Computation of at-sensor Solar Exo-atmospheric Irradiance and Rayleigh Optical Thickness for IRS-1C, -1D, -P4 and -P6 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:

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

Where: L_p denotes path radiance, *d*-earth to sun distance in astronomical units, E_o –bandpass exoatmospheric irradiance, E_d - down welling spectral irradiance from the atmosphere, t_v – atmospheric transmittance along the path from ground to sensor, and t_z – atmospheric transmittance along the path from the sun to ground.

The transmittance terms are calculated using the equations:

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

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

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

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

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

Here $S_k(\lambda)$ is relative spectral response function 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, and are used here. The relative spectral response function was obtained with the help of a well calibrated spectroradiometer and measured by Sensors group at Space Applications Center [3].

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

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

4. Results

Computed at-sensor solar exoatmospheric irradiance in (W m^{-2} μm^{-1}) and Rayleigh optical thickness at mean sea level for IRS-P6 sensors are given Table 1. For comparison, values of IRS-1C/D sensors are also given.

5. 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 and D. Labs, http://rredc.nrel.gov/solar/pubs/spectral/model/t2-1.html

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

Table 1. Computed at sensor solar exo-atmopheric irradiance and Rayleigh Optical thickness for IRS sensors.

Satellite	Sensor/ BandCenter	B2		B3		B4		B5		PA	
		Eo	τr	Eo	τr	Eo	τr	Eo	τr	Eo	τr
IRS-P6	Liss-3	1849.5	0.0886	1553.0	0.0475	1092.0	0.0197	239.52	0.0012	---	---
	Liss-4	1853.6	0.0912	1581.6	0.0497	1114.3	0.0206	--	--	---	---
	AWIFS	1854.7	0.0906	1556.4	0.0478	1082.4	0.0193	239.84	0.0012	---	---
IRS-1C*	Liss-3	1851.1	0.0903	1583.8	0.0481	1102.5	0.0200	240.40	0.0013	---	---
	WIFS	---	---	1602.1	0.0495	1113.6	0.0205	---	---	---	---
	PAN	---	----	---	---	---	---	---	---	1627.1	0.0663
IRS-1D*	Liss-3	1852.2	0.0907	1577.3	0.0476	1096.7	0.0198	240.6	0.0013	---	---
	WIFS	---	---	1598.3	0.0494	1112.8	0.0205	---	---	---	---
	PAN	---	---	---	---	---	---	---	---	1603.9	0.0628
OCM*	(nm)										
B1	414.2	1713.8	0.2944								
B2	441.4	1848.0	0.2278								
B3	485.7	1963.1	0.1563								
B4	510.6	1883.9	0.1273								
B5	556.4	1855.7	0.0901								
B6	669.0	1534.4	0.0431								
B7	768.6	1216.7	0.0247								
B8	865.1	978.9	0.0154								

* Source: [1]