An Analytic Model for Full Spectral Skydome Radiance

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Motivation: Skydome models

- outdoor scenes
- prediction of material appearance
- architecture, outdoor scenes

- alternative: skyboxes

The Preetham Model

- De facto standard analytic skydome model
- Simple closed form formulas
- Outputs tristimulus data, convertible to spectral
- Perez formula, fitted to the outputs of Nishita model
- Fitting results publicly available

luma distribution parameters

$$F(\theta,\gamma) = \left(1 + Ae^{B/\cos\theta}\right)\left(1 + Ce^{D\gamma} + E\cos^2\gamma\right)$$

solar angle

zenith angle

The Preetham Model

inputs

turbidity

solar-zenith angle

once per scene

$$x_z = \begin{bmatrix} T^2 & T & 1 \end{bmatrix} \begin{bmatrix} 0.00166 & -0.00375 & 0.00209 & 0 \\ -0.02903 & 0.06377 & -0.03202 & 0.00394 \\ 0.11693 & -0.21196 & 0.06052 & 0.25886 \end{bmatrix} \begin{bmatrix} \theta_S^3 \\ \theta_S^2 \\ \theta_S \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} A \\ B \\ C \\ D \\ E \end{bmatrix} = \begin{bmatrix} 0.1787 & -1.4630 \\ -0.3554 & 0.4275 \\ -0.0227 & 5.3251 \\ 0.1206 & -2.5771 \\ -0.0670 & 0.3703 \end{bmatrix} \begin{bmatrix} T \\ 1 \end{bmatrix}$$

zenith luminance

luma distribution parameters

for each sample

$$x = x_z \cdot \frac{F_{A,B,C,D,E}(\theta,\gamma)}{F_{A,B,C,D,E}(0,\gamma_s)}$$

output

zenith angles

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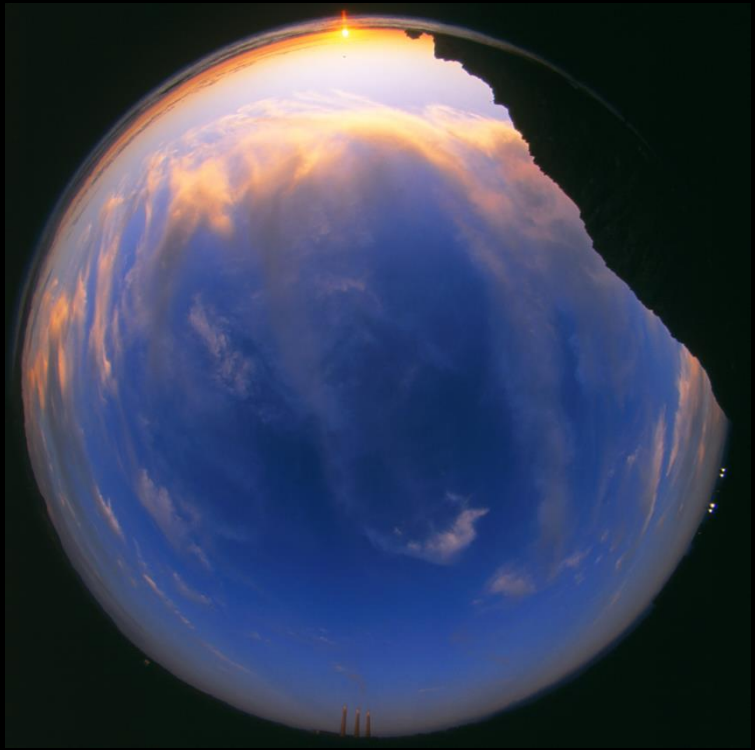
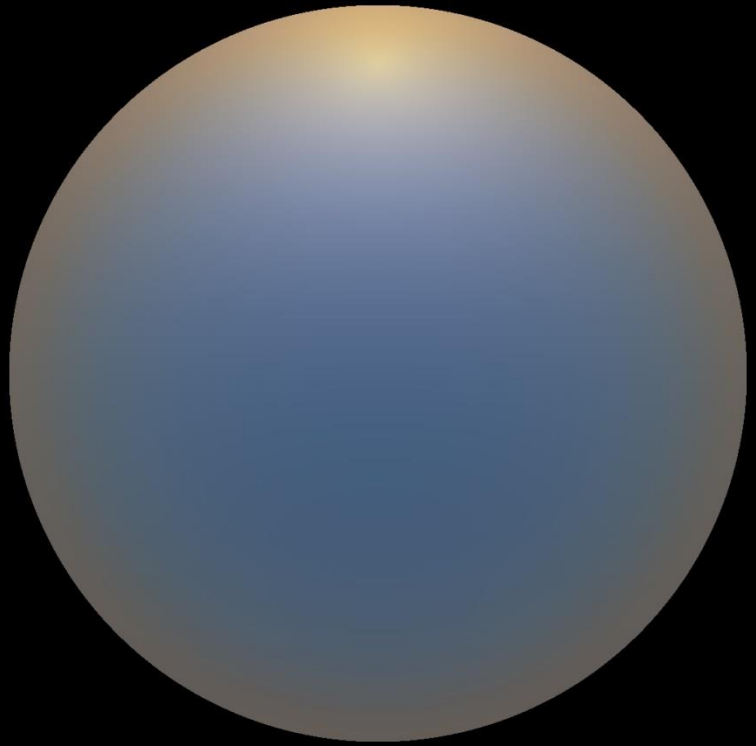
Issues With the Preetham Model

- Simple functions for calculating zenith luminance and luma distribution parameters
  - Only a small subset of possible atmospheric conditions can be captured
- Lack of localised aureole at higher turbidities
- Spectral data are obtained by conversion from trisitmulus data

Issues with the Preetham Model





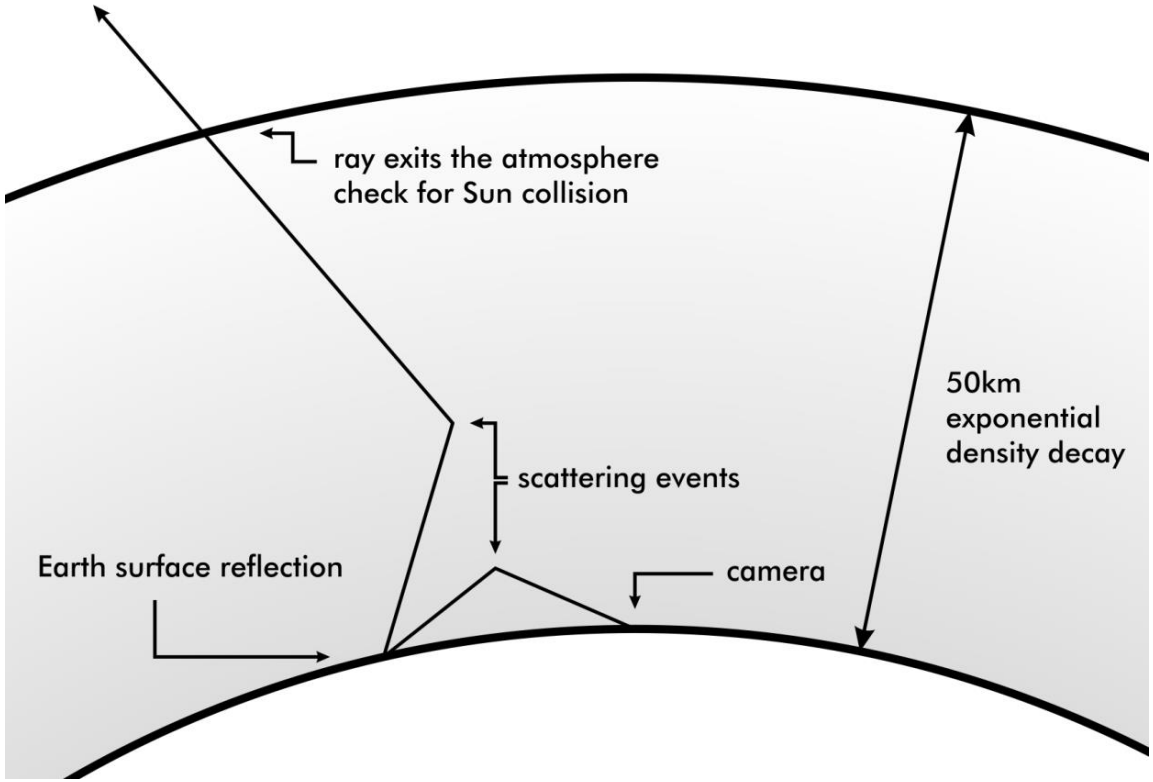
Goals for the New Model

- spectral (including UV)
- larger range of turbidities
- eliminate artifacts
- ground albedo (came later & almost for free)

Obtaining Reference Data

- Brute force Monte Carlo path tracer that incorporates
  - Mie scattering
  - Rayleigh scattering
  - Albedo & colour of Earth surface
- Delta scattering
  - Approaches the simulation as a transport problem, the same way physicists simulate e.g. gamma rays passing through containment shells of nuclear reactors

Obtaining Reference Data



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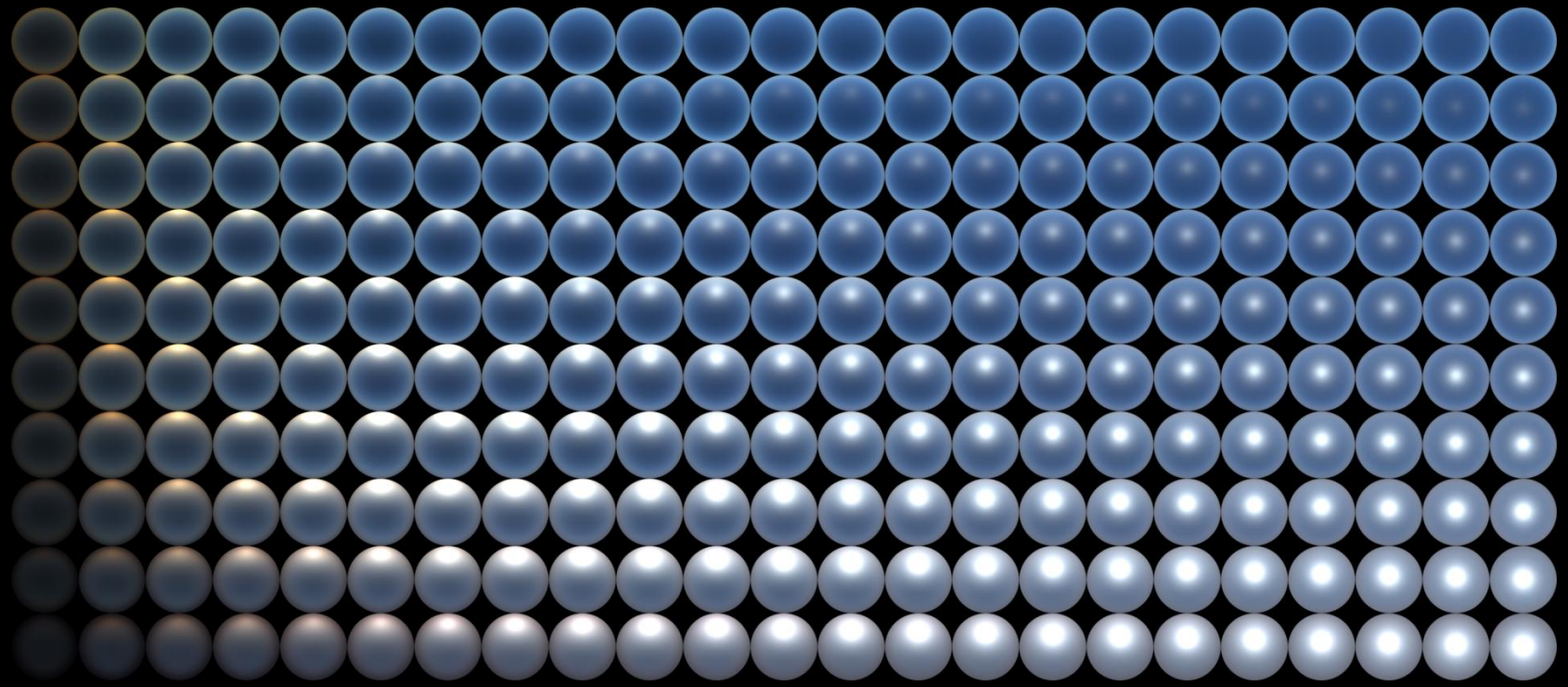
Result: Raw Data



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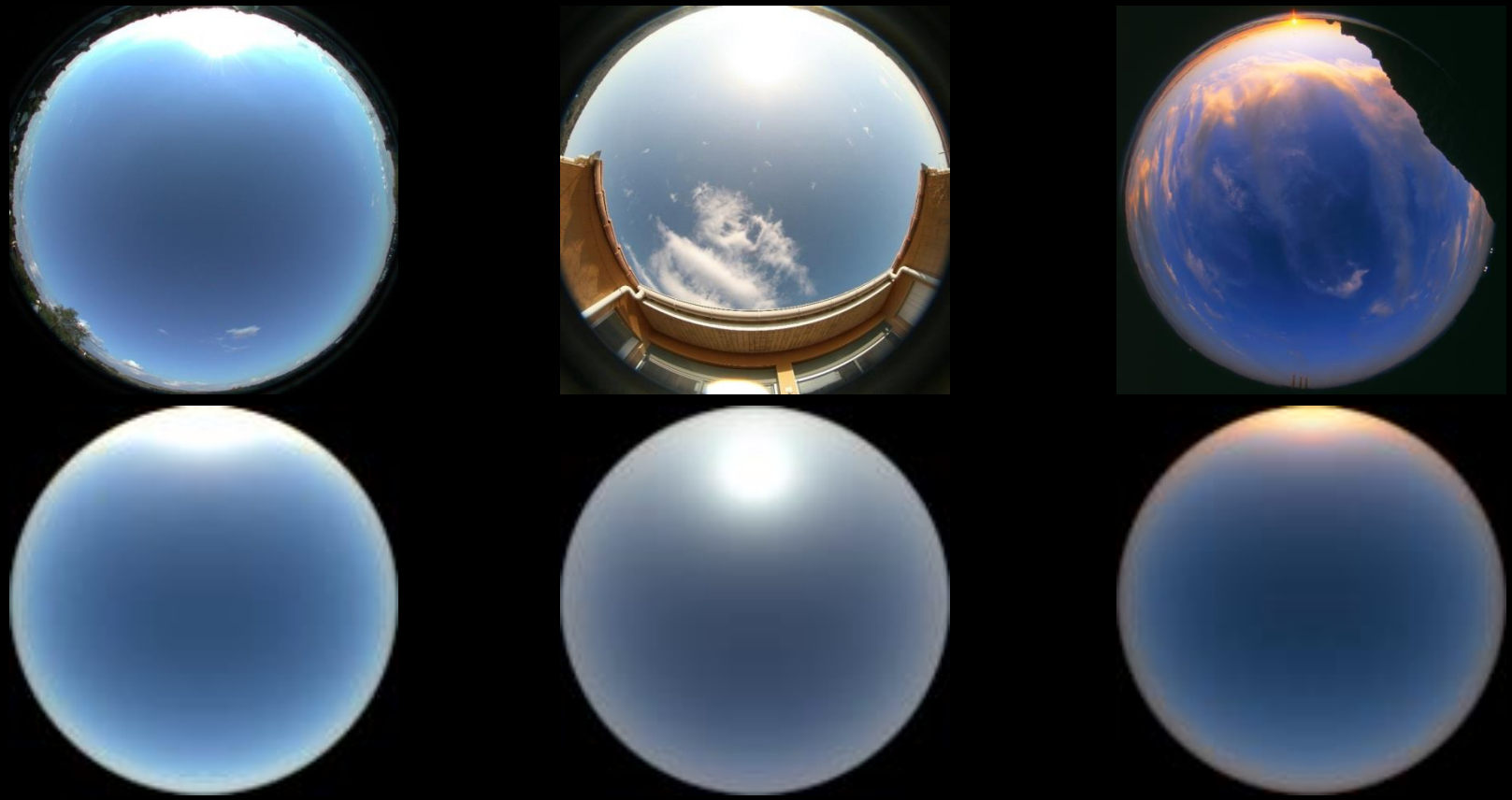
Result: Comparison



Modified formulas for a better fit

original Perez formula

$$F(\theta,\gamma) = \left(1 + Ae^{B/\cos\theta}\right)\left(1 + Ce^{D}\gamma + E\cos^2\gamma\right)$$

fudge factor to prevent divergence to infinity at zenith

supresses luminance peak exending too far up

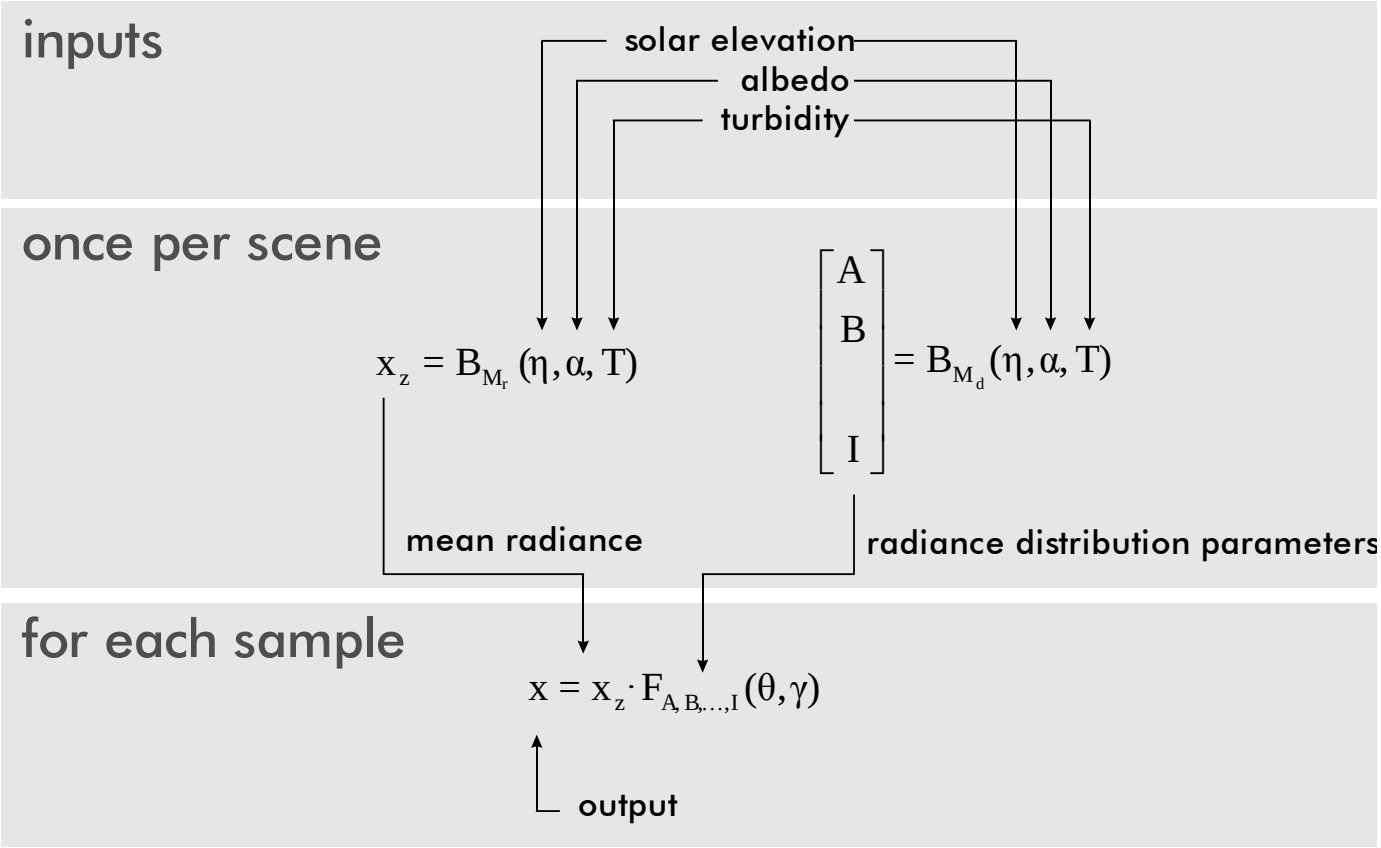
$$F(\theta,\gamma) = \left(1 + Ae^{\frac{B}{\cos\theta + 0.01}}\right)\cdot\left(C + De^{E\gamma} + F\cos^2\gamma + G\,\chi(H,\gamma) + I\cos^{\frac{1}{2}}\theta\right)$$

$$\chi(g,\alpha) = \frac{1+\cos^2\alpha}{(1+g^2 - 2g\cdot\cos\alpha)^{\frac{3}{2}}}$$

anisotropic term for luminance peaks around sun

modified formula

Model flowchart



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How the Fitting was Done

- Levenberg-Marquardt nonlinear optimization
- Yields a mean radiance and radiance distribution array
  - These are then used as control points for Bezier interpolation
- Albedo 0-1
  Turbidity 1-10
  Solar elevation 0-90°
  320nm – 720nm bands, 40nm increment

Results

Sky Colour Patterns (sunset)

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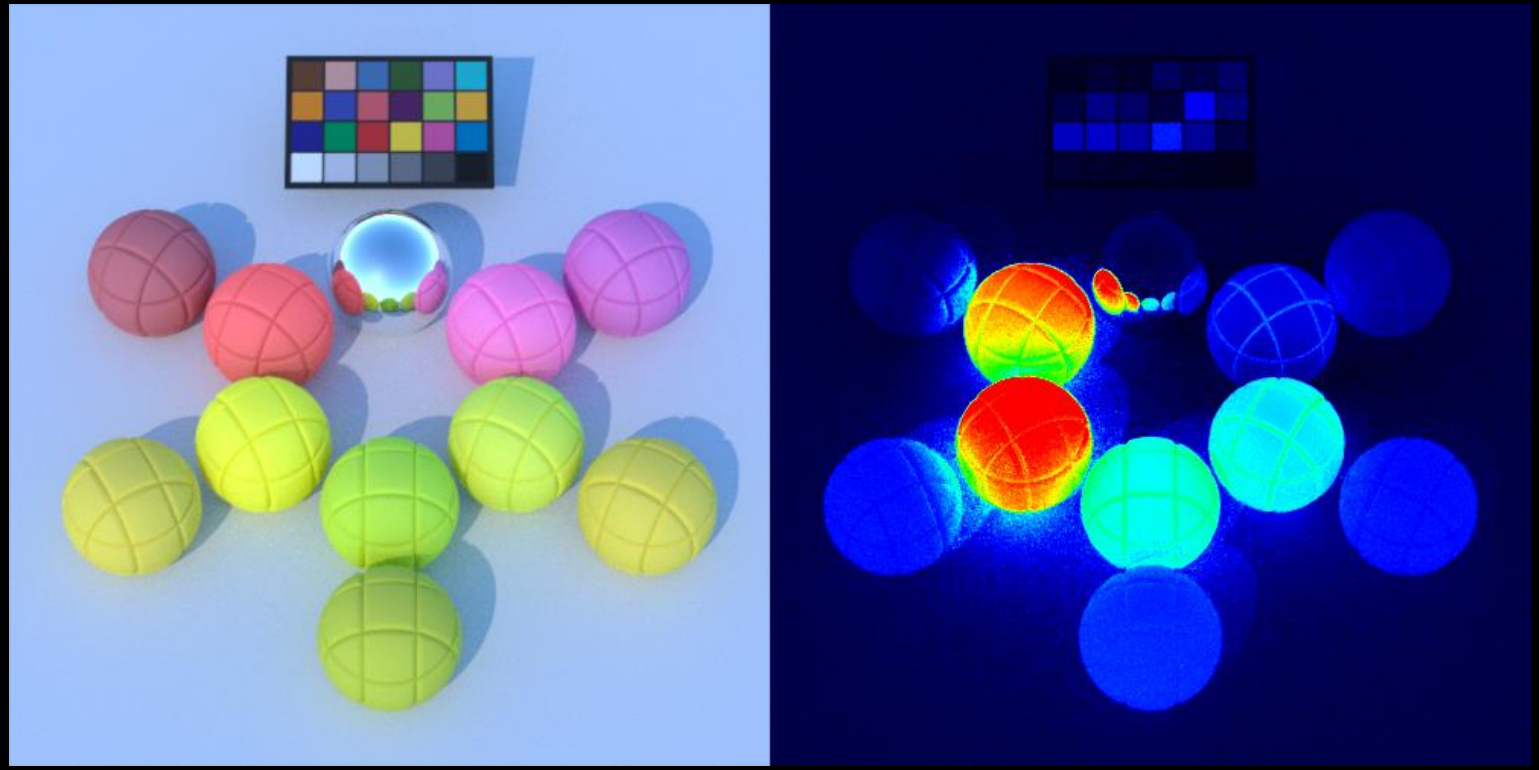
UV & Fluorescence



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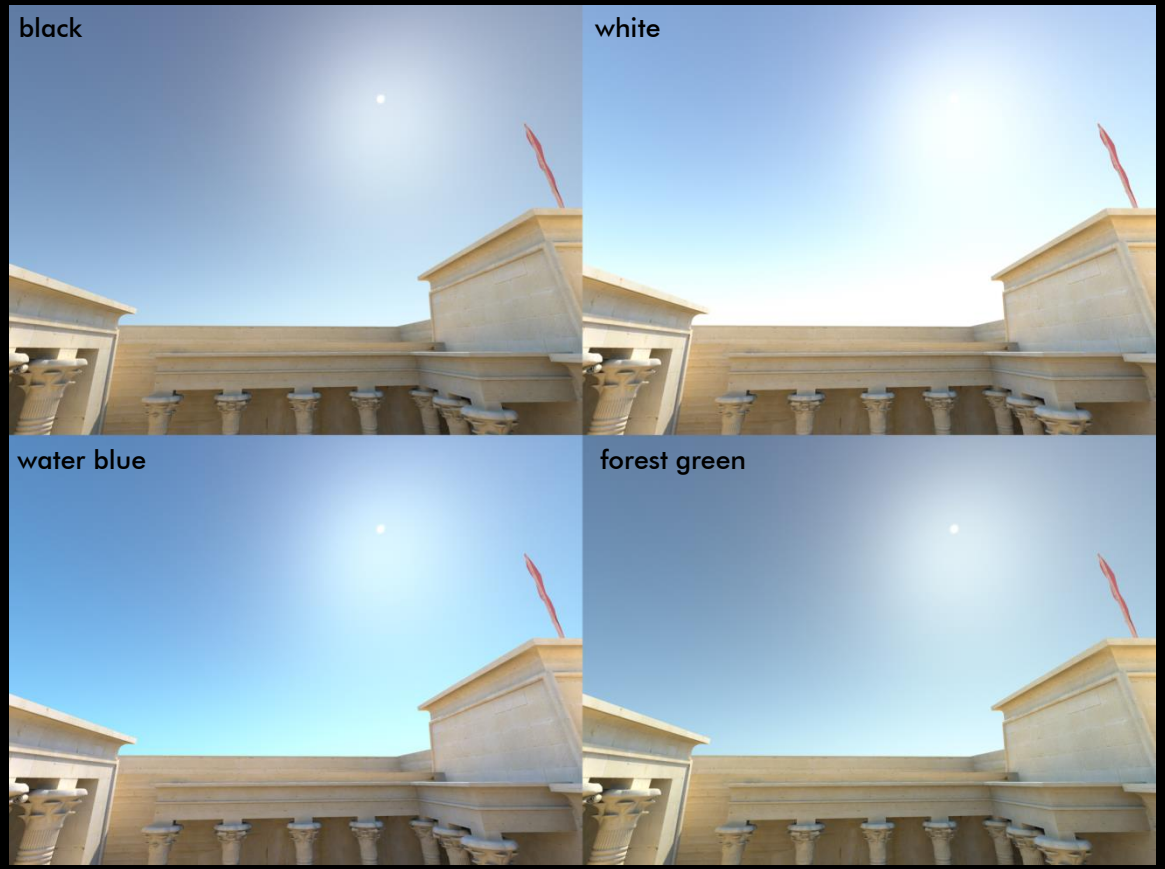
Ground Albedo



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Conclusion

- Reference implementation and data available for download
- Version 1.1 out!
- http://cgg.mff.cuni.cz/projects/SkylightModelling/