Examination of Cross-calibration Between OSMI and SeaWiFS: Comparison of Ocean Color Products

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Much effort has been made in the radiometric calibration of the ocean scanning multispectral imager (OSMI) since after the successful launch of KOMPSAT-1 in 1999. A series of calibration coefficients for OSMI detectors were obtained in collaboration with the NASA Sensor Intercomparison and Merger for Biological and Interdisciplinary (SIMBIOS) project office. In this study, we compare the OSMI level-2 products (e.g., chlorophyll-a concentration) calculated from the NASA cross-calibration coefficients with the SeaWiFS counterparts. Sample study areas are some of diagonostic data sites recommended by the SIMBIOS working group. We will present the preliminary results of this comparative study.
Keywords: OSMI, SeaWiFS, KOMPSAT, Ocean color, Cross-calibration, MSL12

1. INTRODUCTION

The ocean scanning multispectral imager (OSMI) aboard the KOrea Multi-Purpose SATellite (KOMPSAT), which was built and operated by the Korea Astrospace Research Institude (KARI), is designed to observe the global ocean color in support of biological oceanography. Since the successful launch of OSMI on Dec. 21, 1999, it has been collecting the global ocean color data in the six visible spectral bands centered at 412, 443, 555, 765, and 865 nm. KOMPSAT is on a polar orbit at an altitude of 685 km with local crossing time (ascending node) at approximately 10:50 am and the scanner has a ±30 degree scan angle with respect to nadir. OSMI has a ground resolution of approximately 1 km with a swath width of 800 km. It has 96 CCD detectors oriented along track. The bandwidths of the first four bands are 20 nm, and those of the last two near-infrared (NIR) bands are 40 nm. The NIR bands can be used for atmospheric correction.

The primary goal of the NASA SIMBIOS project is to develop methods for the meaningful comparison and merging of data products from multiple ocean-color missions.[1] And both KARI and the SIMBIOS project team have been collaborated to achieve the OSMI cross-calibration since 2001. As a result, a cross-calibration method using SeaWiFS measurements was developed.[2] In this study, the ocean-color products of OSMI derived from a cross-calibration will be compared to the SeaWiFS counterparts. The data processing method will be given in the next section. Then the comparative results between OSMI and SeaWiFS for 8 samples in 5 regions.

2. DATA PROCESSING

The processing algorithms of this study are to use the Multi-Sensor Level-1 to Level-2 (MSl12) software which is freely distributed as part of SeaWiFS Data Analysis System (SeaDAS) software package. It is capable of performing atmospheric correction of top-of-atmosphere (TOA) radiances from several spaceborne ocean remote sensing spectrometers (including SeaWiFS, OCTS, MOS, POLDER, and OSMI) and deriving atmospheric and bio-optical properties using identical algorithms for each sensor.[3]

2.1 Chlorophyll-a Algorithm

The cross calibration coefficients of OSMI based on SeaWiFS measurements were applied to produce the Level-1b. And the resultant ocean color products of OSMI are compared to the SeaWiFS counterparts. The chlorophyll-a algorithm used in the SeaWiFS and OSMI data processing is the one recommended at the SeaBAM (SeaWiFS Bio-optical Mini-workshop) workshop in 1998. This follows the experimental algorithm O`C2 that was formed on the basis of the 1,174 data sets from the observations of the oceans worldwide.[4]

$$\text{Chlorophyll-a} = ch1 + ch2 \times R + ch3 \times R^2 + ch4 \times R^3 \quad (1)$$

where $ch1$ = -0.0929, $ch2$ = 0.2974, $ch3$ = -2.2429, $ch4$ = -0.0077, ch is each wavelength correction coefficient, $R = \log_{10}(R_{rs}(490)/R_{rs}(555))$, and R is the reflectance ratio of 490 nm and 555 nm.

Table 1. Information on the selected diagonostic sites

Diagonostic Sites	Date	Upper left (Lon, Lat) / Lower left (Lon, Lat)	Upper right (Lon, Lat) / Lower right (Lon, Lat)	Number of pixels SeaWiFS	Number of pixels OSMI
BATS	5 April 2002 28 April 2001	(-65.00, 32.70) (-65.48, 31.00)	(-62.90, 32.40) (-63.43, 30.67)	19908 24538	43170 25197
Galapagos_Ocean	4 April 2001	(-92.84, 3.12) (-93.98, -1.94)	(-87.69, 2.29) (-88.79, -2.80)	77185	78905
HOT	22 May 2001	(-158.36, 23.25) (-158.60, 22.39)	(-157.43, 23.12) (-157.67, 22,26)	3788	6866
Korea_SW	20 Feb 2002	(124.61, 32.51) (124.32, 31.65)	(125.64, 32.35) (125.36, 31.49)	5808	24242
Ligurian_Sea	4 June 2001 7 July 2001 2 Sep 2001	(6.67, 43.84) (6.29, 43.00)	(7.86, 43.63) (7.46, 42.78)	6559 5870 6485	19146 5005 20392

Table 2. Comparison of average, standard deviation and variance of OSMI and SeaWiFS in research areas.

		BATS_1 (5 Apr 2002)		BATS_2 (28 Apr 2001)		Galapagos_Ocean (4 Apr 2001)		HOT (22 May 2001)	
		OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS
$[Lw(412)]_N$	Avg	2.3068	1.6133	2.0335	1.7526	1.6012	0.9956	2.6770	2.4061
	S^2	0.2826	0.1509	0.3715	0.1528	0.2536	0.1586	0.2070	0.0589
	S	0.5316	0.3885	0.6095	0.3910	0.5036	0.3983	0.4550	0.2428
$[Lw(443)]_N$	Avg	1.9781	1.7095	1.9446	1.9028	1.5308	1.0514	2.2081	2.0278
	S^2	0.2010	0.1324	0.2354	0.0784	0.2464	0.1297	0.1360	0.0420
	S	0.4483	0.3639	0.4852	0.2801	0.4964	0.3602	0.3688	0.2049
$[Lw(490)]_N$	Avg	1.5098	1.3261	1.5325	1.4961	1.4507	1.0380	1.5603	1.4934
	S^2	0.0703	0.1367	0.1120	0.0342	0.1111	0.0736	0.1023	0.0245
	S	0.2652	0.3697	0.3347	0.1850	0.3333	0.2714	0.3199	0.1565
$[Lw(555)]_N$	Avg	0.5584	0.5352	0.5417	0.5141	0.9208	0.5984	0.5476	0.5094
	S^2	0.0366	0.0326	0.0647	0.0154	0.0413	0.0452	0.0271	0.0065
	S	0.1915	0.1808	0.2543	0.1242	0.2032	0.2126	0.1648	0.0806
		Korea_SW (20 Feb 2002)		Ligurian_1 (4 Jun 2001)		Ligurian_2 (7 Jul 2001)		Ligurian_3 (2 Sep 2001)	
		OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS
$[Lw(412)]_N$	Avg	3.3598	1.4575	1.4410	0.9870	0.4275	0.9810	1.0038	0.6627
	S^2	0.1884	0.0220	0.1720	0.0070	0.5655	0.0830	0.2429	0.0770
	S	0.4341	0.1483	0.4147	0.0841	0.7520	0.2882	0.4928	0.2775
$[Lw(443)]_N$	Avg	3.5186	2.5427	1.4390	1.2684	0.3392	1.1327	1.0821	1.0234
	S^2	0.1355	0.0200	0.1670	0.0633	0.3637	0.1391	0.1775	0.0852
	S	0.3682	0.1416	0.4087	0.2515	0.6031	0.3729	0.4214	0.2920
$[Lw(490)]_N$	Avg	4.4232	3.7893	1.4060	1.0241	0.2878	0.9398	0.9751	0.9681
	S^2	0.0932	0.0610	0.0845	0.0131	0.2610	0.0566	0.1010	0.0494
	S	0.3054	0.2470	0.2908	0.1147	0.5109	0.2379	0.3178	0.2224
$[Lw(555)]_N$	Avg	4.2817	4.2945	0.5174	0.5032	0.1326	0.4699	0.4819	0.4842
	S^2	0.1042	0.0768	0.0117	0.0020	0.0550	0.0142	0.0202	0.0139
	S	0.3228	0.2772	0.1085	0.0448	0.2345	0.1192	0.1421	0.1182

$[Lw(\lambda)]_N$, Avg, S^2, and S are normalized water-leaving radiance, average, variance, and standard deviation, respectively. Units of (mW/cm²μm sr).

2.2 Procedures

To represent typical oceans, we select the coast, open ocean, and complex ocean from total of 38 diagnostic sites. Each selected area is as follows: the coast is the Ligurian Sea, the open ocean is the HOT and the BATS, and the complex oceans are the Korea_SW and the Galapagos Ocean. Table 1 shows the detailed information related to these research areas.

Step 1: Selection of Research Areas

Step 2: Data Match-up

Cloud amounts and the distribution of chlorophyll-a concentration in the images are visually examined for the selected diagnostic sites, and good Level-2 images of SeaWiFS are extracted from the SeaWiFS homepage (http://seawifs.gsfc.nasa.gov/cgi/seawifs_region_extracts .pl?TYP=ocean). The corresponding Level-la images of OSMI are also prepared for Level-2 processing. Due to the differences in the spatial resolution between OSMI (0.85 km) and SeaWiFS (1.1 km), the number of pixels available in the sample area is different (see Table 1).

Step 3: Level-2 Processing

To produce Level-2 data from Level-1a of OSMI, we have used the MSL12 software. Before running MSL12, we must initialize the ozone, the meteorological ancillary data file, and miscellaneous parameters. Also, the cross-calibration coefficients are utilized in this processing.

3. RESULTS & DISCUSSION

3.1 Water-leaving Radiance Comparisons

Table 2 shows the results of statistical calculations for the retrieved water-leaving radiances at each site. Differences of averages between OSMI and SeaWiFS at each band seem to be small except for the Korea_SW site. The reason for the large difference at the Korea_SW site is not clear, and it may need the further validation study with the use of in-situ measurements. Another feature in these differences is easily discernible in Fig. 1.

Table 3. Results of recalculation with the same aerosol option-OSMI (new).

		Korea_SW (20 Feb 2002)		
		OSMI	OSMI (opt2)	SeaWiFS
$[Lw(412)]_N$	Avg	3.3598	3.0106	1.4575
	S^2	0.1884	0.1629	0.0220
	S	0.4341	0.4037	0.1483
$[Lw(443)]_N$	Avg	3.5186	3.1767	2.5427
	S^2	0.1355	0.1239	0.0200
	S	0.3682	0.3520	0.1416
$[Lw(490)]_N$	Avg	4.4232	4.1844	3.7893
	S^2	0.0932	0.0970	0.0610
	S	0.3054	0.3114	0.2470
$[Lw(555)]_N$	Avg	4.2817	4.1338	4.2945
	S^2	0.1042	0.1029	0.0768
	S	0.3228	0.3208	0.2772
[chl]	Avg	2.0885	2.1980	3.1583
	S^2	0.0381	0.0469	0.0763
	S	0.1952	0.2167	0.2762

The OSMI values overestimate the water-leaving radiances compared to those of SeaWiFS except for the Ligurian_Sea. One factor causing such overestimation is that the different aerosol models were selected in the atmospheric correction since OSMI and SeaWiFS used the multi-scattering with maritime (90% rh) and the Gordon-Wang model selection and Siegel NIR iterations for their aerosol options (new), respectively. For the Korea_SW site, we have recalculated the water-leaving radiance and chlorophyll-a concentration of OSMI, assuming the same aerosol model as that of SeaWiFS. The differences of both variables as shown in Table 3 are found to be reduced between OSMI an SeaWiFS.

Table 4. Comparison of chlorophyll-a of OSMI and SeaWiFS in research areas.

		Korea_SW (20 Feb 2002)		Ligrian_1 (4 Jun 2001)		Ligrian_2 (7 Jul 2001)		Ligrian_3 (2 Sep 2001)	
		OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS
[chl]	Avg	2.0885	3.1583	0.2170	0.2661	0.0524	0.2306	0.1872	0.2969
(mg/m^3)	S^2	0.0381	0.0763	0.0044	0.0475	0.0097	0.0119	0.0057	0.0108
	S	0.1952	0.2762	0.0666	0.2179	0.0989	0.1092	0.0755	0.1042

		BATS_1 (5 Apr 2002)		BATS_2 (28 Apr 2001)		Galapagos_Ocean (4 Apr 2001)		HOT (22 May 2001)	
		OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS	OSMI	SeaWiFS
[chl]	Avg	0.1780	0.1763	0.1327	0.1776	0.6219	1.7524	0.1283	0.3319
(mg/m^3)	S^2	0.0096	0.1461	0.0031	0.1037	1.3193	9.9274	0.0063	0.1037
	S	0.0982	0.3822	0.0564	0.3221	1.1486	3.1507	0.0799	0.3221

Avg, S^2,and S are average, variance, and standard deviation, respectively.

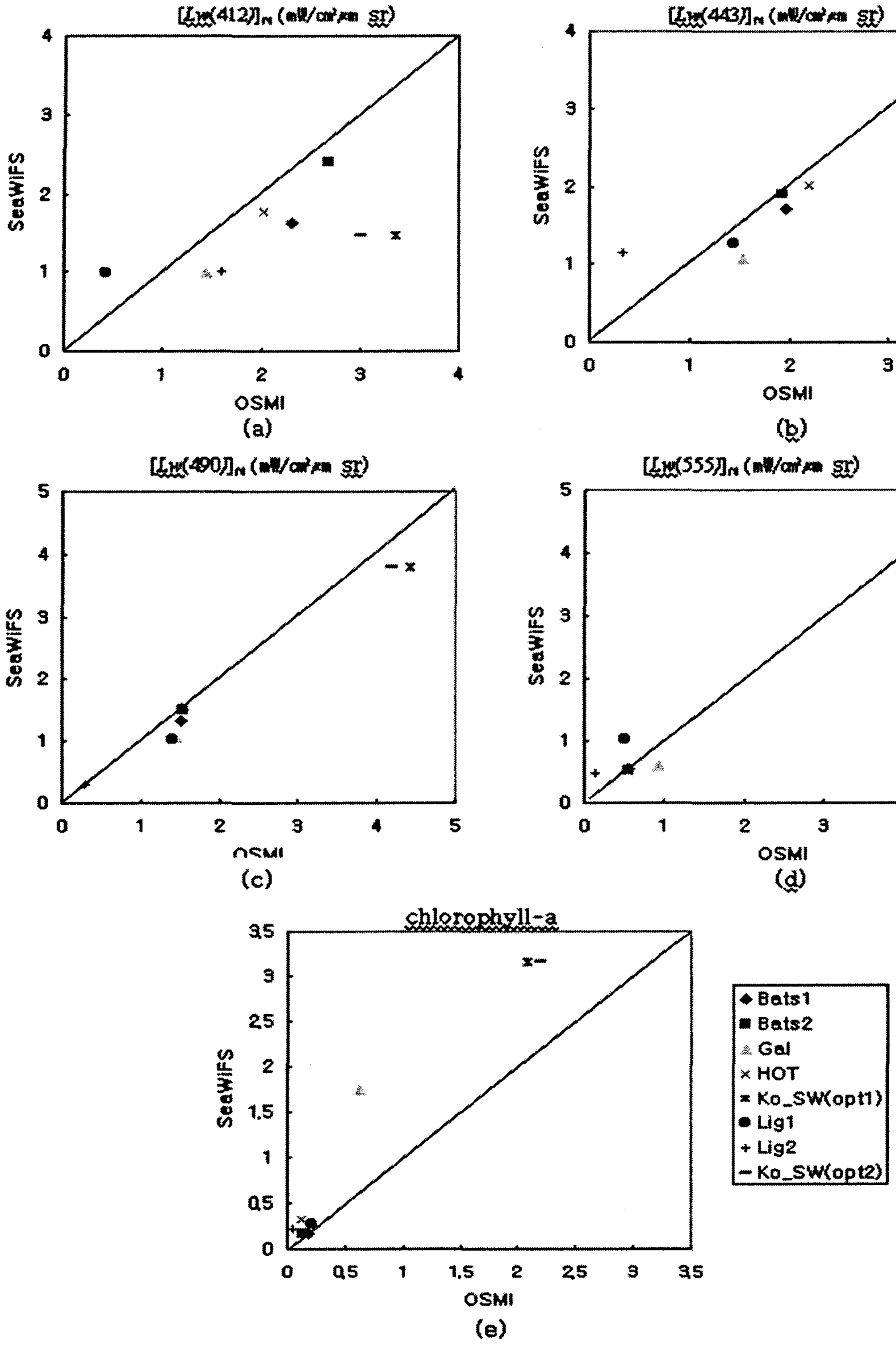

Fig. 1. OSMI-derived normalized water-leaveing radiance and chlorophyll-a compared with those of the SeaWiFS: (a) nLw 412 nm (b) nLw 443 nm (c) nLw 490 nm (d) nLw 555 nm (e) chlorophyll-a.

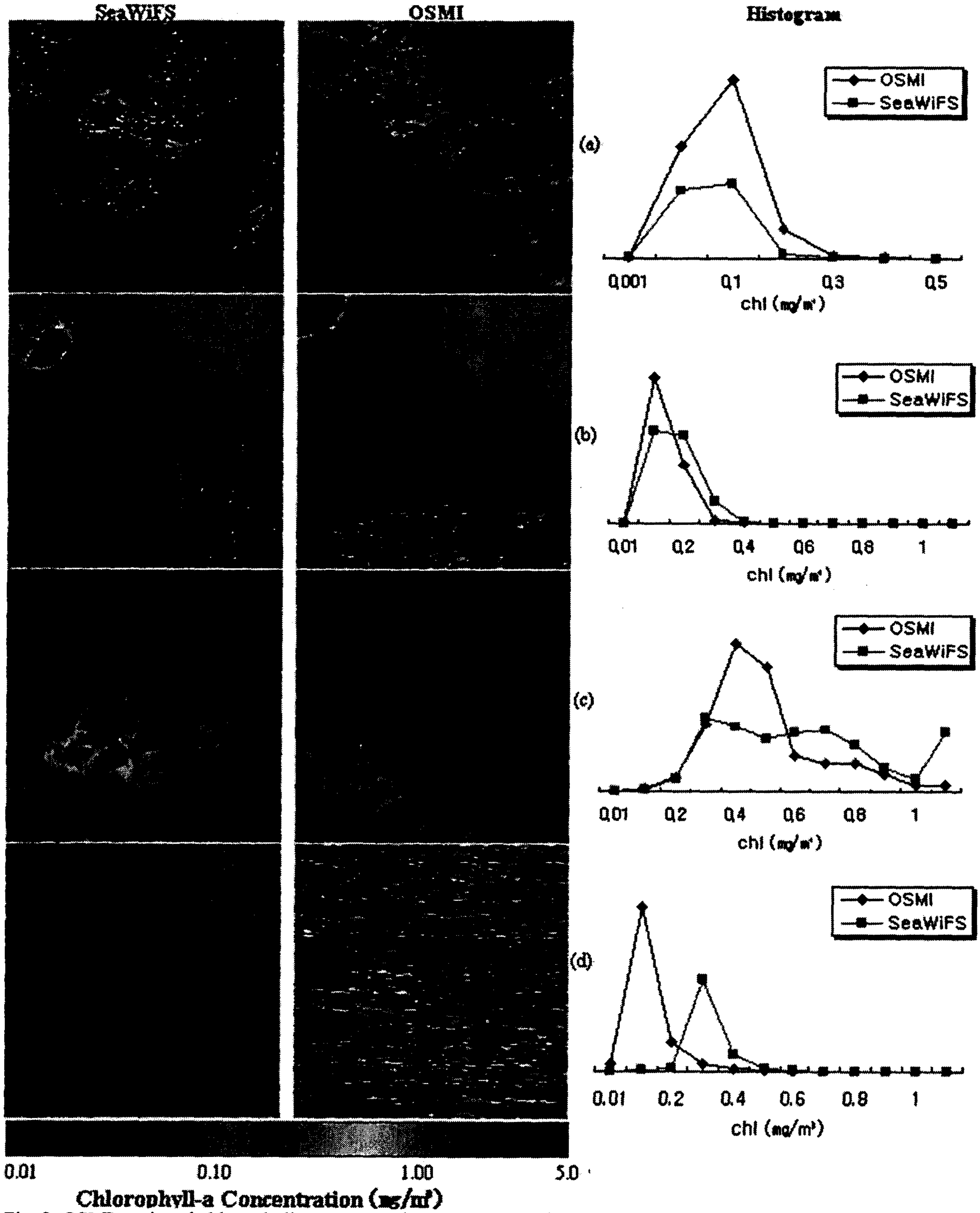

Fig. 2. OSMI-retrieved chlorophyll-a concentration compared to those derived from SeaWiFS measurements for (a) BATS_1 (5 April 2002), (b) BATS_2 (28 April 2001), (c) Galapagos (4 April 2001), (d) HOT (22 May 2001).

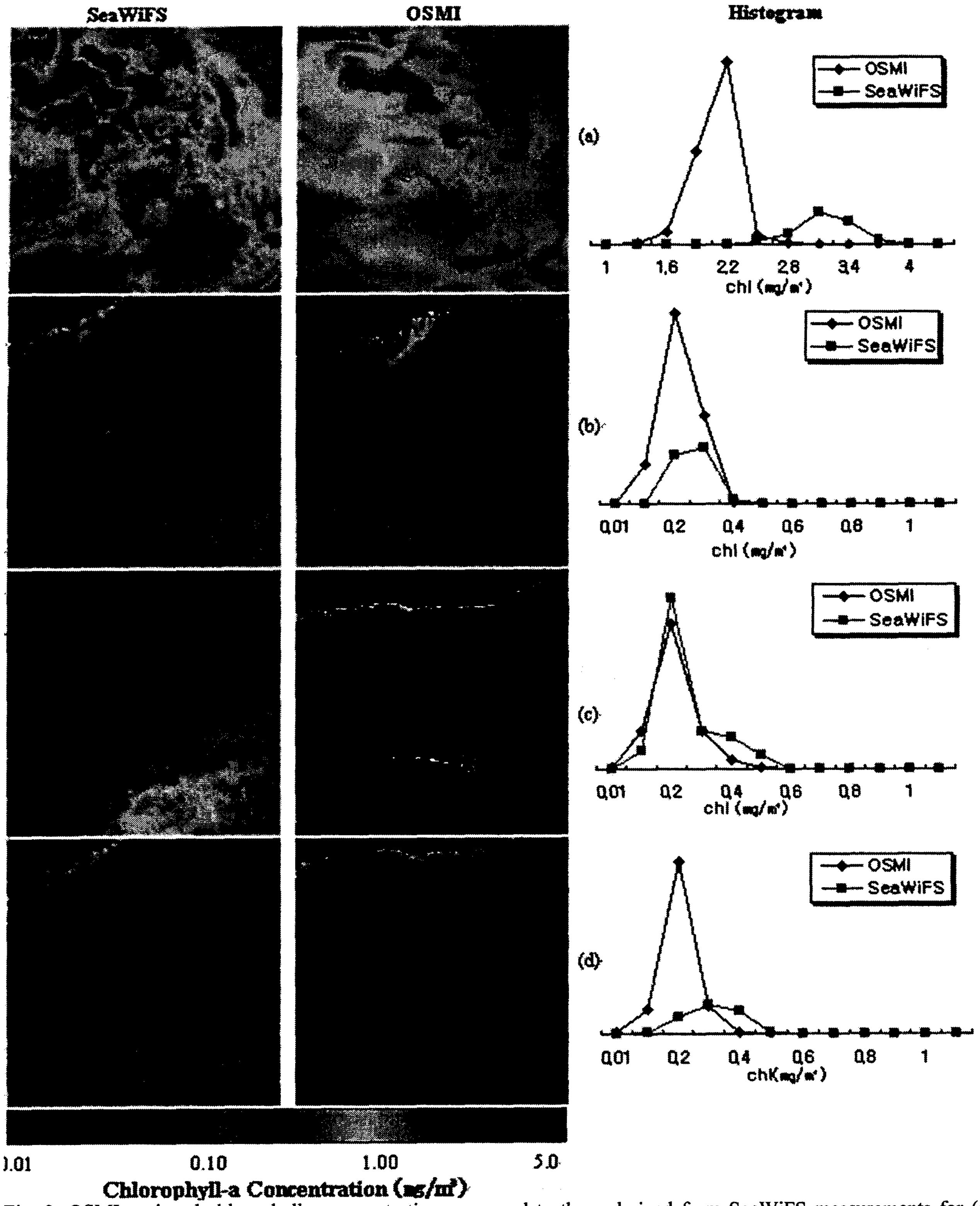

Fig. 3. OSMI-retrieved chlorophyll-a concentration compared to those derived from SeaWiFS measurements for (a) Korea_SW (20 February 2002), (b) Ligurian_1 (4 June 2001), (c) Ligurian_2 (7 July 2001), (d) Ligurian_3 (2 September 2001)

3. 2 Chlorophyll-a Comparisons

Comparisons of chlorophyll-a concentration calculated for OSMI and SeaWiFS at each site, using eq. (1), are shown in Fig. 2 and Fig. 3. The color images of SeaWiFS and OSMI columns are logarithmically scaled from 0.01 to 5 (mg/m^3) and their histograms are plotted in the third column. Some differences in the distribution of chlorophyll-a concentration appear to be associated with clouds and ocean dynamics at the time of imaging. Overall, SeaWiFS estimates of chlorophyll-a concentration are shown to be larger than those of OSMI. This is summarized in Table 3 and well depicted in Fig. 2(e). The systematic underestimation by OSMI would be ascribed to its overestimation of water-leaving radiances. More prominent differences occurred at the Galapagos and Korea_SW sites (See Fig. 2 and Fig. 3) seem to be related to higher sensitivities of SeaWiFS close to the island and in the region that affected by continental sediments. However, such conjecture should be validated with in-situ measurement.

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