ATMOSPHERIC CORRECTION TECHNIQUE FOR GEOSTATIONARY OCEAN COLOR IMAGER (GOCI) ON COMS

Palanisamy Shanmugam and Yu-Hwan Ahn

Ocean Satellite Research Group, Korea Ocean Research and Development Institute, Ansan P.O. Box. 29, Seoul, Korea
Emails: spahnmugam@korid.re.kr; yuahn@korid.re.kr

ABSTRACT: Geostationary Ocean Color Imager (GOCI) onboard its Communication Ocean and Meteorological Satellite (COMS) is scheduled for launch in 2008. GOCI includes the eight visible-to-near-infrared (NIR) bands, 0.5km pixel resolution, and a coverage region of 2500 × 2500km centered at 36N and 130E. GOCI has had the scope of its objectives broadened to understand the role of the oceans and ocean productivity in the climate system, biogeochemical variables, geological and biological response to physical dynamics and to detect and monitor toxic algal blooms of notable extension through observations of ocean color. To achieve these mission objectives, it is necessary to develop an atmospheric correction technique which is capable of delivering geophysical products, particularly for highly turbid coastal regions that are often dominated by strongly absorbing aerosols from the adjacent continental/desert areas. In this paper, we present a more realistic and cost-effective atmospheric correction method which takes into account the contribution of NIR radiances and include specialized models for strongly absorbing aerosols. This method was tested extensively on SeaWiFS ocean color imagery acquired over the Northwest Pacific waters. While the standard SeaWiFS atmospheric correction algorithm showed a pronounced overcorrection in the violet/blue or a complete failure in the presence of strongly absorbing aerosols (Asian dust or Yellow dust) over these regions, the new method was able to retrieve the water-leaving radiance and chlorophyll concentrations that were consistent with the in-situ observations. Such comparison demonstrated the efficiency of the new method in terms of removing the effects of highly absorbing aerosols and improving the accuracy of water-leaving radiance and chlorophyll retrievals with SeaWiFS imagery.

KEY WORDS: Atmospheric correction, GOCI, Ocean color, Northwest Pacific waters, Korea

1. INTRODUCTION

The term atmospheric correction is the key procedure in ocean color data processing as it removes about 80-90% of the top of atmosphere (TOA) signal recorded by the sensor (Ahn and Shanmugam, 2004). A small part remaining is the desired water-leaving radiance that carries immense information concerning biogeochemical properties of the ocean waters. This demonstrates the necessity of an accurate atmospheric correction that eliminates the radiance backscattered from the atmosphere (due to air molecules and aerosols) and possibly reflected by the sea surface but never entering the ocean. For major satellite ocean color missions such as Coastal Zone Color Scanner (CZCS) and Sea-viewing Wide Field-of-view Sensor (SeaWiFS), Gordon (1978) and Gordon and Wang (1994) have proposed the standard atmospheric correction (SAC) algorithms to retrieve the water-leaving radiance from the total radiance measured at the TOA. Due to the difficulties in deriving information regarding the aerosol properties which vary in time and space, these atmospheric correction schemes assume the water-leaving radiances in the bands centered at 670nm, 765nm and 865nm to be zero in order to enable estimation of aerosol optical properties and extrapolate these into the visible. Such approaches are referred to as dark-pixel atmospheric correction techniques, which have been widely accepted for relatively clear waters where they provide satisfactory results with uncertainties < 20% in chlorophyll concentrations from CZCS and < 5% in water-leaving radiance and < 35% in chlorophyll concentrations over Case 1 waters from SeaWiFS (Gordon et al., 1980; Hooker et al., 1992).

However, in more optically complex turbid coastal waters, the SAC schemes do not work well simply because of the assumption of negligible water-leaving radiances at 670nm, 765nm and 865nm, which is invalidated by the turbid water constituents (suspended sediments and possibly bottom reflection) that contribute significant amounts of water-leaving radiance to these bands. This ultimately leads to the satellite-determination of water-leaving radiance in the violet and blue (e.g., SeaWiFS b1 and b2) to be underestimating severally the in-situ observations for highly productive and sediment-dominated waters (Siegel et al., 2000; Ruddick et al., 2000). In addition, the SAC algorithms in the presence of absorbing particles underestimate the water-leaving radiance values in the blue leading to very high chlorophyll concentrations in the coastal waters (Chomko and Gordon, 1998) (Figs. 1a and b).

2. METHOD

An advanced version of SSMM to remove the atmospheric effects and subsequently retrieve the desired water-leaving radiances and pigment concentrations is presented in Fig. 2 and the results using SeaWiFS images of the two Asian dusty days in spring 2000 and 2001 are

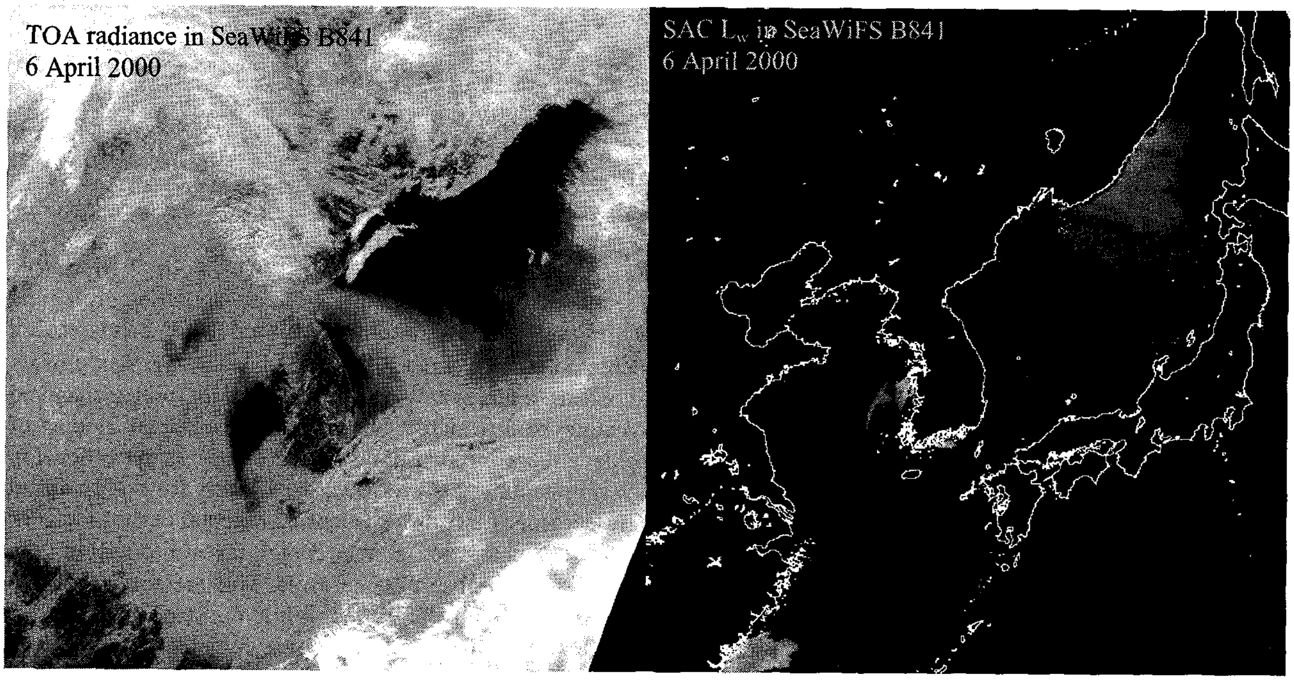


Figure 1a. Color composite image from the top of atmosphere (TOA) radiance in SeaWiFS bands (841) centered at 865nm (red), 490nm (green) and 412nm (blue). (b) The corresponding water-leaving radiance image obtained from the standard atmospheric correction (SAC) algorithm developed by Gordon and Wang (1994).

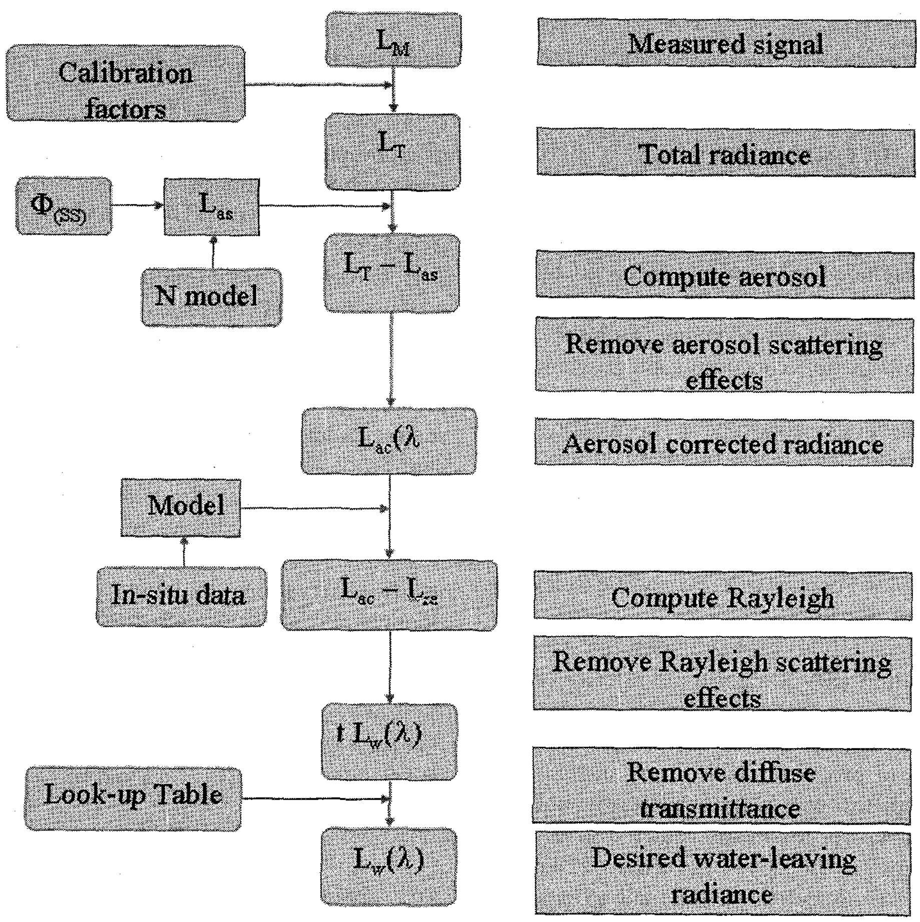


Figure 2. Spectral shape matching method (SSMM) computations to correct atmospheric effects in SeaWiFS imagery

demonstrated in the later sections. The method is further tested on SeaWiFS images collected over highly turbid and phytoplankton dominated waters off the Korean southwest coast and the Yellow Sea. The results are then compared with field measurements and those from standard atmospheric correction and bio-optical algorithms included in the NASA SeaWiFS Data Analysis System (SeaDAS).

3. RESULTS AND DISCUSSION

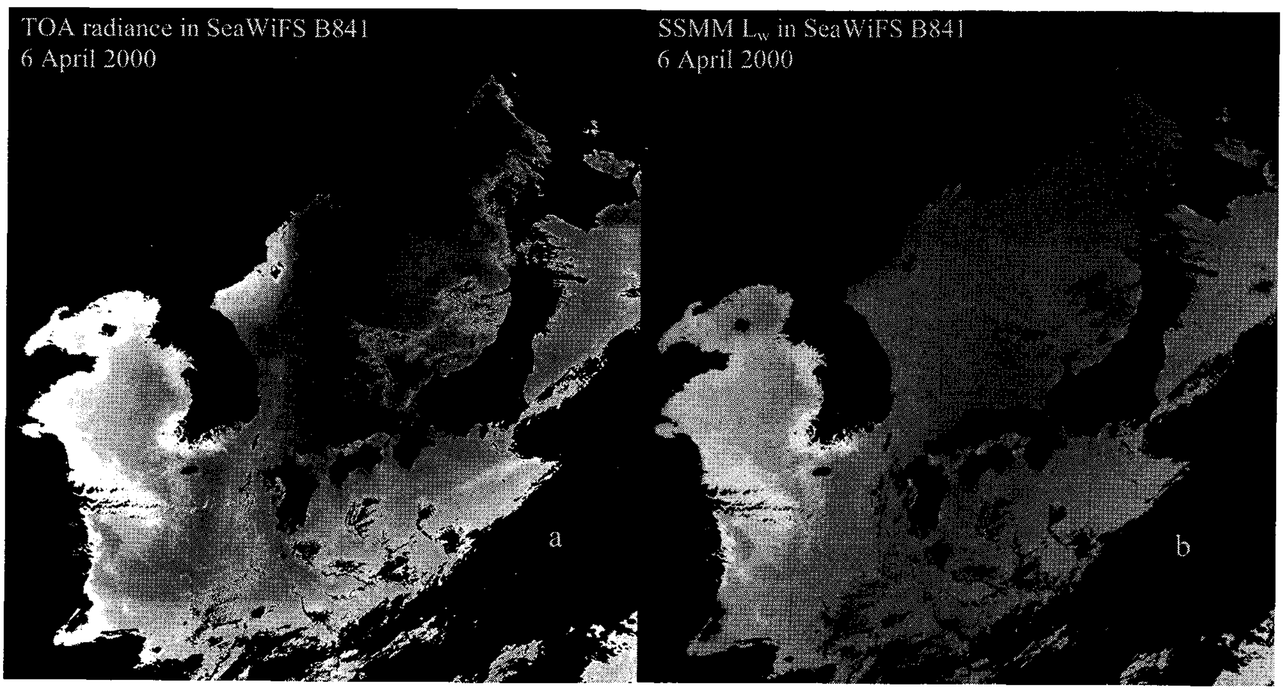
Fig. 3a is an example of the total radiance image (6 April 2000) generated from the three SeaWiFS bands centered at 865nm (red), 490nm (green) and 412nm (blue). This image clearly illustrates the spatial distribution of the yellow dust/ Asian dust aerosols, which were transported over East China, Korea and Japan during spring 2000. The additive effects induced by these aerosols significantly modified the spectral shape of the total radiance signals in coastal and ocean waters. This is primarily because the detected aerosols contained the average concentrations of crustal elements (Ca, Al, Fe, Mg, Mn) accounting for 65-86% of each of their loadings, when the wind speed and aerosol mass loadings severally increased (Yuan et al., 2004; Cheng et al., 2005a). Such high concentrations of ferro-magnesium mineral particles absorbed light much higher than did they reflect.

Fig. 3b is the corrected image of SSMM from the three SeaWiFS bands centered at 865nm (red), 490nm (green) and 412nm (blue). Note that the atmospheric effects were perfectly removed and the retrieved water-leaving radiances demonstrate a cross-shelf transport of suspended sediments from ECS to Korean waters.

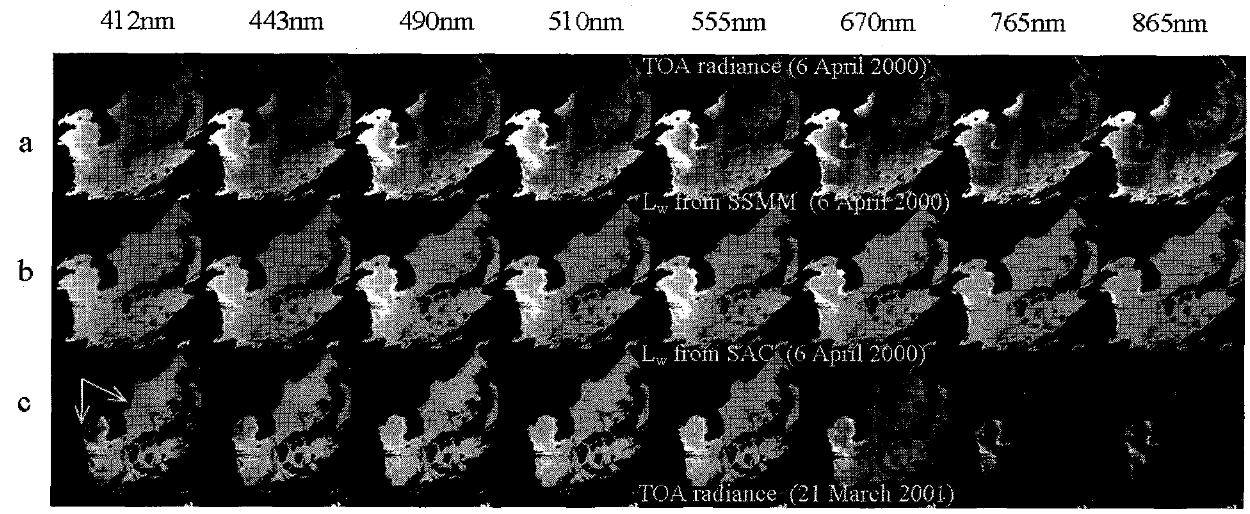
Figs. 4a-c provide a better comparison of the results in eight bands before and after the SAC and SSMM algorithms were employed on SeaWiFS images of 6 April 2000. The brighter areas represent the Asian dust aerosols in the TOA radiance images and suspended sediment distribution in the water-leaving radiance images. While SSMM was capable of retrieving the water-leaving radiance values for the intense aerosols pixels of the ECS, YS, ES and Korean Sea, the SAC algorithm showed a complete failure of the scheme in these areas, yielding low and unphysical negative water-leaving radiance values at 412nm and 443nm in the less-intense aerosols pixels of the ES, ECS and YS. This may be owing to an extensive overcorrection of aerosol effects in the violet and blue bands (Moulin et al., 2001). The SSMM was also successful in recovering most of the turbid coastal areas that were previously masked by the SAC algorithm, which often led to near zero water-leaving radiance values in the relatively clear waters.

The retrieved water-leaving radiances from SAC and SSMM were compared to in-situ data collected from highly turbid coastal waters of the Korean Southwest Sea. Around these areas the filed measurements represented the concentrations of chlorophyll (Chl), suspended sediments (SS) and dissolved organic matter (DOM) to be varying from 0.6–2.5 mg m^{-3}, 2–120 g m^{-3} and 0.38 to 1.8 m^{-1} respectively.

Statistical analysis of the mean relative error (MRE) and root mean square error (RMSE) were performed to provide additional information on how accurately the satellite retrieval agrees with in-situ measurements made on the ship and the results were compared in what follows.



Figures 3a and b. Color composite images from the top-of-atmosphere radiance in SeaWiFS bands centered at 865nm (red), 490nm (green) and 412nm (blue) and corresponding water-leaving radiance retrieved from SSMM.



Figures 4a-c. Comparison of atmospheric correction by the SAC and SSMM algorithms applied to the Asian aerosol dusty SeaWiFS image on 6 April 2000. (a) the top-of-atmosphere (TOA) radiance (mW cm^{-2} μm^{-1} sr^{-1}) in the SeaWiFS spectral bands (1-8), (b) water-leaving radiance (mW cm^{-2} μm^{-1} sr^{-1}) from SSMM, and (c) water-leaving radiance from the SAC algorithm.

Table 1. Mean relative error (MRE) and RMSE deviation (band averaged). Note that MRF and RMSE decrease by a significant amount after the SSMM atmospheric correction scheme was applied to SeaWiFS image data of 20 and 23 October 1998.

Wavelength (nm) / Method	412	443	490	510	555	670	765	865	RMSE
SAC	-0.52	-0.33	-0.28	-0.26	-0.3	-0.5	-0.79	-0.81	0.47
SSMM	0.16	0.42	0.16	0.08	-0.08	-0.003	-0.044	0.46	0.17

Table 1 depicts the values of the MRE and RMSE of water-leaving radiance retrievals with the SAC and SSMM algorithms. In turbid coastal waters, the large MRE (in all the SeaWiFS bands) coupled with the SAC algorithm were significantly reduced and the band averaged RMSE was decreased from 0.47 to 0.17 with SSMM. Similarly, the correlation plots for each band showed that the water-leaving radiance retrievals with SSMM appeared to be better consistent with ship data than those with the SAC algorithm. In particular, the regression slopes of correlation between retrieved and ship-measured water-leaving radiances were close to 1.0, excluding bands 1, 2 and 7 which yielded slightly lower values, 0.42, 0.50 and 0.44, respectively. However, these values are still better than those of the SAC algorithm. SSMM also revealed higher r^2 values of the regressions than the SAC algorithm. The high values of S and r^2 apparently indicate the water-leaving radiances retrieved from SSMM agreeing better with in-situ data. In contrast, the SAC algorithm had poor estimates exhibiting a clear bias toward underestimation in all the SeaWiFS bands. One reason is that the SSMM performed well could be partly explained by the accounted non zero water-leaving radiance into the SSMM.

4. CONCLUSION

A preliminary validation in turbid coastal waters of the Korean Southwest Sea showed the efficiency of SSMM over the SAC in terms of removing the effects of highly absorbing aerosols and improving the accuracy of water-leaving radiance and chlorophyll retrievals with SeaWiFS imagery. In the future refinement of SSMM, it is planned to include a procedure to remove the whitecaps effects, additional aerosol spectral models for both the weakly and strongly absorbing aerosols, and extensive validation with the large match-ups of SeaWiFS and in-situ data in turbid coastal waters.

References

Ahn, Y.H., and Shanmugam, P., 2004. New methods for correcting the atmospheric effects in Landsat imagery over turbid waters. *Korean Journal of Remote Sensing*, 20, pp. 289-305.

Gordon, H. R., and Wang, M., 1994. Retrieval of water-leaving radiance and aerosol optical thickness over the oceans with SeaWiFS: a preliminary algorithm. *Applied Optics*, 33, pp. 443-452.