Annex VI-3

Draft National Report on Ocean Remote Sensing in Korea

(Reviewed by the Second Meeting of NOWPAP WG4)

Contents

1 Status of Remote Sensing Utilization in Marine Environment Monitoring

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 2.3).

KOMPSAT-II
There is a project for developing of environmental analysis technique and software for coastal waters using MSC on KOMPSAT-II since 2003 (see section 3.1).

COMS
There is a project for developing of ocean data processing system for COMS-1 which will be equipped with GOSI of high resolution ocean color and multiple wave length channel based on a geostationary meteorological satellite (see section 3.1).

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 by remote sensing is summarized in Table 1 by sensors with the condition that they are used continuously.

Table 1. Status of Marine Environmental Monitoring by Remote Sensing
SST shows sea surface temperature, CHLA shows *chlorophyll-a* concentration and SS showed 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

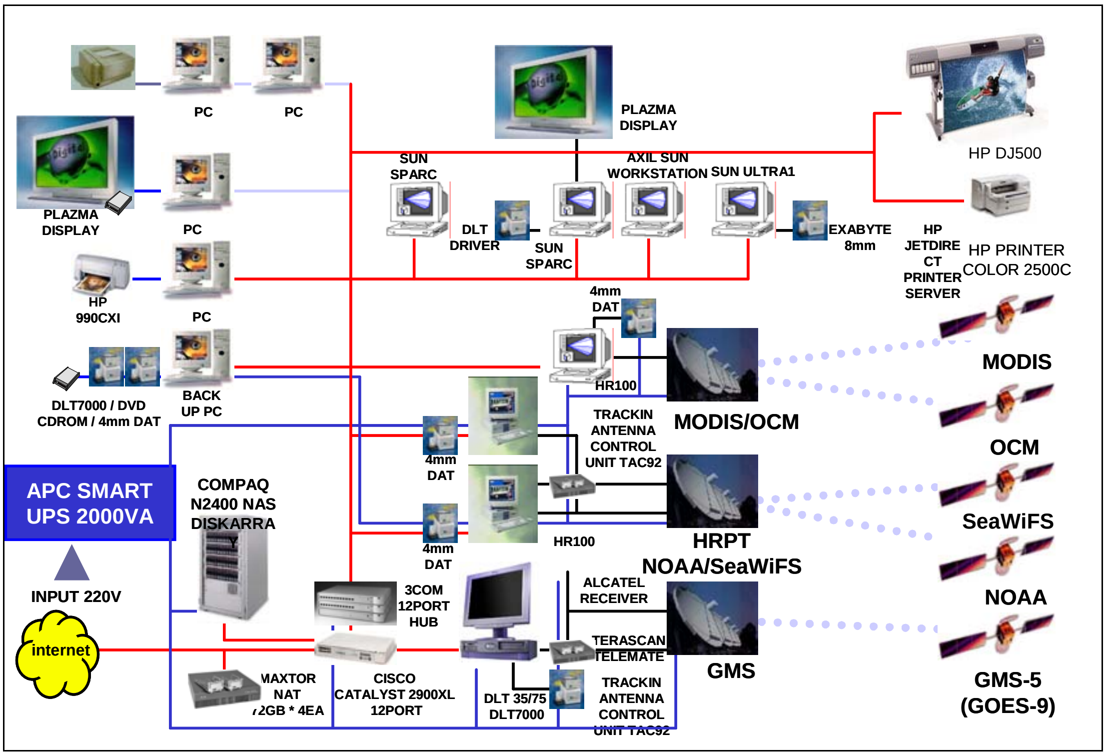
2 Case examples of RS application in marine environmental monitoring

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 1a).

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 1 and Figure 2) providing: SST charts with isothermal lines and 7-day composite color images of SST for nighttime by search condition of measurement data.

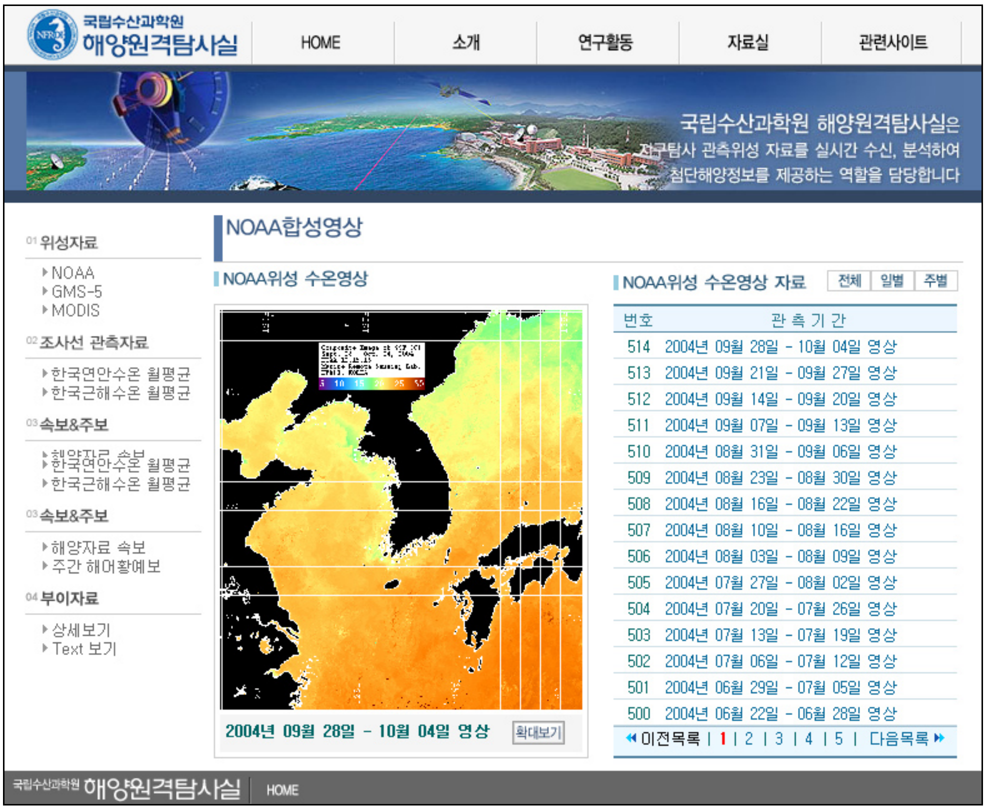
In addition to the above-mentioned data, MODIS suspended solid concentration images, a chart of SeaWiFS *chlorophyll-a* concentration a month is provided since January 2004 to further assist and promote marine environmental conservation and understanding of fish ground formation. The data and information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



(a) Marine Remote Sensing System

(b) Remote sensing data homepage

Figure 1. 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 2. 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 and some universities 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 3). The stripe problem on images of OSMI is studied by KORDI, Pukyong and Yonsei University. 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).

Figure 3. Korea Remote Sensing Center
< http://krsc.kari.re.kr/kari/eng/sub/main_all.htm>

2.3 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 varidate 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).

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-I
Korea Multi-Purpose Satellite-I (KOMPSAT-I) is mainly for ocean observation. KOMPSAT-I, as shown in figure 4, table 2, table 3 and table 4 has two sensors: Panchromatic – Electro Optical Camera (EOC) and Multi-spectral – Ocean Scanning Multi-spectral Imager (OSMI).

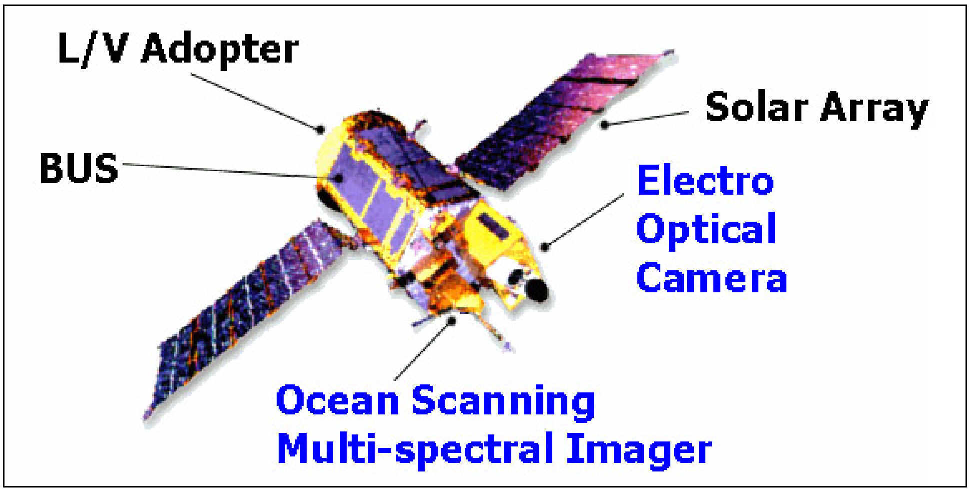


Figure 4. KOMPSAT-1 Overview
Source: KARI

Table 2. 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 3. 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 4. 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-II

Korea Multi-Purpose Satellite II (KOMPSAT-II) is mainly for land observation. KOMPSAT-II, as shown in figure 5, table 5 and table 6 has Multi-Spectral Camera (MSC) including Panchromatic (1 m, 1 band) and Multi-Spectral (4 m, 4 band).

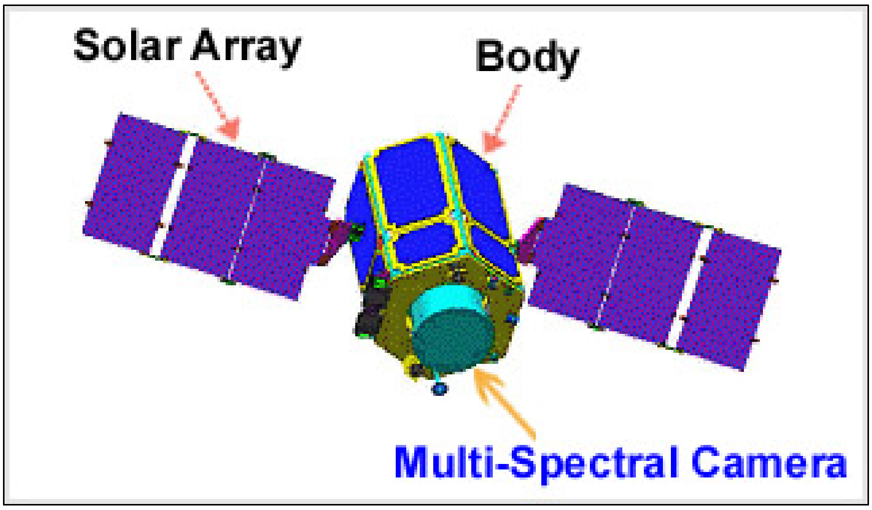


Figure 5. KOMPSAT-2 - Overview
Source: KARI

Table 5. 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 6. 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. 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 7, has two earth observing sensors: Geostationary Ocean Color Imager (GOCI) for estimating *Chlorophyll-a*, suspended solid, CDOM, etc. (Table 8); the meteorological sensor for all weather and land observation (Table 9).

Table 7. 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 8. 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 9. 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

3.2 Algorithm for Geo-physical Parameters

3.2.1 Salinity

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 6 and Figure 7). 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).

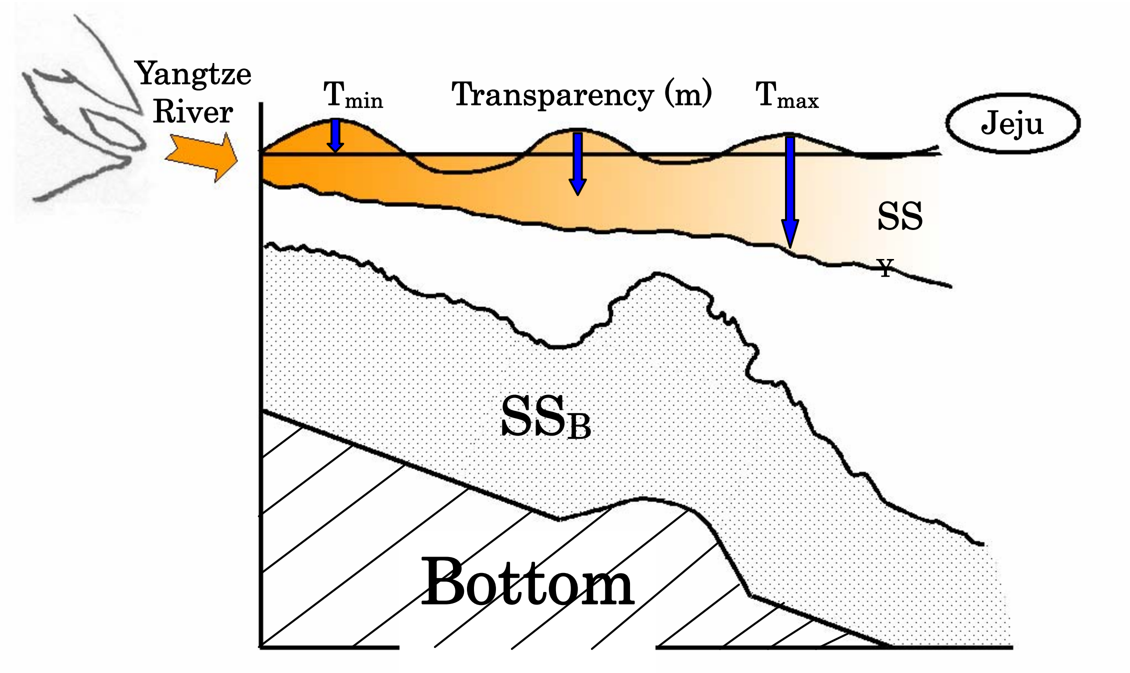


Figure 6. Schematic diagram of the vertical distribution of resuspended solid from the shallow bottom and surface suspended solid from the Yangtze River. SS_Y represents the surface turbid water from the Yangtze River. SS_B represents resuspended sediment from sea-bottom caused by sea wave. Estimated transparency is very high in the waters around Jeju Island than one in the coastal water of the Yangtze River (Suh et al., 2004a).

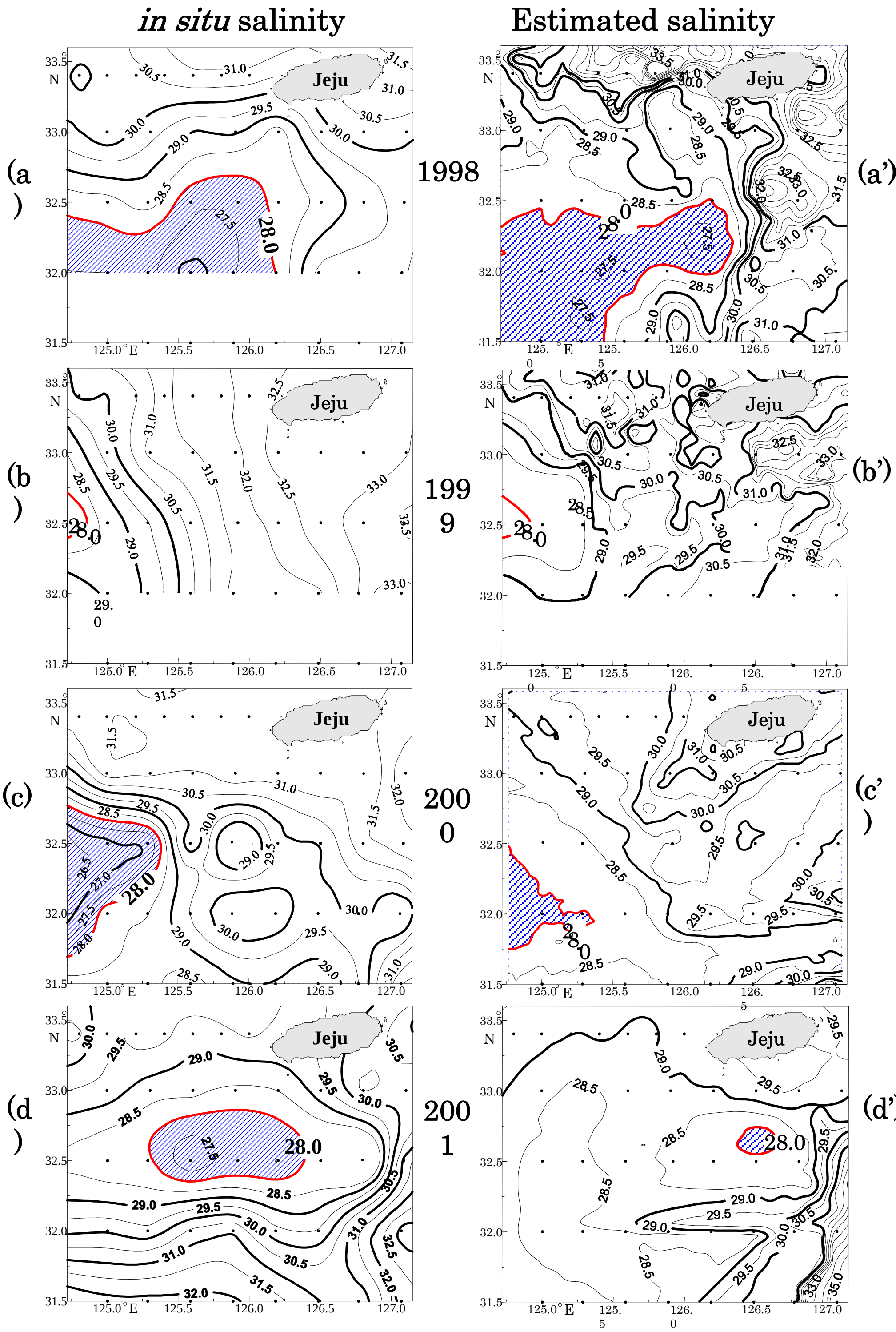


Figure 7. Distribution of surface salinity (psu) in August during 1998-2001. Measured field surface salinity in (a) 6-8 Aug., 1998, (b) 12-20 Aug., 1999, (c) 4-6 Aug., 2000, (d) 17-23 Aug., 2001. Estimated surface salinity from the SeaWiFS data using the developed regional algorithm in (a') 4 Aug., 1998, (b') 19 Aug., 1999, (c') 6 Aug., 2000, (d') 16 Aug., 2001 (Suh et al., 2004a).

3.2.2 *Chlorophyll-a* Concentration

3.2.2.1 Improvement of algorithm 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 8).

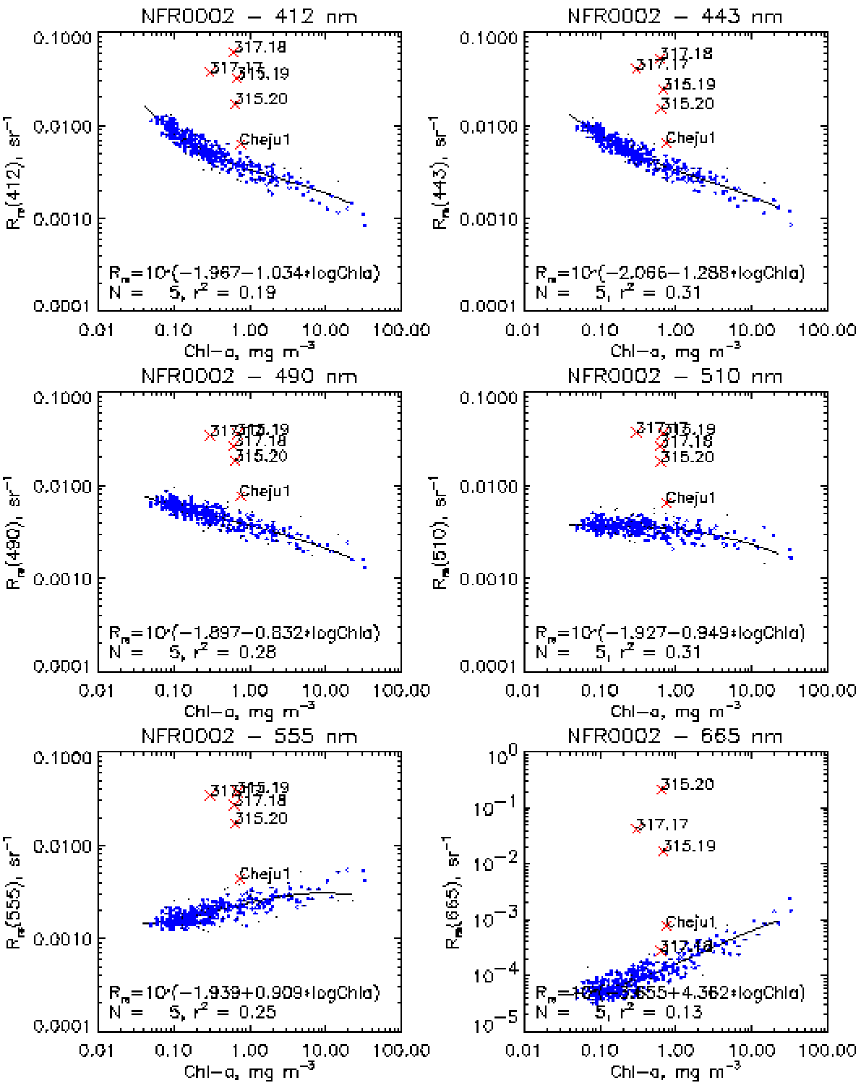


Figure 8. Remote sensing reflectance(Rrs) at SeaWiFS spectral bands(412, 443, 490, 510, 555, 665 nm) for the CalCOFI reference data set (●) and the NFRDI February data (×) in the East China Sea (Suh *et al*., 2001).

3.3 Validation of Geo-physical Parameters

○ Accuracy verification results of present products
- 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
- NFRDI : semi- or delayed data collection mode

○ Empirical equation of chlorophyll *a* in case Ⅱ water
- NFRDI has match up data (140 sets)

○ Comparison between OSMI and SeaWiFS chlorophyll *a*

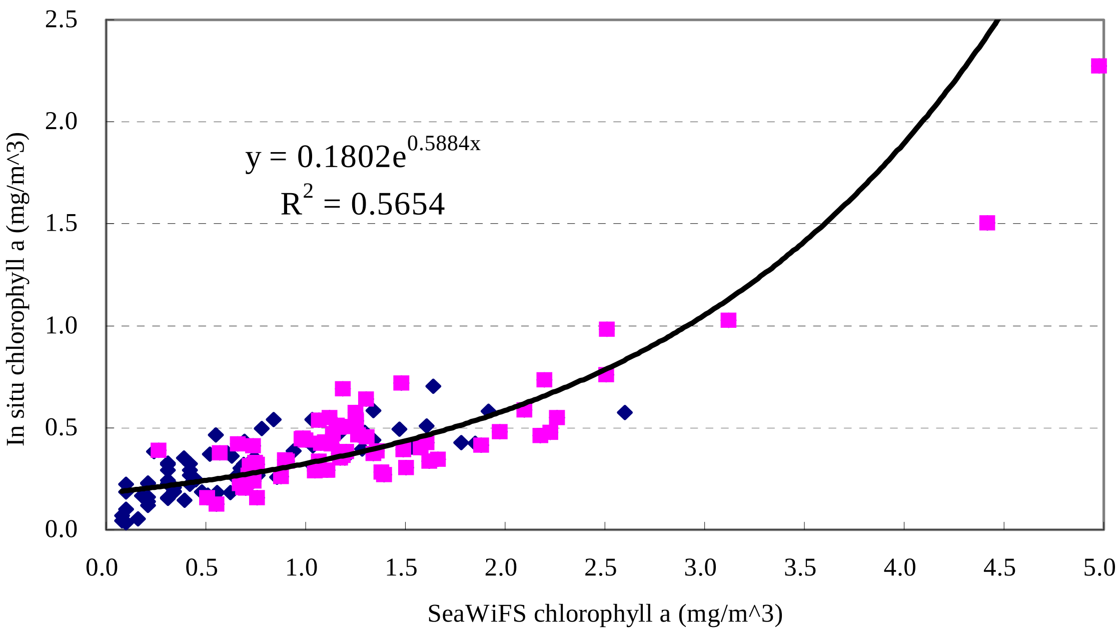


Figure 9. Match up data in the East China Sea between SeaWiFS data and *in situ* data.

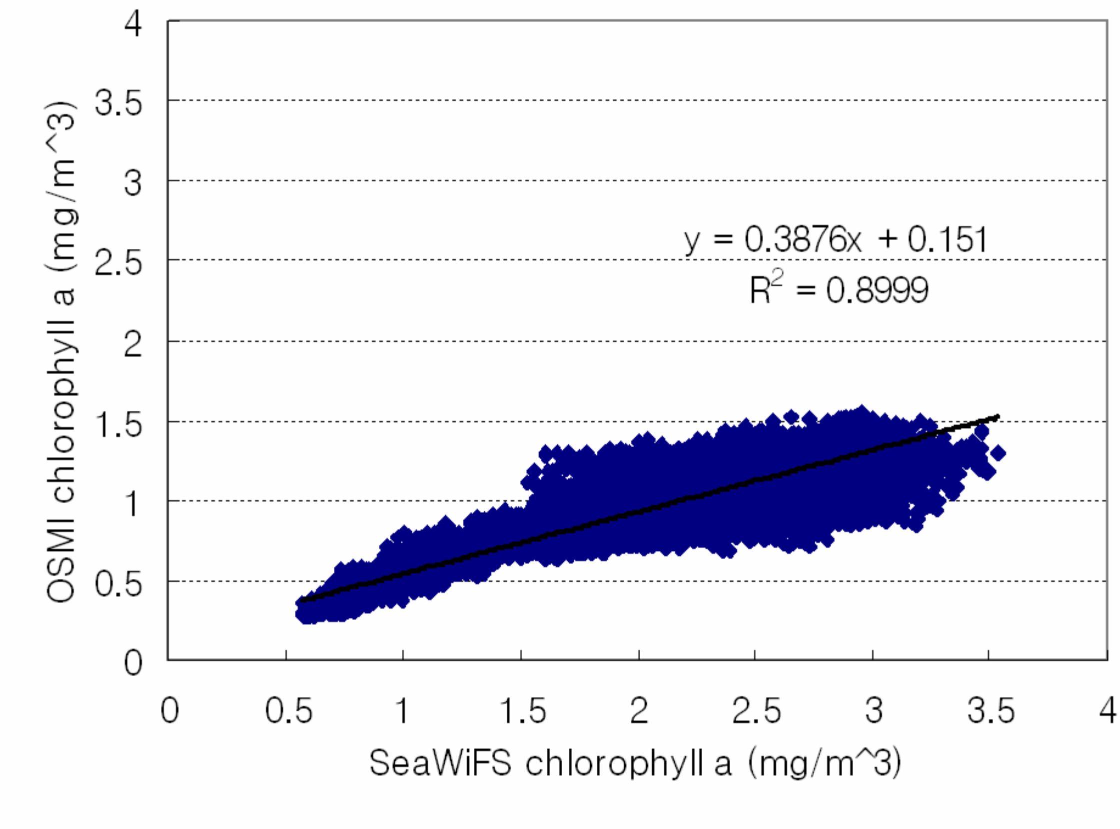


Figure 10. Relationship between chlorophyll a data from OSMI and SeaWiFS in the East China Sea on 15th February, 2004.

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. The distribution between differences in sea surface temperatures during the day and at night also showed a possibility for red tide detection. 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).

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. 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).

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. 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).

5 Strategies/Plans for RS related activities

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 10 and table 11.

Table 10. 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 11. 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

6 Challenges and Prospects

6.1 Present issues and Future Perspective

- The three Gorges dam of China
- MODIS data calibration and validation

6.2 Observation Plan under Consideration (including sensor and satellite)

- To calibrate and validate MODIS data in the East China Sea and he NOWPAP Region from 2004 to 2006

7 Suggested Activites of NOWPAP Region

7.1 Targeting the next two or three years

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

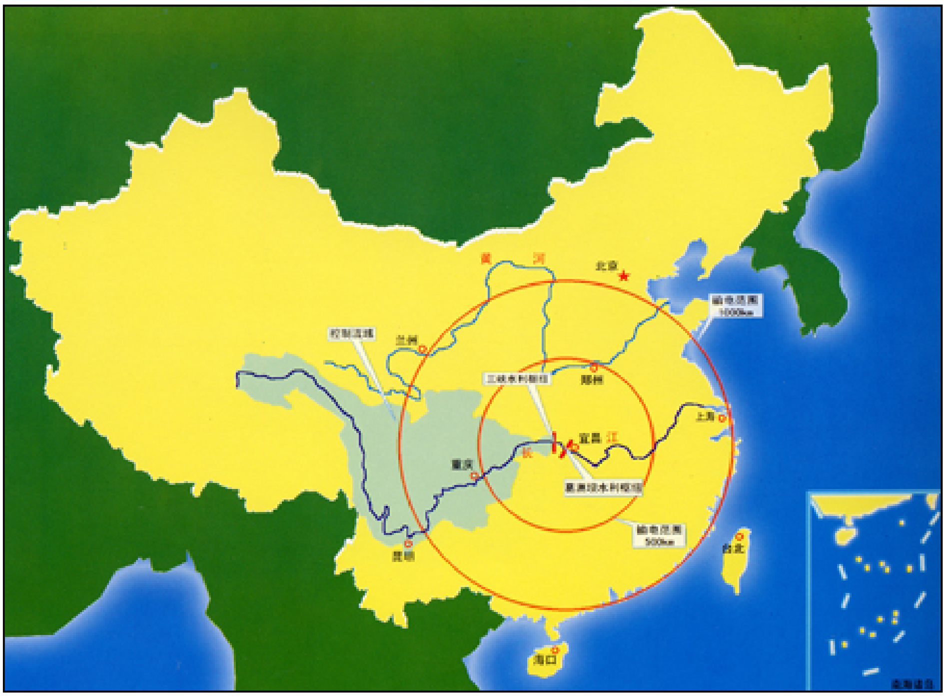
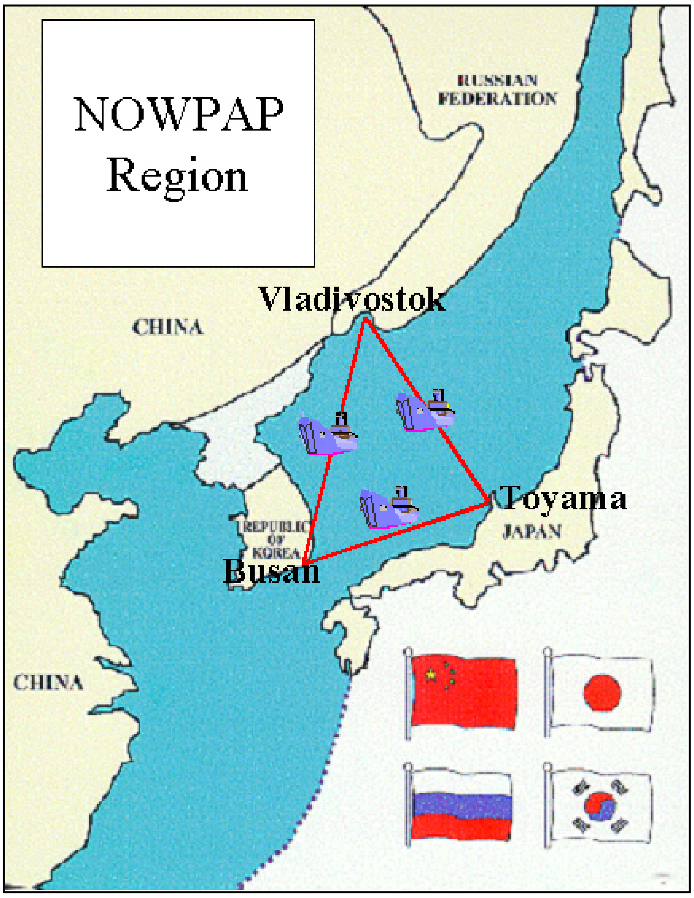


Figure 11. The location of the Three Gorges Dam.

Figure 12. The constructing site of the dam in 2003.

Figure 13. The opended 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.



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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/>

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