Leaf normal distribution functions (LNDFs)

- Turbid media approach (Marshak and Davis, 2005): $g_\mu(\mathbf{x}, \mathbf{y}, t) \geq 0$ is the probability that a planar leaf at point $\mathbf{x}$ and at time $t$, its normal vector has the direction $\mathbf{y}$, is confined to the upper hemisphere $\mathcal{S}_1^+$. Parameterisation of $\mathcal{S}_1^+$ as a function of the azimuth angle $\varphi$ and the cosine $\cos(\theta)$ of the zenith angle $	heta$:

$$ L_0 \left( \frac{\cos \varphi \sqrt{1 - \mu^2}}{\mu}, \frac{\sin \varphi \sqrt{1 - \mu^2}}{\mu} \right) := \omega(\mu, \varphi) $$

with the unit length $L_0$ and the parameter $(\mu, \varphi) \in [0, 1] \times [0, 2\pi]$

- Homogeneous and time independent LNDF with separated angular dependence $g_\mu(\mathbf{y} = \omega(\mu, \varphi)) = g_\mu(\mu) g_\varphi(\varphi)$

- Normalisation condition $\int g_\mu(\mu) d\mu = 1$

- Standard LNDFs which fulfil the above normalisation condition:

  - purely horizontal, erectophile, extremophile, uniform, plagioophile, planophile, rather vertical and purely vertical leaves normals (Otto and Trautmann, 2008a)

  - Simulation of the canopy reflectance (CR) and transmittance (CT) as a function of the cosine of the solar zenith angle $\mu_\infty$ and diffuse light in the UV-VIS spectral range:

$$ E_{\infty} = \frac{E_E}{E_D} $$

for turbid medium assuming bi-Lambertian, elastic leaf scattering

- Time independent and horizontally homogeneous radiative transfer equation for turbid vegetation media assuming bi-Lambertian, elastic leaf scattering

$$ E(L, \lambda) = \frac{\alpha_{\infty}}{\alpha_{\infty} + \alpha_{\infty}} E(L, \lambda) + D(L, \lambda) \left( \frac{\alpha_{\infty}}{\alpha_{\infty} + \alpha_{\infty}} \right) $$

(2008b) for a homogeneous layer using exact GFs

- Input parameters:

  - surface albedo of direct $A_D$, and diffuse $A_D$ total leaf area index $L_A$

  - cosine solar zenith angle $\cos(\theta)$, diffusivity factor $U$

  - hemispherical leaf reflectance and transmittance $r_\infty$ and $t_\infty$, downwelling direct and diffuse irradiances at the top of the vegetation layer $E_D$ and $E_D$

- Simulation of the canopy reflectance (CR) and transmittance (CT) as a function of the cosine of the solar zenith angle $\mu_\infty$ for two ratios of incident direct and diffuse light $T_{\infty} = E_D / E_D$ in the UV-VIS spectral range:

$$ T_{\infty} = 1.0 \quad \text{and} \quad 0.05 \leq T_{\infty} \leq 0.1 \quad \text{as clear sky} $$

$$ T_{\infty} = 0.05 \quad \text{as clear sky} $$

**References**


- Overcast sky conditions

- clear sky

- overcast sky

- horizon

- noon

- morning / evening

- the one-layer solution can be extended to vertically inhomogeneous medium