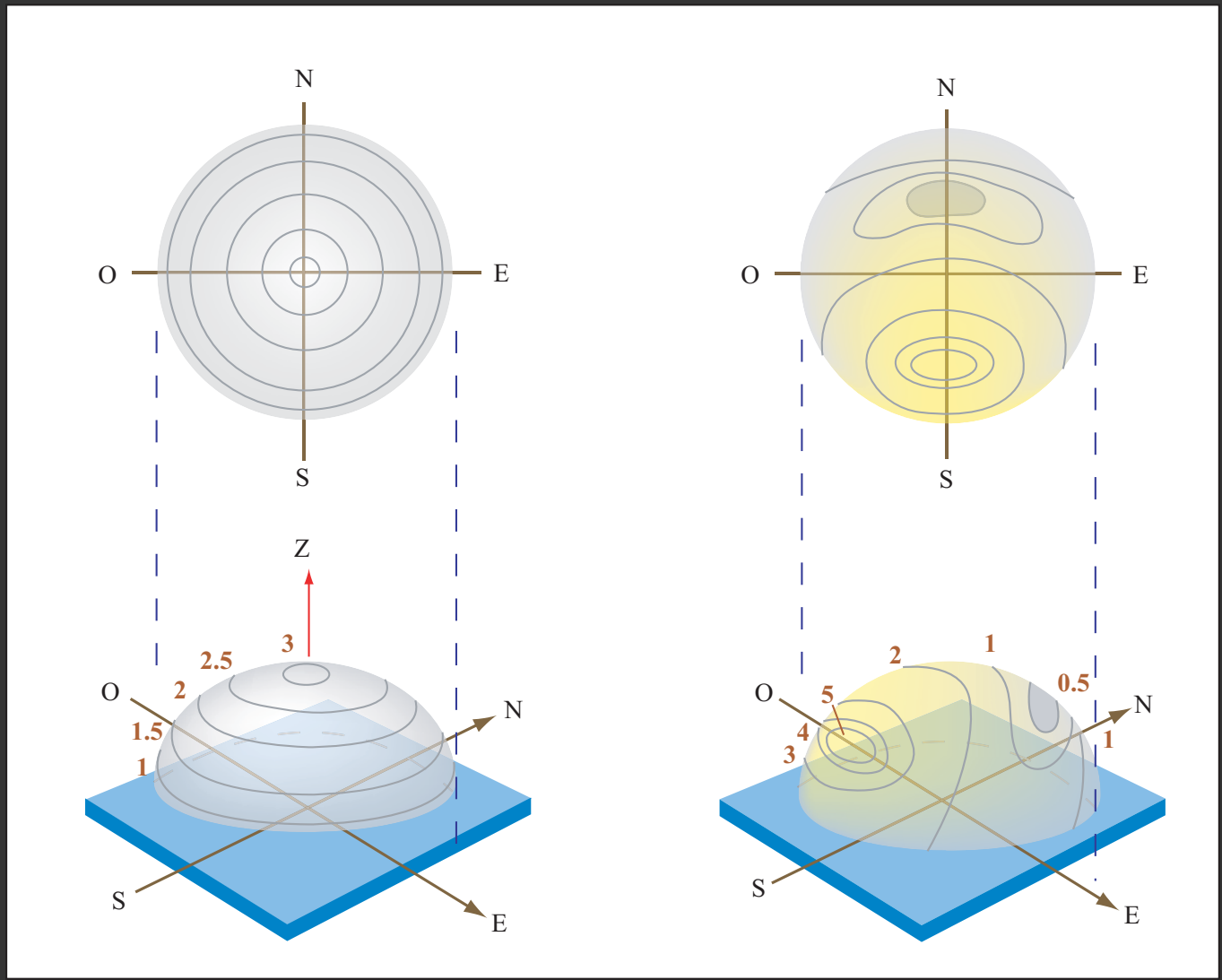
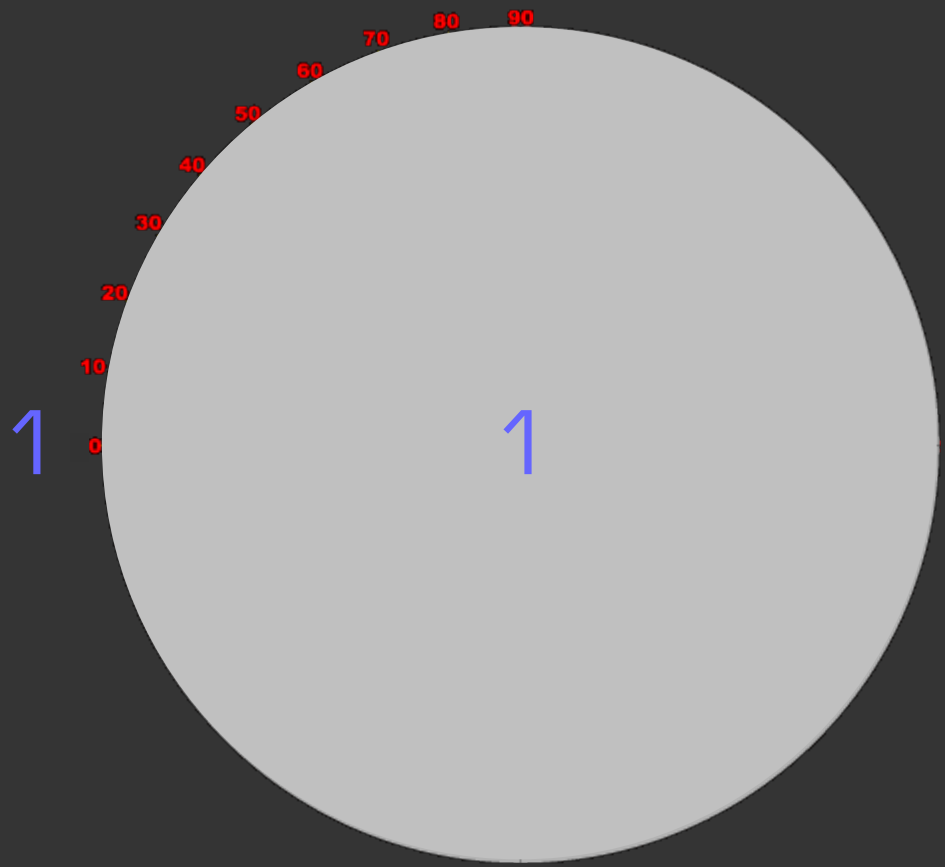



Figure by MIT OCW.

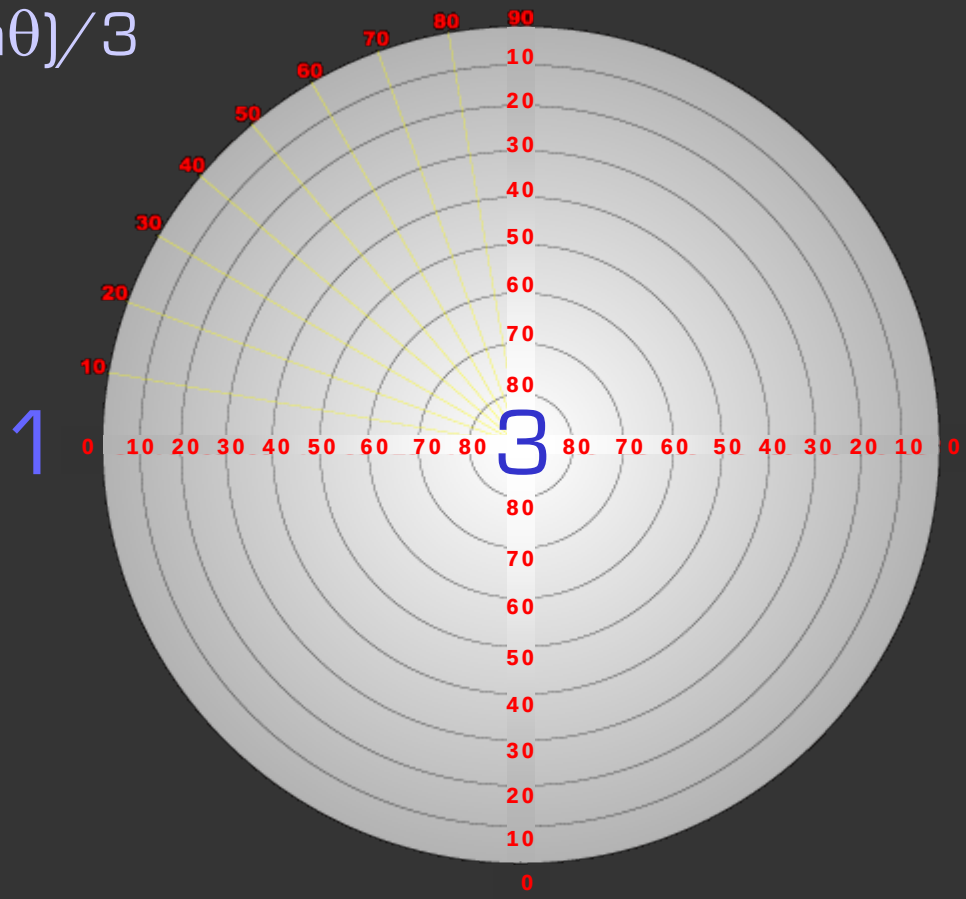
# Sky models

- Overcast sky
  - 7’000 (winter) to 20’000 (summer) lux on ground
  - uniform $L(\theta)=L_z$



# Sky models

- Overcast sky
  - 7'000 (winter) to 20'000 (summer) lux on ground
  - CIE overcast $L(\theta)=L_z(1+2\sin\theta)/3$



# Sky models

- Clear sky
  - 30’000 (winter) to 100’000 (summer) lux on ground

# Sky models

- Clear sky
  - CIE clear sky model

    L = fction of zenith luminance and sun position

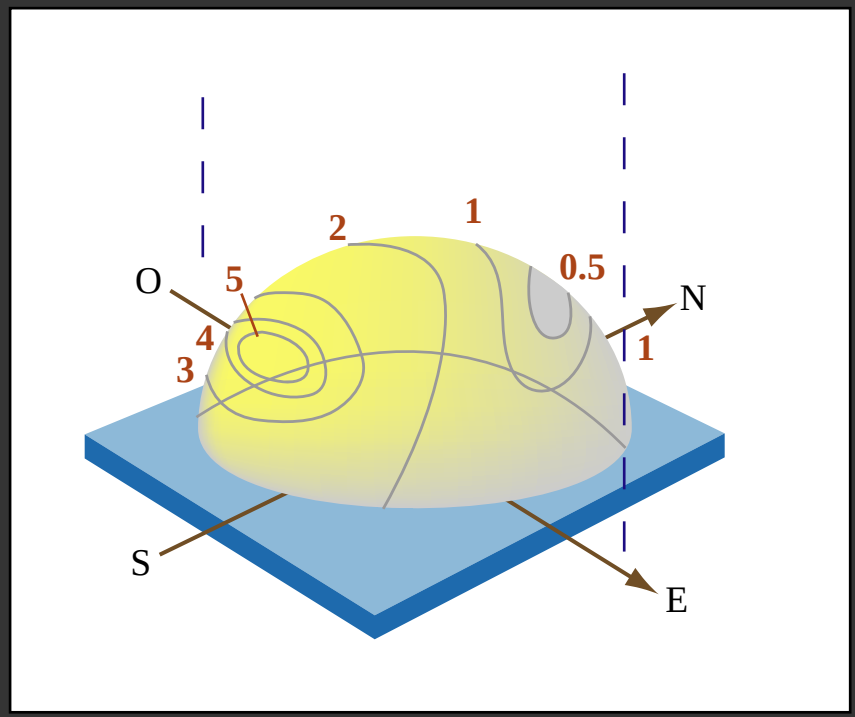



Figure by MIT OCW.

# Sky models

- Clear sky
  - CIE clear sky model

    L = fction of zenith luminance and sun position
  - Perez All Weather sky model (generalization of CIE clear sky)

    L = fction of date, time, direct and diffuse illuminances, and 5 coefficients

  ➔ L fully defined if diffuse and direct irradiance are known

# Daylighting metrics

## Static metrics

- Daylight Factor DF [%]
  - DF = ($E_{point}/E_{outside\ horizontal}$) * 100% (only defined for overcast skies!)

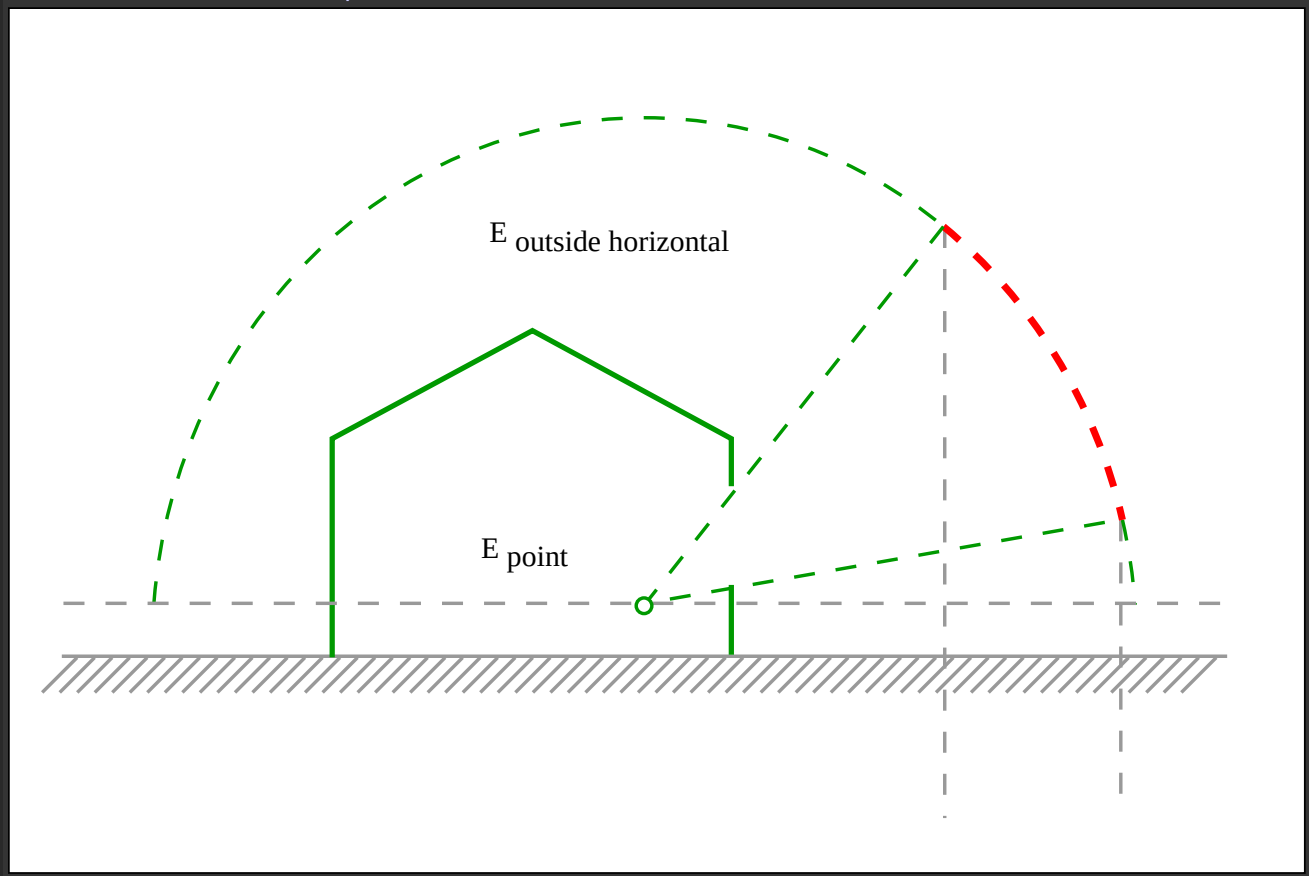



Figure by MIT OCW.

# Daylighting metrics

- Static metrics
  - Daylight Factor DF [%]
    - DF = ($E_{point}$/$E_{outside\ horizontal}$) * 100% (only for overcast skies!)
    - either measured or calculated

below 1% → dark, only suitable for storage areas

1% to 2% → low illumination, suitable for circulation areas

2% to 4% → moderate, for living spaces

4% to 7% → medium, for office work

7% to 12% → high, for precision tasks

over 12% → very high, for exceptional light requirements

# Average Daylight Factor calculation

- Empirical formula

$$DF_{average} = \frac{\sum(W \cdot \tau \cdot \theta \cdot m)}{A(1-R_2)}$$

Figure by MIT OCW.

where

$W$ = Area of each window ($m^2$),

$\tau$ = Transmittance of each glazing material

$\theta$ = Vertical angle of sky as seen from centre of each window

$m$ = Maintenance factor based on angle of glazing and cleanliness (0.5 – 0.9),

$A$ = Total internal surface area of space, including walls, floors, ceilings & windows ($m^2$)

$R_2$ = Area weighted average reflectance of all surfaces making up $A$

(use 0.1 as reflectance for glass).

# LEED Green Building Rating System

- Daylighting credits
  - § 8.1 = Daylight 75% of spaces with GF > 2% (1 credit)
  - § 8.2 = View for 90% of occupied spaces (2 credits)
- Estimation using formula

$$\text{Glazing Factor} = \frac{\text{Window Area [SF]}}{\text{Floor Area [SF]}} \times \text{Window Geometry Factor} \times \frac{\text{Actual } T_{vis}}{\text{Minimum } T_{vis}} \times \text{Window Height Factor}$$

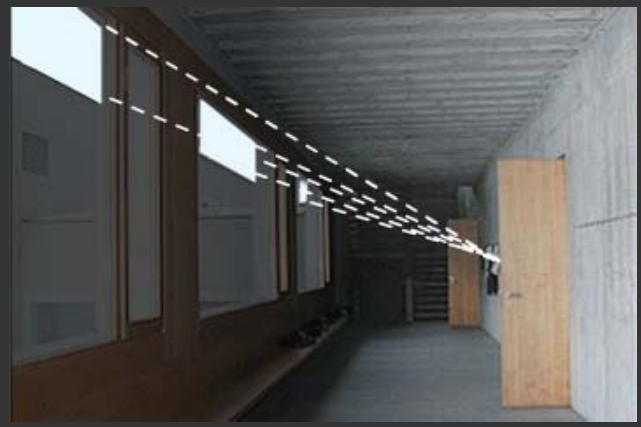
Figure by MIT OCW.

  - Chart for
    - Geometry Factor
    - Min $T_{vis}$
    - Height factor
- No information about glare, overheating…

# Split-flux method for Daylight Factor

UK Building Research Establishment (BRE)

- D [%] = $E_P$ / $E_h$ = sum of:
  - Direct (sky) component: SC



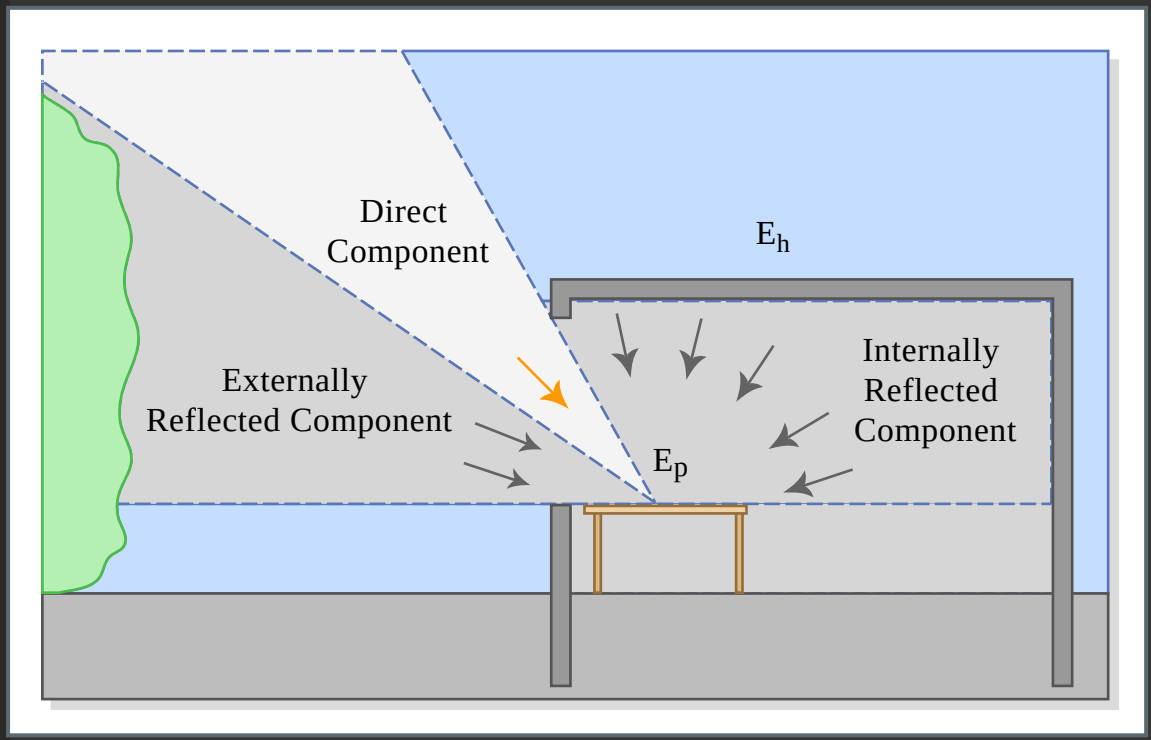
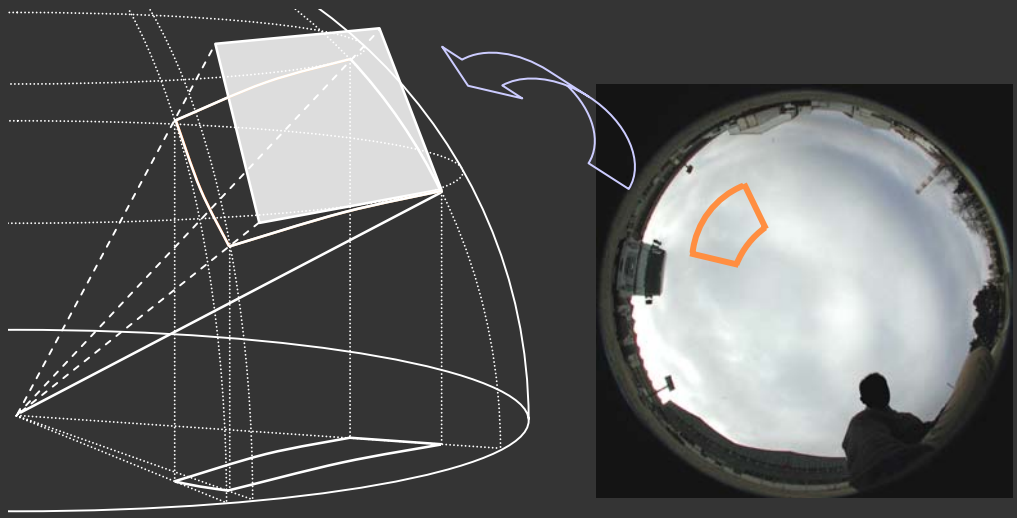



Figure by MIT OCW.

# Split-flux method for Daylight Factor

- D [%] = $E_P$ / $E_h$ = sum of:
  - Direct (sky) component: SC

Illuminance ratio $\dfrac{E_P \text{ from visible sky portion}}{E_h \text{ from whole sky}}$



# Split-flux method for Daylight Factor

- D [%] = $E_P$ / $E_h$ = sum of:
  - Direct (sky) component: SC
  - Externally reflected component: ERC

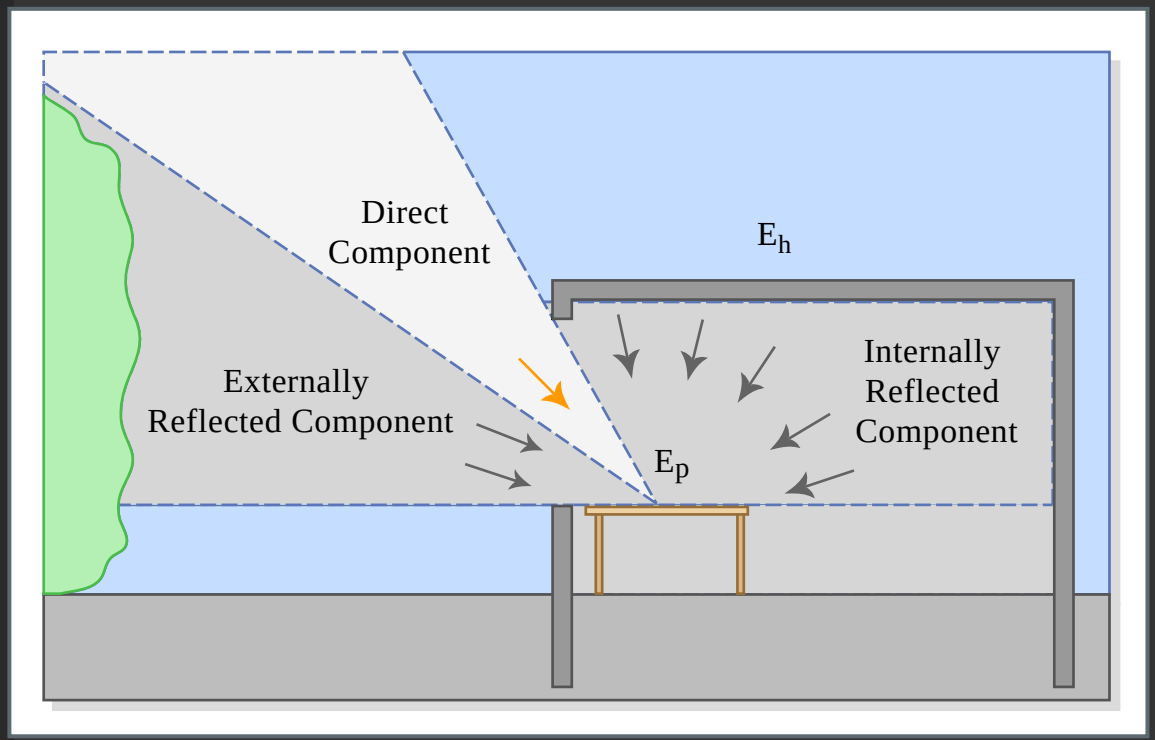
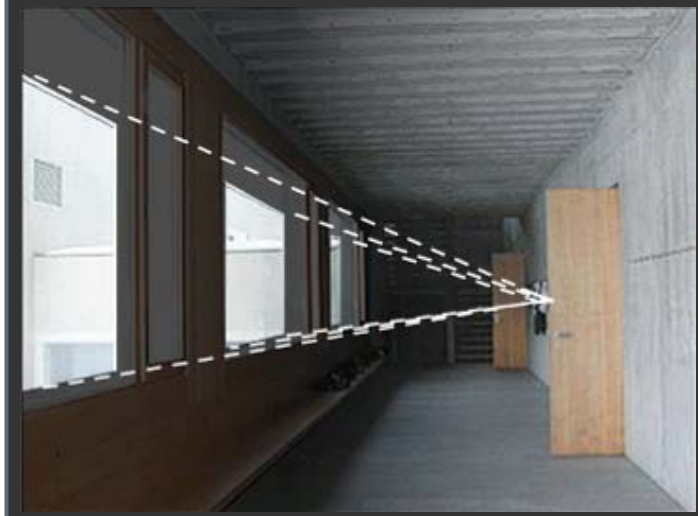


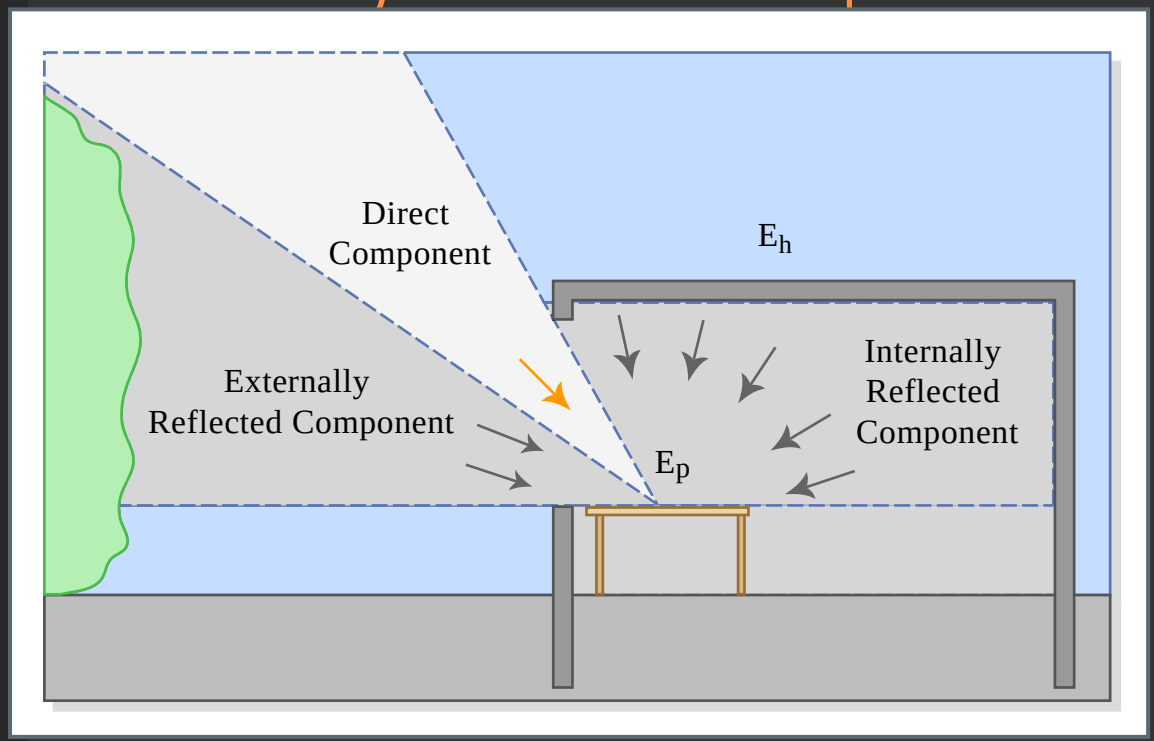

Figure by MIT OCW.

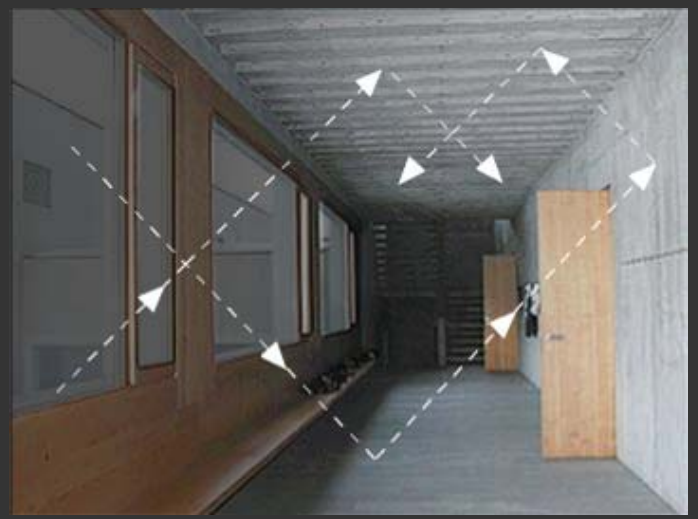


Consider as sky component with different luminance

# Split-flux method for Daylight Factor

- D [%] = $E_P$ / $E_h$ = sum of:
  - Direct (sky) component: SC
  - Externally reflected component: ERC
  - Internally reflected component: IRC



Use formula $Average\,IRC = \frac{0.85W}{A(1-\rho)} \times (C\,\rho_{fw} + 5\,\rho_{cw})$

Figure by MIT OCW.

# Daylighting metrics

- Static metrics
  - Daylight Factor DF [%]: design implications

... but

DF optimized if building is fully glazed !

# Daylighting metrics

## Static metrics

- Daylight Factor DF [%]: design implications

PROS

- simple
- informative on some important issues

CONS

- discards orientation, climate, location, time → important consequences

From F. Anselmo (ARUP), Radiance Workshop, Sept 2006

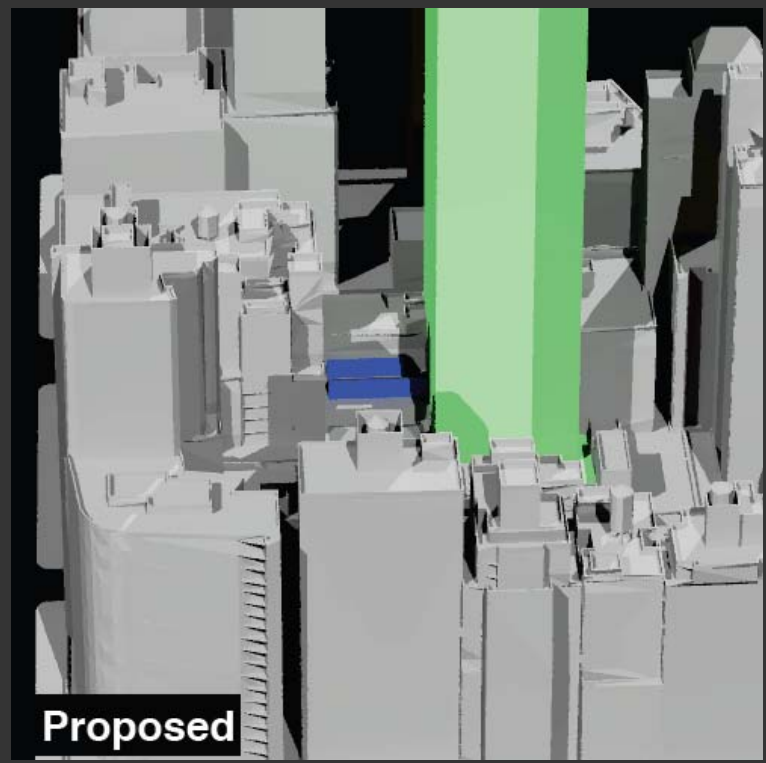
# Daylighting metrics

- Static metrics
  - Daylight Factor DF [%]
  - Combination with avoidance of direct sunlight
    - Shading system, Blinds ...

    → better from an energy standpoint (no overheating), glare but still limited

# Daylighting metrics

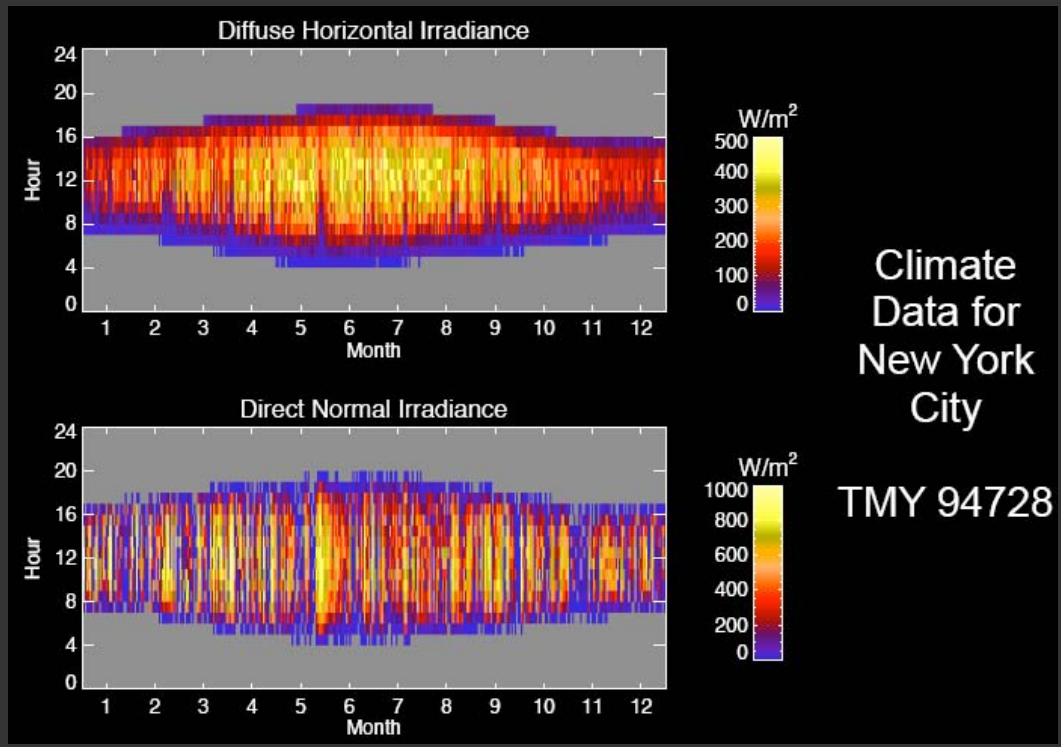
- Static metrics
  - Daylight Factor DF [%]
  - Combination with avoidance of direct sunlight
    - Example illustrating limitations of this combination: tower project next to daylit building
      - skylights are North facing → almost no sun
      - daylit studios' character depends largely on variation of sky conditions




From J. Mardaljevic, Radiance Workshop, Sept 2006

# Daylighting metrics

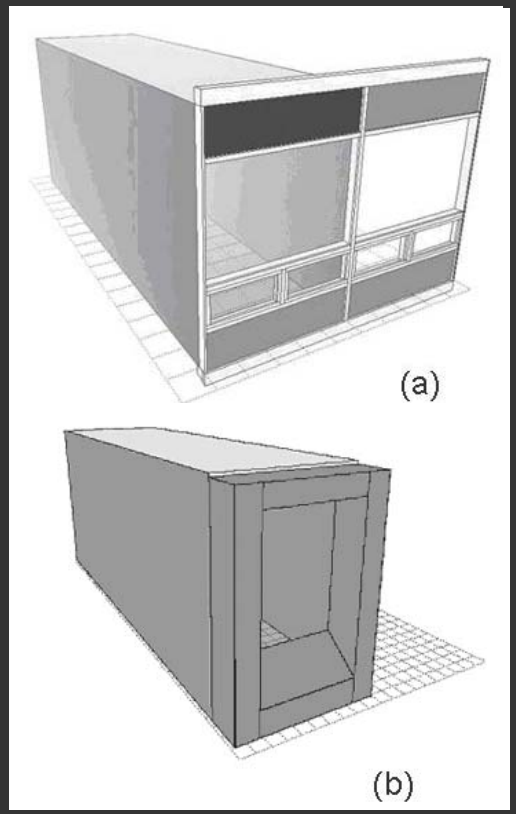
- Dynamic metrics
  - local climate data
    - annual simulations

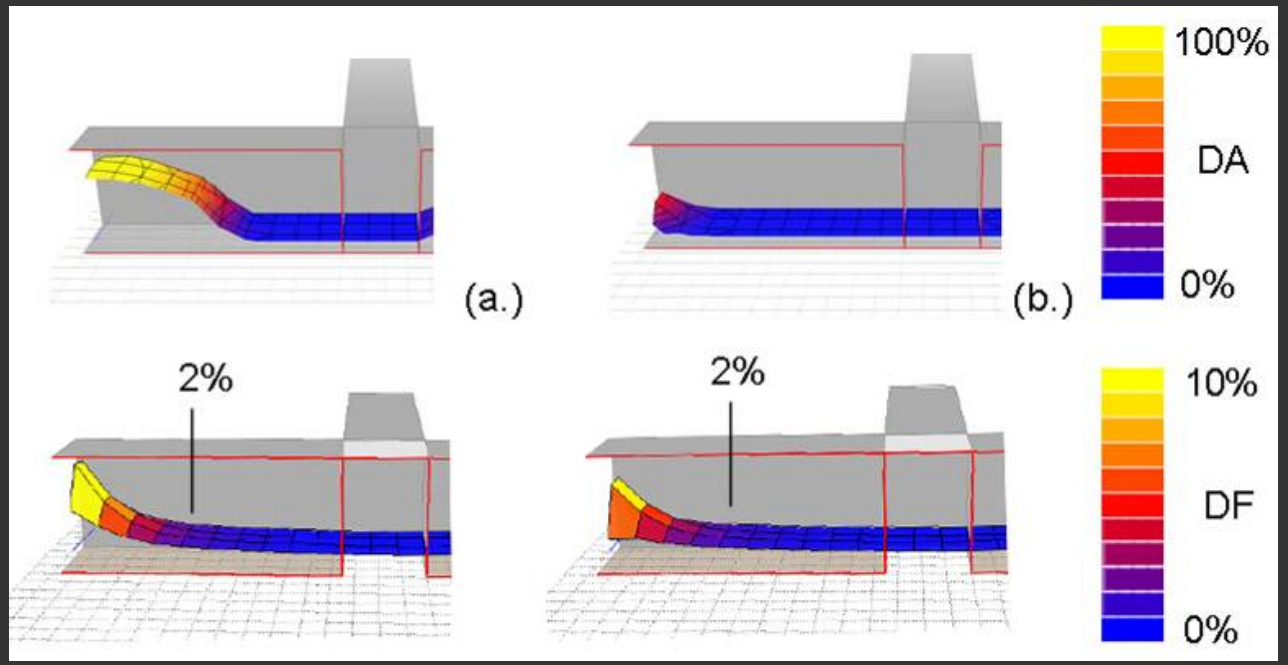



From J. Mardaljevic, Radiance Workshop, Sept 2006

# (Emerging) dynamic daylighting metrics

- Daylight Autonomy (DA)
  - percentage of working hours when a minimum work plane illuminance is maintained by daylight alone




From E. Rice, SMArchS thesis (MIT), May 2006

# (Emerging) dynamic daylighting metrics

- Daylight Autonomy (DA)
  - percentage of working hours when a minimum work plane illuminance is maintained by daylight alone
- Useful Daylight Illuminance (UDI)
  - divides working hours into either < 100 lux, 100 to 2000 lux (Useful Daylight Illuminance) or > 2000 lux
- CHPS criteria
  - continuous DA >40%, >60% and >80% (resp. 1, 2 and 3 credits) for 60% of work plane
- Annual light exposure

# (Emerging) dynamic daylighting metrics

## Points for discussion

- Annual simulations based on local climate data
  - based on local climate data
  - large amount of information → to reduce without reducing value for design
    - decrease calculation time with Daylight Coefficients

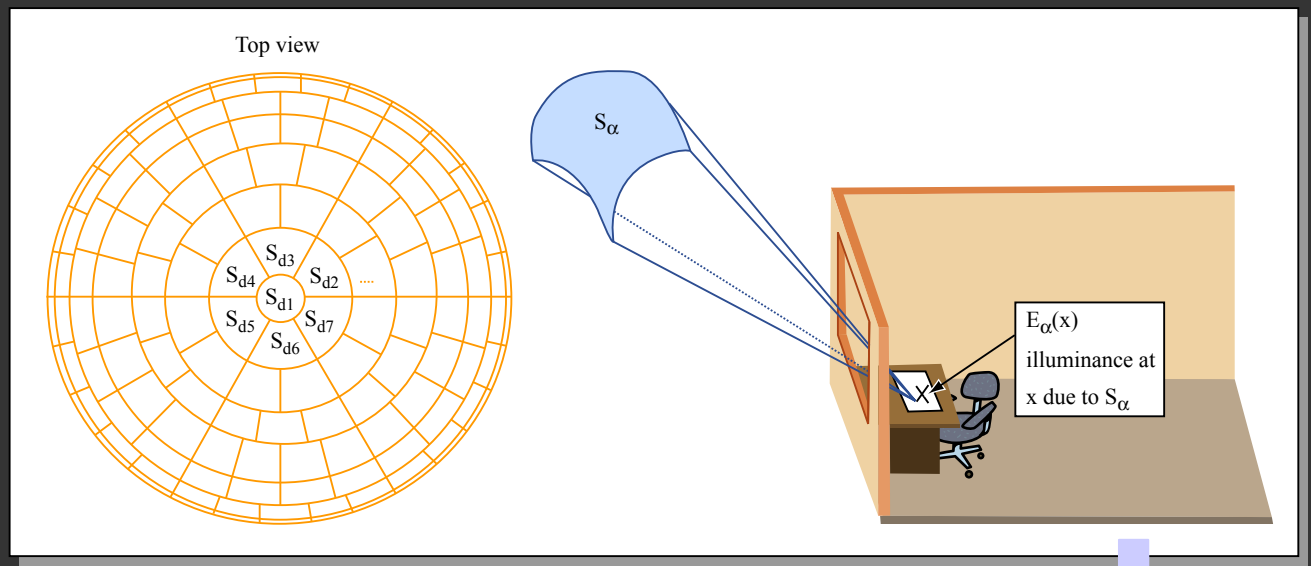
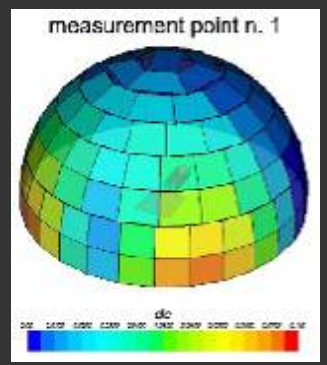



Figure by MIT OCW.




From F. Anselmo (ARUP), Radiance Workshop, Sept 2006

# (Emerging) dynamic daylighting metrics

- Points for discussion
  - Annual simulations based on local climate data
  - Time base (daylit hours vs. occupied hours)
    - unrelated to building use → building form directly related to building site

    vs.
    - related to building use → pros and cons

# (Emerging) dynamic daylighting metrics

- Points for discussion
  - Annual simulations based on local climate data
  - Time base (daylit hours vs. occupied hours)
  - Movable shading devices (venetian blinds)
    - account for user behavior

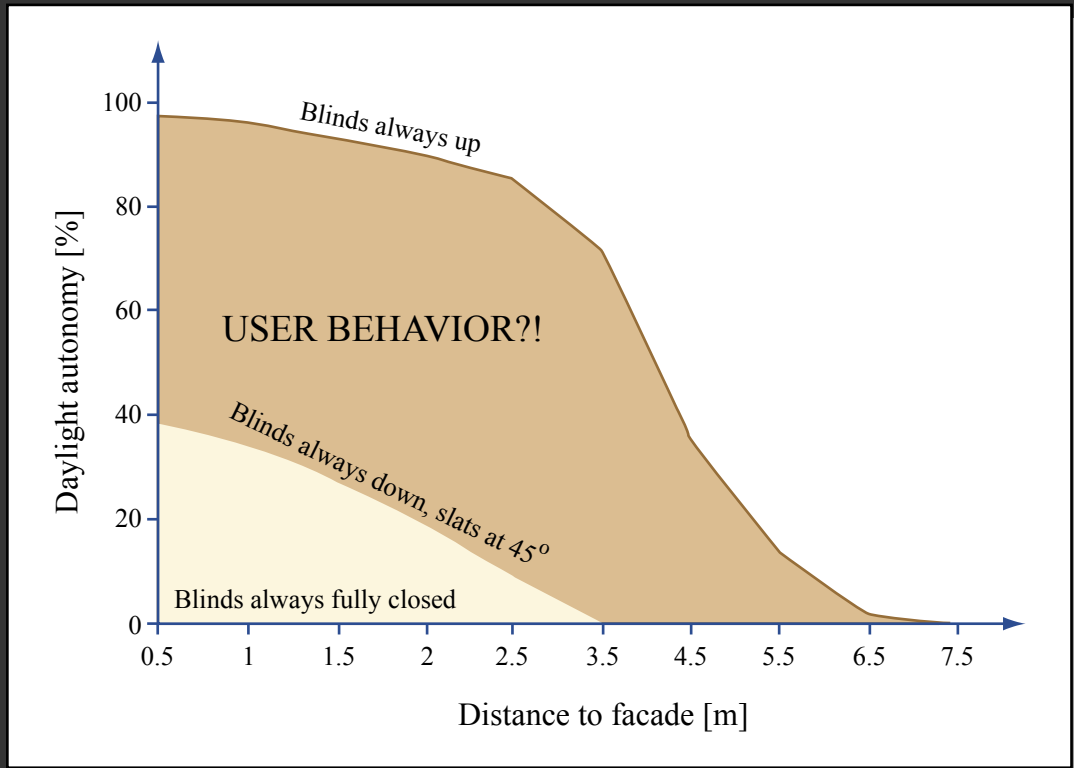



Figure by MIT OCW.