Comparison of CZCS and SeaWiFS pigments

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1. Introduction

Since the launch of the first ocean color sensor, CZCS in 1978, ocean color data are accumulating over the time period expanding two decades. ADEOS/OCTS operated during 1996-1997. SeaWiFS was launched in 1997 and is operating at present. More sensors will continue to operate 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 from different missions will be 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 bands and algorithms (Table 1).

Table 1. Band location and algorithms for CZCS, OCTS, and SeaWiFS.

Sensor	In-water bands (nm)	chlorphyll algorithms	products
CZCS	443, 520, 550	$C_{13} = 1.298 * [Lw(443)/Lw(550)]^{-1.71}$ if $C_{13} > 1.5$ then use C_{23} $C_{23} = 3.3266 * [Lw(520)/Lw(550)]^{-2.40}$	pigment
		$C = 5.56 * \{[Ls(443)+Ls(520)]/Ls(550)\}^{-2.252}$	pigment
OCTS	412, 443, 490, 520, 565	$C = 0.2818 * \{[Lwn(520) + Lwn(565)] / Lwn(490)\}^{3.497}$	chlorophyll
SeaWiFS	412, 443, 490, 510, 555	$C = -0.040 + 10^{(0.341-3.001x+2.811x2-2.041x3)}$ $X = \log_{10} [Rrs(490)/Rrs(555)]$	chlorophyll, CZCS pigment

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

This differences in the band location and algorithms make the comparison a difficult matter. To address the comparison issue and to evaluate the best algorithm for SeaWiFS, a workshop was held where algorithms were compared on an extensive data set (McClain, 199). 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 ocean productivity of the East Sea/Japan Sea, for instance? In other words, the differences in these data are the changes in the real world?

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, spectra of normalized water leaving radiance were extracted (Fig. 2). With these values, following values were calculated: 1) OCTS chlorophyll 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.

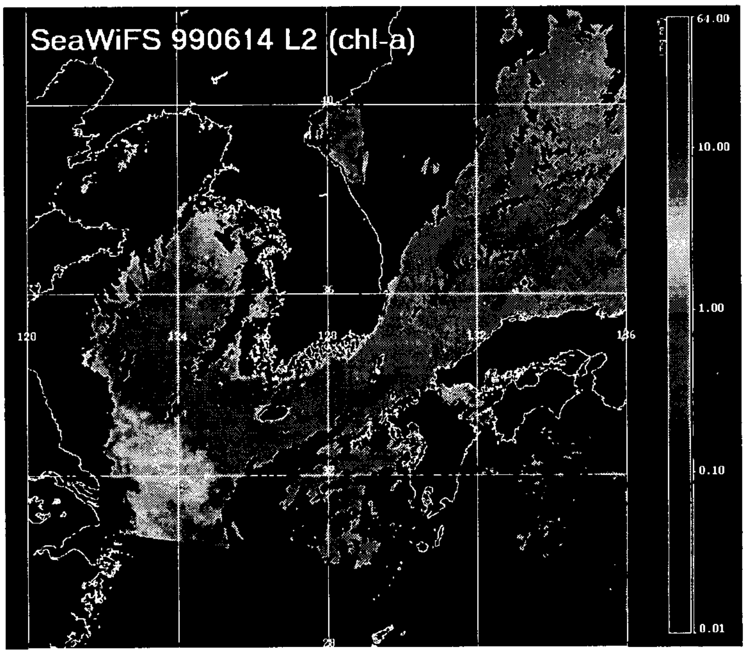

Fig. 1. SeaWiFS chlorophyll image of East Sea/Japan Sea on June 14 in 1999.

In addition to the calculation, above algorithms were also applied to the wavelength-corrected values. Since CZCS and OCTS had different band location, corrections were made to estimate L_{WN} in 520 and 550 nm for CZCS and L_{WN} in 520 and 565 nm for OCTS from L_{WN} in 510 and 555 nm of SeaWiFS data.

L_{WN} at 520 nm was estimated using two methods. As a first hand approximation a linear interpolation was made between the 510-555 nm interval. Secondly, the following relationship found from BBOP data set (Maritorena, 1997) was used.

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

L_{WN} at 565 nm was estimated using following relationship (Maritorena, 1997).

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

L_{WN} at 550 nm was linearly interpolated from 510-555 nm values. In addtion, L_{WN} at 520 nm was linearly extrapolated from 555-565 nm values.

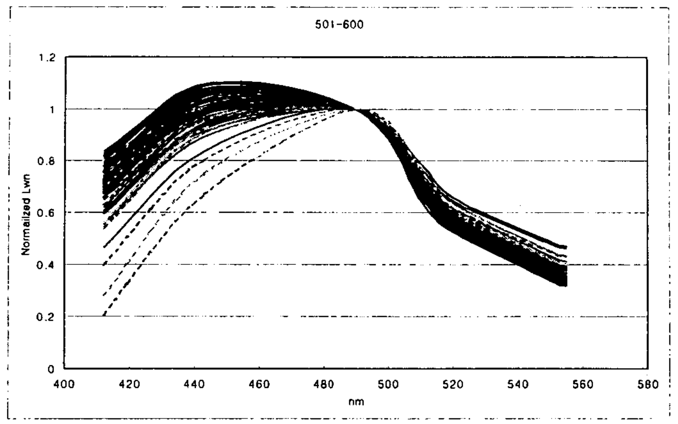

Fig. 2. L_{WN} spectra from 36N line. The values are normalized to 490 nm.

3. Results.

OCTS chlorophyll values were calculated with or without wavelegnth correction (Fig. 3). Correction by linear interpolation gave better results. CZCS pigment values calculated by Gordon algorithm are plotted in Fig. 4. Note all the values are less than SeaWiFS chlorophyll. Here, correction by linear

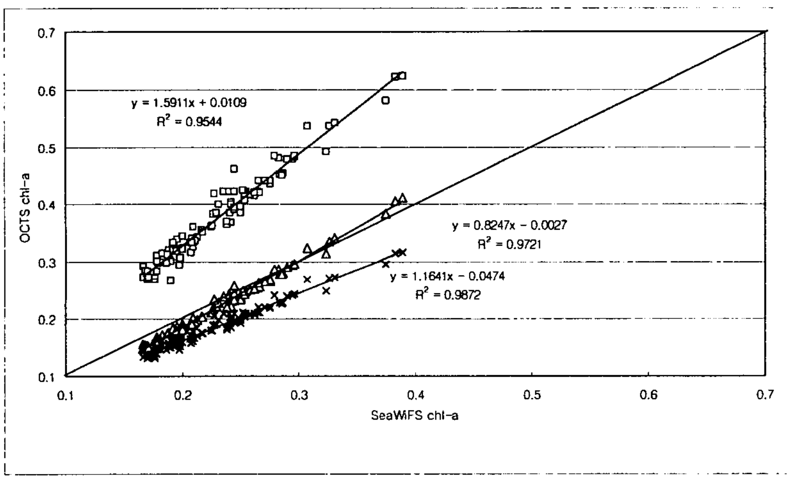

Fig. 3. Chlorophyll values calculated by OCTS algorithm. Rectangles: uncorrected values; triangles: correct by linear interpolation; X: corrected by the equation (1).

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

Table 2. Errors of estimation against SeaWiFS chlorophyll.

	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	0.0293
CZCS pigments (Gordon) with linear interpolation correction	-0.0562	0.0217
CZCS pigments (Gordon) with correction by eq. (1)	0.0663	0.0212
CZCS pigments (Clark) without correction	0.5145	0.1202
CZCS pigments (Clark) with linear interpolation correction	-0.0449	0.0166
CZCS pigments (Clark) with correction by eq. (1)	-0.1991	0.0502

3. Discussion

The discrepancies of the values can be attributed to the differences in the band wavelength and algorithm.

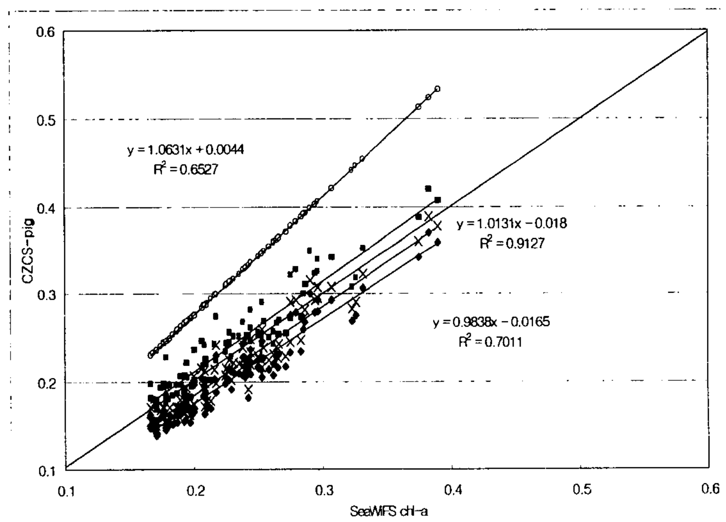

Fig. 4. CZCS pigment values by Gordon algorithm. Diamonds: uncorrected; X: corrected by equation (1); rectangles: corrected by linear interpolation; circles: SeaWiFS pigments.

We tried to adjust the wavelength by 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. Surprisingly, linear interpolation gave a better result. The relationship (1) was derived from the BBOP data set (n=78). The statistical relationship was weaker than (2), and they did not make corrections using (1) in their analysis. The Bermuda sea where the BBOP data were collected would have different bio-optical properties from the East Sea /Japan Sea. Therefore, 510-520 nm relationship could be different since that could be influenced by other variables like CDOM.

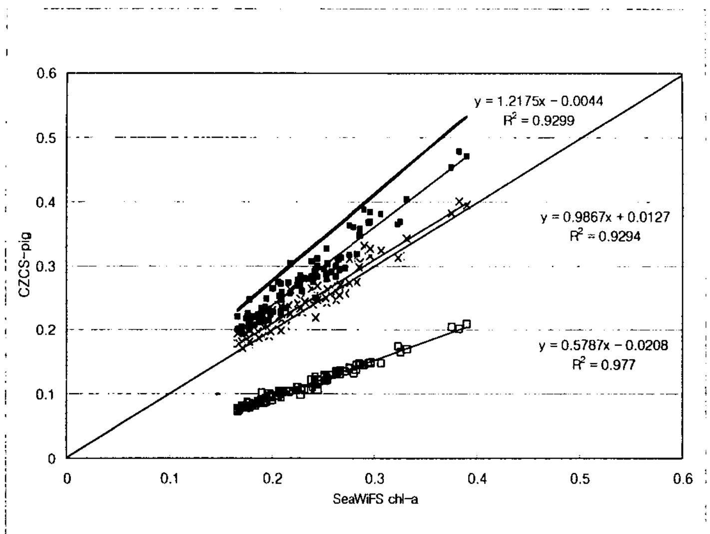

Fig. 5. CZCS pigment values by Clark algorithm. Open rectangles: uncorrected; X: corrected by linear interpolation; filled rectangles: corrected by equation (1); thick line: SeaWiFS pigments.

Theoretically, $\frac{510}{520}$ ratio is a function of chlorophyll. Therefore using (1) over wide range of chlorophyll values will produce a systematic error. In Fig. , that ratio is plotted with SeaWiFS chlorophyll and shows a decreasing trend. The ratios are smaller compared with 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 data with 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 location of the bands (510 and 555 nm), the relationship

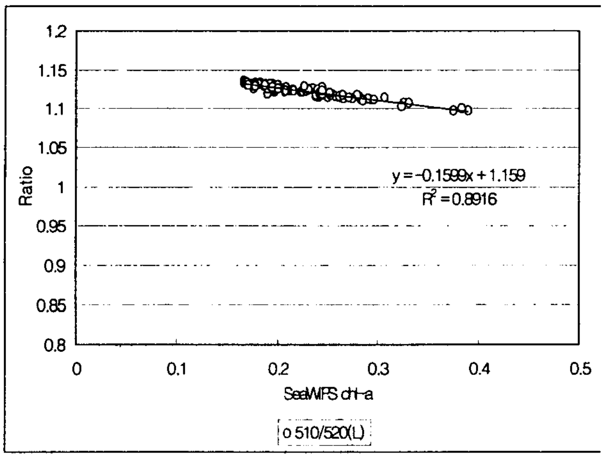

Fig. 6. 510/520 ratio and SeaWiFS chlorophyll.

developed from 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 a 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.

4. References

Clark, D. K., 1981, Phytoplankton pigment algorithm for the Nimbus-7 CZCS. *Oceanography from space,* J. F. R. Gower, Ed., Plenum Press, New York, 227-237.

Gordon, H. R. O. B. Brown, R. H. Evans, J. W. Brown, R. C. Smith, K. S. Baker, and D. K. Clark, 1988, A semi-analytic model of ocean color. J. Geophys. Res. 93:10909-10924.

Kishino, M., 1994, Development of in-water algorithm, contract report to RESTEC of Japan.

McClain, C, R.,1997, SeaWiFS Bio-optical Algorithm Mini-workshop (SeaBAM) Overview. SeaBAM report.

Morel, A., 1988. Optical modeling of the upper ocean in relation to its biogenous matter content (case 1 water). J. Geophys. Res. 93:10749-10768.

O'reilly, J. E., and S. Maritorena, 1997. SeaBAM algorithm evaluation. SeaBAM report.

Maritorena, S., J. E. O'Reilly, 1997, The SeaBAM evaluation data set. SeaBAM report.