A PRELIMINARY EVALUATION STUDY ON THE TYPICAL GLI OCEAN COLOR BAND IMAGE BY SIMULATION

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ABSTRACT

ADEOS-II will be launched in the near future. It's main feature is to collocate many remote sensing instruments in the same platform. Within those sensors, Global Image (GLI) is considered to be a main sensor which will play a key role. In order to understand the characteristics of future GLI images of ocean color, we have first introduced the simulation models briefly, and simulated typical cases of radiance images at visible bands, in which the radiance distribution is based on geographic location, the satellite orbital parameters and sensor properties. The various simulated images of full satellite passes show the distribution of every radiation component (aerosol scattering, Rayleigh scattering, Sun glitter, water-leaving radiance and the total radiance). A method to evaluate the image quality and availability is developed by using the characteristics of image so called the Complex Signal Noise Ratio (CSNR). Meanwhile, a sires of CSNR images are generated from the simulated radiance components for different cases, which can be used to evaluate the quality and availability of GLI images before the ADEOS-II is placed in orbit. Finally, the quality and availability of GLI imagey are quantitatively analyzed by the simulated CSNR data. The results will be beneficial to all scientists who are in charge of GLI mission and to those who plan to use the data from GLI.

KEY WORDS: Radiance, CSNR, Simulation

1. INTRODUCTION

In any successful program of space satellite remote sensing in the world more attention is paid to simulation of the radiance imagery, before the satellite is in the orbit. The radiance imagery of different channels can be simulated with the designed properties of orbit, sensor and certain cases of atmosphere and water. Akashi Y. Nakajima al et have focused on studying GLI's channel 10, 11, 12, 14,and 16, most of which have serious trade-off problem between sensitivity to the measurement targets and difficulty with the atmospheric correction for gaseous absorption, especially for water vapor (Takashi Y. Nakajima al et, 1998). This research will focused on the radiative simulation of the typical visible ocean color channel 2, 4, 6, 7, 8 and 11 of GLI whose the location of centralwavelength are similar to SeaWiFS channel 1,2,3,4,5,6, see in Table1. The simulation results will applied to understand what GLI ocean color channel radiance image will be and how those image will be affected by the sun glitter, the atmospheric and sea conditions, the crossing Equator Time (CET) and so on, as well as to evaluate their quality

In the optical transmission system of ocean color remote sensing, sun-atmosphere-air/water-water-sensor, the transfer of the solar radiation is generally separated into two parts by the atmospheric molecular and aerosol scattering. One part is scattered backward directly to the sensor of the satellite. The other part is scattered forward to arrive at the water surface,in which one part is reflected and other part that is refracted into water and scattered and absorbed by the particles (i.e. chlorophyll, suspended material and yellow substance). Under water, the part of radiance is scattered upward and is leaving to the sensor via atmosphere, which contains the signal of water property. So, the total radiance which is received by the sensor can be split into four components as follows (Delu and Kim, 1999) .

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$$L_t(l) = L_r(l) + L_a(l) + L_{sr}(l) + L_w(l) \tag{1}$$

where $L_t(l)$ is the total radiance received by the sensor, $L_r(l)$ and $L_a(l)$ are the Rayleigh and aerosol path radiance (Gordon and Castano, 1987), $L_{sr}(l)$ is the specularly reflected sun light (sun glitter) and can be calculated from the wave slope distribution as a function of the wind speed(Sturm, 1980, Cox and Munk, 1954), $L_w(l)$ is the water leaving radiance (Doerffer 1980), The four components of the radiance of any pixel in the satellite image can be simulated for each visible band of the sensor in different cases, by means of the models of geolocation and radiative transfer (Pan Delu R.Doerffer Mao Tianming and Li Shujing, 1996).

Table 1: GLI bands and their central wavelength (Yoshio Avaya, March, 1996)

ch1	380 (10)nm	ch20	460 (70)nm	ch24	1050 (20)nm	ch30	3.715 (0.33) μ
ch2	400 (10)	ch21	545 (50)	ch25	1135 (70)	ch31	6.700(0.5)
ch3	412 (10)	ch22	660 (60)	ch26	1240 (20)	ch32	7.300(0.5)
ch4p	443 (10)	ch23	825 (110)	ch27	1380(40)	ch33	7.500(0.5)
ch5p	460 (10)	(250m resolution)		(1km resolution)		ch34	8.600(0.5)
ch6	490 (10)			ch28	1640 (200)	ch35	10.80(1.0)
ch7p	520 (10)			ch29	2210 (220)	ch36	12.00(1.0)
ch8p	545 (10)			(250m resolution)		(1km resolution)	
ch9	565 (10)						
ch10	625 (10)						
ch11	666 (10)						
ch12	680 (10)						
ch13	678 (10)						
ch14	710 (10)						
ch15	710 (10)						
ch16	749 (10)						
ch17	763 (8)						
ch18	865 (20)						
ch19	865 (10)						
(1km resolution, p- piecewise linear)							

The number of bands with the *1 are the number of observation bands and the number of channels correspond to the number of bands as the hardware, that is, two channels for ocean observation and for land and atmosphere observation each.

2. EVALUATION MODELS AND PARAMETERS

2.1 Models

The quality and availability of GLI images are not only dependent on the complex radiation transmission system which has been discussed above in detail, but also very dependent on the technique level of the data processing, such as the accuracy of atmospheric correction. Here, a key index of image, so called complex signal noise ratio, CSNR, is suggested to be employed in the evaluation of the image quality index (IQI). CSNR is defined as follows:

$$CSNR = L_w(l) / L_N(l) \tag{2}$$

where $L_w(l)$ is water leaving radiance. It is an alone useful signal to measure the water properties, which decided by the concentration of phytoplankton, suspended material and yellow substance. $L_N(l)$ is a complex noise which could be contributed by the following resources:

(1) Remained noise from atmospheric correction

In the raw image,(see the right items of Eq.(1)), the amount of $L_a(l)$, $L_r(l)$ and $L_{sr}(l)$ is about 85% of the total radiance received by sensor. The atmospheric correction is necessary before data will be used to extract the water color information. Since the CZCS data was available in 1978, scientists in the word have maken every effort to remove the atmosphere path radiance and sun glitter. But it is not possible to remove all of them so far and even, either in the future because of random variations of air properties with the space and time in the large scale of satellite coverage. It means that the remained noise is still involved in the image for which the atmospheric correction has been made. How much the remained noise will be in the pre-processed image. It is depends on the data correction accuracy of $L_a(l)$, $L_r(l)$ and $L_{sr}(l)$. Supposed that A, B and C are the calculation accuracy respectively to the $L_a(l)$, $L_r(l)$ and $L_{sr}(l)$, with the error relative to their own totals, then their remained noise are A $L_a(l)$, B $L_r(l)$, and C $L_{sr}(l)$, respectively.

(2) Sensor's inherent noise

The sensor's senstivity could normally be characterized by the sensor's signal to noise ratio SNR. The sensor's inherent noise can be approximately estimated as $L_t(l)) / SNR$. Where $L_t(l))$ is the total radiance received by the sensor.

(3) Sensor calibration

The requirement of accuracy of radiance measurement for ocean color is normally less than 5%, with the error relative to the total radiance. The sensor's calibration accuracy at least should meet above requirement. So sensor's calibration error will also contribute the noise for the CSNR.

Based on the above analysis of the noise resources, the total remained noise $L_N(l)$ in the image can be estimated as follows:

$$L_N(l)=\sqrt{\left[\sqrt{A^2+D^2}\,La(l)\right]^2+\left[\sqrt{B^2+D^2}\,L_r(l)\right]^2+\left[\sqrt{C^2+D^2}\,L_{sr}(l)\right]^2+\left[\sqrt{1+D^2}\;L(l)/SNR\right]^2} \quad (3)$$

where A, B and C are the calculation accuracy of $L_a(l)$, $L_r(l)$ and $L_{sr}(l)$ respectively, and D is the sensor calibration accuracy. SNR is sensor's signal noise ratio. It is obvious that the higher CSNR of the pixel is, the better quality of a pixel in the image. Therefore, CSNR is a reasonable index to evaluate the image quality.

Meanwhile, a threshold of CSNR could be decided to whether the pixel is available or not as follows:

$$r \in' (CSNR>CSNR_l) \quad (4)$$

where $CSNR_1$ is the threshold which is the lowest CSNR, for example, if CSNR of one pixel is less than $CSNR_1$, then the pixel will be judged as an unavailable pixel. As mentioned above, the requirement of radiance measurement accuracy is normally 5% with the error relative to total radiance. And thus $CSNR_1$ is 20 in this research. Then the availability of whole images is defined as follows:

$$AVA = N_a / N_t \quad (5)$$

Where AVA is the availability of whole image, N_a is the number of available pixels which is determined by Eq.(4), and N_t is the total number of pixels in the image.

2.2 Parameters of Evaluation

The orbital and sensor parameters of GLI are as follows (Yoshio Avaya, March,1996, Sciences on the GLI Mission):

(1) Obit: 803km altitude, 10:30AM (assumed 8:00-16:00AM) ascending, 98.6 degree inclination and 101min period sun-synchronous

(2) Sensor: 90degree FOV, 1276Pixels each line, 6 bands from 36bands as Table1, Sensor spectral sensitivity S(l) = 1.0.Digitizing 12 bits with gain $G^i = 1.0$, intercept $I^i = 0$.

The parameters of atmosphere, water and the dates are supposed in the simulation as Table 2.

Table 2, Typical simulaltion cases for FLI.

Parameter	**Selected to be simulated**	**notes**
Date	Vernal Equinox Summer Solstice Autumn Equinox Winter Solstice	For typical dates is supposed typical four seasons with the typical sun zenith angle
CET	8:00am-16:00pm	Sun glitter effects in different

		focus on 10:30 am	CET In designed CET
Atmosphere	Pressure	1013.25 g/m^2	Standard air pressure
	Ozone	0.32-0.38 cm(NTP)	Typical air , Iqbal,1983
	Optical vis.	10-50 km	Coastal area to open sea
	precipitation	0.4-4cm here 2cm	Coastal area to open sea
	Wind speed	1.4-5.0 m/s	Coastal area to open sea
Water	Case I	Chlorophyll: 0.25mg/m^3 Sediments: 0.25g/m^3 Yel.staff: 0.001mg/ m^3 Optical vis: 40km Wind speed: 5m/s	Typical open sea status
	Case II	Chlorophyll: 5.0mg/m^3 Sediments: 10.0g/m^3 Yel.staff: 0.1mg/ m^3 Optical vis: 20km Wind speed: 1.4m/s	Typical coastal status

3. DISCUSSION AND RESULTS

Considering the geolocation of Japan and China, the evaluation of data quality is focused on the north hemisphere and the cases of Vernal Equinox represented for all of year, CET=10:30am and in two kind of case water. The CSNR images have been simulated by Equation (2) and the availability is calculated. The distribution of CSNR and the availability are discussed as follows.

3.1 CSNR and availability in the different cases of water

Both of Japan and China cover the typical case 2 water with very high concentration of suspended material, chlorophyll and yellow staff, mean while cover the open sea with thd case 1 water. Based on the results from either SeaWiFS measurement or simulated images. The total radiance arriving at the sensor from case 2 water is much higher than from case1 water, about twice in blue bands, five times in green bands and 10 times in near inferred bands. Consequently from Equation (2), The CSNR and availability of case 2 water is much higher than case 1 water. For example, the availability of case 1 in vertical scanning case is only about 55%, but about 97% of case 2 water in the same condition, and the CSNR is only about 21, but about 79 in case 2. From this point of view, GLI has enough sensitive for coastal water, but need to consider the saturation problem.

3.2 CSNR and availability in different tilt cases

The CSNR images in different scanning cases is shown. With the comparison of CSNR and radiance images, we can easily find the fact that the sun glitter area with high radiance but low CSNR. For understanding more detailed how the sun glitter affects the data quality, the profiles of SCNR and radiance along the A-A (see, Fig.1) are calculated. The result shows that the pixels in the east half image along the A-A are almost distorted by sun glitter, their CSNR is closed to zero. Those profiles also show the fact that the data quality is very depended on the geolocation in the same other cases. Comparing the availability in different scanning cases covering the north hemisphere, We found that the back word tilt scanning case has the highest average availability of band B3,B4,B6,B7,B8 and B9) in whole year, about 80% in case 1 water, 95% in case 2 water, and that the for word tilt scanning case is the lowest availability, about 42 % in case 1 water and 80% in case 2 water , and the vertical scanning case is in the middle, about 62% in case 1 water and 85% in case 2 water. Their distribution of different bands in different case water are shown in Fig. 2 and Fig.3. With the variation of tilt scanning cases in descending orbit, the average availability of the global scale of whole year could be about 67% in case 1 water and 90% in case 2 water.

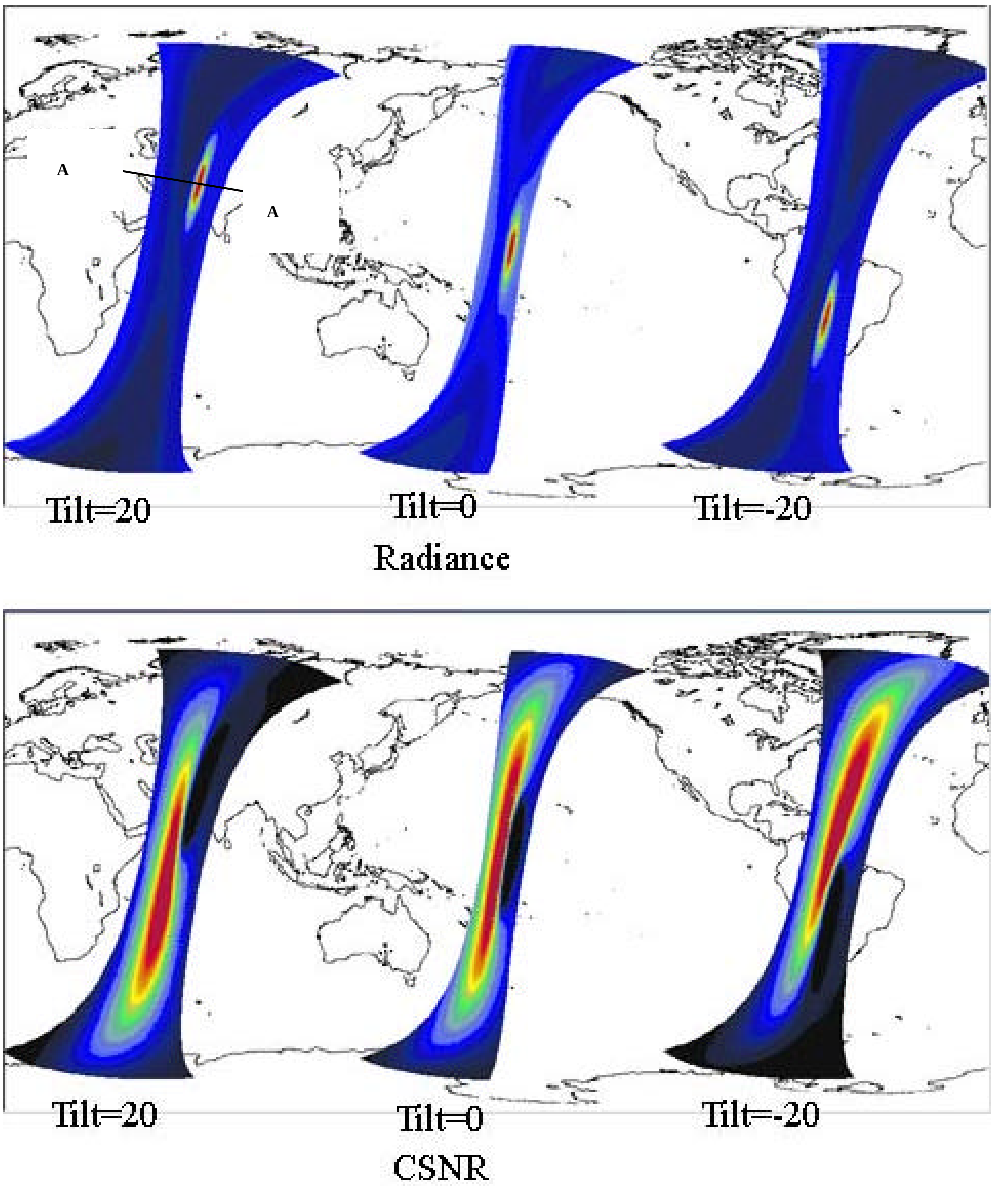

Figure1. Comparison of radiance and CSNR distribution of band 520nm in different scanning cases.

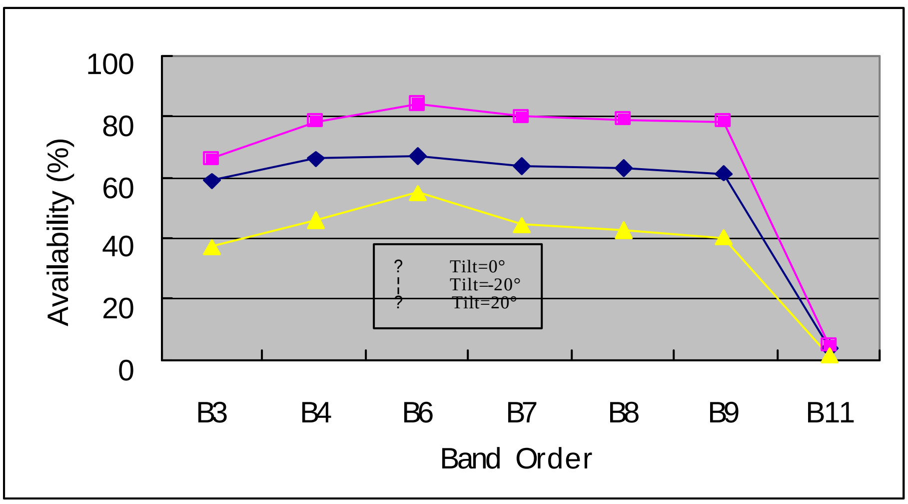

Figure.2 The availability of different band in case 1 water with different scanning cases

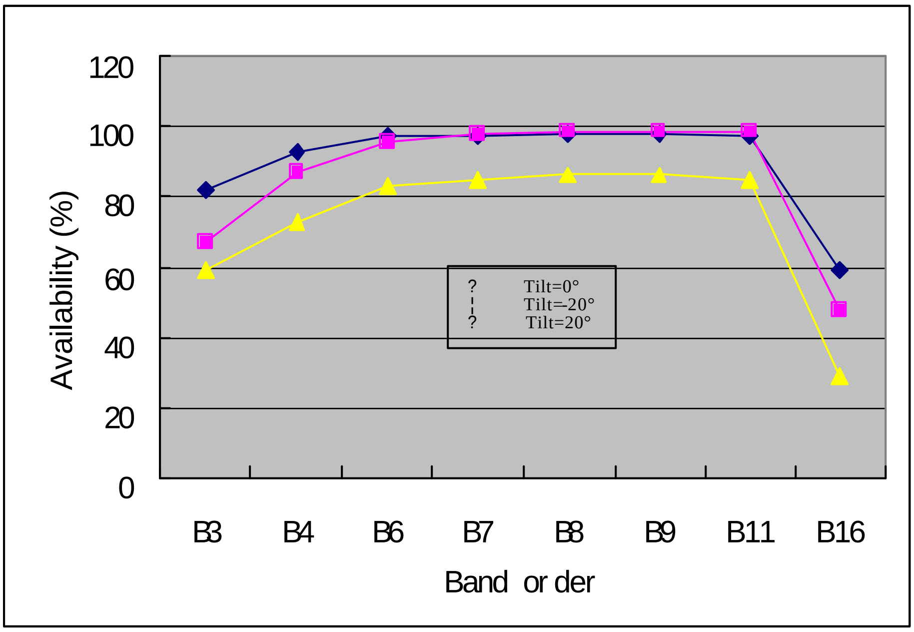

Figure3. The availability of different band in case 2 water with different scanning cases.

4. CONCLUSION

(1) Based on the ADEOS-II orbit and GLI properties and in the several typical cases with assumed air-sea conditions, the evaluation models of image quality and availability have been developed and applied to simulate the CSNR images. The results show that CSNR could be a reasonable index to evaluate the dada's quality and availability.

(2) The GLI data quality and availability are depended on geolocation, time, scanning status and the case of water. The back word scanning has highest data quality and availability. In general, the average availability in the year is about 67% in case I water, and 97% in case II water.

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