Illumination Variations in Near-Equatorial Orbit Imaging: A Case Study with Simulated Data of RAZAKSAT

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Abstract: RAZAKSAT is a second micro-satellite mission by Malaysian Satellite Program and is expected for launch in June 2004. Designed to orbit the earth at low-equatorial orbit, RAZAKSAT will meet Malaysia's immediate needs to rapid data acquisition (real time and more repetitions) to address many operational issues of remote sensing applications, which require availability of current data sets. RAZAKSAT will be among the first remote sensing satellite to orbit the earth at low inclination along the equator, 9° with 685km altitude, hence, allows optimal geographical information and environment change within equatorial region be observed with a unique revisit characteristics. The satellite primary payload is MAC, a push-broom type camera with 2.5m of ground sampling distance (GSD) in panchromatic band and 5m of GSD in four multi-spectral bands. This paper describes on the variation of illumination anticipated from simulated RAZAKSAT image, examine its implication to its ground leaving radiances for major applications.

1.Introduction

In 2001, Malaysia has collaborated with Korea to build their second remote sensing micro-satellite, MACSAT (now referred as RAZAKSAT). It was a joint development program between Astronautic Technology(M) Pte. Ltd, Malaysia and SaTReC Initiative Co. Ltd, South Korea.

The RAZAKSAT mission is to develop and validate technologies for a near Equatorial Orbit (NeQo) remote sensing mini-satellite system to acquire medium high resolution images as fine as 5 metres or better. The launching of this satellite will make RAZAKSAT as one of the few if not the first micro-remote sensing satellite orbiting the equator at relatively low inclination. RAZAKSAT is a second micro-satellite mission by the Malaysian Satellite Program and is expected for launch in June 2004. Designed to orbit the earth at low-equatorial orbit, RAZAKSAT will meet Malaysia's immediate needs to rapid data acquisition (real time and more repetitions) to address many operational issues of remote sensing applications, which require availability of current data sets. RAZAKSAT will be among the first remote sensing satellite to orbit the earth at low inclination along the equator, 9° with 685km altitude, hence, allows optimal geographical information and environment change within equatorial region be observed with a unique revisit characteristics. The satellite primary payload is MAC, a push-broom type camera with 2.5m of ground sampling distance (GSD) in panchromatic band and 5m of GSD in four multi-spectral bands. This paper describes on the variation of illumination anticipated from simulated RAZAKSAT image, examine its implication to its ground leaving radiances for major applications. Variation analysis of ground leaving radiances from various selected targets with RAZAKSAT configuration and temporal solar radiances within equatorial belt is the main focus of this paper. The understanding of illumination variations due to non-synchronous orbit is aimed at supporting the evaluation of availability and performance systems development in their early stages of deployment. In addition, sun glint effects due to earth's changing orientation relative to the sun will also be examined.

2. Background

This study is undertaken to investigate the variation of illumination from simulated RAZAKSAT image due to its non-synchronous orbit. The variation of illumination within scenes captured from a particular orbital track is attributed to the directional changes of spectral reflectance with respect to the sun and sensor positions. The bi-directional reflectance distribution function (BRDF) is one of the simplified approaches adopted to analyse such variations. BRDF, in fact has been used in similar studies in understanding the illumination variations within simulated image per given sets of sun-sensor-geometry parameters in the last two decades (Li et al., 1985; Goudriaan, 1977).

BRDF has been used in the correction of directional effects in time series of vegetation indices and reflectance from coarse resolution sensors (Leroy and Roujean, 1994), simulating directional reflectance (Kimes and Kirchner, 1982; Kimes 1984) and albedo retrieval (Kimes and Deering, 1997). Focussing on selected terrain's targets, the variation of illumination due to sun-sensor geometry in this study is based on Gao (1993), where reflectance model of target of interest is generated given the given scene parameters. Pasture has been used a generic target in simulating the illumination variations in out study.

3. The BRDF Model

The model adopted in this study consists of two transfer equations for the two streams (upward and downward). The reflectance from the whole canopy of vegetation can be expressed as :

$$R = \text{ñ}_S \exp[-(A_2+B_1)L_T] + \frac{A_1}{A_2+B_1} \{\exp[-(A_2+B_1)L_T] - 1\} \qquad (1.0)$$

where
R is the reflectance from the whole canopy, while ñ_S is a soil reflectance coefficient (Table 1).

In order to compute reflectance with (1.0) for different directions, one would only need to determine the parameters H_s, H_v, H_{sv} and H_{svv} which are linked to (1) as :

$$A_1 = -H_{sv} \qquad (1.1)$$
$$B_1 = (1 - \text{þ})\, H_v \qquad (1.2)$$
$$A_2 = (1 - \text{ô})\, H_s - \text{ð}^{-1}\text{þ}\, H_{svv} \qquad (1.3)$$

where
þ is the leaf scattering coefficient,
ô is a leaf transmittance coefficient (value given **Table 1**), and

$$H_s = \text{Ó}\cos \text{è}\, |h_s|\, F(\text{è}) \qquad (1.4)$$
$$H_v = \text{Ó}\cos \text{è}\, |h_v|\, F(\text{è}) \qquad (1.5)$$
$$H_{sv} = \text{Ó}\cos^2 \text{è}\, |h_{sv}|\, F(\text{è}) \qquad (1.6)$$
$$H_{svv} = \text{Ó}\cos^3 \text{è}\, |h_{sv}|\, F(\text{è}) \qquad (1.7)$$

Here

$$|h_s| = (2\text{ð})^{-1} \;{}_0^{2\text{ð}} |h_s| d\text{ö} \qquad (1.8)$$
$$|h_v| = (2\text{ð})^{-1} \;{}_0^{2\text{ð}} |h_v| d\text{ö} \qquad (1.9)$$
$$|h_{sv}| = (2\text{ð})^{-1} \;{}_0^{2\text{ð}} |h_{sv}| d\text{ö} \qquad (2.0)$$
$$|h_{svv}| = (2\text{ð})^{-1} \;{}_0^{2\text{ð}} |h_{svv}| d\text{ö} \qquad (2.1)$$

The algorithm below is a term describing the projection of solar beam in the leaf normal direction.

$$h_s = 1 + \tan \text{è} \tan \text{è}_0 \cos \text{ö} \qquad (2.2)$$
$$h_v = 1 + \tan \text{è} \tan \text{è}_0 \cos (\text{ö} - \text{ö}_v) \qquad (2.3)$$

The algorithm (2.3) describes the transfers of incident solar beam into viewing direction.

$$h_{sv} = \text{á}(h_s h_v) - \text{ô}(h_s h_v) \qquad (2.4)$$
$$h_{svv} = {}_0^{2\text{ð}} \;{}_0^{\text{ð}/2} (\cos^2 \text{è}_v \sin \text{è}_v) h_{sv} |h_v| d\text{è}_v d\text{ö}_v \qquad (2.5)$$

Table 1: Parameters Used in the Model To Simulate Directional Reflectance

	Leaf Optical Properties[a]			
	á	ô	þ	ñ_S
NIR band	0.442	0.514	0.956	0.28

[a]Average values from Blad (1988) adopted.

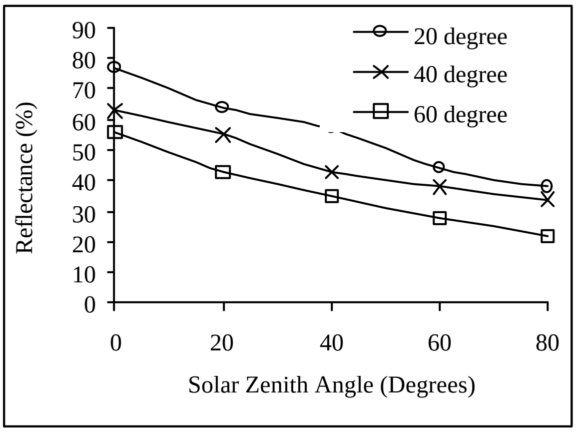

Figure 1: Changes of modelled reflectance at 20^0, 40^0 and 60^0 of solar zenith angle fixed at 9^0 inclination.

4. Results and Discussion

The reflectance variations at particular zenith viewing angles can be computed with respect to fixed sets of parameters such as solar zenith angle, solar azimuth, viewing zenith angle and viewing azimuth angle. This simply means that one could predict the intensity of responses that can be recorded by the sensor, i.e. reflectance at any satellite zenith angles within the solar zenith angles throughout the illuminations period. It is therefore of interest to note that illuminations range in the Razaksat designed for Ne Qo orbit is within 35-65% range of the albedo (Figure 1), with maximum at 0^0 and minimum at 90^0 solar zenith angles.

These results confirmed that changes in solar zenith angles given to specific satellite zenith angle gives a huge effect to reflectance value, and most importantly in the case of planned Razaksat orbital parameters, one could only expect in the worst case a 35% reflectance without taking into account the scattering and absorptions of the atmosphere.

Within the visible wavelengths, both atmospheric perturbations can be as much as 80% of the response, leaving the nett reflectance from one homogenous patch to only 10% of the incident ray. If this the case, then securing Neqo within lower solar angles is highly preferred for relative differentiations among the targets of interest.

Apart from the above, local variations within target such as leaf orientations will also have effect to targeted leaf area (Blad, 1988). Generally speaking, we know that smaller solar zenith angle will give higher reflectance with respect to smaller satellite zenith angle because viewing taken near to nadir will have full coverage of spatial information without being much influenced by shadow its effect.

5. Conclusion

The variations of illuminations of a near equatorial orbit imaging of the planned Razaksat have been demonstrated. Results of this study indicated at different the zenith viewing angles, the small inclinations of Razaksat have less significant impact on the relative variations in the illumination of the scene. When the satellite is far from nadir, resulting in large viewing zenith angle, hence, gives lower reflectance. This, however can be minimised given the high probability of well sun-lit area of the NeQo coverage through out the year.

References

Blad, B. L. (1988), Measuring And Modelling Near Surface Reflected And Emitted Radiation. In *FIFE April 1988 Workshop Report* (P.J. Sellers, Ed).

D.S. Kimes and D. W. Deering (1992), Remote Sensing of Surface hemispherical Reflectance (Albedo) Using Pointable Multispectral Imaging Spectroradiometers. Remote Sensing Environment, 39:85-94.

Gao W. (1993), A Simple Bidirectional Reflectance Model Applied to a Tallgrass Canopy. Remote Sensing Environment. Vol 45. pp:209-224.

Goudriaan, J. (1977), Crop Micrometeorology: A Simulation Study, Wageningen Center for Agricultural Publishing and Documentation, Wageningen, The Netherlands, pp: 249.

Kimes, D.S. (1984), Modeling The Directional Reflectance From Complete Homogeneous Vegetation Canopies With Various Leaf-Orientation Distributions. Journal Optical Soc. Am 1 (7) pp:725-737.

Kimes, D.S., and Kirchner, J.A. (1982), Radiative Transfer Model For Heterogeneous 3-D Scenes. Applied Optics 21. pp 4119-4129.

Leroy, M., and J.L. Roujean, (1994), Sun And View Angle Corrections On Reflectances Derived From NOAA/AVHRR Data. *IEEE Transactions on Geoscience and Remote Sensing,* 32, pp. 684-697.

Li,X. and Strahler, A. H. (1985), Geometric-Optical Modelling of a Conifer Forest Canopy. *IEEE Trans Geosicence remote Sensing.* 23: 705-725.