

Calibration and Validation of the Estimated Chlorophyll *a* Derived from KOMPSAT/OSMI Data and Fisheries Application in the East China Sea

Young-Sang Suh

Marine Environment Team, East Sea Fisheries Research Institute, NFRDI,
Gangneung 210-861, Korea

(Manuscript received 5 October, 2005; accepted 27 October, 2005)

A comparison between the estimated chlorophyll *a* from OSMI, the SeaWiFS and the chlorophyll *a* measured from the research cruises of National Fisheries Research and Development Institute was made. The updated empirical algorithm for calibrating and validating of the estimated chlorophyll *a* in the East China Sea was formulated by relationship between the estimated chlorophyll *a* and the field one. The relationship between the chlorophyll *a* and the band ratio($nLw490/555$) was still highest in the OSMI data after launching of KOMPSAT satellite.

The distributions of OSMI chlorophyll *a* were compared with those of sea surface temperature, zooplankton biomass, and catch amounts of the Pacific mackerel in the East China Sea. In case of the relationships in specially winter seasons of 2002 and 2004, the zooplankton and the fish were totally depended on the distributions of SST than those of chlorophyll *a*.

Key Words : KOMPSAT/OSMI, SeaWiFS, Satellite Remote Sensing, Pacific Mackerel Fishing Ground

1. Introduction

The Ocean Scanning Multi-Spectral Imager (OSMI) is the first Korean ocean monitoring space-borne instrument on the Korean Multi-Purpose Satellite (KOMPSAT-1) developed by the Korean Aerospace Research Institute¹⁾. OSMI on the KOMPSAT was launched on December 21, 1999. The visible bands of OSMI are very similar to the bands of SeaWiFS (Sea Viewing Wide Field-of-View Sensor) on Orbview-2 ocean color observation satellite developed and launched by NASA in 1997 (Table 1). Quantification of concentration is usually achieved by the development of empirical or semi-empirical models correlating the radiance (or reflectance), as measured by remote sensor, with the ground truth data²⁾.

Variations in phytoplankton concentrations results from changes of the ocean color caused by phytoplankton pigments. Thus, ocean spectral reflectance for

low chlorophyll waters are blue and high chlorophyll waters tend to have green reflectance. In the Korean regions, clear waters and the open sea in the Kuroshio regions of the East China Sea have low chlorophyll. As one moves even closer to the northwestern part of the East China Sea, the situation becomes much more optically complicated, with contributions not only from higher concentration of phytoplankton, but also from sediments and dissolved materials from terrestrial and sea bottom sources³⁾. The color often approaches yellow-brown in the turbidity waters (Case 2 waters). To verify satellite ocean color retrievals, or to develop new algorithms for complex Case 2 region requires ship-based studies.

Suh *et al.*⁴⁾ studied the relationship between *in situ* chlorophyll *a* measurements onboard the Korean NFRDI's ship and the estimated chlorophyll *a* from the SeaWiFS satellite data using the ocean color chlorophyll 2 algorithm (OC2)⁵⁾ in the region of the northern East China Sea. Suh *et al.*⁶⁾ determined the total suspended solid mass, and compared it with SeaWiFS (OSMI) spectral band ratio ($nLw 490nm/ nLw 555 nm$). The development of the regional algorithms to

Corresponding Author : Young-Sang Suh, Marine Environment Team, East Sea Fisheries Research Institute, NFRDI, Gangneung 210-861, Korea
Phone: +82-33-660-8530
E-mail: yssuh@nfrdi.re.kr

Table 1. Characters of SeaWiFS and OCMI band

Spectral Band	Wavelength (nm)	Band Width	Wavelength (nm)	Intended Use
1	402-422	20		Gelbstoffe
2	433-453	20	433-453	chlorophyll Absorption
3	480-500	20	480-500	Pigment Concentration
4	500-520	20	500-520	Chlorophyll Absorption
5	545-565	20	545-565	Sediments
6	660-680	20	660-680	Atmospheric Aerosols
7	745-785	40		Atmospheric Aerosols
8	845-885	40	845-885	Atmospheric Aerosols

quantify chlorophyll *a* and suspended solid in the Korean waters was carried out by Suh *et al.*⁷⁾ and Ahn *et al.*⁸⁾.

Recently, Gong and Suh⁹⁾, studied on the effect of the environmental conditions on the structure and distribution of Pacific saury in the Tsushima Warm Current region. The main fishing grounds with high aggregation of different sized groups of fish around the frontal zone can be easily detected by a remote sensing satellite and ocean color during the northward migrating season (Apr.-June), before advection of low salinity and warm superficial water originating from the East China Sea.

In Korea, mackerel are commercially caught chiefly by purse seines, and in negligible quantities by drift gill nets and set nets. The fishery is limited largely to the area around Jeju Island. Its occurrence seems to be consistent enough to support a regular fishery all year round off the island, but most of annual catches is taken during the late summer and fall¹⁰⁾. Therefore, it is not efficient work to find out the fishing ground formation of mackerel in winter season. However, it is very curious that which is more prefer ocean parameter between chlorophyll *a* and water temperature to efficiently find out the fishing ground in winter.

The purpose of this study is to develop an empirical algorithm for calibrating and validating OSMI level 2 data, and to review the first practical application with the information of chlorophyll *a* and sea surface temperature derived from OSMI and NOAA satellites to the Korean fisheries.

2. Data and Method

2.1. Estimated Chlorophyll *a* Derived from KOMPSAT/OSMI

Even though the spectral resolution of OSMI are

very similar to the those of SeaWiFS (Table 1), we usually cannot use the same algorithm to estimate chlorophyll *a*. The reason is that the radiance of digital numbers can be different to the same spectrum between OSMI and SeaWiFS.

By the way, Suh *et al.*¹¹⁾ showed the possibility for OSMI data using of the same as OC2⁵⁾ related to the SeaWiFS data processing. Characteristic response of the OSMI bands to estimate chlorophyll *a* was also shown (Fig. 1). Reciprocal action between the field chlorophyll *a* and the band ratio of the OSMI (nLw410/555, nLw443/555, nLw490/555) was studied. Relationship between the chlorophyll *a* and the band ratio(nLw490/555) was highest in the OSMI bands. It is suggested that OC2 algorithm including the band ratio(nLw490/555) be used to get much better estimation of chlorophyll *a* from OSMI than the ones from the updated algorithms as OC4.

Therefore, we processed 5 imageries of OSMI data in 2002, 2003 and 2004 using OC2 algorithm to understand the seasonal variation of chlorophyll *a* related to the density of phytoplankton in the northern East China Sea in this study. However, we could not get the measured data in field for calibrating and validating OSMI estimated chlorophyll *a* data at the same time and location excluding the data in February of 2002 and 2004.

2.2. Measured Chlorophyll *a* in Field

We filtered appropriate amount of volume of seawater sample on GF/F filter. Also we prepared a blank, which was a GF/F filter with filtered sea water. We placed the filter on a histoprep, wrapped in aluminum foil, and stored in LN2 Dewar/Dry shipper. The samples stored in LN2 Dewar, placed the filter in a 1ml test tube, filled with 10ml 90% acetone, seal top with paraffin, wrapped the entire test tube with alumi-

Calibration and Validation of the Estimated Chlorophyll *a* Derived from KOMPSAT/OSMI Data and Fisheries Application in the East China Sea

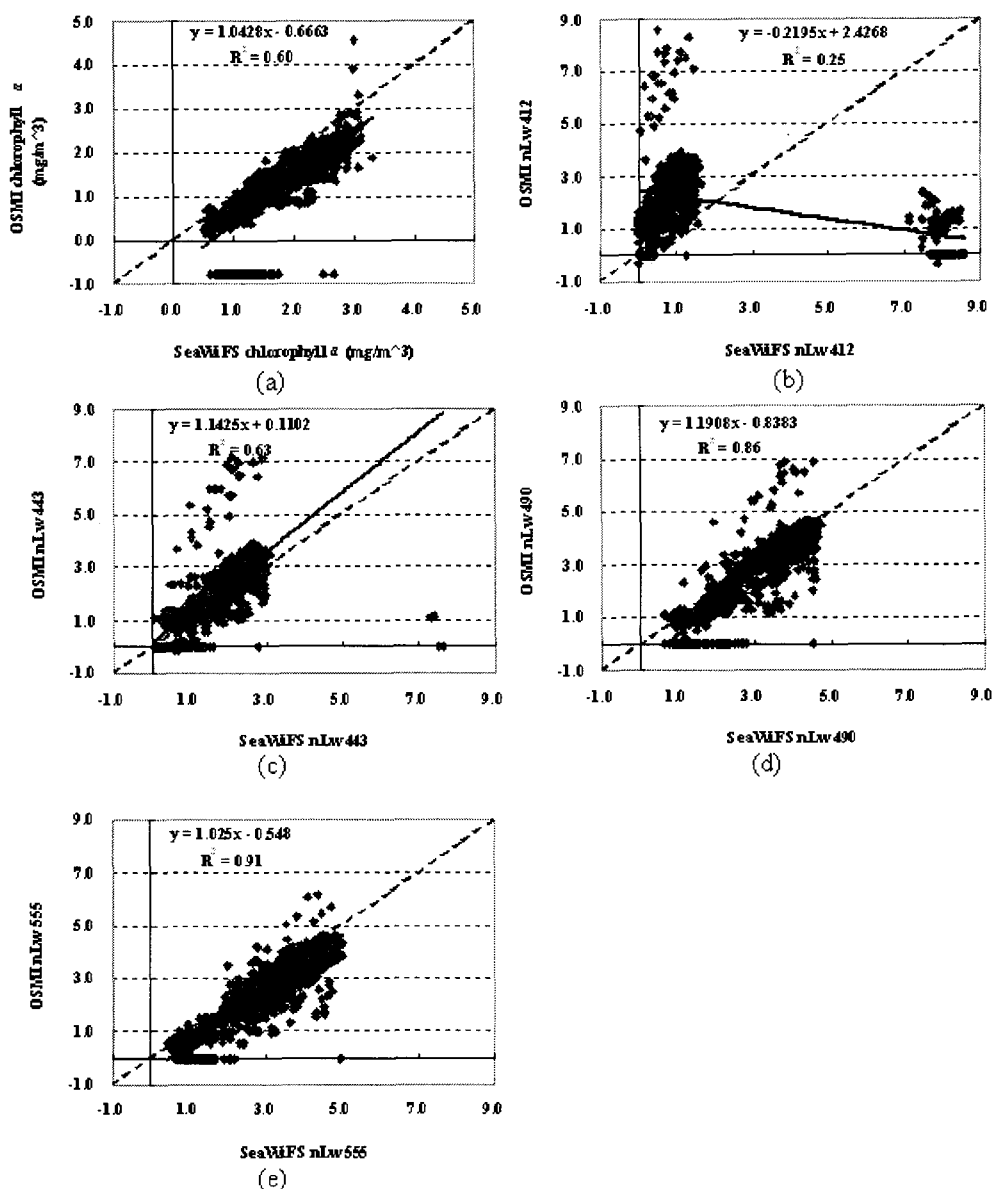


Fig. 1. Relationships between data from SeaWiFS and OSMI in the southern part of the Korean waters on 20th February, 2002. (a) The estimated chlorophyll *a* using ocean color algorithm 2 (O'Reilly, 1998). The normalized water leaving radiance(nLw) at (b) 412 nm, (c) 443 nm, (d) 490 nm, (e) 555 nm (Suh et al., 2002).

num foil and stored in refrigerator for approximately 24 hours. Samples should be read between 24-36 hours for best results.

After extraction, brought samples out and let tubes equilibrate to room temperature. We turned on the fluorometer and let it warm up for about 20-30 minutes. There should be a standard chlorophyll that should be

measured on the fluorometer at the beginning of every chlorophyll sample reading to test the integrity of the fluorometer.

We took each sample and wiped the tube with Kimwipes and inserted in the sampled compartment. We read and recorded reading under Rb value. We placed 3 drops of 10% HCl in the test tube, seal top

with paraffin, inverted several times gently, and placed test tube with sample back into the sample compartment⁽¹²⁾.

2.3. Measured Zooplankton Biomass in Field

Zooplankton samples were collected vertically from 100m to surface using NORPAC net (mesh size: 300 μ m, diameter: 0.225m). All samples were preserved in a 4% buffered-formalin solution and analysed with regard to abundance and biomass.

2.4. Monthly Total Catch Amounts of Pacific Mackerel in Ground Field

The distribution of monthly total catches (ton) by statistical sea block (0.5°× 0.5°) from Korean purse seine fishing in February of 2002 and 2004.

3. Results

3.1. Calibration and Validation Method for Chlorophyll *a*

The relationship between the measured ocean color in the fields of the East China Sea and the estimated ocean color data of level 2 from the OSMI and SeaWiFS satellites was studied. The relationship between the measured chlorophyll and the SeaWiFS (OSMI) chlorophyll can be expressed by the following equations (1) (Fig. 2) and (2) (Fig. 3) in the northern part of the East China Sea.

$$\text{Chl} = 0.1802\exp(0.5884(\text{XSeaWiFS})), \quad R^2 = 0.57 \quad (n=140) \quad (1)$$

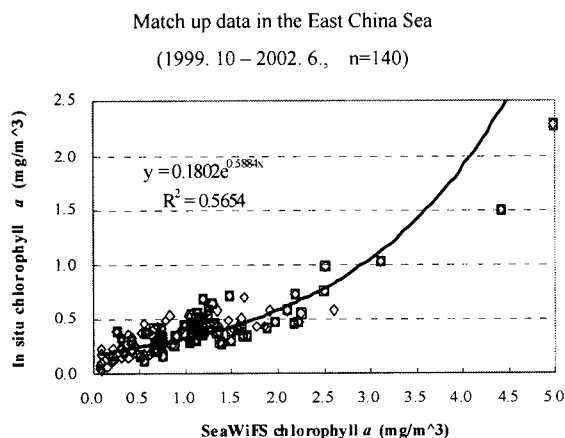


Fig. 2. Relationship between the field chlorophyll *a* (mg/m³) and the estimated chlorophyll *a* derived from SeaWiFS satellite in the southern part of the Korean waters from October, 1999 to June, 2002.

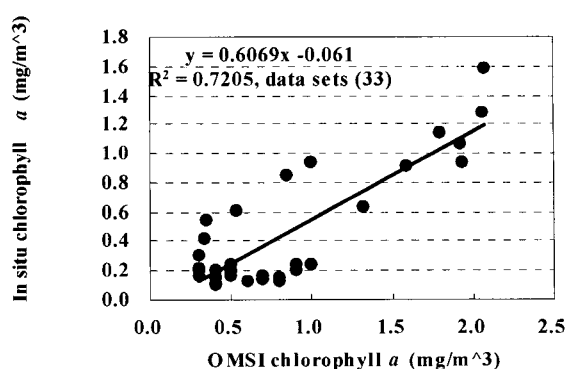


Fig. 3. Relationship between the field chlorophyll *a* (mg/m³) and the estimated chlorophyll *a* derived from OSMI satellite in the southern part of the Korean waters in February 15, 2004.

$$\text{Chl} = 0.6069(\text{XOSMI}) - 0.061, \quad R^2 = 0.72 \quad (n=33) \quad (2)$$

where, XSeaWiFS is the estimated chlorophyll *a* from SeaWiFS satellite data (Fig. 4 and 5). XOSMI is the estimated chlorophyll *a* from OSMI satellite data using the OC 2 algorithm (Fig. 6).

To compare between the corrected chlorophyll *a* using (1) the simple calibration/validation(CAL/VAL) method of SeaWiFS and the estimated chlorophyll *a* data is shown in Fig. 7. The chlorophyll *a* values derived from the simple CAL/VAL method of OSMI are very similar to those of the simple CAL/VAL of SeaWiFS (Fig. 8 and 9).

3.2. Application of the Estimated Chlorophyll *a* and Sea Surface Temperature derived from KOMPSAT/OSMI and NOAA/AVHRR

The northern East China Sea is regarded as an important fisheries ground in the Korean waters. To understand the seasonal variation of chlorophyll *a* related to the density of phytoplankton in the East China Sea, we processed the OSMI data in 2003 and 2004. The distributions of chlorophyll densities derived from OSMI data in the East China Sea were 0.2-1.6 mg/m³ in Oct., 0.3-1.6 mg/m³ in Dec., 2003 and 0.2-2.4 mg/m³ in Feb., 0.2-1.1mg/m³ in Jun., 0.2-0.8mg/m³ in Aug., 2004.

We compared the distributions of OSMI chlorophyll *a* (mg/m³), sea surface temperature(°C), zooplankton biomass (mg/m³), and monthly total catch amounts (ton) of Pacific mackerel in the East China Sea in

Calibration and Validation of the Estimated Chlorophyll *a* Derived from KOMPSAT/OSMI Data and Fisheries Application in the East China Sea

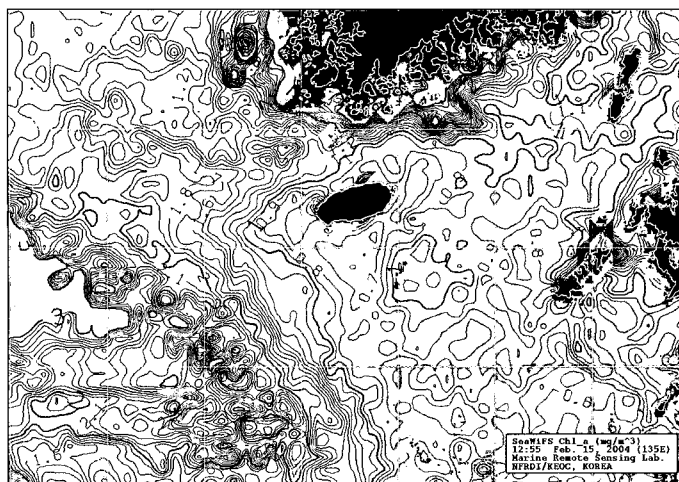


Fig. 4. Distribution of estimated chlorophyll *a* (mg/m³) derived from SeaWiFS satellite on 15th February, 2004.

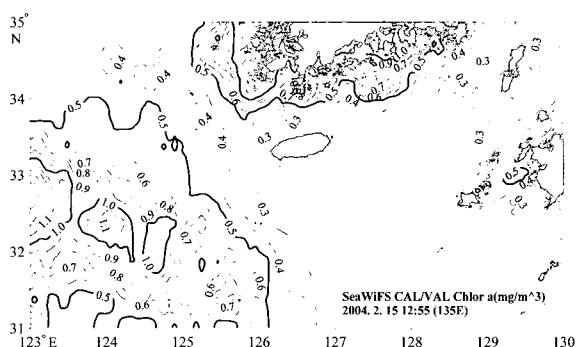


Fig. 5. Distribution of estimated chlorophyll *a* (mg/m³) derived from SeaWiFS-CAL/VAL empirical equation on 15th February, 2004.

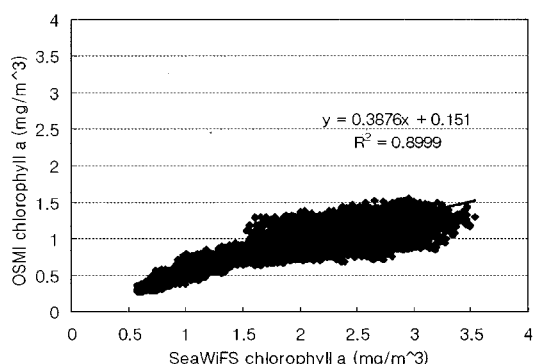


Fig. 7. Relationship between chlorophyll *a* data from OSMI and SeaWiFS in the East China Sea on 15th February, 2004.



Fig. 6. Distribution of estimated chlorophyll *a* (mg/m³) derived from OSMI satellite on 15th February, 2004.

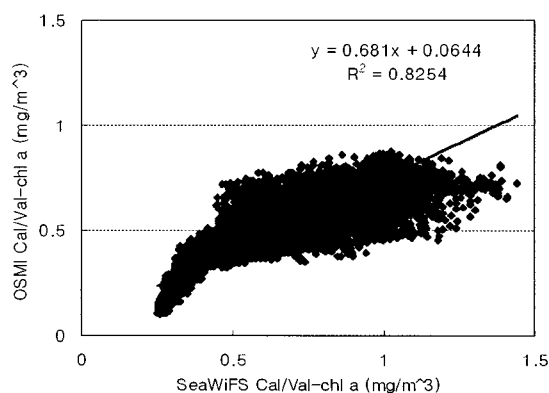


Fig. 8. Relationship between Cal/Val chlorophyll *a* data from OSMI and SeaWiFS in the East China Sea on 15th February, 2004.

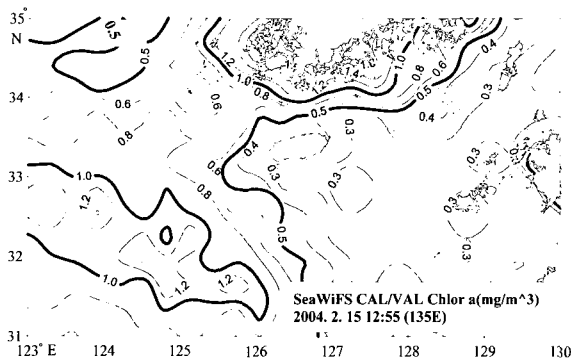
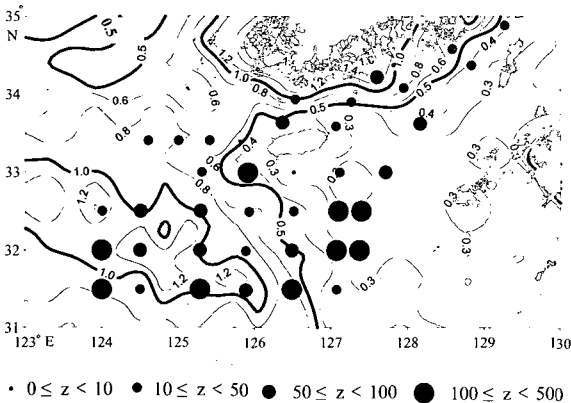
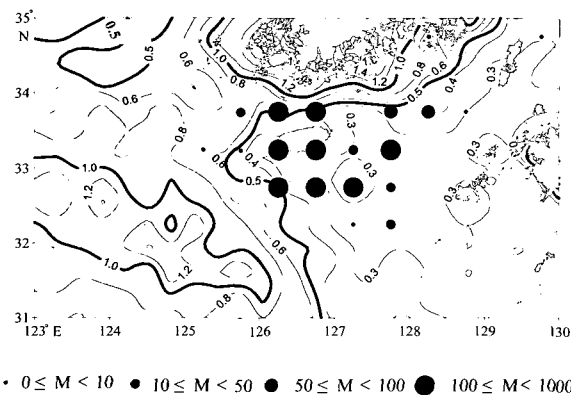


Fig. 9. Distribution of estimated chlorophyll *a* (mg/m^3) derived from OSMI-CAL/VAL empirical equation on 15th February, 2004.



(a)



(b)

Fig. 10. Horizontal distributions of (a) zooplankton biomass (mg/m^3) and (b) monthly total catch amounts (ton) of Pacific mackerel by statistical sea blocks ($0.5^\circ \times 0.5^\circ$) and the estimated chlorophyll *a* derived from OSMI data in February, 2004.

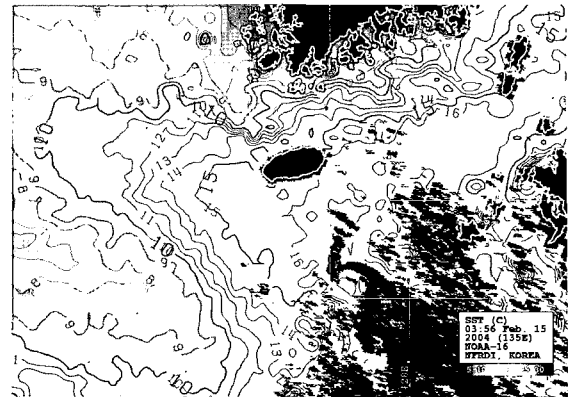


Fig. 11. Sea surface temperature ($^\circ\text{C}$) derived from NOAA-16 satellite around the southern part of the Korean waters on 15th February, 2004.

Feb., 2002 and 2004 (Fig. 10 and 11).

In case of comparison between the estimated chlorophyll *a* from OSMI data and zooplankton biomass measured in field in February of 2004, the zooplankton biomass more than $50 \text{ mg}/\text{m}^3$ was distributed in the concentration of chlorophyll from 0.5 to $1.2 \text{ mg}/\text{m}^3$. However, the monthly total catch amounts of the Pacific mackerel more than 100 ton were distributed in the concentration of chlorophyll from just 0.3 to $0.5 \text{ mg}/\text{m}^3$. It was not agreed to the fisheries textbook. In case of comparison between the estimated sea surface temperature (SST) derived from NOAA/AVHRR data and zooplankton biomass measured in field in February of 2004, the zooplankton biomass more than $50 \text{ mg}/\text{m}^3$ was distributed in cold water lower than 10°C and even in warm water higher than 15°C . However, the total catch amounts more than 100 ton were just distributed in the only warm water more than 15°C .

4. Conclusions

The ocean color of the northern East China Sea is optically complicated due to the contributions not only from concentration of phytoplanktons, but also from suspended solids^{6,7,11}. The empirical algorithm for calibrating and validating of OSMI chlorophyll *a* as level 2 data in the East China Sea in specially winter season was updated. In order to validate satellite ocean color retrievals and to develop simple CAL/VAL method for complex case 2 regions, routine ship-based studies should be continuously required. In case of relationships between distributions of chlorophyll *a* de-

Calibration and Validation of the Estimated Chlorophyll *a* Derived from KOMPSAT/OSMI Data and Fisheries Application in the East China Sea

rived from OSMI ocean color data, SST derived from NOAA infrared data and amounts of zooplankton, Pacific mackerel in the winter seasons of 2002 and 2004, the distributions of zooplankton and the fish were totally depended on the those of SST.

According to the results of the fishery oceanographic studies on the mackerel purse-seine fishing grounds off the southwestern coast of Korea, the optimum water temperatures for the fishery range from 10 to 15 in winter¹⁰⁾. The cold water mass contacts with the warm water of the Tsushima Current to produce an oceanic front in southwestern part of Jeju Island¹³⁾. The coastal water of mainland China, cooled from surface to bottom in winter, extends its range into the East China Sea. During winter their intersection leads to the occurrence of coastal front, which establishing a more stable state in winter runs parallel to the coast line from the Jeju Strait to the vicinity of the Tsushima Island (Fig. 11).

Acknowledgements

This study was funded by the research project 『The application of satellite data for fisheries oceanography』 of the Korea Aerospace Research Institute and RP-2005-ME-33 of the National Fisheries Research and Development Institute(NFRDI). I express my gratitude to Ms. Na-Kyung Lee and Dr. Lee-Hyun Jang of the NFRDI for the production of the figures. My gratitude is extended to Mr. Sun-Gu Lee and Dr. Yong-Seung Kim of the Korea Aerospace Research Institute for the development of KOMPSAT/OSMI satellite data bases.

References

- 1) Cho, Y. M., S. S. Yong, H. Y. Paik and *et al.*, 1997, Ocean scanning multi spectral imager (OSMI), Proceedings of the Fifth International Conference on Remote Sensing for Marine and Coastal Environments, San Diego, California, I, 459-466.
- 2) Yacobi, Y. Z., A. Gitelson and M. Mayo, 1995, Remote sensing of chlorophyll in Lake Kinneret using high spectral-resolution radiometer and Landsat TM: spectral features of reflectance and algorithm development, J. Plankton Research, 17(11), 2155-2173.
- 3) Lee, N. K., Y. S. Suh and Y. S. Kim, 2003, Satellite remote sensing to monitor seasonal horizontal distribution of resuspended sediments in the East China Sea, J. of Korean Association of Geographic Information Studies, 6(3), 151-161.
- 4) Suh, Y. S., B. G. Mitchell, L. H. Jang, S. G. Lee and S. J. Yoo, 2001, Calibration and validation of ocean color satellite imagery, J. Korean Environmental Sciences Society, 10(6), 431-436 (in Korean).
- 5) O'Relly, J. E., S. Maritorena, B. G. Mitchell, D. A. Siegel, K. L. Carder, S. A. Graver, M. Kahru and C. McClain, 1998, Ocean color chlorophyll algorithms for SeaWiFS, J. of Geophys. Res., 103, 24937-24953.
- 6) Suh, Y. S., L. H. Jang, B. G. Mithchell, M. Kahru, K. Prasad and H. Y. Shin, 2002, Study of the Korean waters using the CAL/VAL of the OSMI level 2 data, J. Korean Society of Remote Sensing, 18(3), 137-139.
- 7) Suh, Y. S., L. H. Jang, N. K. Lee and B. K. Kim, 2002, Development of the regional algorithms to quantify chlorophyll *a* and suspended solid in the Korean waters using ocean color, J. Korean Fish. Soc., 35(3), 207-215.
- 8) Ahn, Y. H. and J. E. Moon, 1998, Specific absorption coefficients for the chlorophyll and suspend sediment in the Yellow and Mediterranean Sea, J. of the Korean Society of Remote Sensing, 14(4), 353-365.
- 9) Gong, Y. and Y. S. Suh, 2003, Effect of the environmental conditions on the structure and distribution of Pacific saury in the Tsushima Warm Current region, J. of the Environmental Sciences, 12(11), 1137-1144.
- 10) Gong, Y., Y. J. Kang and S. Y. Cho, 1972, Fishery oceanographic studies on the mackerel purse-seine fishing grounds off the southwestern coast of Korea, Bul. of Fisheries Research and Development Agency, 9, 95-110.
- 11) Suh, Y. S., N. K. Lee, L. H. Jang, J. D. Hwang, S. J. Yoo and H. S. Kim, 2002, Characteristic response of the OSMI bands to estimate chlorophyll *a*, J. Korean Society of Remote Sensing, 18(4), 187-199.
- 12) Strickland, J. D. H. and T. R. Parsons, 1968, A Practical Handbook of Seawater Analysis, 311pp.
- 13) Gong, Y., 1971, A study on the south Korean coastal front, J. of Oceanogr. Soc. Korea, 6(1), 25-36.