

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 $\beta^{\text{aerosol}} = \sigma^{\text{aerosol}}n$. Here σ^{aerosol} denotes aerosol extinction cross section and n denotes particle density. The total extinction is a sum of the aerosol and molecular contributions, $\beta = \beta^{\text{aerosol}} + \beta^{\text{air}}$, where β^{air} is modeled as a function of altitude and wavelength λ [5]. The *optical depth* along a photon path S is

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

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

$$t = \exp(-\tau). \quad (2)$$

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 ϖ^{aerosol} . The *scattering coefficient* due to aerosols in the volume is $\alpha^{\text{aerosol}} = \varpi^{\text{aerosol}}\beta^{\text{aerosol}} = \varpi^{\text{aerosol}}\sigma^{\text{aerosol}}n$. For non-isotropic scattering, an angular function defines the probability of photons to scatter into each direction. Let $\omega, \psi \in \mathbb{S}^2$ (unit sphere) represent photon or ray directions. The fraction of energy scattered from direction ψ towards direction ω is determined by a *phase function* $P(\omega \cdot \psi)$. 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* $-1 \leq g \leq 1$, can approximate aerosol scattering [5]