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Communication

Comparison of CZCS and SeaWiFS Pigments for Merging the Higher Level Ocean Color Data

Jong-Chul Jeong* and Sin-Jae Yoo**

Dep. Geoinformatics Eng. Namseoul University*

Korea Ocean Research and Development Inst.**

Abstract : Many ocean color sensors are being operated at present and will be continued to operate in the coming years. However, these ocean color sensors have different spectral bands locations and higher level product algorithms.

Thus the continuity of ocean color data from the satellite with different missions will be important for monitoring of oceanographic variation with long term research. In this study, CZCS band and algorithm are compared with OCTS and SeaWiFS algorithm for estimating chlorophyll. Missing bands of OCTS and CZCS for chlorophyll algorithm are estimated by linear-interpolation using SeaWiFS data. We were able to evaluate the effectiveness of the correction methods using linear interpolation method. Surprisingly, linear interpolation gave a better result than those of other bands.

Key Words : CZCS, OCTS, SeaWiFS, Chlorophyll Algorithm, Linear Interpolation.

1. Introducton

Since the first launch of ocean color sensor, CZCS in 1978, ocean color data have been accumulated over the time period expanding two decades.

ADEOS/OCTS operated during 1996~1997. SeaWiFS launched in 1997 is operating at present. More sensors will be operated in the coming years.

One of the important utilities of ocean color data is long-term monitoring of the ocean productivity. Thus the continuity of ocean color data obtained from different missions is important. This requires proper comparison.

One complication, however, is that comparison of data from different sensors is not straightforward. For examples, the three sensors mentioned above have different spectral bands and algorithms (Table 1).

CZCS and OCTS had 520 nm band while SeaWiFS uses 510 nm band. And, CZCS had 550 nm band and OCTS had 565 nm band while SeaWiFS has 555 nm band. Since the different bands are used, the algorithms are different.

This differences in the spectral band and the algorithms make the comparison a difficult matter. To

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address the comparison issue and to evaluate the best algorithm for SeaWiFS, a workshop was held. The algorithms were compared by extensive data set(McClain, 1997). The standard SeaWiFS algorithm for chlorophyll and CZCS pigment (chlorophyll plus phaeopigment) was chosen as a result of the comparison (Table 1).

We ask a question: Can we compare the old CZCS data and SeaWiFS data to evaluate long term change in the productivity of the East Sea, for instance? In other words, the differences in these data are the changes in the real world?

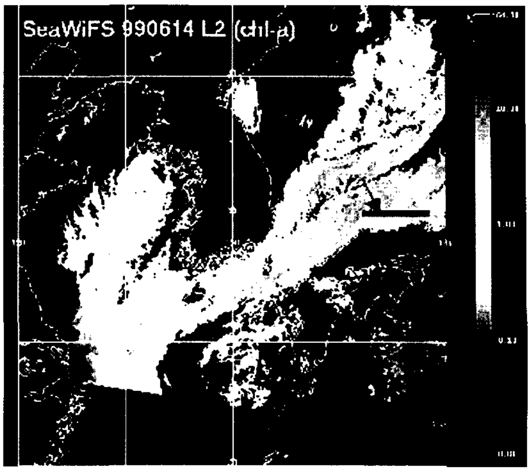

Fig. 1. SeaWiFS chlorophyll image in the East Sea on June 14, 1999.

2. Data and Processing

SeaWiFS level 0 data of June 14 in 1999 was processed to level 2 by SeaDAS 3.2. Fig. 1 is the chlorophyll image calculated by OC2 algorithm. A line was chosen on the latitude 36N. From every pixel on this line, the spectra of normalized water leaving radiance were extracted(Fig. 2). With these values, following values were calculated: 1) OCTS chlorophyll data were estimated by OCTS algorithm (Kishino, 1994), 2) CZCS pigment values by CZCS branching algorithm (hereafter PG; Gordon et al, 1992), 3) CZCS pigment values (hereafter PC) by Clark (1981), and 4) CZCS pigment values by SeaDAS algorithm. The algorithms are described in the Table 1.

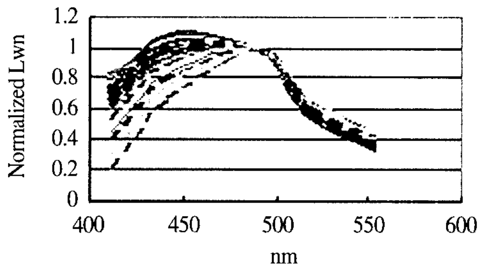

Fig. 2. Lwn spectra from 36N line. The values are normalized to 490 nm.

In addition to the calculation, above algorithms were also applied to the wavelength-corrected values. Since

Table 1. Spectral Bands and Algorithms for CZCS, OCTS and SeaWiFS.

Sensor	In-water bands (nm)	chlorphyll and pigment algorithms
CZCS	443, 520, 550	$C_{13} = 1.298\,[Lw(443)/Lw(550)] - 1.71$ if $C_{13} > 1.5$ then use C_{23} $C_{23} = 3.3266\,[Lw(520)/Lw(550)] - 2.40$
		$C = 5.56\,\{[Ls(443)+Ls(520)]/Ls(550)\} - 2.252$
OCTS	412, 443, 490, 520, 565	$C = 0.2818\,\{[Lwn(520) + Lwn(565)]/Lwn(490)\} - 3.497$
Sea-WiFS	412, 443, 490, 510, 555	$C = -0.040 + 10\,(0.341 - 3.001x + 2.811x^2 - 2.041x^3)$ $X = \log_{10}[Rrs(490)/Rrs(555)]$ CZCS pigment = 1.34 chl-a 0.98

CZCS and OCTS had different spectral band, corrections were made to estimate LWN(normalized water leaving radiance) of 520 and 550 nm in CZCS bands and LWN of 520 and 565 nm in OCTS bands using Lwn of 510 and 555 nm from SeaWiFS spectral bands.

Lwn at 520 nm was estimated using two methods. As a first hand approximation a linear interpolation was made in between the 510 ~555 nm interval. Secondly, the following relationship was found from BBOP data set (Maritorena and O'reilly, 1997) was used.

$$R_{rs}(510) = 1.3239 \cdot R_{rs}(520) - 0.0004 \qquad (1)$$

Lwn at 565 nm was estimated using following the relationship (Maritorena and O'reilly, 1997).

$$R_{rs}(555) = 1.0628 \cdot R_{rs}(565) - 0.0002 \qquad (2)$$

Lwn at 550 nm was linearly interpolated from 510~555 nm values. In addtion, Lwn at 520 nm was linearly extrapolated from 555 ~565 nm values.

3. Results

OCTS chlorophyll values were calculated with or without the correction of wavelegnth(Fig. 3).

Correction using linear interpolation gave better results. CZCS pigment values were calculated by Gordon algorithm are plotted in Fig. 4. Note all the values are less than SeaWiFS chlorophyll. Here, correction using linear interpolation gives highest values.

CZCS-pigments by Clarke algorithm are plotted in Fig. 5. Correction using Eq. (1) gives the closest values to the SeaWiFS pigments. The errors of the estimation are summarized in Table 2.

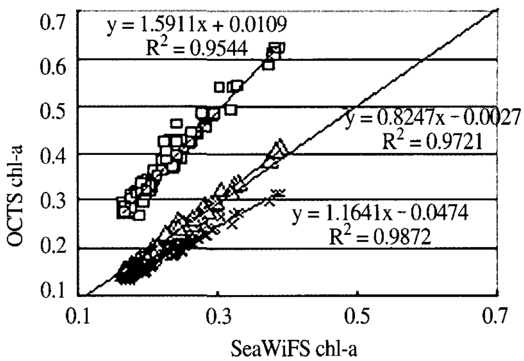

Fig. 3. Chlorophyll values were calculated by OCTS algorithm.
□ : uncorrected values;
△ : correct by linear interpolation;
X : corrected by the equation (1).

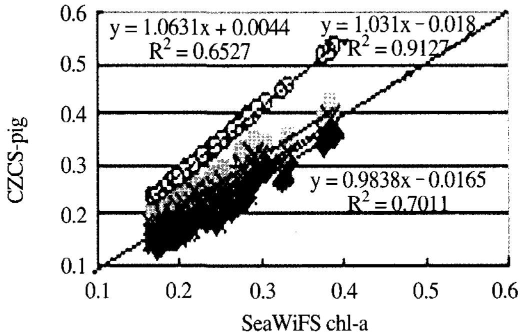

Fig. 4. CZCS pigment values were estimated by Gordon algorithm.
◇ : uncorrected values
X : corrected values using the equation (1)
□ : corrected by linear interpolation;
○ : SeaWiFS pigments.

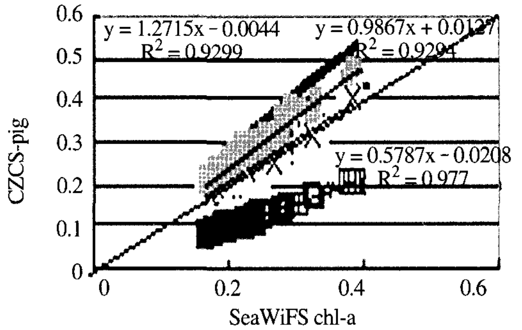

Fig. 5. CZCS pigment values were estimated by Clark algorithm.
□ : uncorrected values
X : corrected values using linear interpolation
■ : corrected by equation (1)
thick line : SeaWiFS pigments.

Table 2. Errors of Estimation against SeaWiFS Chlorophyll and CSCZ Pigment.

	Average relative error	RMSE
OCTS chlorophyll without correction	-0.6386	0.1508
OCTS chlorophyll with linear interpolation correction	0.0488	0.0136
OCTS chlorophyll with correction by Eq. (1)	0.1877	0.0447
CZCS pigments (Gordon) without correction	0.2063 (0.3572)	0.0293 (0.1151)
CZCS pigments (Gordon) with linear interpolation correction	-0.0562 (0.2354)	0.0217 (0.0781)
CZCS pigments (Gordon) with correction by Eq. (2)	0.0663 (0.3240)	0.0212 (0.1044)
CZCS pigments (Clark) without correction	0.5145 (0.6481)	0.1202 (0.2100)
CZCS pigments (Clark) with linear interpolation correction	-0.0449 (0.2436)	0.0166 (0.0815)
CZCS pigments (Clark) with correction by Eq. (2)	-0.1991 (0.1312)	0.0502 (0.0455)

( ) : errors of estimation against SeaWiFS pigments

4. Discussions

The discrepancies of the estimated values from satellite data can be attributed to the differences in the band wavelength and algorithm. We tried to adjust the different wavelength using two different methods. Assuming that OCTS algorithm when used with OCTS band data produces the same chlorophyll values as SeaWiFS chlorophyll, we can evaluate the effectiveness of the correction methods. Linear interpolation gave a better result.

The relationship Eq. (1) was derived from the BBOP data set (n=78). The statistical relationship was weaker than Eq. (2), and they did not make corrections using Eq. (1) in their analysis. The Bermuda sea where the BBOP data were collected would have different bio-optical properties from the East Sea. Therefore, the relationship of the 510-520 nm could be different since

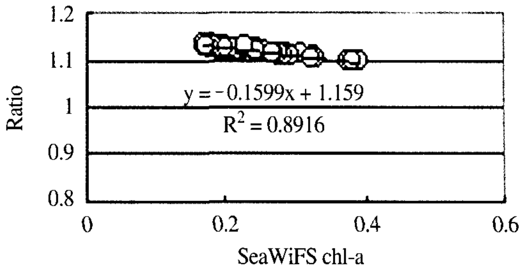

Fig. 6. Band ratio(510/520 nm) and SeaWiFS chlorophyll.

that could be influenced by other variables like CDOM.

The band ratio(510/520nm) is a function of chlorophyll concentration. Therefore, using Eq. (1) over wide range of chlorophyll values will produce a systematic error. In Fig. 6, that ratio is plotted with SeaWiFS chlorophyll and shows a decreasing trend. The ratios are smaller than those of Morel's(1988) and Gordon *et al*'s (1988) models. The data set used here has chlorophyll range of 0.1 ~0.45 mg/m^3. If the wider range of chlorophyll values were used, the error would be greater.

SeaWiFS standard CZCS-pigment algorithm is different from original CZCS pigment algorithm. To avoid the problem of differences in the spectral bands (510 and 555 nm), the developed relationship using SeaBASS data set was used (McClain, 1997), instead of using the CZCS algorithm.

What is intriguing is that the corrected CZCS pigment values are much closer to the SeaWiFS chlorophyll values. The Gordon algorithm was derived from the limited number of data (n=49). When the algorithm was tested with SeaBAM data set, there was a systematic underestimation although the correlation was very high (O'reilly and Maritorena, 1997). Thus one can question the validity of the original CZCS pigment algorithm.

The results of this analysis show that SeaWiFS pigments and CZCS pigments are not the same or comparable variables. For comparison of old CZCS data with the SeaWiFS data, this issue should be clarified.

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