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Multi scatter, Multi view Monte Carlo radiative transfer

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1 Theoretical background

Extinction: Radiance is a flow of photons. Light propagation through the atmosphere is affected by interaction with air molecules and aerosols (airborne particles). Atmospheric constituents have an *extinction cross section* for interaction with each individual photon. Per unit volume, the *extinction coefficient* due to aerosols is $\beta^{\rm aerosol} = \sigma^{\rm aerosol} n$. Here $\sigma^{\rm aerosol}$ denotes aerosol extinction cross section and n denotes particle density. The total extinction is a sum of the aerosol and molecular contributions, $\beta = \beta^{\rm aerosol} + \beta^{\rm air}$, where $\beta^{\rm air}$ is modeled as a function of altitude and wavelength λ [5]. The *optical depth* along a photon path S is

$$\tau = \int_S d\tau = \int_S (\beta^{\rm aerosol} + \beta^{\rm air}) dl = \int_S (\sigma^{\rm aerosol} n + \beta^{\rm air}) dl = \tau^{\rm air} + \int_S \sigma^{\rm aerosol} n dl \, , \tag{1}$$

where $\tau^{\rm air} = \int \beta^{\rm air} dl$. Through a non-scattering atmosphere, the *transmittance* exponentially decays with the optical depth:

$$t = \exp(-\tau) \, . \tag{2}$$

Scattering: Suppose that a photon interacts with a single particle. The unitless *single scattering albedo* ϖ of the particle, determines a probability for scattering. The aerosol single scattering albedo is $\varpi^{\rm aerosol}$. The *scattering coefficient* due to aerosols in the volume is $\alpha^{\rm aerosol} = \varpi^{\rm aerosol} \beta^{\rm aerosol} = \varpi^{\rm aerosol} \sigma^{\rm aerosol} n$. For non-isotropic scattering, an angular function defines the probability of photons to scatter into each direction. Let $\boldsymbol{\omega}, \boldsymbol{\psi} \in \mathbb{S}^2$ (unit sphere) represent photon or ray directions. The fraction of energy scattered from direction $\boldsymbol{\psi}$ towards direction $\boldsymbol{\omega}$ is determined by a *phase function* $P(\boldsymbol{\omega} \cdot \boldsymbol{\psi})$. The phase function is normalized: its integral over all solid angles is unity, and is often approximated by a parametric expression. Specifically, the Henyey-Greenstein function, parameterized by an *anisotropy parameter* $-1 \geq g \geq 1$, can approximate aerosol scattering [5]