National Report on Ocean Remote Sensing in Korea

Contents

1 Status of Remote Sensing Utilization in Marine Environment Monitoring

History of the marine satellite remote sensing in Korea

National Fisheries Research and Development Institute (NFRDI) received NOAA/APT (Automatic Picture Transmission) satellite data to monitor oceanic variations around the Korean peninsula for 4 years (1976-1989). It was first time to use satellite data for understanding ocean variations. NFRDI and Seoul National University received NOAA/AVHRR (High Resolution Picture Transmission) satellite data to study on the abnormal phenomena in the Korean waters for 7 years (1989-1995). NFRDI has been receiving the satellite data since 1989.

NFRDI started to receive GMS/SVISSR (Stretched-visible and Infrared Spin Scan Radiometer) satellite data to understand the variation of sea surface temperature in the western Pacific Ocean in 1995. However, NFRDI has been started to receive GOES data instead of GMS data since 2003. In case of ocean color satellite data, NFRDI has been receiving SeaWiFS, MODIS and OCM satellites data on real time basis since 1998.

Korea Ocean Research and Development Institute (KORDI) has been operating NOAA satellite receiving station since 1995. And then, KORDI has been operating SeaWiFS satellite receiving station on delay mode basis since 1998.

Korea Aerospace Research Institute (KARI) launched the KOMPAST-1 (Korean Multi-Purpose SATellite) on December 21, 1999. Korea Multi-Purpose Satellite-I (KOMPSAT-I) is mainly for ocean observation. KOMPSAT-I, as shown in figure 1, table 1, table 2 and table 3 has two sensors: Panchromatic – Electro Optical Camera (EOC) and Multi-spectral – Ocean Scanning Multi-spectral Imager (OSMI).

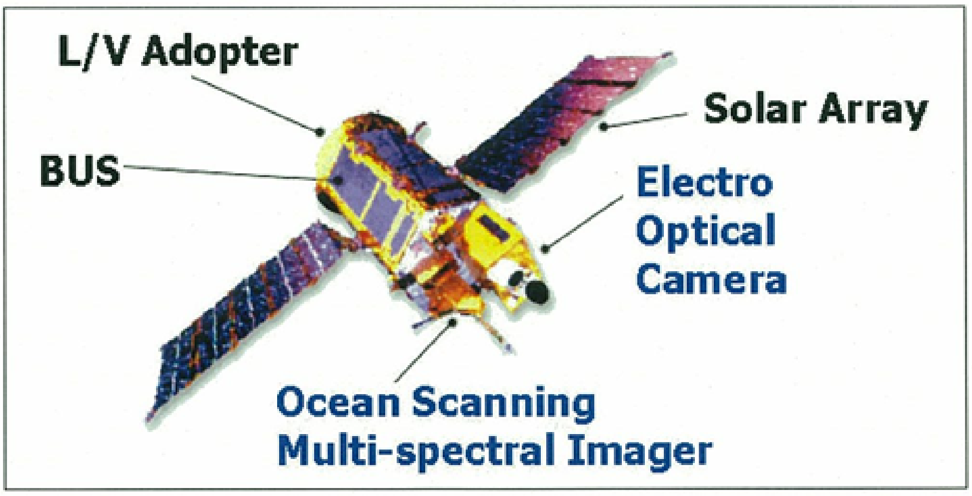


Figure 1. KOMPSAT-1 Overview
Source: KARI

Table 1. KOMPSAT-1 Characteristics
Source: KARI

Date	1999 -
Spacecraft Mass	510 kg
Generated Power	636 W
Design Life	More than 3 years
Orbit	Sun-Synchronous Sub-Recurrent Repeat Cycle: 28 days Sub Cycle: 2 days Altitude: 685 km (at Equator) Inclination: 98 deg.
Size	Diameter 53inch, Height 98 inch
Onboard Camera	EOC, OSMI

Table 2. Major characteristics of EOC

Channels	1 (panchromatic, 510-730 nm)
Spatial resolution	6.6 m
Field of view	1.42° (Push-bloom)
Data transmit	Real time base X-band
Data rate	<25Mbps
Scan width	15 km
Revisit	28 Days
Orbital altitude	685 km
Weight	34kg
Power	46W

Table 3. Major characteristics of OSMI

Channels	6 (400-900 nm)
Spatial resolution	850 m at Nadir, 1,000 m at edges
Field of view	6.83° (Whisk-bloom)
Data transmit	Real time base X-band
Data rate	<600Kbps
Scan width	800 km
Revisit	3 Days
Orbital altitude	685 km
Weight	18kg
Power	30W

Spectral Band	Band Center (nm)	Band Width	Intended Use
1	412	20	Gelbstoffe
2	443	20	Chlorophyll Absorption
3	490	20	Pigment Concentration
4	555	20	Sediments
5	670	20	Atmospheric Aerosols
6	865	40	Atmospheric Aerosols

KOMPSAT-I/OSMI

There was a feasibility study of Korea-NASA cooperative research for earth observing satellite during Sept. 1, 2001 - June 30, 2004. The feasibility study was carried out by joint study of KOMPAST/OSMI calibration and validation using SeaWiFS and in-situ measurements (see section 3.3).

Products of *chlorophyll-a* concentration by SeaWiFS and OCM real time data, sea surface temperature by NOAA/AVHRR real time data as well as suspended solid by MODIS real time data, have been actively used for monitoring projects such as "operation of application system to produce ocean information derived from earth observation satellites" (see section 2.1).

Present status of marine environmental monitoring using remote sensing is summarized in Table 4.

Table 4. Status of Marine Environmental Monitoring by Remote Sensing
SST shows sea surface temperature, CHLA shows *chlorophyll-a* concentration
and SS shows suspended solid

Sensor	Satellite	Variables	Observing Cycle	Intended use of data
AVHRR	NOAA Series (12,15,17)	SST	(3-6 times/day)	• Understanding of ocean dynamics • Locating fishing grounds including thermal front information
SeaWiFS	OrbView-2	CHLA	1 day	• Finding of fishing grounds • Understanding of red tide • Detecting of low salinity water
OSMI	KOMPSAT-1	CHLA	3 day	• Finding of fishing grounds
MODIS	Terra/Aqua	SST SS	(2 times /day)	• Monitoring for water quality • Understanding of ocean dynamics
OCM	IRS-P4	CHLA	2 day	• Understanding of red tides • Understanding of ocean dynamics • Tracking of rivers run off
EOC	KOMPSAT-1	Fishing boat Fishing farm	28 day	• Understanding of fisheries conditions

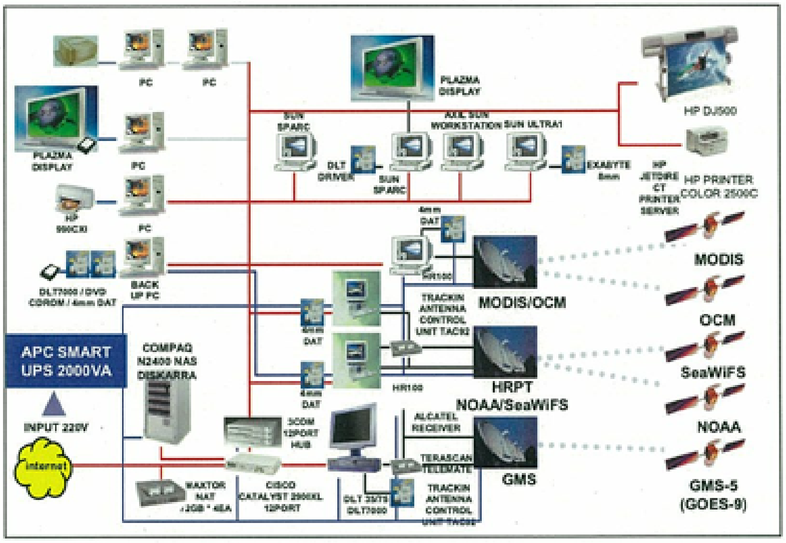
2 Case examples of RS application in marine environmental monitoring

2.1 Marine Environmental Watch Project on Real Time Basis

National Fisheries Research and Development Institute (NFRDI) under the Ministry of Maritime Affairs and Fisheries (MOMAF) of Korea has been operating satellite remote sensing system to carry out operation of application system to products ocean information derived from earth observation satellites since 1996 to provide useful basic information for finding fishing ground and marine environmental conservation. Receiving targets are NOAA/AVHRR, Orbview-2/SeaWiFS, Terra (Aqua)/MODIS, IRS-P4/OCM and GMS (GOES)/SVISSR that are expected for marine environment and fishing ground environment monitoring (Figure 2a).

Measured data obtained by receiving ground station are automatically processed for Korean waters and saved as database expecting past and future study. The contents are opened through the Internet (Figure 2 and Figure 3) providing: SST charts with isothermal lines and 7-day composite color images of SST for nighttime by search condition of measurement data.

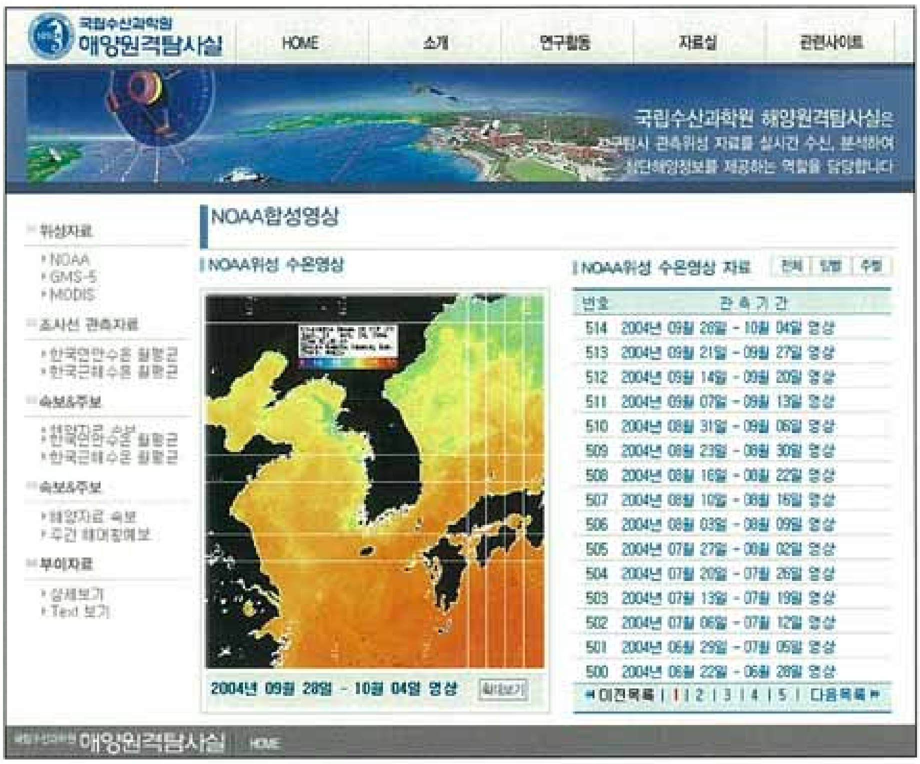
In addition to the above-mentioned data, MODIS suspended solid concentration images, a chart of SeaWiFS *chlorophyll-a* concentration a month have been provided since January 2004 to further assist and promote marine environmental conservation and understanding of fish ground formation. The data and information are distributed by internet website of NFRDI.



(a) Marine Remote Sensing System

(b) Remote sensing data homepage

Figure 2. Receiving System and Marine Remote Sensing Laboratory Homepage
< http://www.nfrda.re.kr/korea/mrsl/index.html>



(a) SST derived from NOAA

(b) RGB images derived from MODIS

Figure 3. Website service of satellite data.
< http://www.nfrda.re.kr/korea/mrsl/data_mrsl.htm>

2.2 Project for public application research of satellite data (Ocean)

KARI, KORDI, NFRDI, Pukyoung University and Yonsei University are carrying out the project from public application research of marine satellite data for 3 years (2002 – 2004) as a first stage of the project. The major satellite data is OSMI. OSMI receiving data and processing data as level 1 are provided by KARI (Figure 4). The stripe problem on images of OSMI is studied by above organizations.

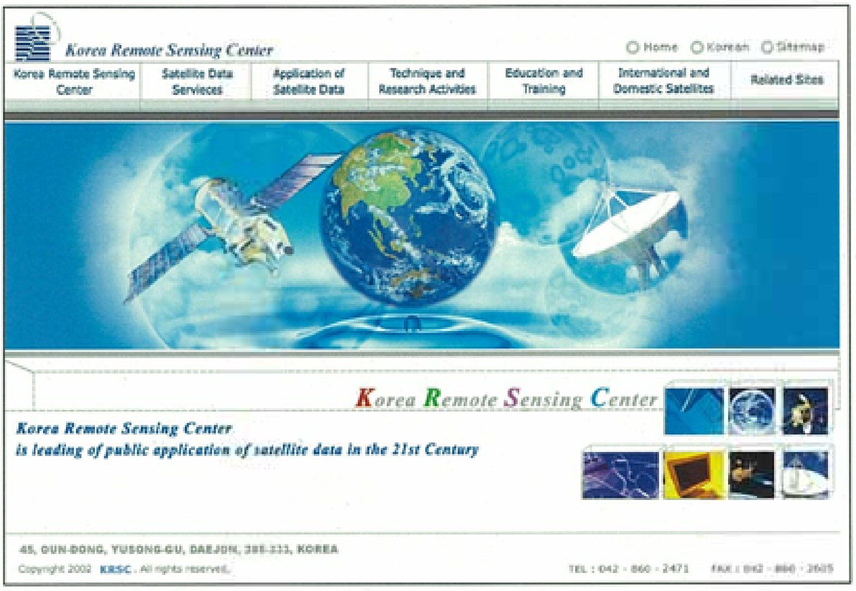


Figure 4. Korea Remote Sensing Center
< http://krsc.kari.re.kr/kari/eng/sub/main_all.htm>

The application of OSMI satellite data for fisheries oceanography is studied by NFRDI (Suh et al., 2002a; Suh et al., 2002b; Suh et al., 2001).
Even though the spectral resolution of OSMI is very similar to the one of SeaWiFS (Table 5), 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. However, Suh et al. (2002c) showed the possibility of the using of the same as OC2 algorithm (O'Relly *et al.*, 1998) (Figure 5).

Table 5. Characters of SeaWiFS and OSMI

	SeaWiFS		OSMI	
Spectral	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

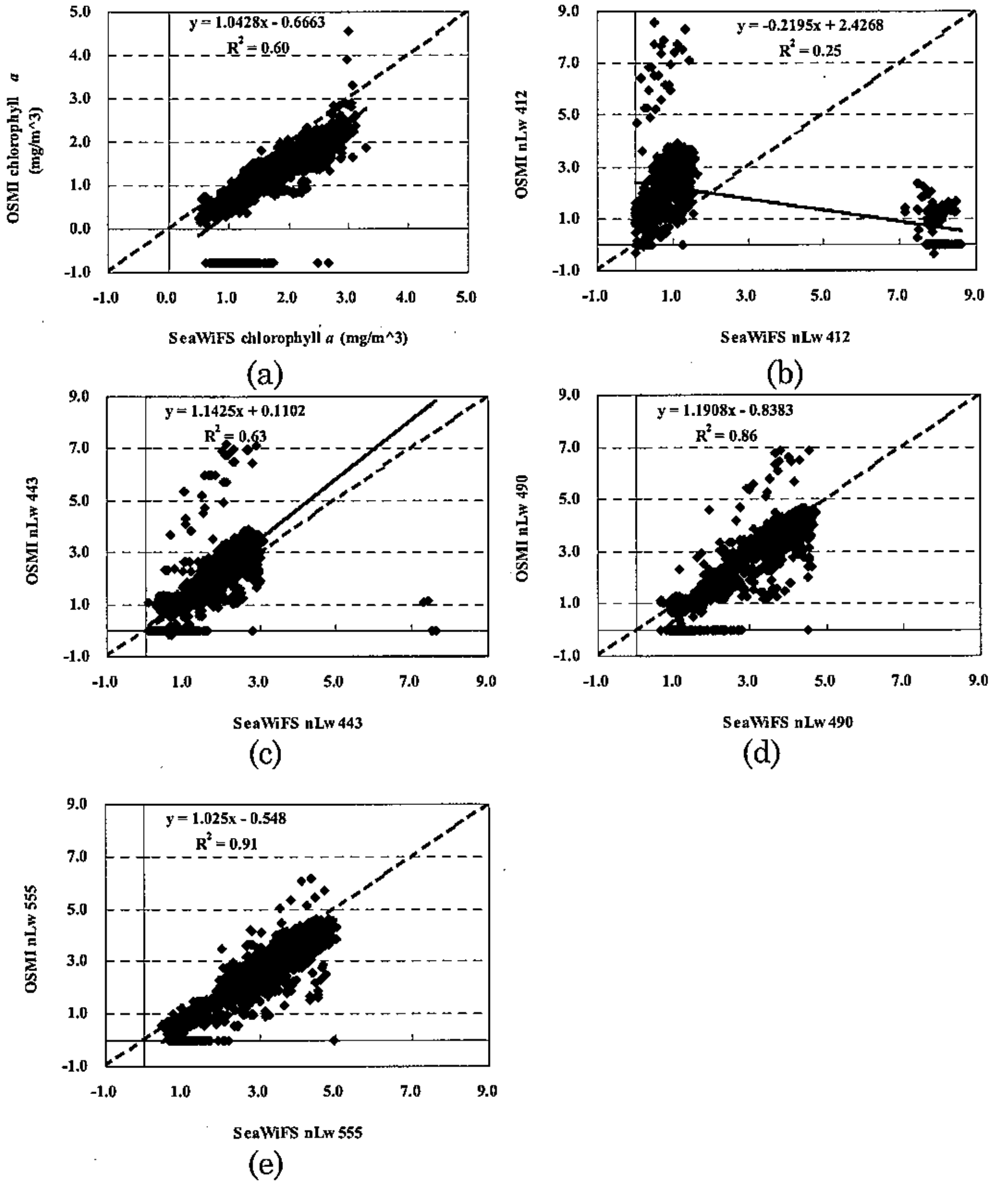


Figure 5. Relationships between data from SeaWiFS and OSMI in the southern part of the Korean waters on 20th February, 2002. (a) The estimated chlorophyll *a* using ocean color algorithm 2 (O'Reilly, 1998). The normalized water leaving radiance (nLw) at (b) 412 nm, (c) 443 nm, (d) 490 nm, (e) 555 nm (Suh et al., 2002).

The relationship between the measured chlorophyll *a* and the estimated chlorophyll *a* from OSMI can be expressed by the following equation (1) in the northern part of the East China Sea.

$$\text{Chl } a = 0.6069(X_{OSMI}) - 0.061,\ R^2 = 0.72 \qquad (n=33) \qquad (1)$$

Where, X_{OSMI} is the estimated chlorophyll *a* from OSMI satellite data using the OC 2 algorithm (Figure 6).

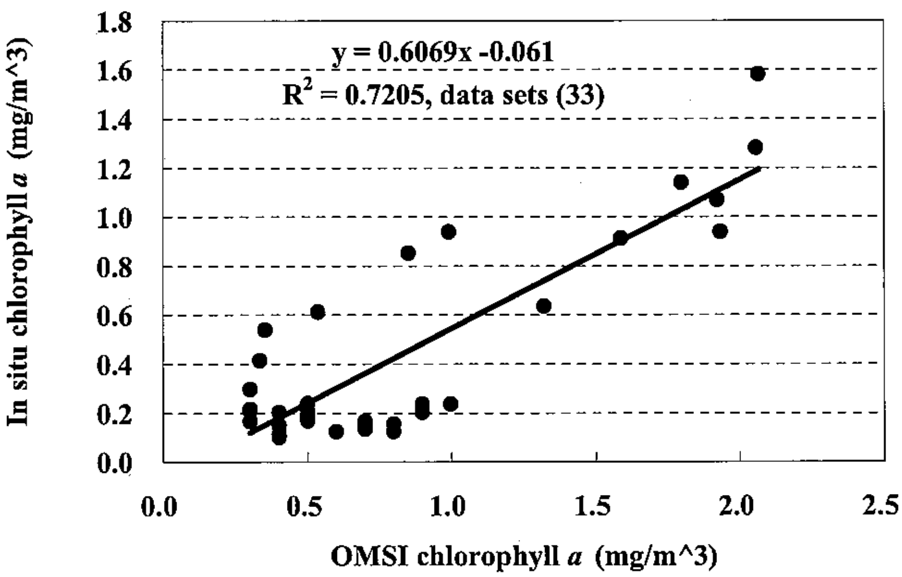


Figure 6. Relationship between the field chlorophyll a (mg/m^3) and the estimated chlorophyll a derived from OSMI satellite in the southern part of the Korean waters in February 15, 2004.

The northern East China Sea is regarded as an important fisheries ground around the Korean waters. To understand the seasonal variation of chlorophyll *a* related to the density of phytoplankton in the northern East China Sea, NFRDI processed the OSMI data in 2004. The distributions of chlorophyll densities derived from OSMI data in the East China Sea were 0.2-2.4 mg/m^3 in Feb., 0.2-1.1mg/m^3 in Jun and 0.2-0.8mg/m^3 in Aug., 2004. NFRDI compared the distributions of OSMI chlorophyll *a* (mg/m^3), sea surface temperature (℃) and zooplankton biomass (mg/m^3), monthly total catch amounts (ton) of Pacific mackerel in the East China Sea in Feb., 2004 (Figure 7 and Figure 8).

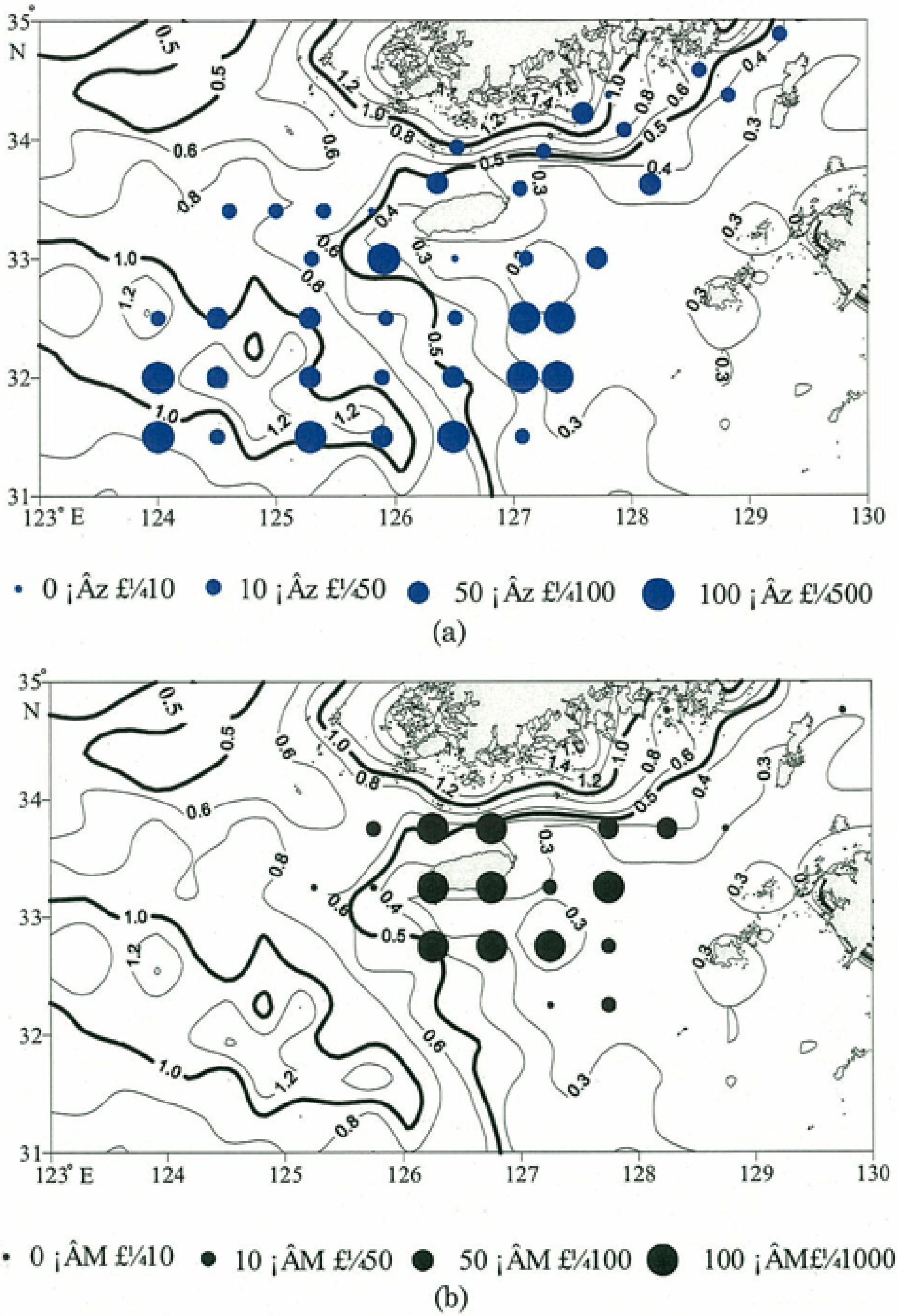


Figure 7. Relationship between horizontal distribution of (a) zooplankton biomass (mg/m^3), (b) monthly total catch amounts (ton) of Pacific mackerel and the estimated chlorophyll *a* derived from OSMI data in February, 2004.

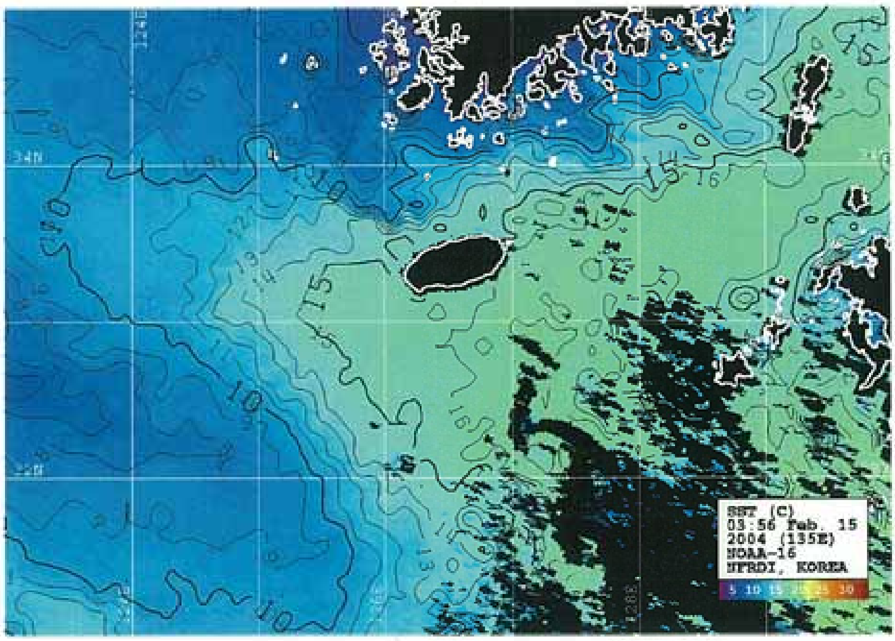


Figure 8. Sea surface temperature (℃) derived from NOAA-16 satellite around the southern part of the Korean waters on 15th February, 2004.

3 Status of Research and Development on remote sensing technology for marine environment

3.1 Sensor and Satellite

The Korean earth observing satellite program consists of two series: KOMPSAT and COMS.

KOMPSAT-II

There is a project of KARI for developing of environmental analysis technique and software for coastal waters using MSC (Multi-Spectral Camera) on KOMPAST-II (Korea Multi-Purpose Satellite II) is mainly for land observation. KOMPSAT-II, as shown in figure 9, table 6 and table 7 has MSC including Panchromatic (1 m, 1 band) and Multi-Spectral (4 m, 4 band). This satellite will be launched in the end of 2005.

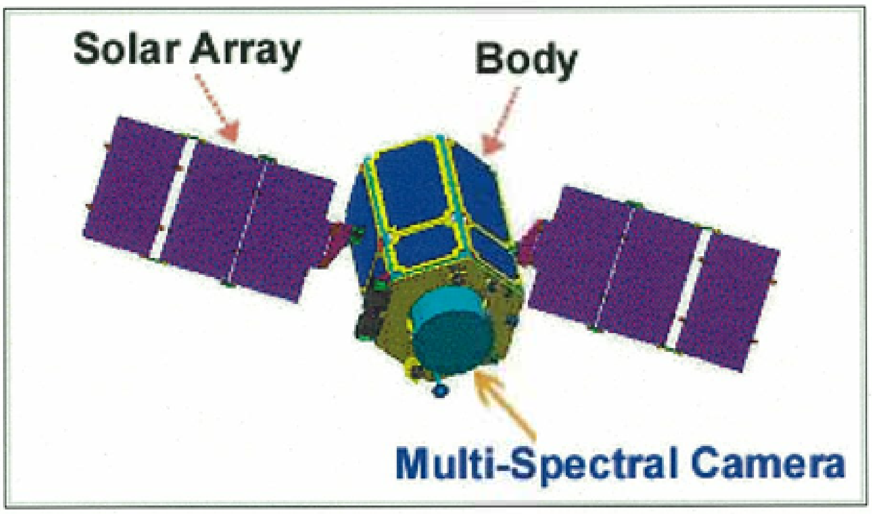


Figure 9. KOMPSAT-2 - Overview
Source: KARI

Table 6. KOMPSAT-2 Characteristics
Source: KARI

Date	4th Quarter, 2004
Spacecraft Mass	765 kg
Generated Power	850 W
Design Life	More than 3 years
Orbit	Sun-Synchronous, near-polar Altitude: 685 km (at Equator) Inclination: 98 deg.
Size	Height 40 m, Weight 213 ton
Onboard Camera	MSC

Table 7. Major characteristics of MSC

Image Mode	Panchromatic	Multi-spectral
Spatial Resolution	1 m	4 m
Imaging Bands	1	4
Spectral Range	500-710 nm	450-520 nm
		520-600 nm
		630-690 nm
		769-900 nm
Swath Width	15 km	
Data rate	350Mbps	

COMS

Communication Ocean and Meteorology Satellite, COMS satellite is mainly for atmospheric and marine observation. This satellite will be launched in 2008. The location of COMS will be between 116E and 128E. COMS has three major missions. The three missions are weather monitoring, ocean monitoring and satellite communication. The weather monitoring missions are especially useful for monitoring impending weather systems and tracking the movements of storms over great distances. The ocean monitoring missions are monitoring of marine environments around the Korean peninsula, production of fishery information (*Chlorophyll-a*, SST, etc.) and monitoring of long-term/short-term change of marine ecosystem. The satellite communication missions are in-orbit verification of the performance of advanced communication technologies and experiment of wide-band mult-media communication service.

COMS, as shown in table 8, has two earth observing sensors: Geostationary Ocean Color Imager (GOCI) for estimating *Chlorophyll-a*, suspended solid, CDOM, etc. (Table 9). GOCI will be very useful for monitoring red tied and variations of ocean color related to the pollution in the NOWPAP region. We will be able to get the ocean color information with 500 m spatial window and 1-hour temporal window from the GOCI during daytime. The meteorological sensor for all weather and land observation (as shown in table 10).

Table 8. COMS Characteristics

Mass	2.5 – 3.0 tons (TBD)
Generated Power	3 kW (TBD)
Design Life	More than 7 years
Orbit	Geo-Synchronous
Size	Height 40 m, Weight 213 ton
Payload	Meteorological Imager
	Ocean Sensor (GOCI)
	Ka-band Transponder

Table 9. Major characteristics of GOCI

Spectral Band	Band Center (nm)	Band Width	Intended Use
1	412	20	CDOM, Atmospheric Correction
2	444	20	Chlorophyll Absorption
3	490	20	Chlorophyll Absorption
4	555	20	Chlorophyll Absorption
5	625	20	Sediments
6	680	10	Sediments, Atmospheric Correction
7	745	20	Atmospheric Correction
8	865	40	Atmospheric Correction

Table 10. Major characteristics of Meteorological Imager

Spectral Band	Band Center (nm)	IFOV (km)	Intended Use
1	600	1	Daytime cloud imagery, RGB color composite, Detection of special event (yellow dust, fire, haze, etc.)
2	800	1	Aerosol optical depth, RGB color composite, NDVI
3	1,600	1	Snow cover, Cloud phase, Aerosol optical depth, Tropical cyclone center fixing
4	3,800	4	Nighttime fog/stratus, Fire detection, Surface temperature
5	6,200	4	Upper atmospheric water vapor, Upper atmospheric motion vector
6	7,200	4	Middle atmospheric water vapor, Upper atmospheric motion vector
7	7,900	4	Low atmospheric water vapor, Upper atmospheric motion vector, Cloud phase
8	11,000	4	Standard IR split window channel (cloud, Sea surface temperature, Yellow dust, ash, etc.)
9	12,000	4	Standard IR split window channel (cloud, Sea surface temperature, Yellow dust, ash, etc.)
10	13,700	4	Thin Cirrus detection, Altitude assignment, pseudo-sounding

National space program in Korea is scheduled by KARI as bellows;

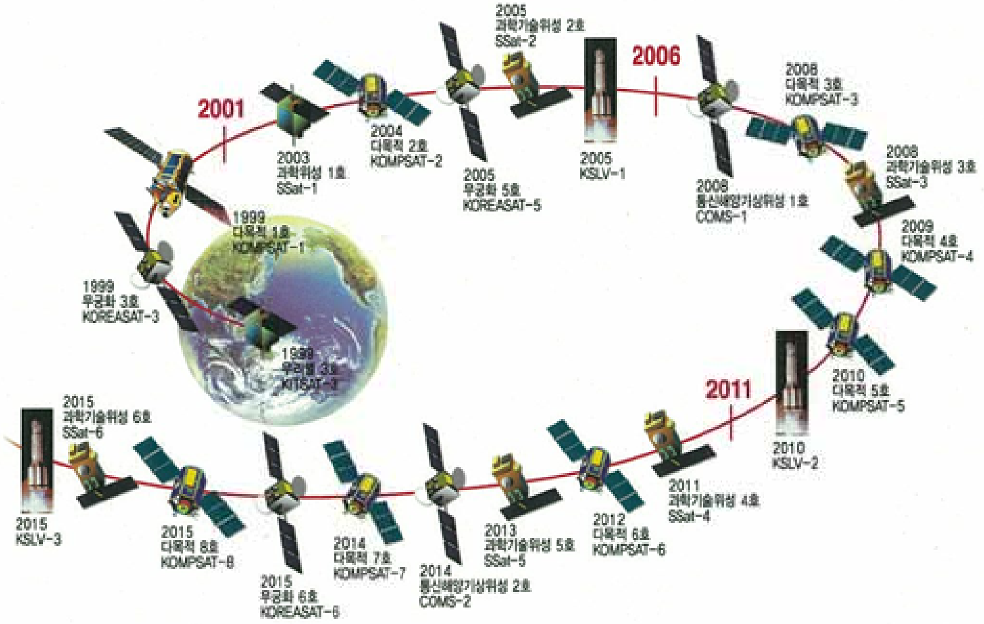


Figure 10. Korean space program related to the KOMPSAT series and the COMS series from 2001 to 2015.

3.2 Algorithm for Geo-physical Parameters

Sea Surface Salinity for the East China Sea in Summer Season

In the summer of 1998-2001, a huge flood occurred in the Yangtze River in the eastern China. Low salinity water less than 28 psu from the river was detected around the southwestern part of the Jeju Island, which is located in the southern part of the Korean Peninsula. We studied how to detect low salinity water from the Yangtze River, that cause a terrible damage to the Korean fisheries. We established a relationships between low salinity at surface, turbid water from the Yangtze River and digital ocean color remotely sensed data of SeaWiFS sensor in the northern East China Sea, in the summer of 1998, 1999, 2000 and 2001 (Figure 11 and Figure 12). The salinity charts of the northern East China Sea were created by regeneration of the satellite ocean color data using the empirical formula from the relationships between *in situ* low salinity, *in situ* measured turbid water with transparency and SeaWiFS ocean color data (normalized water leaving radiance of 490 nm/555 nm).

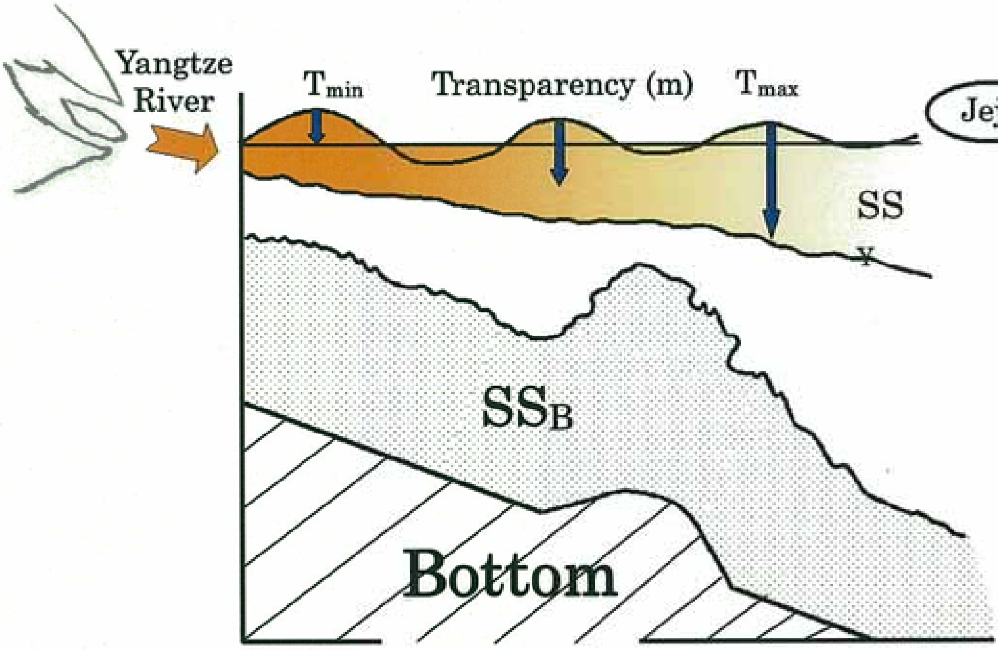


Figure 11. Schematic diagram of the vertical distribution of resuspended solid from the shallow bottom and surface suspended solid from the Yangtze River. SS_Y represents the surface turbid water from the Yangtze River. SS_B represents resuspended sediment from sea-bottom caused by sea wave. Estimated transparency is very high in the waters around Jeju Island than one in the coastal water of the Yangtze River (Suh et al., 2004a).

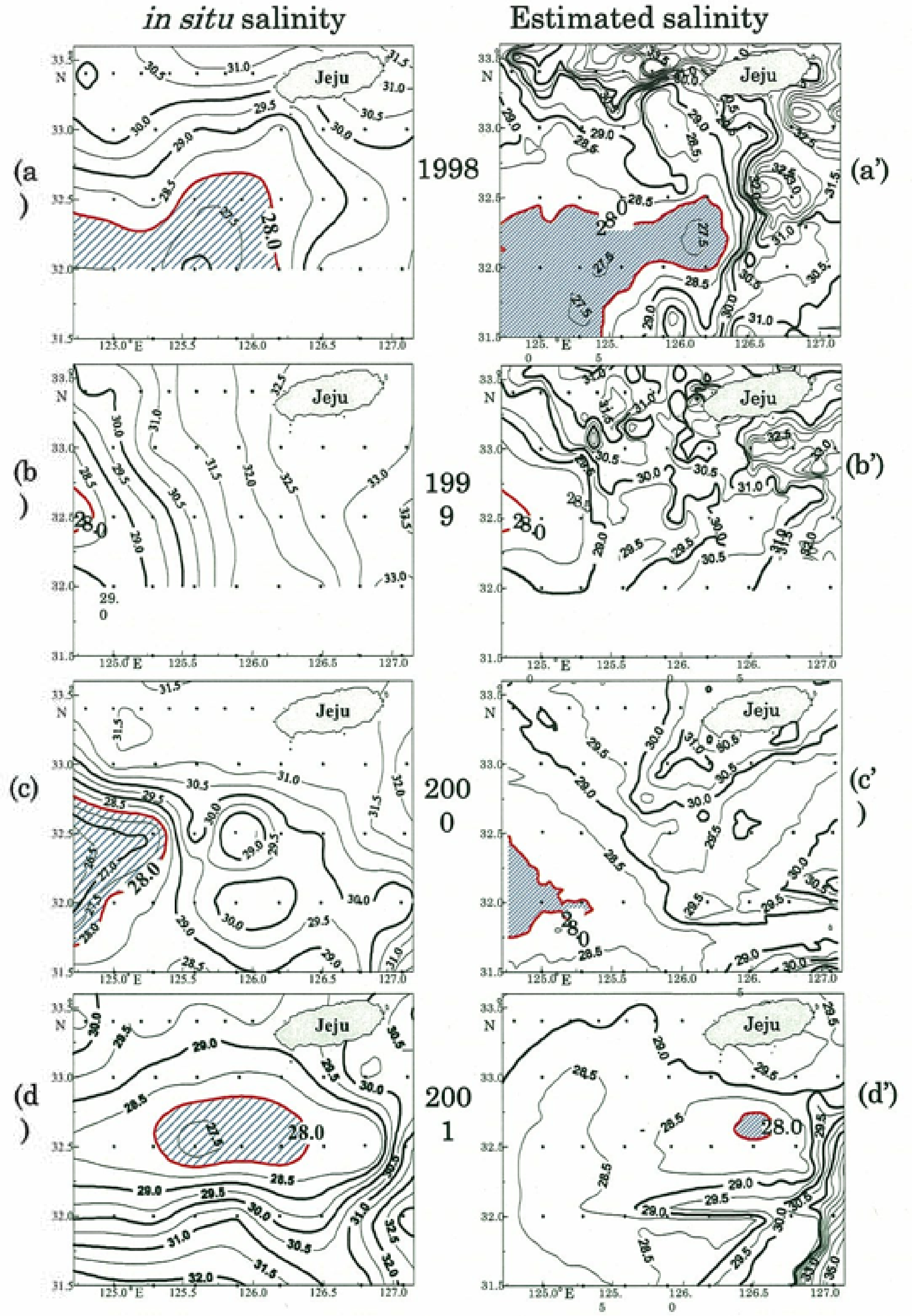


Figure 12. Distribution of surface salinity (psu) in August during 1998-2001. Measured field surface salinity in (a) 6-8 Aug., 1998, (b) 12-20 Aug., 1999, (c) 4-6 Aug., 2000, (d) 17-23 Aug., 2001. Estimated surface salinity from the SeaWiFS data using the developed regional algorithm in (a') 4 Aug., 1998, (b') 19 Aug., 1999, (c') 6 Aug., 2000, (d') 16 Aug., 2001 (Suh et al., 2004a).

3.3 Validation of Geo-physical Parameters

3.3.1 Improvement of algorithm for *chlorophyll-a* concentrations in case II water

For the estimation of physical quantities, Korean scientists have not been using standard algorithm such as OC2 algorithm in the turbid water, the Yellow Sea and the western East China Sea. NFRDI of Korea studied that remote sensing reflectances are different between case I and case II water as follows (Figure 13).

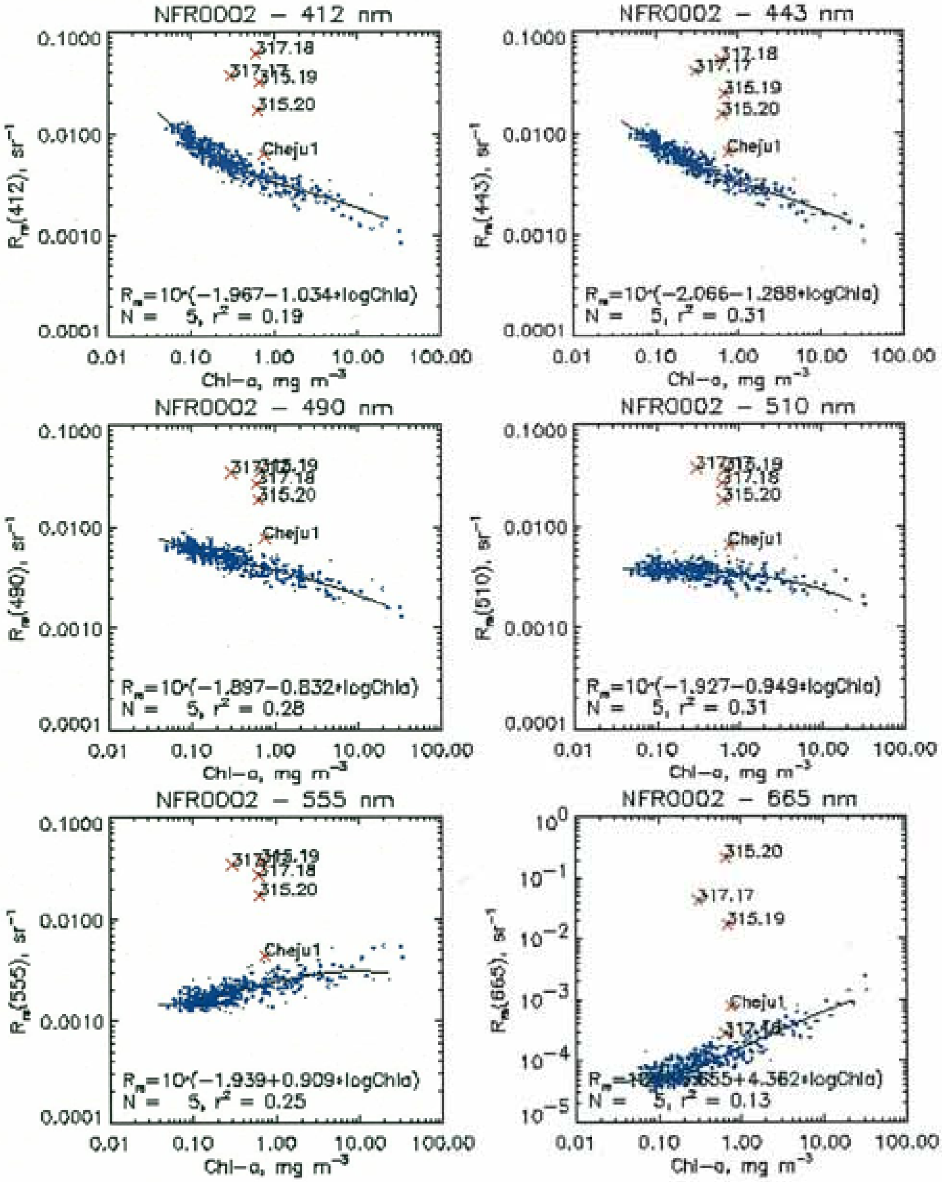


Figure 13. Remote sensing reflectance(Rrs) at SeaWiFS spectral bands(412, 443, 490, 510, 555, 665 nm) for the CalCOFI reference data set (●) and the NFRDI February data (×) in the East China Sea (Suh *et al.*, 2001).

3.3.2 Validation and calibration of geo-physical parameters in the East China Sea

- ○ Accuracy verification results of present products in the East China Sea
  - Temperature and salinity using Seabird CTD since 1988
  - Chlorophyll sample store using liquid nitrogen since 1998
- ○ In situ data arrangement situation under the Near GOOS umbrella
  - KORDI: real time data collection mode to public
  - NFRDI: semi- or delayed data collection mode to public
- ○ Empirical equation of chlorophyll *a* in case Ⅱ water (Figure 14)
  - NFRDI has match up data (140 sets)
  - The above match up data will be opened for scientists in the NOWPAP area in the near future.
- ○ Comparison between OSMI and SeaWiFS chlorophyll *a* (Figure 15).

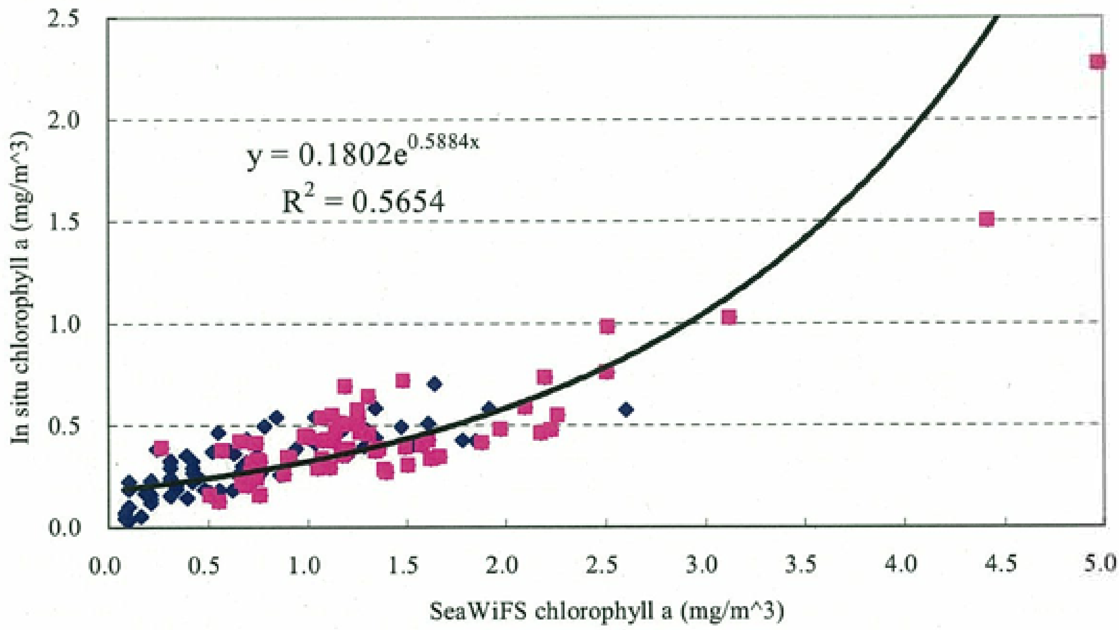


Figure 14. Match up data in the East China Sea between SeaWiFS data and *in situ* data.

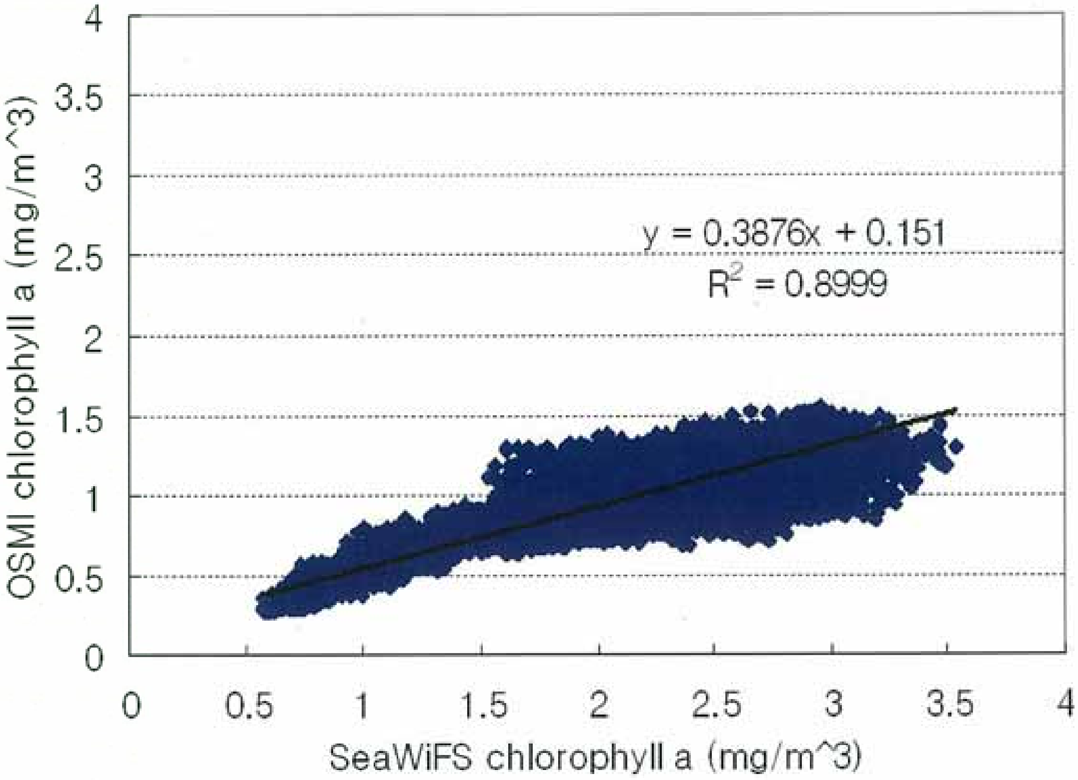


Figure 15. Relationship between chlorophyll a data from OSMI and SeaWiFS in the East China Sea on 15th February, 2004.

3.3.3 A feasibility study of Korea-NASA cooperative research for EOS

A joint study of KOMPASAT OSMI Cal/Val using SeaWiFS and in-situ measurements

KARI and SIMBIOS team of NASA carried out the joint study to calibrate and validate OSMI *chlorophyll-a* data for 3 years (Sept. 2001 – June, 2004). Global scale OSMI data are calibrated and validated with Marine Optical Buoy (MOBY) giant buoy data and in-situ data in Antarctic (Kim and Lee, 2003; Fargion et al., 2002).

4 Introduction of latest findings

4.1 Feasibility of Red Tide Detection Around Korean Waters Using Satellite Remote Sensing

The monitoring activities at the National Fisheries Research and Development Institute (NFRDI) in Korea have been extended to include all the coastal waters of Korea after the outbreak of *Cochlodinium polykrikoides* blooms in 1995. We used several alternative methods including climatological analysis, spectral and optical methods which may offer potential detection of the major species of red tide in Korean waters. In the climatological analysis, NOAA, SeaWiFS, OCM satellite data was chosen using the known *C. polykrikoides* red tide bloom data and the area was mapped by helicopter reconnaissance and ground observation. The relationship between the distribution of sea surface temperature to *C. polykrikoides* bloom areas was studied. The anomalies of SeaWiFS chlorophyll *a* imageries against the imageries of non-occurring red tide for August, 2001 showed where the *C. polykrikoides* occurred. The anomalies of chlorophyll *a* concentrations from the satellite data during red tide outbreaks showed a similar distribution of *C. polykrikoides* in the red tide in August, 2001 (Figure 16). The distribution between differences in sea surface temperatures during the day and at night also showed a possibility for red tide detection (Figure 17). We used a corrected vegetation index (CVI) to detect floating vegetation and submerged vegetation containing algal blooms. The results of from the optical absorption of *C. polykrikoides* in the ultraviolet band (340nm) showed that if we use the optical characteristics from each red tide, we will be able to establish the feasibility of red tide detection (Suh et al., 2004b).

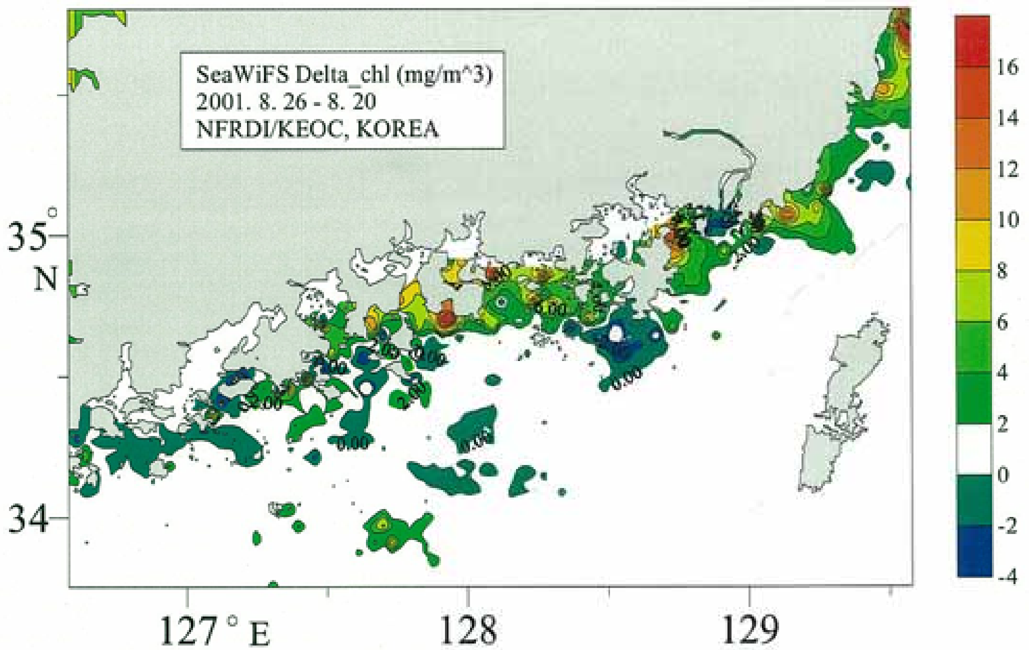
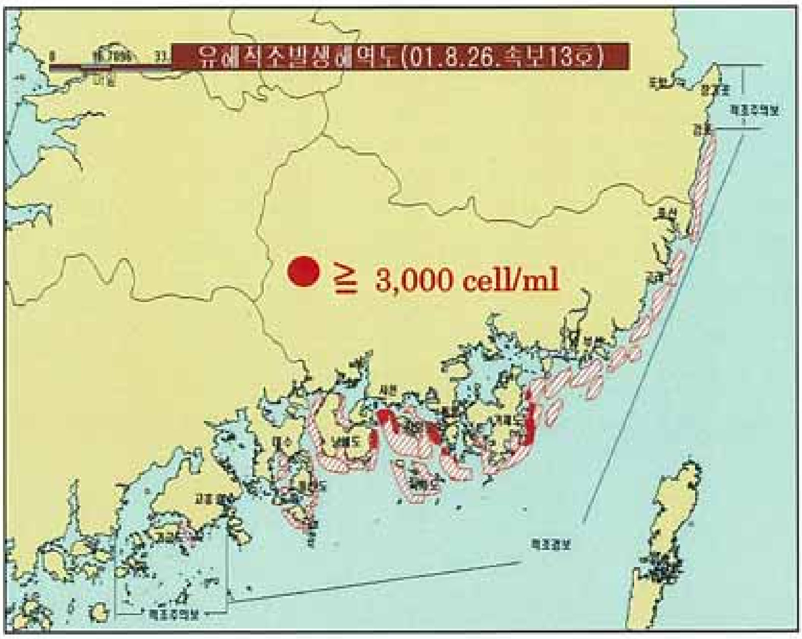
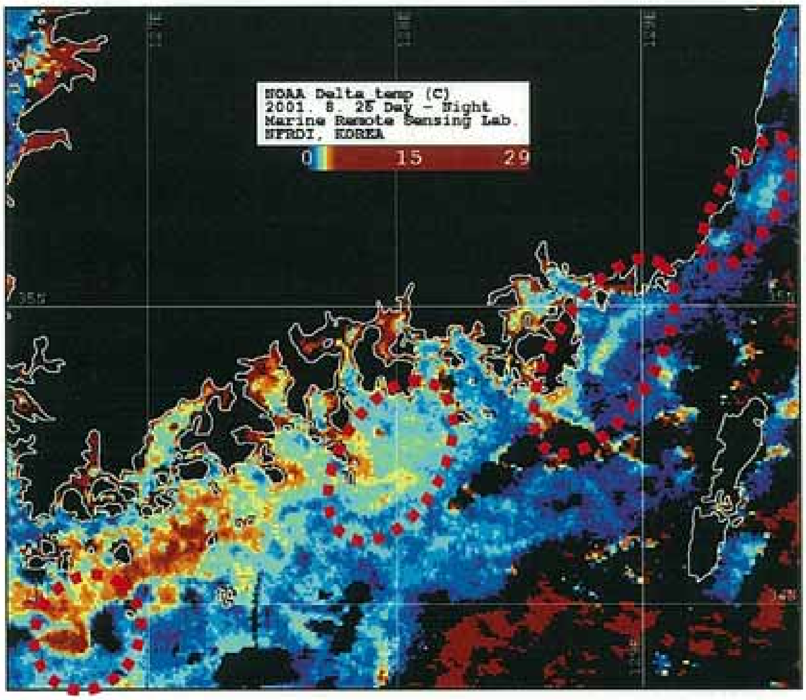


Figure 16. Distribution of difference in chlorophyll *a* between before *C. polykrikoides* red tide occurring, in August 20th and after the red tide occurring in August 26th, 2001.



(a)

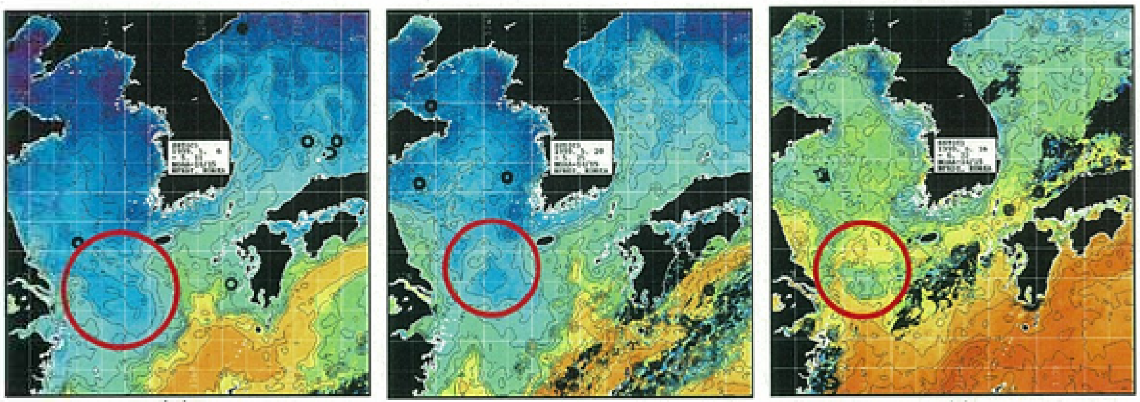


(b)

Figure 17. Distributions of harmful algal bloom in Korean coastal waters in August 26th, 2001 (a) and estimated area of red tide occurrence ( ) on the imagery of delta temp (℃) in Aug. 26th, 2001.

4.2 Temporal and Spatial Variation of the Mesoscale Cold Core Eddy in the East China Sea Using Satellite Remote Sensing

The mechanism of cold core eddy formation was investigated using boundary conditions between the East China coastal cold water and the Kuroshio Warm Current, wind data related to the monsoon which was measured by QuikSCAT, and the bottom topography of the East China Sea. When winds blow from the southeast at an intensity comparable to that in the winter period in 1999 and 2003, the warm Kuroshio and Tsushima Current became stronger, and temperatures were considerably higher than those of the extended cold water of the coast of the East China. At that time, the cold water was captured by warm water from the Kuroshio and the Tsushima Current. This facilitated the formation of mesoscale cold core eddies with diameter of 150km in the East China Sea in May, 1999 and February, 2003 (Figure 18). The cold core eddy which was detected by NOAA, SeaWiFS and QuikSCAT satellites. The East China Sea is considered to be important not only as a good fishing ground but also nursery and spawning area for many kinds of fishes. Therefore, it would be worth studying spatio-temporal variations of the cold core eddy in the environmental conditions of the northwestern East China Sea using systematic remote sensing techniques (Suh et al., 2004c).



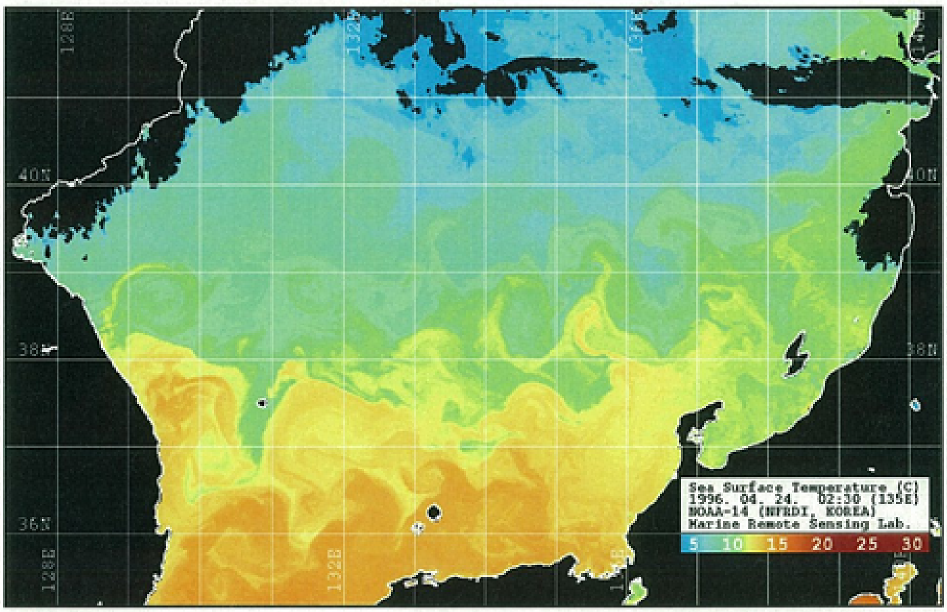
(a) (b) (c)

Figure 18. Formation of cold core eddy was measured around the waters of Scotra Rock using the infrared thermal imageries from NOAA satellite 14 and 15. (a) Step Ⅰ (May 6-11, 1999). (b) Step Ⅱ (May 20-25, 1999). (c) Step Ⅲ (June 16-22, 1999).

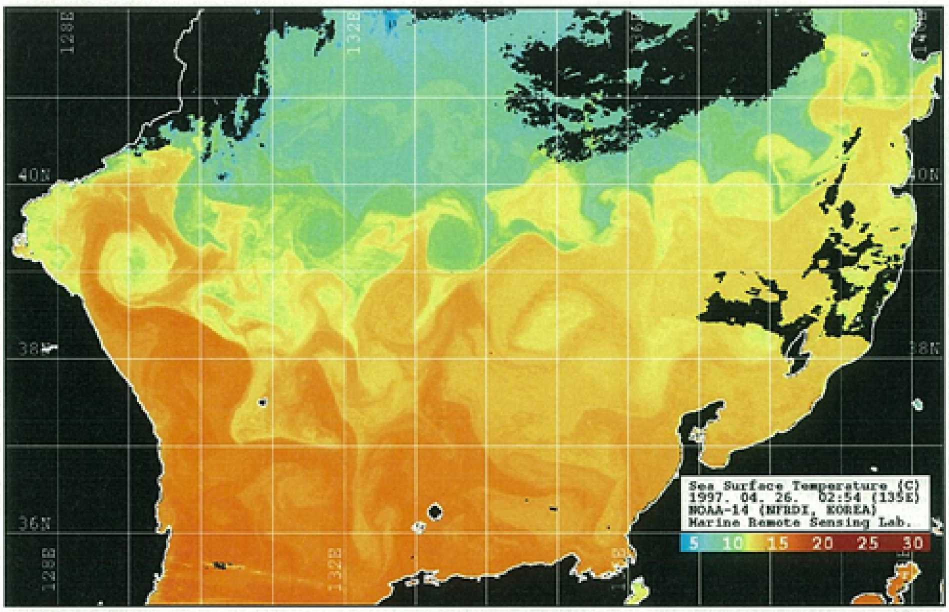
4.3 Effect of the Environmental Conditions on the Structure and Distribution of Pacific Saury in the Tsushima Warm Current Region

To provide evidence that the changes in oceanic environmental conditions are useful indices for predicting stock structure and distribution of the Pacific saury (*Cololabis saira*), the body length compositions and catch per unit fishing effort were examined in relation to the sea surface temperature (SST) anomalies in the Tsushima Warm Current (TWC) region (Figure 19 and Figure 20). The size of the fish became larger (smaller) than the average in the same size category during the season of higher SST (lower SST) as opposed to the normal SST. The year-to-year changes in body size caused by the changes in the environmental conditions led the stock to be homogeneous during the period of high stock level from the late 1950s to early 1970s and in the 1990s.

The changes in body size manifested by higher (lower) occurrence rates of larger (smaller) sized groups in relation to temperature anomalies suggest that the changes in the environmental conditions affect the distribution and the structure of the stock in the TWC region. Therefore, if the SST anomaly derived from satellite data is large enough in the early spring months (Mar. or Apr.), it is possible to predict whether or not sea temperature will be favorable for large sized groups of saury at normal or slightly earlier time of commencement of the fishery in spring (Apr.-June) (Gong and Suh, 2003).



(a)



(b)

Figure 19. Satellite images showing the positions of the sub-polar thermal fronts in the NOWPAP Region (excluding Yellow Sea) in April 24, 1996 (a) and April 26, 1997 (b).

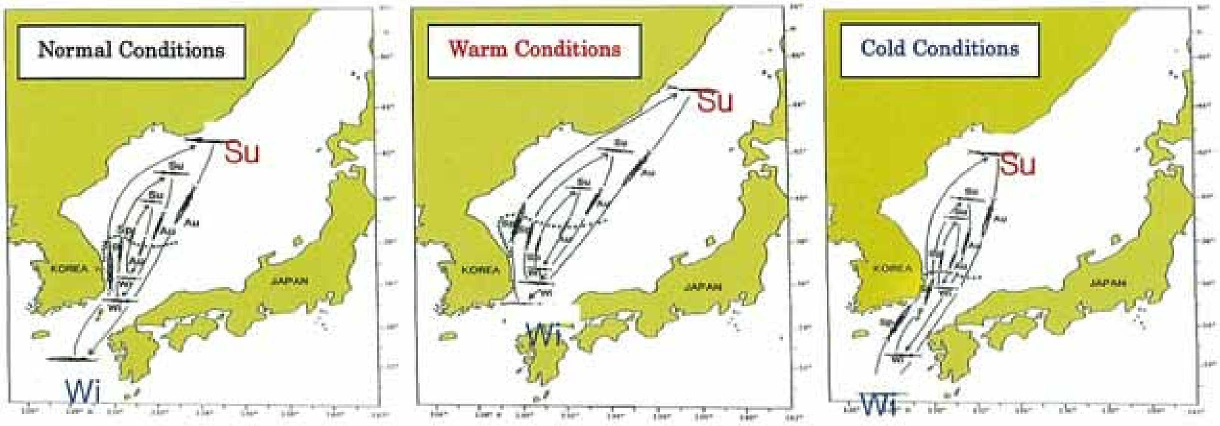


Figure 20. Migration model for Pacific saury in the oceanographic conditions (Gong et al. 1983). Su : Summer, Wi : Winter, Au : August, Sp : September.

4.4 New methods for correcting the atmospheric effects in Landsat imagery over turbid (Case-2) waters

Atmospheric correction of Landsat Visible and Near Infrared imagery (VIS/NIR) over aquatic environment is more demanding than over land because the signal from the water column is small and it carries immense information about biogeochemical variables in the ocean. This paper introduces two new methods, path-extraction and spectral shape matching method (SSMM), for the correction of the atmospheric effects in the Landsat VIS/NIR imagery in order to the retrieval of meaningful information about the ocean color, especially from Case-2 waters around Korean peninsula. The results of these methods are compared with the classical atmospheric correction approaches based on the 6S radiative transfer model and standard SeaWiFS atmospheric algorithm. The atmospheric correction scheme using 6S radiative transfer code assumes a standard atmosphere with constant aerosol loading and a uniform, Lambertian surface, while the path-extraction assumes that the total radiance (L_{TOA}) of a pixel of the black ocean (referred by Antoine and Morel, 1999) in a given image is considered as the path signal, which appears to be nearly constant over the sub scene of Landsat VIS/NIR imagery. The assumption of SSMM is nearly similar, but it extracts the path signal from the L_{TOA} by using match-up in-situ data of water-leaving radiance from typical clear or turbid waters, and extrapolate it to be the spatially homogeneous contribution of the scattered signal owing to atmospheric aerosols and Raleigh particles as well as direct reflection of light on the sea surface. The overall shape and magnitude of the atmospherically corrected radiance spectra by SSMM appears to have good agreement with the in-situ spectra collected over clear and turbid waters. The path-extraction reproduces in-situ spectra over turbid waters, but it yields significant errors over clear waters owing to the invalid assumption of zero water-leaving radiance for the black ocean pixels. Because of the standard atmosphere with constant aerosols and models adopted in 6S radiative transfer code, a large error is possible between the retrieved and in-situ spectra. The efficiency of spectral shape matching has also been explored using SeaWiFS imagery over turbid waters and compared with the standard SeaWiFS atmospheric correction algorithm, which fails in highly turbid waters due to the assumption that values of water-leaving radiance in the two NIR bands are negligible to enable retrieval of aerosol reflectance in the correction of SeaWiFS imagery. Validation suggests that the accurate retrieval of water-leaving radiance is not feasible with the invalid assumption of the classical algorithms, but is feasible with SSMM. The potential advantage of this method is that it can be easily adopted for any satellite optical imagery over any region of interest (Ahn and Shanmuganm, 2004).

5 Strategies/Plans for RS related activities

5.1 New Satellite data supply and distribution

NFRDI of Korea is going to set up the new system for analyzing of Orbview-3 and MTSAT in 2004 and 2005 as shown in table 11 and table 12.

Table 11. Orbview-3 characteristics
Source: http://www.orbimage.com/corp/orbimage_system/ov3/index.html#specs

Image Mode	Panchromatic	Multi-spectral
Spatial Resolution	1 m	4 m
Imaging Bands	1	4
Spectral Range	450-900 nm	450-520 nm
		520-600 nm
		630-690 nm
		769-900 nm
Swath Width	8 km	
Revisit Time	Less than 3 days	
Orbital Altitude	470 km	
Nodal Crossing	10:30 AM	
System Life	Minimum 5 years	

Table 12. MTSAT characteristics
Source: http://www.bom.gov.au/sat/MTSAT/MTSAT.shtml

Image Mode	Visible	Infrared
Spatial Resolution	1.25 km	5 km
Imaging Bands	1	4
Spectral Range	550-800 nm	10,300-11,300 nm
		11,500-12,500 nm
		6,500-7,000 nm
		3,500-4,000 nm

5.2 Domestic and international research cooperation including product delivery and distribution system, holding workshop

- ○ The first Korean exporters meeting of marine satellite remote sensing was held in NFRDI, Korea in March 2004(The second meeting will be held in NFRDI, April 2005)
  - 10 Korean experts of satellite remote sensing attended.
  - The sections were classified as bellows;
    - Red tide monitoring
    - Ocean physical application
    - Ocean color application
- ○ Marine remote sensing subcommittee was established under the Korean Society of Oceanography in May 2004. International Symposium on Remote Sensing 2004 & 20th Anniversary of the Korean Society of Remote Sensing was be held in Jeju, Korea in 27-29 October 2004.
- ○ The second Japan-Korea Workshop on ocean color remote sensing (JKWOC-Ⅱ) was held in KORDI, KOREA in 19-22 December 2004.
  - 16 Japanese participants, 1 Chinese participant and 16 Korean participants attended at the meeting
  - The sections were classified as bellows;
    - Ocean color activities
    - Ocean physical applications
    - Ocean ecosystem applications
    - Ocean environmental monitoring
    - Atmospheric problems
    - Ocean environmental monitoring
    - Ocean color algorithms

5.3 Agreement on New Generation Sea Surface Temperature Project between NFRDI of KOREA and Tohoku University of Japan

- ○ NFRDI had agreement on New Generation Sea Surface Temperature Project between Marine Remote Sensing Laboratory and Center for Atmospheric and Oceanic Studies under the academic agreement the NFRDI and the Graduate School of Science, Tohoku University in April, 2004.

5.4 Satellite data distribution system in Korea

- ○ Table 13 is related to the distribution system in Korea

5.4.1 MODIS, EOC and OSMI data distribution of KARI

- ○ KARI : MODIS data (free), EOC and OSMI data (non-free)

5.4.2 NOAA/AVHRR data distribution of NFRDI

- ○ NFRDI : NOAA/AVHRR data (free)

5.4.3 NOAA/AVHRR data distribution of KORDI

○ KORDI : NOAA/AVHRR data (free)

Table 13. Organization, delivery contents and URL of product delivery and distribution system in Korea

Name	URL	Organization	Country	Category	Sensor	Application	Keyword
Marine Remote Sensing Laboratory (MRSL)	http://www.nfrdi.re.kr/home/eng_nfrdi/center/laboratory.php, http://www.nfrda.re.kr/korea/mrsl/index.html	National Fisheries Research and Development Institute	Korea	Operation and Research	NOAA-(from 9 up to 17) satellites (radiometers AVHRR/ HRPT) TERRA (MODIS) AQUA (MODIS) GMS-5 (radiometer S-VISSR) GOES-9 (radiometer S-VISSR)	SST, Ocean color	SST, sea surface structure charts, sea eddy characteristics, chlorophyll-a images
Ocean Color Research Laboratory (OCRL)	http://ocrl.kordi.re.kr/	Korea Ocean Research and Development Institute	Korea	Research	NOAA, SeaWiFS	SST, Ocean color	SST, Ocean color
Mutipurpose Satellite Division	http://www.kari.re.kr/jsp/english/re1205_home.htm	Korea Aerospace Research Institute	Korea	Operation, Distribution	MODIS, OSMI	Ocean color	raw data, uncalibrated chlorophyll-a images
Korea Meterological Administration	http://www.kma.go.kr/eng/wis/wis03_cw03.jsp	Korea Meterological Administration	Korea	Operation	NOAA, GOES-9, MODIS	SST, Yellow dust	images
Marine Meteorology and Earthquake Research Laboratory	http://marweb.metri.re.kr/english/index.html	Korea Meterological Administration	Korea	Research	NOAA	SST	images

5.5 Research activity of ocean color in Korea

- Ocean color research activities at NFRDI
  - NFRDI has established satellite data receiving station (IRS-P4, MODIS, NOAA) and Fisheries environmental monitoring program under MOMAF
  - The major applications at NFRDI are to the delineation of fishing ground information

- Ocean color research activities are spurred at three laboratories established within KORDI
  - Ocean optics and Ocean color Remote sensing technique development (including atmospheric correction) and physical/chemical ocean application

- Ocean color research activities at KARI
  - OSMI and MODIS data reception and management
  - Distribution of satellite data to users

- Coastal Ocean color monitoring at University
  - Pukyung national university conduct research in developing applications of coastal ocean monitoring technique by airborne.
  - Coastal application /GIS

- Atmospheric problems
  - Meteorological application of COMS

6 Challenges and Prospects

6.1 Present issues and Future Perspective

- To develop next generation SST (NGSST) for monitoring coastal water in NOWPAP region.
  - NFRDI and Tohoku University already developed the NGSST for monitoring open sea. Now, we need SST data with high resolution and cloud free to understand abnormal phenomena in coastal water on real time basis.

6.2 Observation Plan under Consideration (including sensor and satellite)

- To calibrate and validate Terra and Aqua/MODIS data in the NOWPAP region excluding Yellow Sea.
  - SeaWiFS was launched in 1997. So, NFRDI and other institute in Korea were able to get lots of match up data to calibrate and validate for SeaWiFS data. However, we do not have enough data for MODIS.

7 Suggested Activities of NOWPAP Region

7.1 Targeting the next two or three years

○ Monitoring on the effect of three Gorges dam on oceanographic environments

- The importance of monitoring changes in the Yangtze River due to the Three Gorges Dam, as these changes influence waters in the sea of NOWPAP region (Figure 21, 22 and 23)
- So, we would like to propose the monitoring influence of the Three Gorges Dam as NOWPAP projects

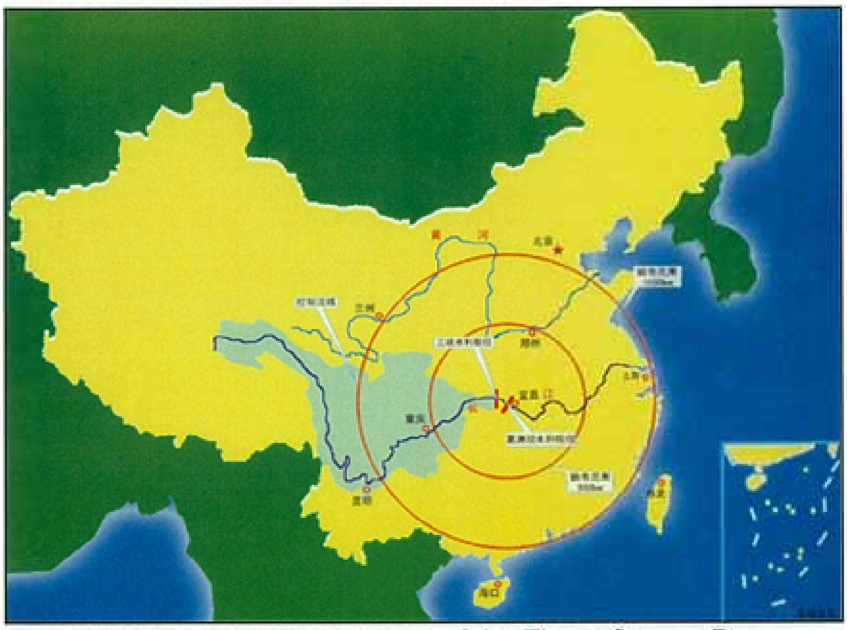


Figure 21. The location of the Three Gorges Dam.

Figure 22. The constructing site of the dam in 2003.

Figure 23. High-resolution satellite imagery of the opened dam in 2004.

○ Data production for ocean color calibration and validation using Ferry boats between Busan of Korea, Toyama of Japan and Vladivostok of Russia.
- It is important to set up the cooperative ferry monitoring of NOWPAP region for the ocean color of CAL/VAL (Figure 24).

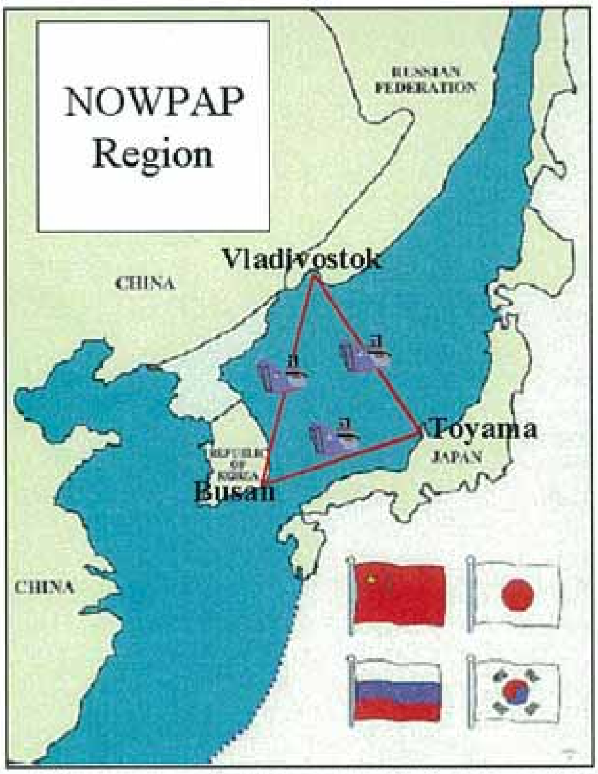


Figure 24. Scheme of the cooperative ferry monitoring to calibrate and validate ocean color satellite data in the NOWPAP region.

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NFRDI < http://www.nfrdi.re.kr/>

KODC < http://kodc.nfrdi.re.kr/>

KARI < http://www.kari.re.kr>

KORDI < http://www.kordi.re.kr/>

KMA < http://www.kma.go.kr/>

List of Acronyms

AVHRR	Advanced Very High Resolution Radiometers
COMS	Communication, Ocean and Meteorological Satellite
CVI	Corrected Vegetation Index
DMSP	Defense Meteorological Satellite Program
EOC	Electro Optical Camera
EOS	Earth Observing System
GMS	Geostationary Meteorological Satellite
GOCI	Geostationary Ocean Color Imager
IRS-P4	Indian Remote Sensing Satellite
KARI	Korea Aerospace Research Institute
KODC	Korea Oceanographic Data Center
KOMPSAT	KOrean Multi-Purpose SATellite
KORDI	Korea Ocean Research and Development Institute
MOMAF	Ministry of Maritime Affairs and Fisheries
MOBY	Marine Optical BuoY
MODIS	Moderate Resolution Imaging Spectrometer
MTSAT	Multi-functional Transport Satellite
MSC	Multi Spectral Camera
NASA	National Aeronautics and Space Administration
NFRDI	National Fisheries Research and Development Institute
NOAA	National Oceanic and Atmospheric Administration
NOWPAP	Northwest Pacific Action Plan
NPEC	Northwest Pacific Region Environmental Cooperation Center
OLS	Operational Linescan System
OSMI	Ocean Scanning Multispectral Imager
QuikSCAT	Quick Scatterometer
S-VISSR	Stretched-Visible Infrared Spin Scan Radiometer
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SIMBIOS	Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies
SST	Sea Surface Temperature
UNEP	United Nations Environment Programme
WG4	Working Group 4