PRACTICAL ILLUMINATION CORRECTION OF SATELLITE IMAGERY IN CONSIDERATION OF ANISOTROPIC SKYLIGHT COMPONENT

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1. INTRODUCTION

In satellite images over rugged terrain, we can find some topographic effect entangled with atmospheric effects [1]. Without correcting these effects, it is difficult to evaluate the satellite images for land cover classification or multi-temporal monitoring of natural environment.

Iikura[2] derived a unified simple correction formula $(DN - B)/(\cos\beta + C)$ from a physical model of signal detected by sensor on board. Although either of the parameters B or C is ignored in the practical illumnation correction such as C correction method [3], and modified cosine method [4], both methods seem to work well for satellite images with high sun elevation by estimating one of these parameters from regression of digital nunbers (DNs) to cosine of solar incident angle (β).

In this paper, we will estimate these parameters based on the radiative transfer equation (6s) [5] and exact calculation of topographical parameters such as sky view factor. It will be shown that the parameter C becomes smaller than we expected when we take account of an anisotropic skylight component which is propotional to $\cos\beta$.

2. PHYSICAL BACKGROUND

For estimating surface reflectance of a target point from a satellite image, we have to evaluate various possible radiation and irradiation sources. At-sensor radiation(L_s) of the target pixel consists of the reflected irradiation(I_o), the path-radiance(L_p) and background radiation(L_b) as $L_s = T_s \cdot \rho \cdot I_o + Lp + L_b$ where ρ is the target reflectance, s is the sensor scan angle, and T_s is the transmittance from target to satellite. The target irradiation (I_o) is also broken down into the direct solar beam, the diffuse sky irradiation E_d and the reflected irradiation from adjacent slope E_t as $I_o = E_o T_\theta \cos\beta + E_d + E_t$ where T_θ is the transmittance from the sun to the target, θ is the solar zenith angle.

From these relations, we have the reflectance as follows

$$\rho = \frac{L_s - Lp - L_b}{T_s(E_o T_\theta \cos\beta + E_d + E_t)}$$

For practical corection scheme, let us use the digital number instead of the reflectance and radiation. Then we have $DN' = (DN - B)/(\cos\beta + C)$ where DN is an original digital number and DN' is a corected digital number, which could be regarded as the conventional C correction method. It should be also noted that the diffuse sky component E_d is not isotropic. Hays [6] proposed to use the following expression,

$$E_d = E_d^h\{T'_\theta \cos\beta + (1 - T'_\theta \cos\theta)V_d\}$$

where E_d^h is the diffuse sky component for flat surface, V_d is the terrain configuration factor, and T'_θ is the transmittance by scattering (no absorption).

Then, the correction parameters B and C are related to the physical quantities as follows,

$$B = a + b \times (L_p + L_b)$$

$$C = \frac{E_d^h(1 - T'_\theta \cos\theta)V_d + E_t}{E_o T_\theta + E_d^h T'_\theta}$$

In the case of isotropic sky component, the parameter C becomes $C = (E_d + E_t)/E_o T_\theta$ as shown by Iikura[2].

3. PARAMETER ESTIMATION W ITH ANISOTROPIC SKYLIGHT COMPONENT

A radiative transfer code (6S) for flat terrain is used for Landsat TM image (June 16, 1985, p107r32) under the following conditions: mid latitude summer atmosphere with marine type aerosol of 30 km horizontal visibility, sun elevation angle of 62.7°, and a normal vegetation for ground surface.

3.1 Sky view factor V_d

We calculate angles H_ϕ from zenith to horizon for 64 azimuth directions ϕ , and sum sky lights from these directions to obtain V_d. As this operation is performed to every pixels in the image, we need an efficient algorithm [2].The result would be compared to that of the conventional approximation $V_d = (1 + \cos S)/2$ where S is the slope.

3.2 Reflected irradiation

Radiation from a pixel P contributes to irradiation at the target pixel M as

$$L_{PM} = (L_p dS_M \cos T_M dS_P \cos T_P)/r_{MP}^2$$

where dS_M dS_P denote the areas of pixel P, T_M and T_P are angles between surface normal and line MP, and r_{MP} is a distance between pixel M and pixel P. If we assume lambertian surface, L_P can be obtained by calibrating a digital number of pixel P into radiation. Reflected radiance at pixel M is a sum of the L_{PM} for pixels which is visible from M, that is, viewshed of M. Therefore, we have to obtain the viewshed for this calculation [2].

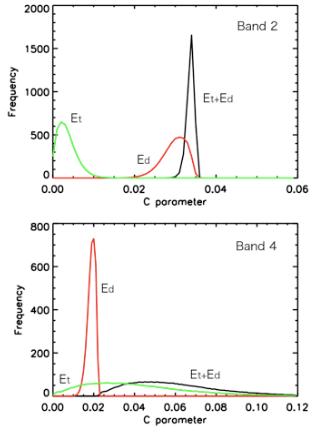

Fig. 1. Histogram of sky light and reflected irradiation

4. CONCLUSION

Table 1 shows that the correction parameter C for anisotropic sky light component is small for every bands, and seems negligible in the case of summer data with high sun elevation. In infrared bands, however, it is noted the deviation due to E_d is large as shown in Fig.1. For the image with low sun elevation, exact treatment like this might be required.

Table 1. Correction parameters calculated based on physical model

Band	1	2	3	4	5	7
B	71.54	23.38	18.84	28.73	20.20	7.83
C (anisotropic)	0.04591	0.03433	0.02639	0.06460	0.03611	0.02145
C (isotropic)	0.26973	0.21933	0.19035	0.21717	0.15682	0.12665

5. REFERENCES

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