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**Basic terminology of radiative transfer in optical
remote sensing**

光学遥感辐射传输基本术语

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Basic terminology of radiative transfer in optical remote sensing

1 Scope

This Standard specifies the general terminology involved in the radiative transfer of optical remote sensing in the 0.38 μm ~15 μm spectral band, the terminology for interaction between electromagnetic radiation and ground, and the terminology for interaction between electromagnetic radiation and atmosphere.

This Standard applies to optical remote sensing and its applications.

2 General terminology

2.1 [Electromagnetic] radiation

- a) The phenomenon that energy is emitted from a source to space in the form of electromagnetic waves.
- b) Energy travels through space in the form of electromagnetic waves.

[GB/T 4365-2003, definition 161-01-10]

2.2 [Electromagnetic] spectrum

The graph which represents the wavelength or frequency distribution of electromagnetic radiation.

[GB/T 14950-2009, definition 4.109]

2.3 Solar radiation

Electromagnetic radiation from the sun.

2.4 Solar radiation spectrum

The graph which shows the distribution of solar radiant energy by wavelength or frequency.

Note: Modify GB/T 14950-2009, definition 4.108.

2.5 Radiant energy

The radiant flux of a radiant source in a unit solid angle in a given direction.

Note: The unit is Watts per spherical degree (W/sr).

2.14 Spectral radiant intensity

Radiant intensity at unit wavelength.

Note: The unit is Watts per spherical degree micrometer [W/(sr • μm)].

2.15 Monochromatic radiation

Radiation with a single wavelength or frequency.

2.16 Optical radiation

Electromagnetic radiation having a wavelength between a transition region to X-rays (about 1 nm) and a transition region to radio waves (about 1 mm).

2.17 Visible radiation

Optical radiation which can directly cause visual perception.

Note: There is no clear limit on the spectral range of visible radiation. It depends on the radiant power reaching the retina and the responsiveness of the observer. The lower limit is generally between 360 nm and 400 nm. The upper limit is between 760 nm and 830 nm. Its spectral range is usually 0.38 μm ~0.78 μm .

2.18 Ultraviolet radiation

Optical radiation with a wavelength less than the wavelength of visible radiation.

2.19 Infrared radiation

Optical radiation with a wavelength greater than the wavelength of visible radiation.

Note: The spectral range of infrared radiation is usually 0.78 μm ~15 μm , which can be divided into near-infrared radiation (0.78 μm ~1.4 μm), shortwave infrared radiation (1.4 μm ~3 μm), middle infrared radiation (3 μm ~6 μm), and thermal infrared radiation (6 μm ~15 μm).

2.20 Thermal radiation

- a) The emission of radiant energy due to the thermal excitation of particles of matter (e.g., atoms, molecules, ions).
- b) The radiation emitted by this process.

2.30 Lambert's [cosine] law

The radiant intensity emitted by an ideal diffuse reflection surface is proportional to the cosine of the angle between the direction of light exit and the normal of the diffuse reflection surface.

Note: Its expression is: $I(\theta) = I_0 \cos(\theta)$, where $I(\theta)$ is the radiant intensity in the θ direction; I_0 is the radiant intensity in the normal direction.

2.31 [Absolute] blackbody; full radiator, full emitter; Planckian radiator

An ideal thermal radiator which can absorb all incident radiation in any incident direction, wavelength, and polarization state.

Note: The emissivity of a blackbody at any wavelength is equal to 1.

2.32 Grey body

Thermal radiator with emissivity between 0~1 that does not change with wavelength.

2.33 Selective radiator

The thermal radiator whose spectral emissivity varies with wavelength in the considered spectral range.

[GB/T 2900.65-2004, definition 845-04-10]

2.34 Lambertian radiator; Lambertian surface

The radiator or radiating surface which radiates at an angle specified by Lambert's cosine law.

[GB/T 14733.12-2008, definition 731-01-38]

2.35 Point radiant source

The radiant source with a sufficiently small size. Its size, compared with its distance from the irradiated surface, can be ignored in calculation and measurement.

Note: Point sources which radiate uniformly in all directions are called isotropic point sources or uniform point sources.

[GB/T 2900.65-2004, definition 845-01-19]

2.36 Standard radiant source

3 Terminology for interaction between electromagnetic radiation and ground objects

3.1 Reflectance

The ratio of the radiant flux reflected by an object to the incident radiant flux.

3.2 Absorptance

The ratio of the radiant flux absorbed by an object to the incident radiant flux.

3.3 Transmittance

The ratio of the radiant flux passing through an object to the radiant flux incident on the object.

3.4 [Hemispherical] emissivity

The ratio OF the radiant exitance of a thermal radiator TO the radiant exitance of a blackbody at the same temperature.

3.5 Spectral characteristics of ground objects

USE the form of a spectral curve to describe the characteristics of the reflection, absorption, emission, scattering, and transmission of ground objects as a function of wavelength.

3.6 Bidirectional reflectance distribution function; BRDF

The ratio OF the micro-increment of the reflected radiance in a specific direction of the object surface TO the micro-increment of the incident irradiance in a specific direction.

Note: The unit is per spherical degree (sr^{-1}).

3.7 Bidirectional reflectance factor

The ratio OF the reflected radiance of an object surface in a particular direction TO the reflected radiance of an ideal diffuse reflector in that direction under the same irradiance.

3.8 Albedo

The ratio OF the radiant flux reflected from an object surface to the hemisphere (2π) space TO the radiant flux incident on the object surface from the hemisphere (2π) space.

4 Terminology for interaction between electromagnetic radiation and atmosphere

4.1 Atmospheric window

Some specific electromagnetic wave bands where the atmosphere does not have a strong attenuation effect (absorption, scattering, etc.) on electromagnetic wave transfer.

4.2 Atmospheric radiation

Electromagnetic radiation scattered and emitted by atmospheric molecules and particles.

4.3 Atmospheric up-welling radiance; atmospheric path radiance

The radiance which directly reaches the remote sensor from the atmospheric scattered solar radiation and the emitted radiation of the atmosphere itself without reflection from the ground.

Note: The unit is Watts per square meter spherical degree [$\text{W}/(\text{m}^2 \cdot \text{sr})$].

4.4 Atmospheric down-welling radiation

The atmospheric scattered solar radiation and the emitted radiation of the atmosphere itself received by the earth's surface.

Note: The unit is Watts per square meter (W/m^2).

4.5 Diffuse sky radiation

Atmospheric scattered solar radiation received by the earth's surface from hemisphere (2π) space.

Note: The unit is Watts per square meter (W/m^2).

4.6 Atmospheric effect

Scattering, refraction, absorption, scintillation caused by interaction with the atmosphere during the propagation of electromagnetic radiation, and the emission of the atmosphere itself.

4.7 Atmospheric attenuation

The phenomenon that when the electromagnetic radiation is propagated in the atmosphere, it is absorbed and scattered by the atmosphere and the radiant

4.15 Mie scattering

The scattering of a scatterer (e.g. atmospheric aerosol, raindrops, etc.) whose size is close to the wavelength of the incident electromagnetic wave.

Note: Mie scattering intensity is independent of wavelength.

4.16 Forward scattering

The scattering in which the angle between the propagation direction of the scattering radiation and the original incident direction is less than 90° when the electromagnetic radiation propagates in the atmosphere.

4.17 Backscattering

The scattering in which the angle between the propagation direction of the scattering radiation and the original incident direction is greater than 90° when the electromagnetic radiation propagates in the atmosphere.

4.18 Atmospheric aerosol

A relatively stable suspension system formed by dispersion of liquid or solid particles in the atmosphere.

[GB/T 31159-2014, definition 2.1]

4.19 Atmospheric aerosol particle; particulate matter; PM

Solid and liquid particles suspended in the atmosphere.

[GB/T 31159-2014, definition 2.2]

4.20 Aerosol absorption coefficient

The physical quantity which characterizes the degree of attenuation of radiant energy caused by atmospheric aerosol absorption.

Note: The value is equal to the sum of the absorption cross-sections of all aerosol particles in a unit volume. The commonly-used units are per meter (m^{-1}) and per kilometer (km^{-1}).

[GB/T 31159-2014, definition 4.8]

4.21 Aerosol scattering coefficient

The physical quantity which characterizes the degree of attenuation of radiant energy caused by atmospheric aerosol scattering.

Appendix A

(Informative)

Radiative transfer models

A.1 Shortwave radiative transfer model

Assume that the sky is uniform Lambertian, i.e., isotropic radiation, and that the earth's surface is homogeneous Lambertian; ignore the refraction, turbulence, and polarization of the atmosphere. The shortwave radiative transfer model for monochromatic light can be abbreviated, see equation (A.1):

$$\rho^*(\theta_s, \theta_v, \varphi_s - \varphi_v, \lambda) = \rho_0(\theta_s, \theta_v, \varphi_s - \varphi_v, \lambda) + \frac{\rho(\lambda)}{[1 - \rho(\lambda) \cdot S]} [e^{-\tau(\lambda)/\mu_s} + t_d(\theta_s, \lambda)] [e^{-\tau(\lambda)/\mu_v} + t_d(\theta_v, \lambda)] \quad \dots\dots (A.1)$$

Where:

$\rho^*(\theta_s, \theta_v, \varphi_s - \varphi_v, \lambda)$ - Apparent reflectance at the entrance pupil of the remote sensor;

θ_s - Solar zenith angle, in degrees (°);

θ_v - View zenith angle, in degrees (°);

φ_s - Solar azimuth, in degrees (°);

φ_v - View azimuth, in degrees (°);

λ - Wavelength, in micrometers (μm), wave number (cm⁻¹);

$\rho_0(\theta_s, \theta_v, \varphi_s - \varphi_v, \lambda)$ - Atmospheric path reflectance;

$\rho(\lambda)$ - Target true reflectance;

S - Atmospheric hemispherical albedo;

τ - Atmospheric optical depth;

μ_s - Solar zenith angle cosine;

μ_v - View zenith angle cosine;

$e^{-\tau(\lambda)/\mu_s}$ - Direct atmospheric transmittance from the sun to the ground;

θ' - Incident zenith angle, in degrees ($^{\circ}$);

φ' - Incident azimuth, in degrees ($^{\circ}$);

$L_d(\theta', \varphi', \lambda)$ - Atmospheric down-welling spectral radiance in a particular direction, in Watts per square meter spherical degree micrometer [$W/(m^2 \cdot sr \cdot \mu m)$];

θ_s - Solar zenith angle, in degrees ($^{\circ}$);

φ_s - Solar azimuth, in degrees ($^{\circ}$);

$L_{sun}(\lambda)$ - Solar spectral irradiance at the top of the atmosphere, in Watts per square meter micrometer [$W/(m^2 \cdot \mu m)$].

Note: The middle infrared nighttime radiative transfer is not affected by solar radiation. Its nighttime radiative transfer model is the same in the form as the thermal infrared radiative transfer model, with only differences in wavelength. See A.3 for details.

A.3 Thermal infrared radiative transfer model

Under clear sky atmospheric conditions, assume that the atmospheric level is uniform. Under the condition of local geothermal balance, the influence of atmospheric scattering is not considered. The thermal infrared radiative transfer model for monochromatic light can be abbreviated, see equation (A.3):

$$L(\theta_v, \varphi_v, \lambda) = \tau(\theta_v, \varphi_v, \lambda) \cdot \varepsilon(\theta_v, \varphi_v, \lambda) \cdot B(T_s, \lambda) + \int B(T_p, \lambda) \frac{\partial \tau(\theta_v, \varphi_v, p, \lambda)}{\partial p} dp + \iint \tau(\theta_v, \varphi_v, \lambda) \cdot \rho_b(\theta_v, \varphi_v, \theta', \varphi', \lambda) \cdot L_d(\theta', \varphi', \lambda) \cos(\theta') \sin(\theta') d\theta' d\varphi' \quad \dots\dots (A.3)$$

Where:

$L(\theta_v, \varphi_v, \lambda)$ - Spectral radiance at the entrance pupil of the remote sensor, in Watts per square meter spherical degree micrometer [$W/(m^2 \cdot sr \cdot \mu m)$];

θ_v - View zenith angle, in degrees ($^{\circ}$);

φ_v - View azimuth, in degrees ($^{\circ}$);

λ - Wavelength, in micrometers (μm);

τ - Atmospheric transmittance;

ε - Target emissivity;

$B(T_s, \lambda)$ - Planckian function, in Watts per square meter spherical degree micrometer [$W/(m^2 \cdot sr \cdot \mu m)$];

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