At-sensor Solar Exo-atmospheric Irradiance, Rayleigh Optical Thickness and Spectral parameters of RS-2 Sensors

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1. Introduction

Solar exoatmospheric irradiance and Rayleigh optical thickness within pass band of each spaceborne sensor are to be estimated for calculating the most basic physical parameter, namely ground reflectance [1]. The general formula for calculating the ground reflectance (ρ) is:

$$\rho \quad = \quad \frac{\pi(Ls - Lp)d^2}{t_v(E_o \cos\theta_s t_z + E_d} \tag{1}$$

Where: *Lp* denotes path radiance, *d*-earth to sun distance in astronomical units, *Eo* ï bandpass exoatmospheric irradiance, *Ed* - down welling spectral irradiance from the atmosphere, *tv* ï atmospheric transmittance along the path from ground to sensor, and *tz* ï atmospheric transmittance along the path from the sun to ground.

The transmittance terms are calculated using the equations:

$$t_v = \exp(-\tau \sec\theta_v) \quad and \quad t_z = \exp(-\tau \sec\theta_s)\ . \tag{2}$$

Here θ_v and θ_s are, respectively, the zenith angles of the sun and sensor. The parameter τ is known as the total optical thickness of the atmosphere, which includes the effect of aerosol particles, ozone, water vapor and atmospheric molecules. Out of these, molecular or Rayleigh contribution depends strongly on wavelength and can be estimated from

$$\tau_r = \exp(-0.1188 * h - 0.00116 * h^2)\{0.00859 * \lambda^{-4}(1 + 0.0013 * \lambda^{-2} + 0.00013 * \lambda^{-4})\} \tag{3}$$

Where h is the height of the surface above sea level in kilometers.

2. Computation of at-sensor Solar Exo-atmospheric Irradiance

The bandpass solar exo-atmospheric irradiance is an average solar irradiance weighted by corresponding spectral band response function. It is computed from

$$\langle E_o(\lambda) \rangle_k = \frac{\int E_o(\lambda)\, S_k(\lambda)\, d\lambda}{\int S_k(\lambda)\, d\lambda} \tag{4}$$

Here $S_k(\lambda)$ is relative spectral response function [3] for the sensor for the band K of the sensor and $E_o(\lambda)$ is the extraterrestrial solar irradiance. The integration interval is within the pass band of the sensor. Neckel and Labs [2] have published updated values of the extraterrestrial solar irradiance. Thuillier extraterrestrial solar irradiance values are also used by application scientists [4]. Figure 1 shows the plots of these two references of solar irradiances.

3. Computation of the at-sensor Rayleigh Optical Thickness

The Rayleigh optical thickness is calculated from the extraterrestrial solar irradiance $E_o(\lambda)$ and relative spectral response $S_k(\lambda)$ as defined by the equation

$$\langle \tau_r(\lambda) \rangle_k = \frac{\int \tau_r(\lambda)\, E_o(\lambda)\, S_k(\lambda)\, d\lambda}{\int E_o(\lambda)\, S_k(\lambda)\, d\lambda} \tag{5}$$

4. Normalized bandwidth & effective wavelength computation

The Normalized bandwidth of band k is the total integrated wavelength of a spectral band k is given by

$$BW_k = \int S_k(\lambda)\, d\lambda \tag{6}$$

Here $S_k(\lambda)$ is the relative spectral response function of the band integrated over the spectral region of response. Relative spectral response is taken as 1% cutoff at both sides of the response values. Effective wavelength is the wavelength that would produce the same penetration as an average of the various wavelengths. The Effective wavelength of a band is the integral of weighted by wave length and normalized by the bandwidth.

$$\lambda_{eff(k)} = \frac{\int \lambda_k S_k(\lambda)\, d\lambda}{\int S_k(\lambda)\, d\lambda} \tag{7}$$

5. Results

The estimated at-sensor solar exo-atmospheric irradiance and Rayleigh optical thickness at mean sea level for RS-2 sensor are given in **Table 1**.

6. References

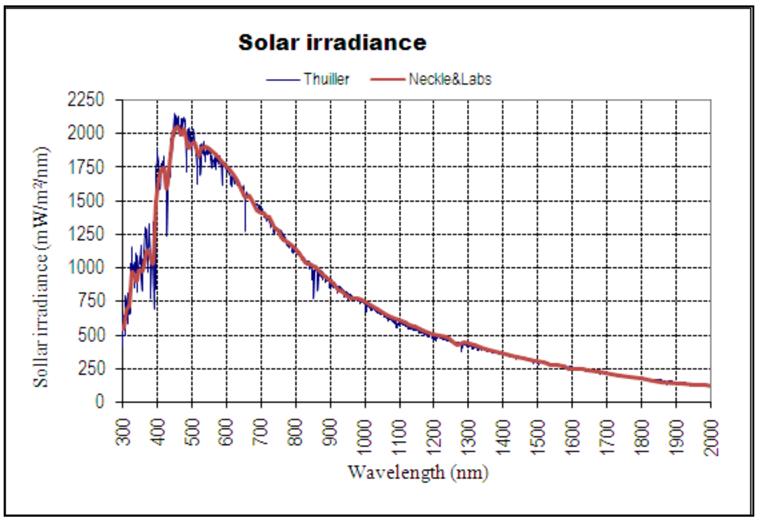
[1]. M.R. Pandya et al, IEEE Transactions on Geoscience and Remote Sensing, vol. 40, No. 3, pp.714-718, 2002.

[2]. H. Neckel & D. Labs, http://rredc.nrel.gov/solar/pubs/spectral/model/t2-1.html

[3] A.S. Kiran Kumar, Space Applications Center, Ahmedabad (private communication).

[4] Gyanesh Chander, USGS EROS, USA (private communication).

Figure 1 Solar Irradiance spectra available for computation



In Table below: following are units of parameters listed:

- Effective Bandwidth **(Eff bw)** is in **nm.**
- Effective Wavelength **(Eff wl)** is in **nm.**
- The at sensor Exo-atm. Solar irradiance, **Eo_NL** (Neckal & Labs) in **mW cm^{-2} μm^{-1}**
- The at sensor Exo-atm. Solar irradiance, **Eo_Th** (Thuiller) in **mW cm^{-2} μm^{-1}**
- Rayleigh Optical thicknesses τ_**NL** (Neckal & Labs) and τ_**Th** (Thuiller) are in non-dimensional [**nd**] units
- AWiFS-A sensor stands for East CCD data (B & D quadrants in the full scene)
- AWiFS-B sensor stands for West CCD data (A & C quadrants in the full scene)

Table 1 Spectral Characteristics of RS-2 LISS-4 Sensor

Sat.	Sensor	Band	Eff bw	Eff wl	Eo_NL	Eo_Th	τ_NL	τ_Th
RS2	LISS-4	B2	64.48	557.17	185.33	181.89	0.08845	0.08844
RS2	LISS-4	B3	58.87	649.02	157.77	156.96	0.0478	0.0478
RS2	LISS-4	B4	72.30	807.54	111.36	110.48	0.0199	0.0199

Table 2 Spectral Characteristics of RS-2 LISS-3 Sensor

Satellite	Sensor	Band	Eff bw	Eff wl	Eo_NL	Eo_Th	τ_NL	τ_Th
RS2	LISS-3	B2	55.06	561.49	184.86	181.83	0.0856	0.0856
RS2	LISS-3	B3	52.94	651.13	156.902	155.92	0.0471	0.0471
RS2	LISS-3	B4	74.36	811.72	110.423	108.96	0.0196	0.0196
RS2	LISS-3	B5	124.42	1619.05	24.33	24.38	0.00123	0.00123

Table 3 Spectral Characteristics of RS-2 AWIFS Sensor

Satellite	Sensor	Band	Eff bw	Eff wl	Eo_NL	Eo_Th	τ_NL	τ_Th
RS2	AWIFS-A	B2	51.81	558.11	185.421	182.296	0.0877	0.0877
RS2	AWIFS-B	B2	55.18	557.28	185.440	182.367	0.0883	0.0882
RS2	AWIFS-A	B3	55.43	651.22	156.860	155.960	0.0470	0.0470
RS2	AWIFS-B	B3	54.46	650.64	157.090	156.590	0.0472	0.0472
RS2	AWIFS-A	B4	76.96	816.54	109.364	108.059	0.0192	0.0192
RS2	AWIFS-B	B4	78.24	817.19	109.208	107.898	0.0192	0.0192
RS2	AWIFS-A	B5	138.99	1629.16	23.923	23.944	0.0012	0.0012
RS2	AWIFS-B	B5	129.13	1630.21	23.873	23.893	0.0012	0.0012