Simulated Radiances of the OSMI over the Oceans

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Abstract

Prior to launch, simulated radiances of the Ocean Scanning Multispectral Imager (OSMI) will be very useful to guess the real imagery of OSMI and to check the data processing system for OSMI. The data processing system for OSMI which is one sensor of Korea Mult i - Purpose Satellite (KOMPSAT) scheduled for launch in 1999 is being developed based on the SeaWiFS Data Analysis System (SeaDAS). Such a simulation should include the spectral bands, orbital and scanning characteristics of the OSMI and KOMPSAT spacecraft. The simulation is also very helpful for finding and preparing for problem areas before launch. This paper describes a method to create simulated radiances of the OSMI over the oceans. Our method for constructing a simulated OSMI imagery is to propagate a KOMPSAT orbit over a field of Coastal Zone Color Scanner (CZCS) pigment values and to use the values and atmospheric components to calculate total radiances. A modified Brouwer - Lyddane model with drag was used for the realistic orbit prediction, the CZCS pigment data were used to compute water - leaving radiances, and a variety of radiative transfer models were used to calculate atmospheric contributions to total radiances detected by OSMI. Imagery of the simulated OSMI total radiances for 6 nominal bands was obtained. As expected, water - leaving radiances were only a small fraction of total radiances and sun glint contaminations were observed near the solar declination. Therefore, atmospheric correction is very important in the calculation of pigment concentration from total radiances. Because the imagery near the sun's glitter pattern is virtually useless and must be discarded, more advanced mission planning will be required.

1. Introduction

The Ocean Scanning Multispectral Imager (OSMI), one of four instruments aboard Korea Multi - Purpose Satellite (KOMPSAT) scheduled for launch in 1999, is an ocean color sensor. It has 6 nominal bands; four chiefly for identification of in - water substances, each of 20 nm band width and centered at 412, 443, 490, 555 nm and two for atmospheric correction, each of 40 nm band width and centered at 765 and 865 nm. The data processing system for OSMI is being developed based on the SeaWiFS Data Analysis System (SeaDAS). The development of a simulated imagery is essential to the data processing system and to prepare for successful mission by exploring problems in sensor design, spacecraft operations, orbital anomalies prior to launch. A simulated OSMI imagery should include the spectral bands, orbital and scanning characteristics of the OSMI and KOMPSAT spacecraft.

In this paper, a method for producing simulated radiances of the OSMI over the oceans will be explained. Because of availability of the eight year Coastal Zone Color Scanner (CZCS) data, the CZCS pigment data from NASA/JPL were used to calculate water - leaving radiance which is a part of OSMI total radiances. In addition, a variety of radiative transfer models were used to calculate OSMI total radiances.

2. Method

The OSMI total radiances were geolocated using an orbital model to provide the OSMI - like viewing and solar geometries. SeaTrack, which is an orbit prediction software for SeaWiFS mission, was used to calculate the KOMPSAT positions and velocities. The program is not satellite specific, and therefore can be used to track satellites other than SeaStar/SeaWiFS (Lambert et al., 1993). The modified Brouwer - Lyddane model with atmospheric drag was chosen as the prediction model for SeaTrack. Based on sub - satellite longitude, latitude, scan and tilt angles, the viewing (spacecraft zenith, θ, and azimuth angle, ϕ) and solar (solar zenith, θ_0, and azimuth angle, ϕ_0) geometries can be calculated.

The basic equation of radiative transfer for ocean color can be divided into the radiance contributions from atmospheric and oceanic components:

$$L_t(\lambda) = T_s(\lambda)L_w(\lambda) + L_r(\lambda) + L_a(\lambda) + T_d(\lambda)L_g(\lambda) \tag{1}$$

where $L_t(\lambda)$ is the total radiance received by a sensor at the top of the atmosphere (TOA) in a spectral band centered at a wavelength λ, $L_w(\lambda)$ is the water - leaving radiance, $L_r(\lambda)$ is the Rayleigh radiance, $L_a(\lambda)$ is the aerosol radiance, $L_g(\lambda)$ is the sun glint radiance. In this equation, $T_d(\lambda)$ and $T_s(\lambda)$ are the direct and diffuse transmittance of the atmosphere.

The normalized water - leaving radiance, $L_{wn}(\lambda)$, which is independent of viewing and solar geometry, is computed from Gordon et al.'s(1988a) semi - analytic radiance model

$$L_{wn}(\lambda) = \frac{(1 - \rho_n)(1 - \rho_N)F_0(\lambda)R(0^-,\lambda)}{n^2Q[1 - rR(0^-,\lambda)]} \tag{2}$$

where ρ_n(= 0.021) is the Fresnel reflectance of the sea surface for normal incidence, ρ_N(= 0.043) is a normalized mean value of surface reflectance for direct and diffuse irradiance for a flat sea, $F_0(\lambda)$ is the extraterrestrial irradiance corrected for Earth - sun distance, $R(0^-,\lambda)$ is the irradiance reflectance just below the sea surface, n(= 1.341) is the seawater refractive index, Q is the irradiance - to - radiance ratio, and r(= 0.48) is the water - air reflectance for totally diffuse irradiance.

The transmitted water - leaving radiance, $T_sL_w(\lambda)$, is expressed by Gordon(1990) as

$$T_s(\lambda,\theta)L_w(\lambda) = T_s(\lambda,\theta)L_{wn}(\lambda)(1 - \rho)T_s(\lambda,\theta_o)\cos\theta_o \tag{3}$$

where ρ is the weighted direct plus diffuse reflectance and viewing/solar geometries are considered.

The Rayleigh radiance, $L_r(\lambda)$, has been computed using the single scattering approximation (Gordon et al., 1988b)

$$L_r(\lambda) = \tau_r(\lambda)F_o(\lambda)p_r(\theta,\theta_0,\lambda)/4\pi \tag{4}$$

where $p_r(\theta,\theta_0,\lambda) = \{P_r(\theta_-,\lambda) + [\rho(\theta) + \rho(\theta_0)]P_r(\theta_+,\lambda)\}/\cos\theta$, $\cos\theta_\pm = \pm \cos\theta_0 \cos\theta - \sin\theta_0 \sin\theta \cos(\phi-\phi_0)$, $P_r(\alpha) = 0.75(1 + \cos^2\alpha)$, $\rho(\theta)$ is the Fresnel reflectance, $\tau_r(\lambda)$ is the Rayleigh scattering optical thickness.

Following Gordon and Castano(1989), the aerosol radiance, $L_a(\lambda)$, is determined by

$$L_a(\lambda) = \omega_a\tau_a(\lambda)p_aF_0'(\lambda)/\cos\theta \tag{5}$$

where ω_a is the single scattering albedo of the aerosol, $\tau_a(\lambda)$ is the optical thickness, p_a is a factor for the probability of scattering to the spacecraft, and $F_0'(\lambda)$ is the extraterrestrial irradiance corrected for Earth - sun distance and modified by the absorbing gases in the atmosphere.

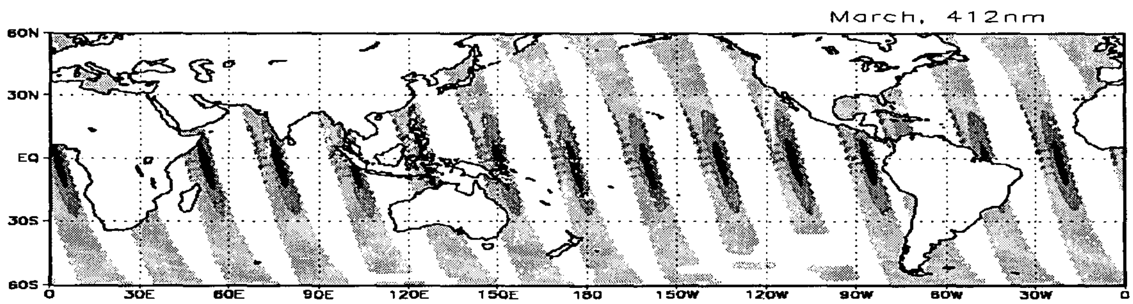
Sun glint radiance, $L_g(\lambda)$, at the sea surface for a given viewing and solar geometry can be calculated by (Cox and Munk, 1954) :

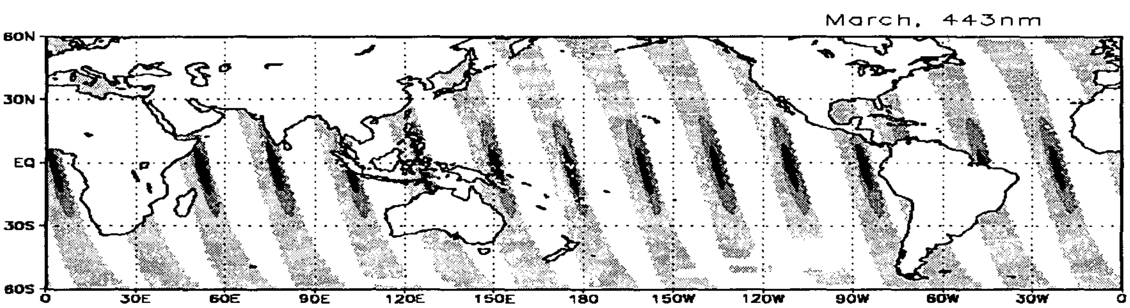
$$L_g(\lambda) = \frac{0.021 T_d(\lambda,\theta_0) F_0(\lambda) p_w(\theta,\phi,\theta_0,\phi_0,W)}{4\cos\theta \cos^4\theta_N} \quad (6)$$

where $p_w(\theta,\phi,\theta_0,\phi_0,W)$ is the probability of seeing sun glitter, W is wind speed, θ_N is the angle with respect to nadir of the sea surface slopes to produce a reflection angle to the spacecraft (Viollier et al., 1980). Finally, the simulated total radiance at the sensor, given in (1) is calculated by summing (3), (4), (5), and $T_d(\lambda,\theta)$(6) (See Gregg et al., 1993 for details).

3. Results and Discussion

Simulated radiances of the OSMI over the oceans for 6 bands are shown in Figure 1. It is found that the bands show progressively less total radiance from 412 nm to 865 nm. Sun glint is apparent near the solar declination. The phenomenon is also observed in the simulated sun glint radiances for June, September and December (Figures not shown). Especially in 865 nm, where the atmospheric and oceanic contributions to the total radiances are small, the ratio of sun glint radiance is high (Table 1). Therefore, pixels having a glint radiance of Lg (865 nm) greater than a fixed threshold are masked out before images are processed in the SeaDAS. The results suggest that more advanced mission planning will be required to prevent contamination of sun glint and to acquire global ocean color data.





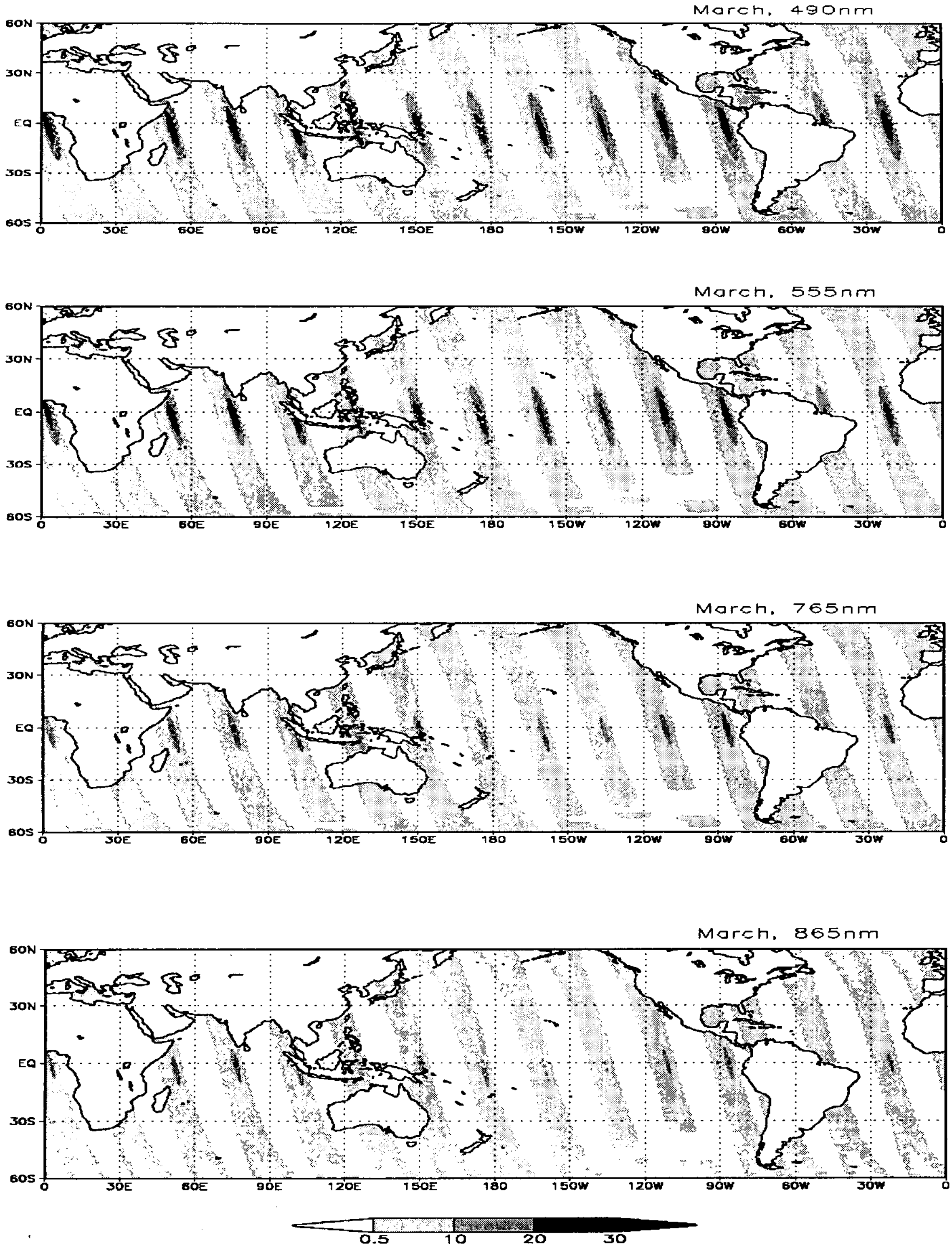


Figure 1. Simulated total radiances for OSMI 6 bands in 21 March.
Units are mW cm^{-2} μm^{-1} sr^{-1}.

Table 1. Averaged values of water - leaving radiance, Rayleigh radiance, aerosol radiance and sun glint radiance (units are mW cm^{-2} μm^{-1} sr^{-1}). The values in the parenthesis are ratio of each radiance to total radiances.

Band	water - leaving	Rayleigh	aerosol	sun glint	total
412 nm	0.562 (5.9%)	5.699 (60.2%)	1.942 (20.5%)	1.270 (13.4%)	9.473
443 nm	0.506 (5.9%)	4.644 (54.1%)	2.030 (23.7%)	1.399 (16.3%)	8.579
490 nm	0.301 (4.4%)	3.139 (46.1%)	1.935 (28.4%)	1.434 (21.1%)	6.809
555 nm	0.065 (1.4%)	1.805 (36.5%)	1.697 (34.3%)	1.375 (27.8%)	4.942
765 nm	0.000 (0.0%)	0.327 (15.2%)	0.903 (42.0%)	0.920 (42.8%)	2.150
865 nm	0.000 (0.0%)	0.162 (10.2%)	0.674 (42.5%)	0.750 (47.3%)	1.586

In Table 1, the water - leaving radiance which has direct relationship with pigment concentration is only a small fraction of total radiances. Especially, the value is zero in 765 and 865 nm. It is confirmed that backscattered radiation by air molecules and aerosols is predominant in forming the radiance detected at the TOA in the visible (VIS) part of the spectrum and aerosols have an important role in the near infrared (NIR) part of the spectrum. Because aerosol scattering is spectrally varying, specific information about aerosol is needed. This information is available in the NIR, where water - leaving radiance vanishes and atmospheric contribution to the TOA radiance becomes 100%. In the ocean color detection from space, the process of deriving the normalized water - leaving radiance from imagery of ocean is usually defined atmospheric correction. As well known, the application of 765 and 865 nm to atmospheric correction is straightforward in principle: one assesses the contribution of the atmosphere in the NIR and extrapolates it into the VIS. It is recommended that two channels for atmospheric correction should be sufficiently distant to each other in the NIR to capture the spectral trend with some accuracy; in addition they should not be too far from the VIS to ensure a safe extrapolation. The last condition to select two channels for atmospheric correction is to avoid prominent atmospheric absorption bands (water vapor and oxygen) which exist in the NIR.

4. Conclusions

Over the oceans, the simulated radiances of OSMI were developed in advance of launch. The simulated radiances are resonable comparing to radiances of SeaWiFS. The more realistic simulation will increase the success of the mission by exposing problems in sensor design, spacecraft operations, orbital anomalies prior to launch. Therefore, we need continuing revision of the data set to preserve realism.

5. References

Cox, C., and W. Munk, 1954: "Measurement of the roughness of the sea surface from photographs of the sun's glitter", *J. Mar. Res.*, **44**, 838 - 850.

Gordon, H.R., 1990: "Radiometric considerations for ocean color remote sensors", *Applied Optics*, **29**, 3228 - 3236.

------, and Castano, 1989: "Aerosol analysis with Coastal Zone Color Scanner: A simple method for including multiple scattering effects", *Applied Optics*, **28**, 1320 - 1326.

------, O.B. Brown, R.H. Evans, J.W. Brown, R.C. smith, K.S. Baker, and D.K. Clark, 1988a: "A semianalytic radiance model of ocean color", *J. of Geophys. Res.*, **93**, 10909 - 10924.

------, J.W. Brown, and R.H. Evans, 1988b: "Exact Rayleigh scattering calculations for use with the Nimbus-7 Coastal Zone Color Scanner", *Applied Optics*, **28**, 1320 - 1326.

Gregg, W.W., F.C. Chen, A.L. Mezaache, J.D. Chen, and J.A. Whiting, 1993:" The simulated SeaWiFS Data set, Version 1", *SeaWiFS Technical Report Series*, Vol 9.

Lambert, K.S., W.W. Gregg, C.M. Hoisington, and F.S. Patt, 1993: "SeaTrack - Ground station orbit prediction and planning software for sea-viewing satellites", *NASA Reference Publication* 1331.

Viollier, M., D. Tanre, and P.Y. Deschamps, 1980: "An algorithm for remote sensing of water color from space", *Bound. Layer Meteorology*, **18**, 247 - 267.