Annex X
Draft Integrated Report on Ocean Remote Sensing in the NOWPAP Region

Contents

1 Introduction

Frequent occurrence of large-scale red tide in the coastal areas of China and Korea, apparently originating from eutrophication, is now a serious issue causing increase in fishery damages, environment deterioration, and food poisoning from consumption of fish. Establishment of extensive and continuous monitoring system for observing the emergence of eutrophication (phytoplankton bloom) and red tide is essential to prevent such issues. In the past, observation has been made through reports from fishermen and periodical measurements of water quality by research institutes, costing much labor and expense. Phytoplankton blooms are sporadic in time and isolated in space, and are therefore hard to monitor by conventional (surface) means. The blooms can color surface waters over large areas and can therefore be imaged from space. Satellite ocean color sensors enable high frequency observation covering wide sea area, and capture spatial and temporal change of *chlorophyll-a* concentration, including intensive phytoplankton bloom. At present, no method has been found to determine from satellite data whether a bloom is “harmful” in its effects on humans, fish or other organisms. Practical application of remote sensing as a monitoring tool for eutrophication and red tide is expected based on the usage of more specific signatures of the blooms detected by satellite optical sensors.

Meanwhile, much of the traffic in the Northwest Pacific Ocean, one of the most crowded sea area in the world, is comprised of many tankers and heavy fuel oil cargoes. The potential risk of oil spills by accidents from these vessels is very high, damaging the local fishery and tourism, and subsequently degrading the marine environment to a great degree. Also, illegal oil dumping is not a negligible issue. Remote sensing, having wider coverage than the conventional methods and all-weather capability, is expected to detect widespread oil spills effectively and accurately at low level of false alarms, which is critical to minimize the damages and operational expenses.

Consequently, we propose that, for the time being, eutrophication and oil spill should be the main targets of marine environmental monitoring by remote sensing, as both of them are common environmental issues in the NOWPAP Region and both are expected to be targets for the remote sensing applications. Other targets can be included, depending on the importance of the monitoring and technical feasibility.

Remote sensing can provide data and information on *chlorophyll-a* concentration, suspended solids (SS), colored dissolved organic matter (CDOM), primary productivity of phytoplankton, red tide, sea surface temperature (SST) fields, and can help to analyze mechanisms of eutrophication and red tide, to predict red tide, and to provide information for adaptation and mitigation for eutrophication. Concerning eutrophication monitoring, for the time being, monitoring parameters should be 1) *chlorophyll-a* concentration that is already in practical use and is a good indicator of eutrophication; and 2) primary productivity that is estimated by observed *chlorophyll-a* concentration, SST, and photosynthetically available radiation (PAR). Monitoring red tide by remote sensing would be considered in a mid- and long-term range in accordance with the progress of observation technologies because it has many issues yet to be solved.

Concerning oil spill monitoring, remote sensing can provide data and information on early detection of spills, size estimates, damage assessment, location of oceanic dynamic features (current and river outflow fronts, eddies, etc.), fields of physical oceanic and atmospheric parameters (wind, waves, SST, etc.), and can help to identify the polluters including accidents and illegal discharge of waste waters from ships, to predict the movement and weathering of the spill, and possibly the nature and thickness of the oil.

We have set the final goal of our activities as ‘establishing cooperative marine environmental monitoring by remote sensing, to contribute to conservation of marine environment in the NOWPAP Region’. To achieve the goal, there are many things to be considered thoroughly including: identification and solution of technical issues of marine environmental monitoring by remote sensing; and technical and financial arrangement in the NOWPAP Region. This Integrated

Report aims at sharing common understanding which is necessary to discuss these issues and informing the progress internationally.

2 Status of Remote Sensing Utilization in Marine Environmental Monitoring

Presently, various sensors have been utilized for a marine environmental monitoring by remote sensing in the NOWPAP Region. Sea-viewing Wide Field-of-view Sensor (SeaWiFS) and Moderate Resolution Imaging Spectrometer (MODIS) are mainly utilized for monitoring of red tide and eutrophication. Domestic product, Chinese Ocean Color and Temperature Scanner (COCTS) and Charge-coupled Device (CCD), are used in China and Ocean Colour Monitor (OCM) with high spatial resolution is also used in Korea. For locating the fishery ground, Advanced Very High Resolution Radiometers (AVHRR) is mainly used. Apart from that, Multi-channel Visible and IR Scan Radiometer (MVISR), product from China, is used in China and Russia, and Ocean Scanning Multi-spectral Imager (OSMI) and Electro Optical Camera (EOC) which are both product of Korea, are used in Korea. For detecting oil spills and sea ice, both Synthetic Aperture Radar (SAR) and Advanced Synthetic Aperture Radar (ASAR) are used commonly. These sensors, together with Advanced Microwave Scanning Radiometer for Earth Observing System (AMSR-E) from Japan and Altimeter, greatly contribute in understanding the dynamics of various maritime phenomena, such as current, fronts, eddies, upwellings, internal and surface ocean waves, and so on as well as atmospheric phenomena such as cyclones, fronts, convective eddies, mesoscale cells and rolls. In China, Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+) and also sensors installed in China Brazil Earth Resources Satellite (CBERS), which were jointly developed by China and Brazil, are used for monitoring coastal erosion in estuaries of big rivers.

2.1 China

China has taken a great progress of ocean environment remote sensing in last 3 years. The third space ship Shen Zhou-3 (SZ-3), the first ocean satellite Hai Yang-1A (HY-1A) and the fourth space ship SZ-4 have been respectively launched in March, May and December 2002. Their sensors on the spacecraft have reasonable availability and measurement accuracy. Chinese Moderate Imaging Spectra Radiometer (CMODIS) on SZ-3, COCTS and Coastal Zone Imaging (CZI) on HY-1A data are applied for ocean remote environment detection and show the great application potentiality, such as coastal water quality monitoring, fishery resources protection, development and utilization, coastal engineering environment, and oceanography.

Ocean is very important strategy in national economy of China. Chinese government is realizing day by day that one or two satellites is not enough to understanding what have happened or what will be happened in huge Chinese ocean area. The series satellite program for marine application is necessary to be planed and developed. Three series of marine remote sensing satellite are planned in China for future. They are ocean color satellite series HY-1, dynamic satellite series HY-2 and comprehensive satellite series HY-3 (Pan Delu, 2004).

2.2 Japan

To contribute to the conservation of the global environment, which provides a common basis for human living, Japan has so far developed and operated two earth-observing satellites, Advanced Earth Observing Satellite (ADEOS) and ADEOS-II, under National Space Development Agency of Japan (NASDA) (now Japan Aerospace Exploration Agency (JAXA)). Ocean Color and Temperature Scanner (OCTS) equipment on the ADEOS satellite has contributed to ocean environmental monitoring by ocean color, as did OrbView-2 SeaWiFS, launched by the US in 1997 (Saino, 1998; Kawamura and the OCTS-team, 1998; Shimada *et al.*, 1998). ADEOS-II was equipped with Global Imager (GLI) on the OCTS development, which enabled frequent, accurate and global observations of various geo-physical parameters in the ocean (Ishizaka *et al.*, 2004). The results were later applied to MODIS higher-level products by JAXA Earth Observation Research and application Center (EORC), targeting the sea surrounding Japan.

Products from MODIS and from AVHRR have been used for monitoring projects such as the

Marine Environmental Watch Project, monitoring of areas frequently damaged by red tides, search for fishing area, and primary productivity on a global level. In addition, AMSR-E and its higher-level products have been used in the development of the New Generation Sea Surface Temperature (NGSST) for Open Ocean.

2.3 Korea

National Fisheries Research and Development Institute (NFRDI) has been receiving NOAA AVHRR data to study on the abnormal phenomena in the Korean waters since 1989. And then, NFRDI has been receiving SeaWiFS, MODIS and OCM data on real time basis since 1998. Korea Ocean Research and Development Institute (KORDI) has been operating SeaWiFS receiving station on delay mode basis since 1998.

Korea Aerospace Research Institute (KARI) launched KOMPSAT-I (Korean Multi-Purpose Satellite) in December 1999. KOMPSAT-I is used mainly for ocean observation, and it has two sensors: panchromatic - EOC and multi-spectral - OSMI. During 2001-2004, joint study on OSMI calibration/validation using SeaWiFS and *in situ* data was carried out, under cooperation scheme between Korea and National Aeronautics and Space Administration (NASA) of US. Products of *chlorophyll-a* concentration by SeaWiFS and OCM data, sea surface temperature by AVHRR data as well as suspended solid by MODIS data, have been actively used for monitoring projects such as 'operation of application system to produce ocean information derived from earth observation satellites'.

2.4 Russia

Okean-7 and Okean-8, equipped with a wavelength of 3 cm Real Aperture Radar (RAR), were launched in 1994 and 1995, with the last RAR images taken by Okean-7 in February 2000. RAR images with their spatial resolution of 1-3 km have been an important source of meso-scale and sub-synoptic scale information on sea ice, near-surface winds for air-sea interaction, and ocean dynamics. Radar images have been used operationally, especially in preparation of maps of ice conditions.

Almaz-1 and Almaz-1 B, equipped with a wavelength of 9.6 cm SAR, was launched in 1991 and operated during 18 months. The SAR images provided significant capability for observing ocean processes and brought about series of quantitative scientific findings and theoretical advances in open-ocean, coastal-ocean and marine operations, sea ice, and marine boundary layer meteorology, environmental monitoring including oil spill detection (Mitnik, 2003; Wilson, 2005).

Federal Space Program (FSP) of Russia (2001-2005) includes remote sensing of the Earth, hydro-meteorological observations, ecological monitoring and catastrophe monitoring. In particular, the following problems are solved by using these technologies: monitoring of sources of pollution in the atmosphere, water and soil, and providing information to the state and regional units to enable environmental control; operational monitoring of natural and technological crisis; launching Meteor-M and Electro-L and utilizing them in international hydro-meteorological observation system; receiving, processing and distributing remote sensing data from Russian and foreign satellites. This project on 2006-2015 forecasting the significant increase of finances of Space sector was recently approved by Russian government.

In Federal Target-Oriented Program 'World Ocean' (2003-2007), the main goal is to investigate dynamic phenomena and processes in the Far Eastern Seas and in the Northwest Pacific Ocean on the basis of development and application of remote acoustic, optical and passive and active microwave techniques. The project will allow studying the structure, composition and spatial distribution of meso- and submeso-scale unhomogeneities, their temporal variability using remote techniques in the Japan and Okhotsk Seas including a shelf zone and transition zone between shallow waters and deep sea. Systems of operational detection and forecast of transfer and degradation of oil pollution adapted to the Primorye and Sakhalin shelf conditions will be created.

3 Case Examples of Remote Sensing Application in Marine Environmental Monitoring

3.1 China

In order to monitor the ice in Bohai Sea, various sensors, AVHRR, S-VISSR, and SeaWiFS were used and many different methods were developed. And an operational system has been put into work. The scientists from China Ocean University and the First Institute of Marine Sciences of SOA in Qingdao, and National Ocean Environment Prediction Center of SOA conducted many studies in the application of remote sensing technologies to sea ice studies.

Institute of Geography of Chinese Academy of Sciences (CAS) and Institute of Oceanography of CAS has conducted many researches for the coastal monitoring, including coastal bank erosion and shoreline changes in the Yellow River Delta with Landsat images (Figure 1).

Many researches have been devoted to the monitoring of red tides in China coastal oceans. Early work was focused on application of NOAA and SeaWiFS data by the researchers in the Second Institute of Marine Science of SOA. Various methods to extract red tides information from the satellite images has developed, and successfully applied these methods to red tide monitoring in Bohai. Also a semi-analytical method to detect the red tide by MODIS images on the basis of the many spectral measures and analysis has been proposed (Figure 2).

In the early 1990's, a comprehensive survey of land use and land cover along the coastal zone was conducted with using Landsat TM/ETM. Based on the results, land use and land cover database was also developed. Central and provincial governments are using this database for the regional planning and management.

3.2 Japan

In order to promote NOWPAP, the Ministry of the Environment of Japan has been working with the Northwest Pacific Region Environmental Cooperation Center (NPEC) to prepare the Marine Environmental Watch Project utilizing satellite remote sensing, which is in operation since March 2002, receiving AVHRR and Multi-channel Visible and Infrared Scan Radiometer. Measured data are widely available through the Internet, providing images and data of *chlorophyll-a*, SST and Normalized Difference Vegetation Index, and so on, Those provided data can be searched by observation date, and cloud coverage and other parameters(Figure 3).

In the coastal area of the Uwajima Sea, water temperature varies enormously due to the intrusion of the Kuroshio current from the Pacific Ocean. To quickly provide information on water temperature changes to fishermen and others with SST images by AVHRR and ocean color images by MODIS, Ehime prefecture and the Center for Marine Environmental Studies at Ehime University collaboratively operate the Coastal Information System. The ocean color images by MODIS are adopted from higher-level products provided by EORC, JAXA (Figure 4).

Researchers in the faculty of fisheries at Nagasaki University organized 'Ariake Sea Project'. The effort is currently being made to accumulate daily images of *chlorophyll-a* concentrations in the Ariake Sea, derived from MODIS higher-level products distributed by EORC, JAXA. The goal of this work is to clarify red-tide dynamics through the analysis of these data (Figure 5).

3.3 Korea

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 AVHRR, SeaWiFS, MODIS, OCM and SVISSR that are expected for marine environment and fishing ground environment monitoring. The contents are opened through the Internet providing: SST charts with isothermal lines and 7-day composite color images of SST for nighttime by search condition of measurement data. MODIS suspended solid concentration images, a chart of SeaWiFS *chlorophyll-a* concentration a month have been provided since January 2004 (Figure 6).

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). Especially the application of OSMI data for fisheries oceanography is studied.

3.4 Russia

V.I. Il'ichev Pacific Oceanological Institute of Far Eastern Branch of Russian Academy of Siences (POI FEB RAS) carries out research on three ongoing ESA projects dealing with the oceanic dynamic phenomena study in the NOWPAP Region: The results of preliminary POI research on oil spill detection and monitoring are summarized in the CEARAC Website as shown in Figure 7. Database consists now of several tens of ERS-1 and ERS-2 SAR images. Number of SAR images is supposed to increase and provide annotation for each image.

The FEB RAS Centre for the Regional Satellite Monitoring of Environment is receiving, processing, transferring, and archiving NOAA, GMS, and FY-2 data for monitoring of the ocean and the atmosphere. The Centre products include the calibrated images, SST maps, and the surface current velocities computed with the using of marine marker technique. The Centre conducts the Regional Satellite Monitoring of various objects and processes in the frames of scientific programs and applications of Institutes participated.

The most fruitful approach is the joint usage and analysis of the various satellite products. This approach was realized in All-Russia scientific-research and planning-construction Institute for Economy, Information and Automatic Systems of Management where information technology of remote determination of primary productivity in the ocean was developed. Data from NOAA, TOPEX/Poseidon, SeaWiFS and ERS-2 as well as information on catch are used in the system to produce a new product by integration of various data (Figure 8)

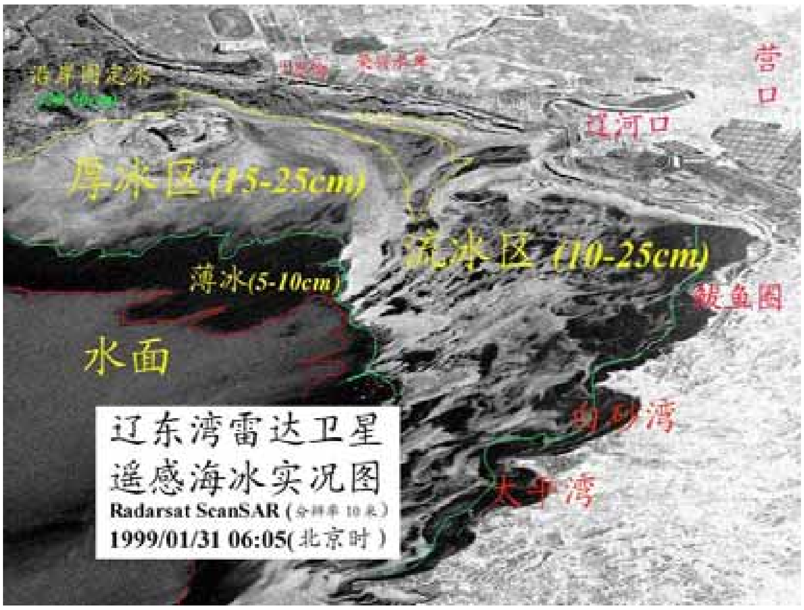
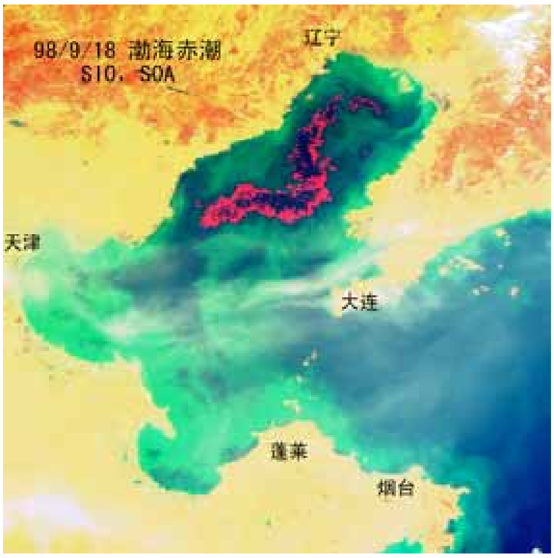
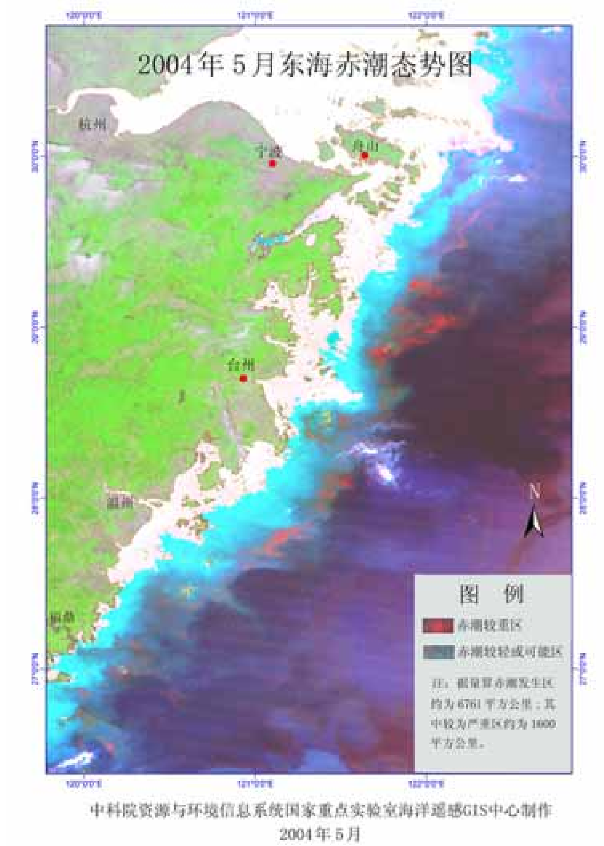


Figure 1. Bohai Ice monitoring by using ScanSAR in January 1999



(a) September 1998 (SeaWiFS)



(b) May 2004 (MODIS)

Figure 2. Red tide monitoring in China

Figure 3. Marine Environmental Watch Project
http://www.nowpap3.go.jp/jsw/eng/index.html

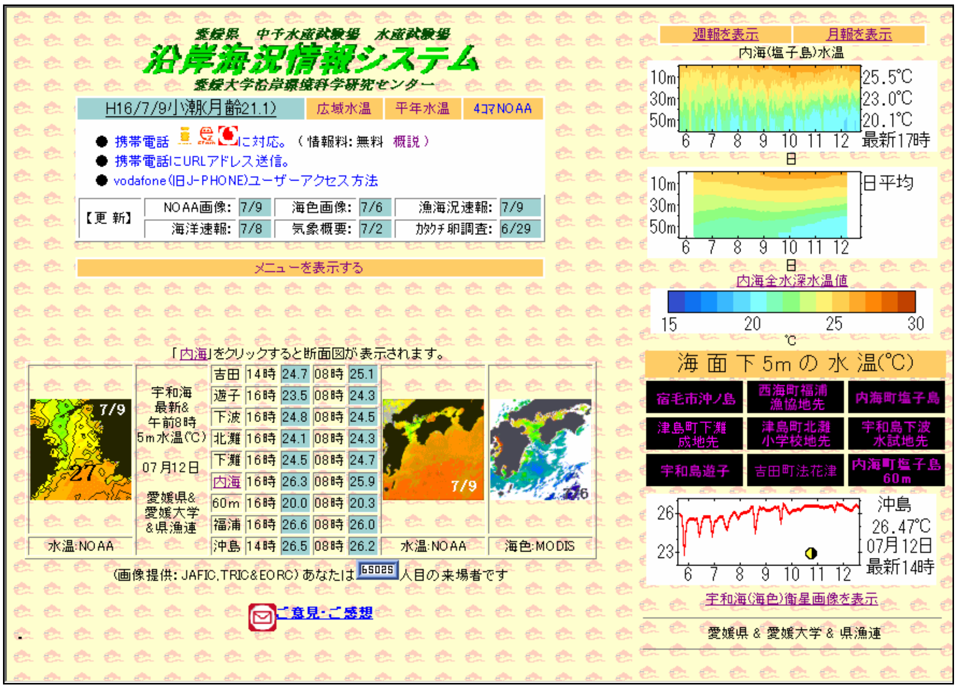


Figure 4. Ehime Prefecture Coastal Information System
http://www8.ocn.ne.jp/~ehchusui/

Figure 5. Links to *Chlorophyll-a* Images of the Ariake Sea by MODIS
<http://w3.fish.nagasaki-u.ac.jp/FISH/KYOUKAN/ISHIZAKA/MODIS/>

Figure 6. Marine Remote Sensing Laboratory, NFRDI
<http://www.nfrda.re.kr/korea/mrsl/data_mrsl.htm>

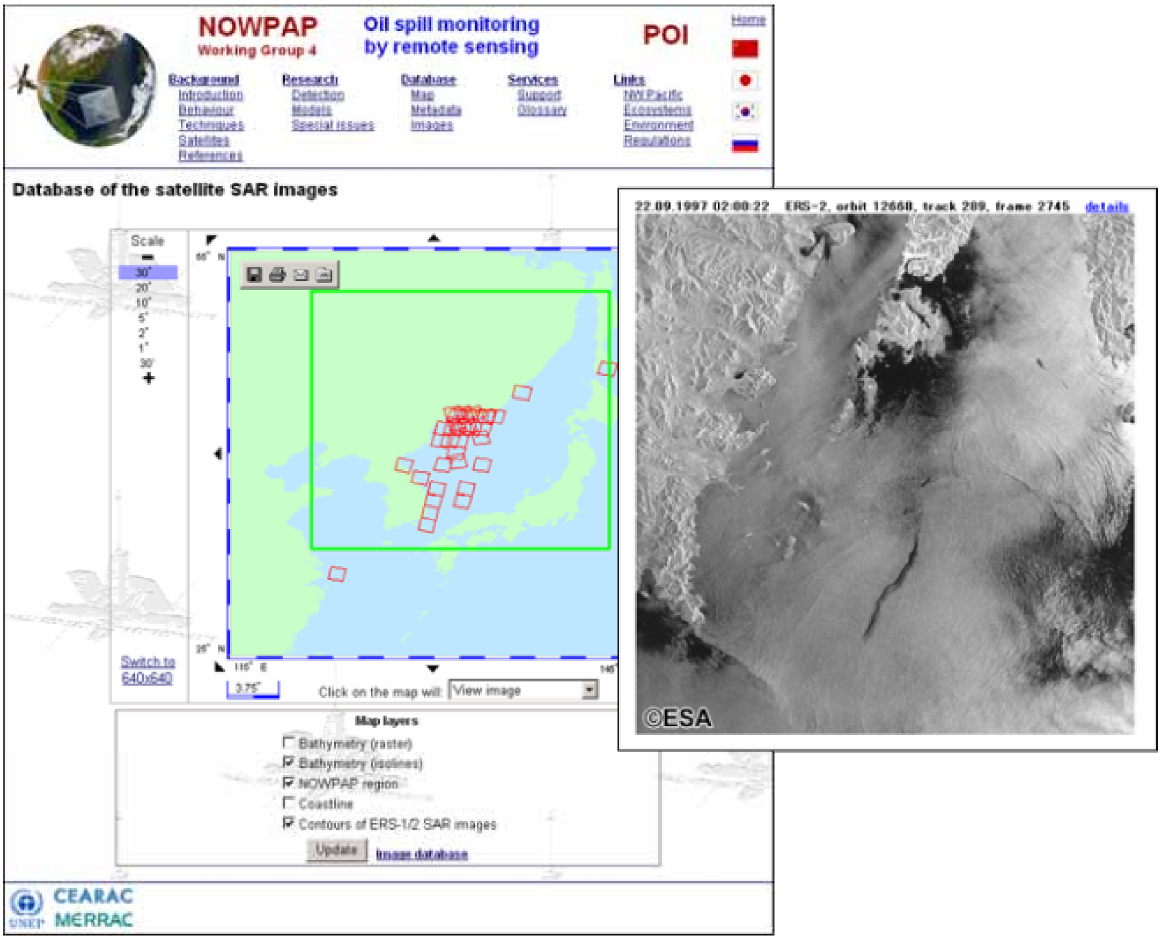


Figure 7. Oil spill monitoring in the NOWPAP Region, POI
http://cearac.poi.dvo.ru/

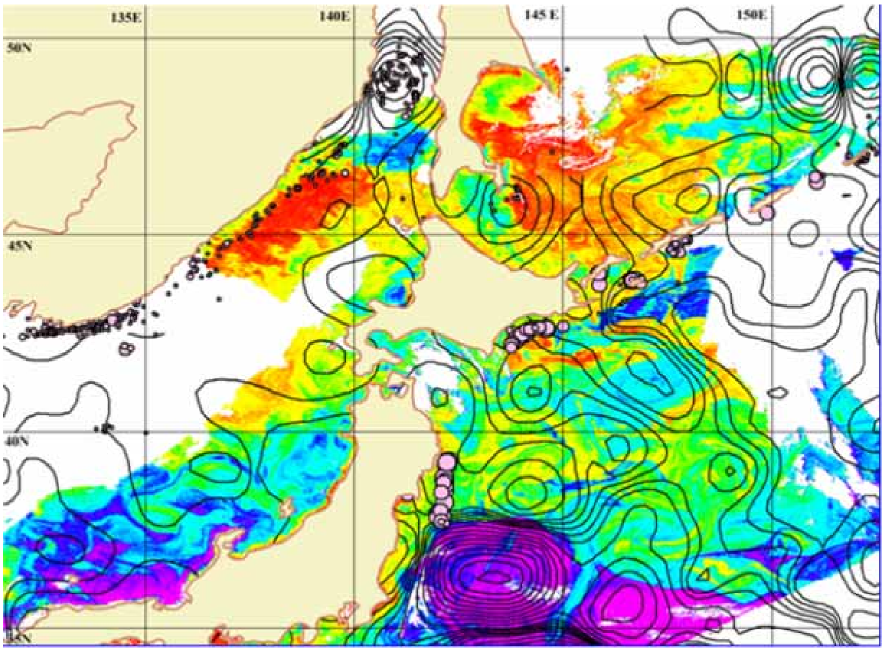


Figure 8. Integration of satellite products with fishing boat catch

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

4.1 Sensor and Satellite

4.1.1 HY-1B (China)

As HY-1A was out of work, HY-1B will be launched in late 2005. The technical indicators are same as HY-1A.

4.1.2 ALOS (Japan)

The aim of using ALOS, the Advanced Land Observing Satellite, is to improve the land observing technologies, i.e. cartography, regional observation, disaster monitoring, resources surveying, and technology development, of Japanese Earth Resources Satellite-1 (JERS-1) and ADEOS by collecting global land-observation data with high resolution.

ALOS, as shown in Figure 9, has three earth observing sensors: the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping; the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) for precise land coverage observation; and PALSAR for day and night and all-weather land observations. In oceanography and coastal zone related research, an algorithm for products from PALSAR data, such as data sets for sea-surface wind and wave-height, sea ice, and oil spills, is discussed. For oil spill detection, use of PASLAR and AVNIR-2 is expected to contribute to effective surveillance, collection and reduction of oil-spill damage. Furthermore, progress on studies in air-sea interactions, sea waves and the dynamics of phenomena in the coastal and open ocean, is expected to accelerate clarification of the mechanisms and modeling of eutrophication and related red tides.

Measuring ocean phenomena such as surface-wind waves, internal waves, sea-surface roughness and other features is dependent on characteristics of synthetic aperture radar, including observation frequency, polarization and off nadir angle. JERS-1 made observations primarily over land from 1992 to 1998. JERS-1 SAR provided many unique images over the ocean and provided oceanic information on surface-wind waves, eddies, currents and surface roughness (Asanuma *et al.*, 2003). It is expected that ALOS PALSAR will take over JERS-1 SAR for producing the data for marine applications.

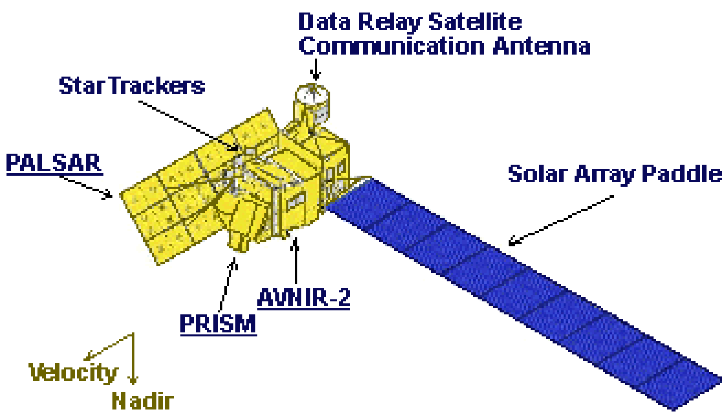


Figure 9. ALOS - Overview -
Source: ALOS@EORC

4.1.3 KOMPSAT-II (Korea)

Korea Multi-Purpose Satellite II (KOMPSAT-II), as shown in Figure 10, will carry Multi-spectral Camera (MSC) of very high spatial resolution (4 m) and spectral resolution corresponding to Landsat-5 TM, which will enable enhanced understanding of intricate and striking patterns of small-scale biological and physical phenomena, especially in the coastal area. KARI will launch KOMPSAT-II in the end of 2005.

4.1.4 COMS (Korea)

COMS, Communication Ocean and Meteorology Satellite, is mainly for atmospheric and marine observation. It will be launched in 2008. COMS has three major missions: 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-/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 multi-media communication service.

COMS, as shown in Figure 11, has two earth observing sensors: Geostationary Ocean Color Imager (GOCI) for estimating *chlorophyll-a*, suspended solid, CDOM, etc. GOCI will be very useful for monitoring red tide and variations of ocean color related to the marine pollution, with a spatial resolution of 500 m and a temporal resolution of 1 hour.

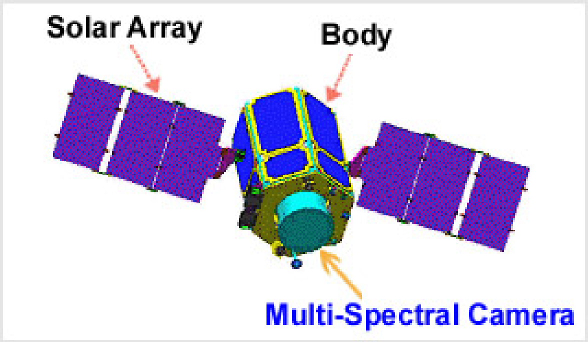


Figure 10. KOMPSAT-2 - Overview -
Source: KARI

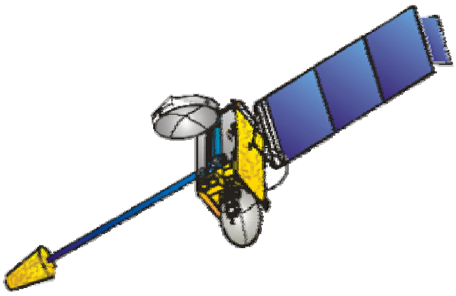


Figure 11. COMS - Overview -
Source: KARI

4.1.5 Meteor-3M #2 (Russia)

Meteor-3M #2 will be launched in 2006. Observations of the ocean will be carried out with the usage of several sensors such as MTVZA-OK, MSU-EU, MSU-S, MIVZA, and MTVZA.

4.2 Algorithms for Geo-physical Parameters

4.2.1 Sea Surface Temperature

The NGSST Development Group, with members from Tohoku University, NFRDI, etc., has been working on a new satellite-based SST product that overcomes the weakness of the present operational SST products. The group opened the website of 'New Generation Sea Surface Temperature for Open Ocean Ver. 1.0 Real-time Demonstration Operation' in June 2003. The new SST product, 'Merged SST', is generated from objectively merged SST data obtained by AVHRR, MODIS and AMSR-E, enabling the provision of proper SST data on a relatively small scale and with a quick response time (Figure 12). Merged SST needs data of the target day and its previous 4 days. The delay to its broadcast is one day. Currently, the NGSST is under development and is targeting coastal areas with a spatial resolution of 1 km and a distribution frequency of 4 times per day.

This NGSST is a project of the Ocean Remote Sensing Programme of United Nations Educational, Scientific and Cultural Organization (UNESCO)/ The Intergovernmental Oceanographic Commission (IOC)/ IOC Sub-Commission for the Western Pacific (WESTPAC), and is supported by IOC and the Special Coordination Funds for Promoting Science and Technology for the 'New Generation Sea Surface Temperature'.

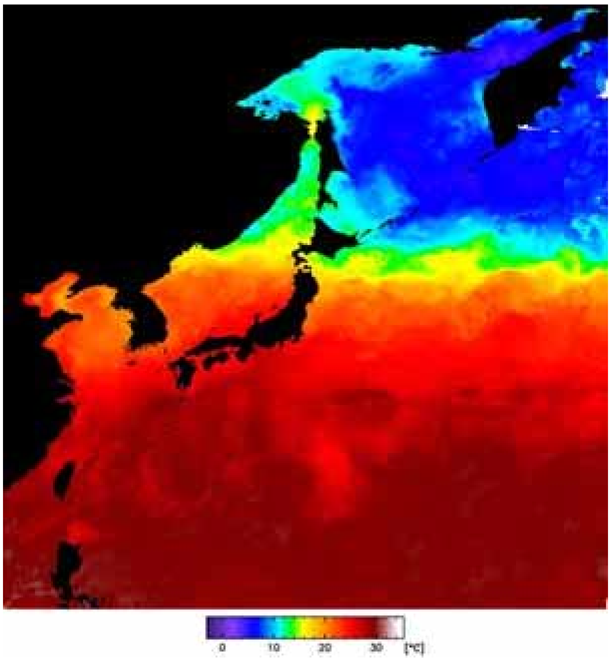
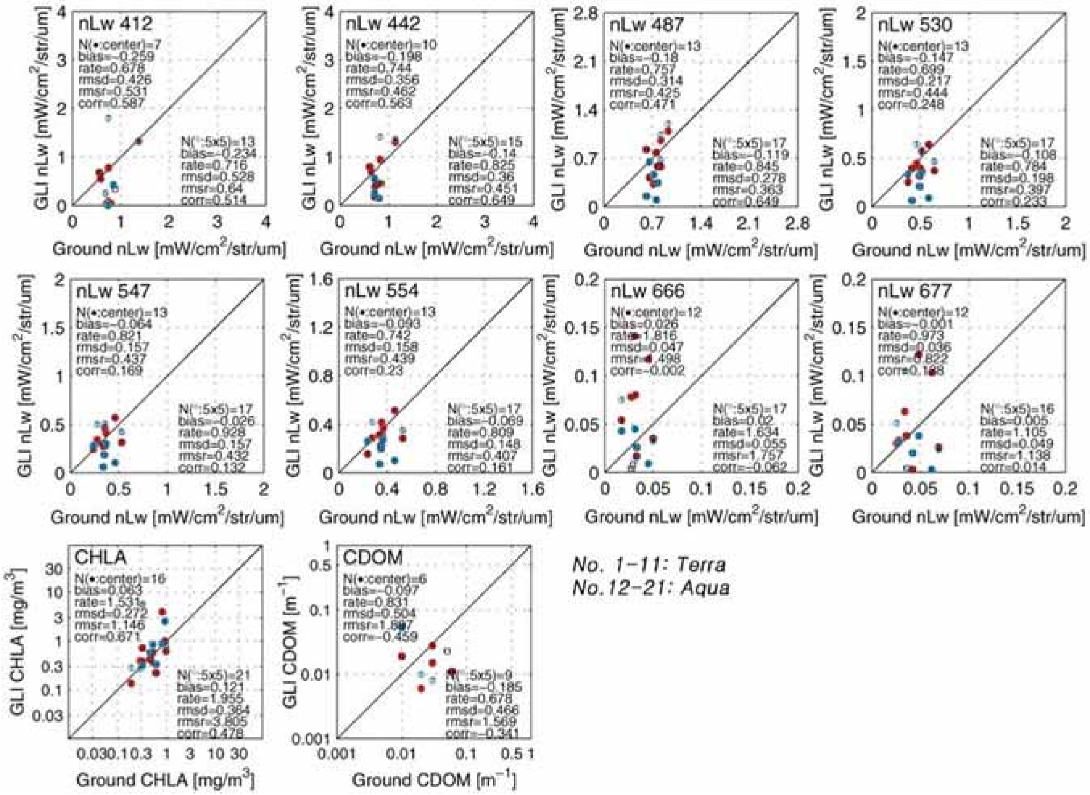


Figure 12. New Generation Sea Surface Temperature on July 12, 2004

4.2.2 *Chlorophyll-a* Concentration

For the estimation of physical quantities of *chlorophyll-a* concentration, EORC, JAXA has been using an algorithm prepared for ADEOS-II GLI since 2002, when the center started near real-time processing of MODIS data. After the launch of ADEOS-II at the end of 2002, calibration, verification and algorithms were made for GLI. In May 2004, the results were applied to MODIS higher-level products to improve their accuracy. The improved algorithms were verified in ocean color observations in the East China Sea from February to March 2004, and the estimated radiance spectrum and *chlorophyll-a* concentration agreed well with the *in situ* data (Figure 13). There was some discrepancy between the estimated values and *in situ* data, which was due to an atmospheric correction error caused by aerosol absorption, and will be a future research topic (Murakami *et al*., 2004).

Toyama Bay Project is on-going as 3 year project commencing from 2003, aiming to show the effectiveness of remote sensing as a monitoring technique for the marine environment. The project is conducted as a NOWPAP project, with the cooperation of the Ministry of the Environment of Japan, NPEC, Nagasaki University, Toyama University, Toyama Prefectural Fisheries Experimental Station and Toyama Prefectural Environmental Science Research Center. In 2003, *in situ* surveys and accuracy verification was conducted for SST and *chlorophyll-a* concentration of AVHRR and MODIS. In the fiscal year 2004, the project continued the same surveys and obtained more *in situ* data to improve the in-water algorithms that estimate *chlorophyll-a* and SS concentrations. In order to demonstrate the effectiveness of remote sensing, the project will attempt to develop more accurate in-water algorithms using past SeaWiFS data.



X-axis shows *in situ* data. Y-axis shows data estimated by MODIS. Red dots show Terra. Blue dots show Aqua.

Figure 13. Comparison between *in situ* and estimated data (Murakami *et al*., 2004)

4.2.3 Primary Productivity

A depth and time resolved primary productivity model was proposed and validated with *in situ* and simulated *in situ* incubations using 13C in the western Pacific Ocean. In this model, a vertical distribution of PAR is modeled based on the *chlorophyll-a* concentration in the surface layer, where the assumption that the surface *chlorophyll-a* concentration determines the light field. A vertical distribution of *chlorophyll-a* concentration is modeled with an empirical equation, in which a *chlorophyll* maximum is observed along the vertical distribution of PAR. A carbon fixation rate is modeled as a function of PAR and temperature, in contrast to previous studies, a temperature dependent function is significantly improved. With finding an optimum vertical distribution of PAR for various combination of *chlorophyll-a* concentration and diffused attenuation coefficient, the depth and time resolved primary productivity model exhibited a good correlation with *in situ* and simulated *in situ* incubation (Asanuma, 2004). Figure 14 shows the global distribution of primary productivity that was estimated through applying this model to GLI data.

4.2.4 Sea Surface Salinity

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. Method to detect low salinity water from the Yangtze River that causes a terrible damage to the Korean fisheries was studied. Co-relation between low salinity at sea surface, turbid water from the Yangtze River and SeaWiFS data in the northern East China Sea, were unraveled in the summer of 1998-2001 (Figure 15, Suh *et al.*, 2004a).

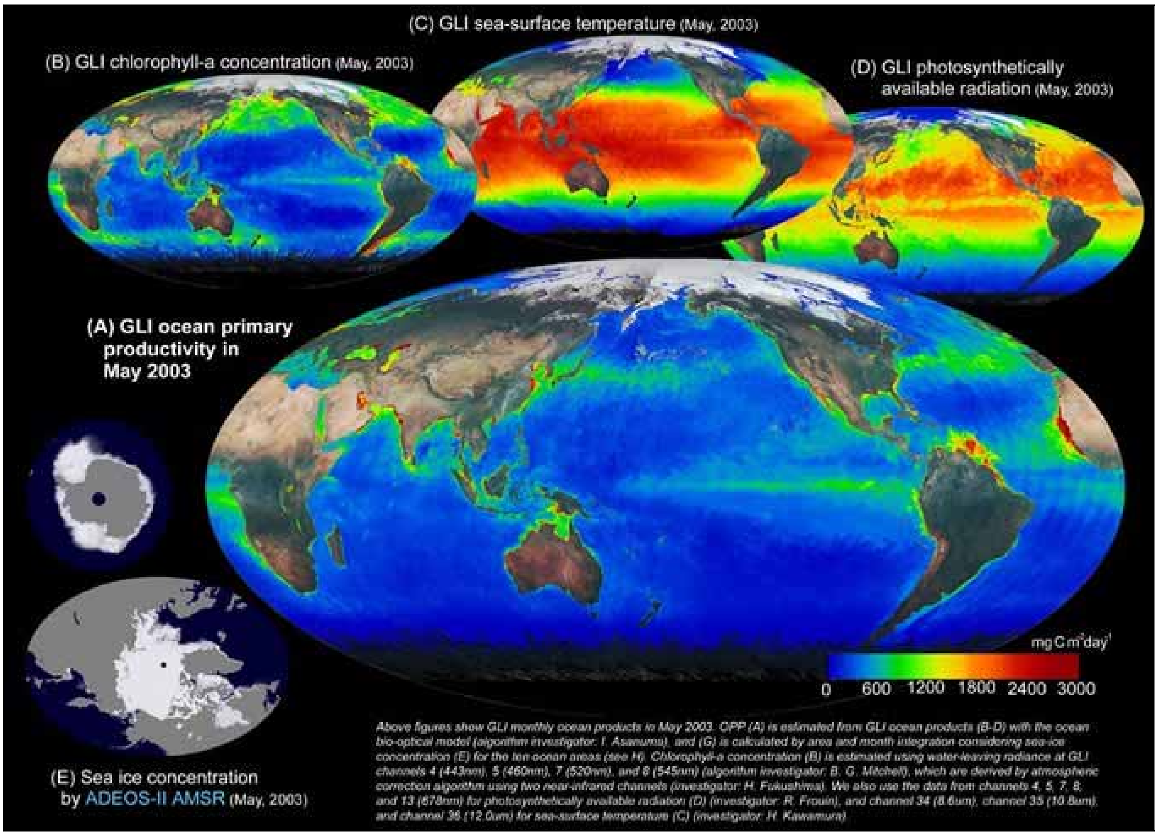
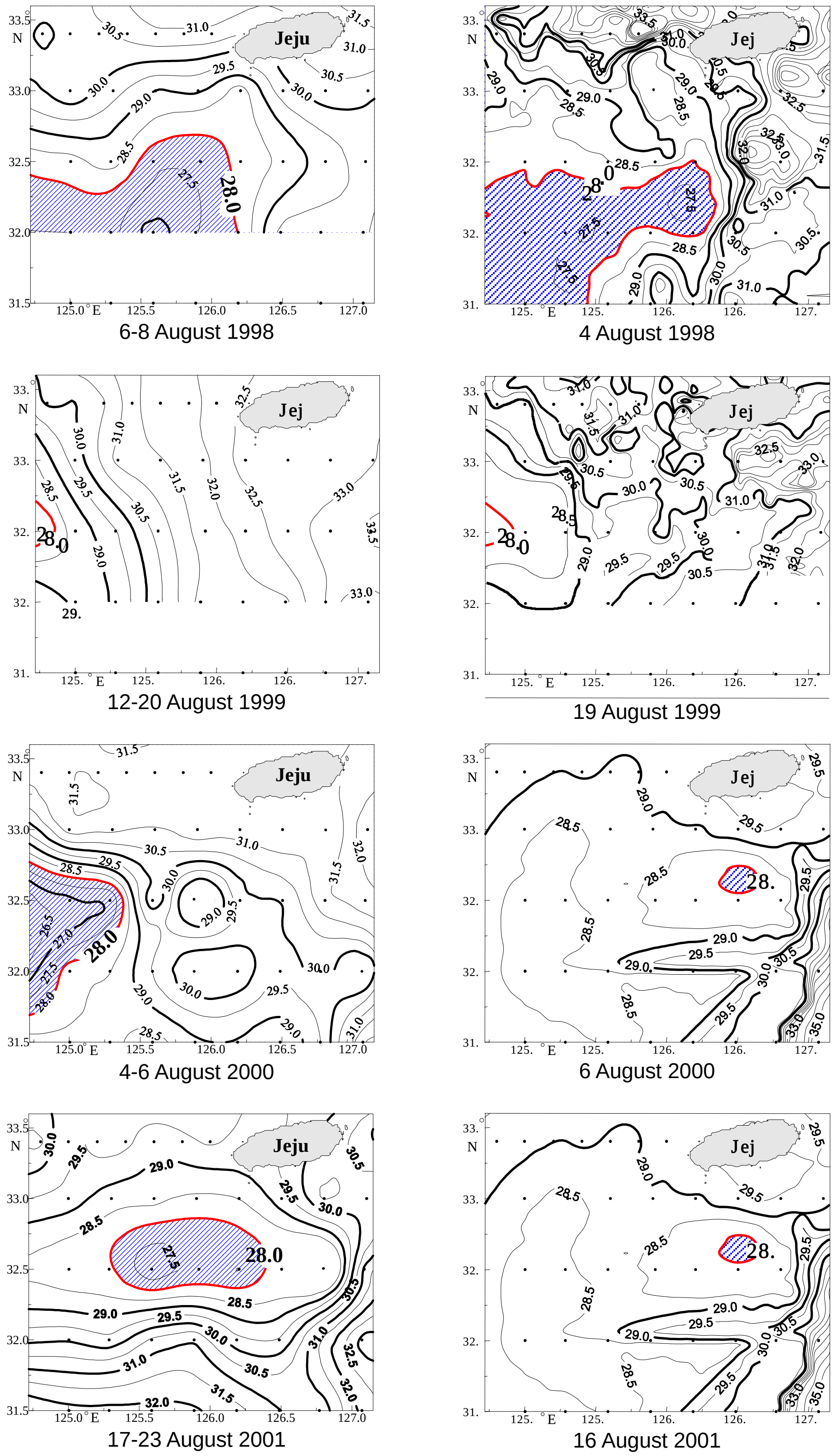


Figure 14. GLI Ocean Primary Productivity in May 2003
Source: EORC, JAXA



in situ salinity Estimated salinity by SeaWiFS data

Figure 15. Sea surface salinity (PSU) in August during 1998-2001 (Suh *et al.*, 2004a)

4.3 Validation of Geo-physical Parameters

4.3.1 GLI Match-up Analysis

The JAXA/EORC GLI ocean group has been validating various physical quantities estimated from GLI data by match-up data sets, to recognize errors in higher-level products and to adjust parameters and to improve the algorithms. Match-up data sets consist of the *in situ* data and the clipped data from GLI when observed in the same position at the same or nearly the same time. These data sets are managed by JAXA. Some of the data can only be used for calibration and validation or algorithm development.

Validated results of the product by match-up data are shown in Table 1. The results suggest that the accuracy of *chlorophyll-a* concentration is good as a whole, but it is not good enough in coastal waters. They also suggest that CDOM is underestimated. This is probably due to differences in CDOM concentrations among the various target areas that occurred during algorithm development and validation.

Table 1. Summary of GLI Validation (version 1 products)
(JAXA/EORC GLI Ocean Group, 2004 with modification)

Parameter code	Parameter name	Final target	Ver. 1 Accuracy	Notes
NWLR	normalized water leaving radiance	-35-+50% (offshore) -50-+100% (coastal area)	16-47% (CH01-09) 84-284% (CH10-12)	- Select vicarious calibration coefficients (vical coef.) of SeaWiFS Apr-Jul base - Bad results longer the 565nm are due to low (<1/20) nLw over the ocean - looks better than the early OCTS - problem under absorptive aerosol
PAR	photosynthetically available radiation	-10-+10% (10 km/month)	11%	- agrees well with SeaWiFS PAR and Tropical Atmosphere Ocean (TAO) solar irradiance
CHLA	*chlorophyll-a* concentration	-35-+50% (offshore) -50-+100% (coastal area)	130%	- large scatter is caused by coastal points - comparable quality to OCTS
CDOM	colored dissolved organic matter absorption at 440 nm	-50-+100%	(82%)	- insufficient sample size (now increasing)
SS	suspended sediment concentration	-50-+100%	(34%)	- insufficient sample size
K490	attenuation at 490 nm	-35-+50%	(78%)	- insufficient sample size (now increasing)
SST	bulk sea surface temperature	0.6 K	0.6 K	- cloud detection problem - Electric noise on Middle and Thermal Infrared (MTIR) image

4.3.2 Project on Ocean Productivity Profiling System

The 'Project on Ocean Productivity Profiling System' aims at providing data for real-time validation of estimated primary productivity by ocean color remote sensing (Saino, 2001). As shown in Figure 16, the underwater automatic escalation buoy is composed of an underwater winch below the euphotic zone and a measurement buoy that rises from the winch to the water's surface. The measurement buoy has a Fast Repetition Rate Fluorometer (FRRF) and Profiling Reflectance Radiometer (PRR) for obtaining vertical profiles. The system can be kept at calm depth to reduce the influence of waves and minimize the attachment of organisms. It can also transfer the measured data in real time, and the winch can be controlled in real time by acoustic and radio communications. Model 1 has recently been repeatedly tested in the ocean.

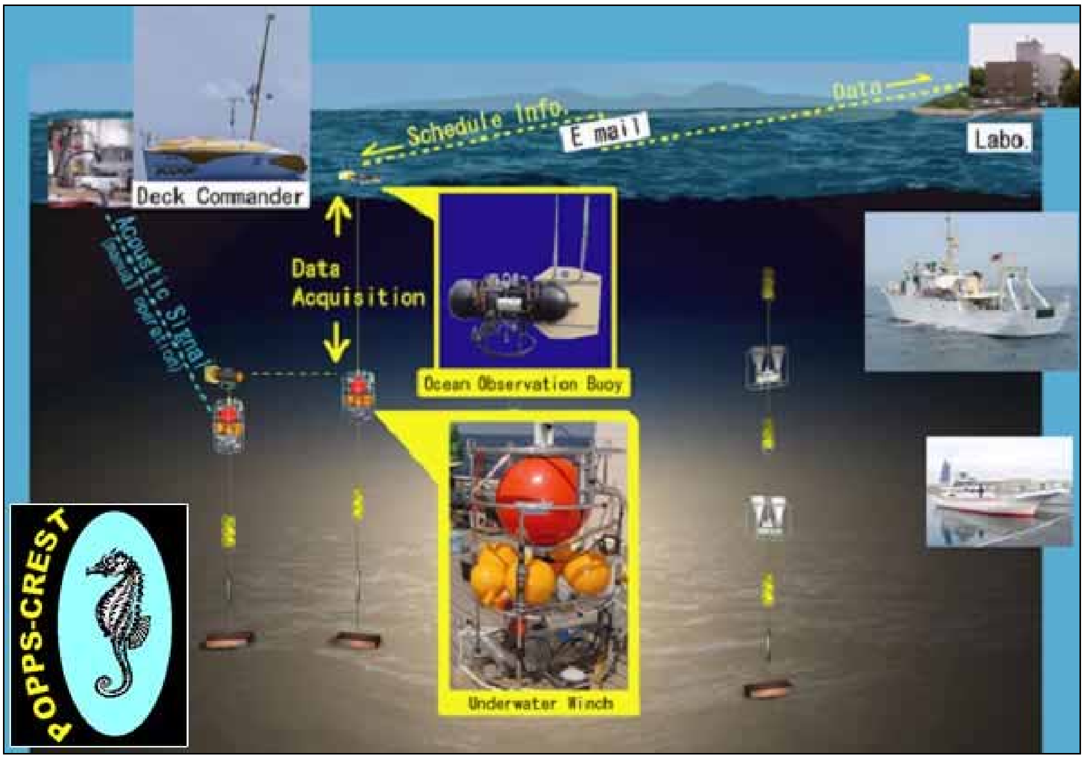


Figure 16. Project on Ocean Productivity Profiling System (POPPS)

4.3.3 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 studied that remote sensing reflectances are different between case I and case II water as shown in Figure 17. They conducted the following activities for validating and calibrating.

1) Accuracy validation of current product targeting on East China Sea
2) Development of *in situ* data collection system using NEAR-GOOS
3) Development of empirical equation on *chlorophyll-a* concentration in case II water
4) Comparison between OSMI and SeaWiFS derived *chlorophyll-a* concentration

NFRDI collected 140 sets of match-up data. These data sets will be open to scientists in the NOWPAP Region in the near future.

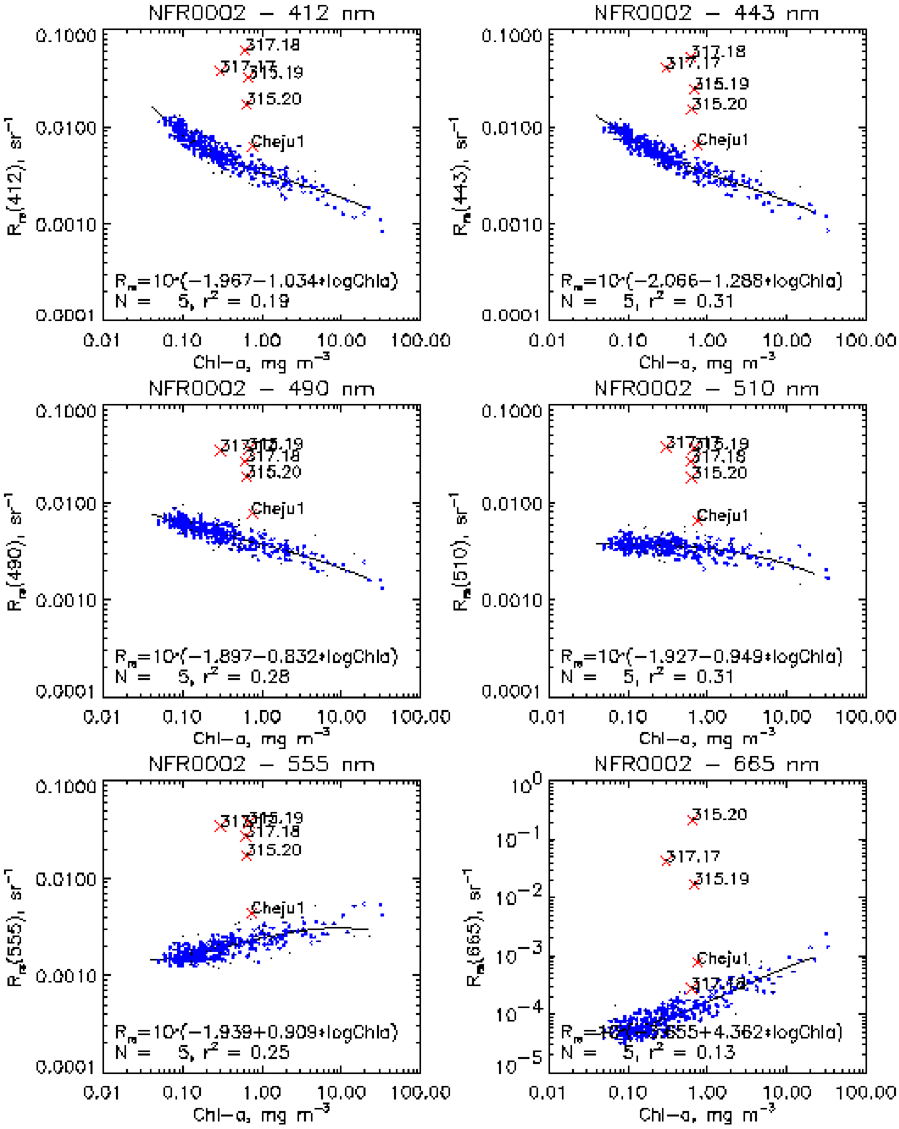


Figure 17. SeaWiFS spectral bands for the CalCOFI reference data set (●) and NFRDI February data (×) in the East China Sea (Suh *et al.*, 2001)

4.3.4 Validation of SST Retrieval Algorithm using AMSR-E, NEAR-GOOS and POI GIS

Aqua AMSR-E and ADEOS-II Advanced Microwave Scanning Radiometer (AMSR) measurements were provided by JAXA within the cooperation between JAXA and POI FEB RAS in the ADEOS-II Research activity. Also, match up data sets were prepared by JAXA and provided to Principal Investigators.

Comparison of satellite-derived and *in situ* data can be performed everyday using POI GIS, as shown in Figure 18. User selects the area and period of observations and uses GIS to download both the available AMSR-E and *in situ* data of SST, wind speed, and wind direction. The GIS extracts this data from its databases and also from NEAR-GOOS project database. The former contains the data collected on NEAR-GOOS site through Global Telecommunication System. Then user calls up SST and wind speed retrieval algorithms from the GIS analytical support system. The retrieved SST and wind speed fields are displayed in map windows of GIS. Retrieval errors are computed by comparison of the satellite-derived and *in situ* values for each algorithm under investigation.

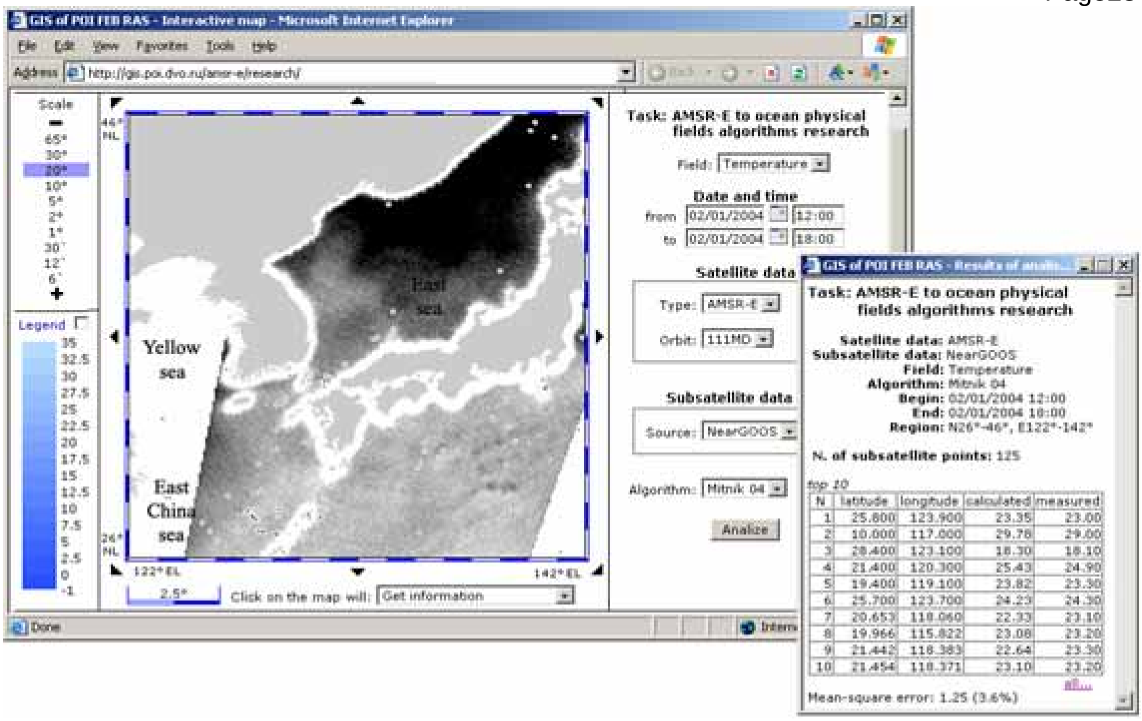


Figure 18. Validation of SST retrieval algorithm using AMSR-E, NEAR-GOOS and GIS POI

5 Introduction to the latest findings

5.1 Seasonal and interannual variability of sea surface *chlorophyll-a* concentration in the NOWPAP Region

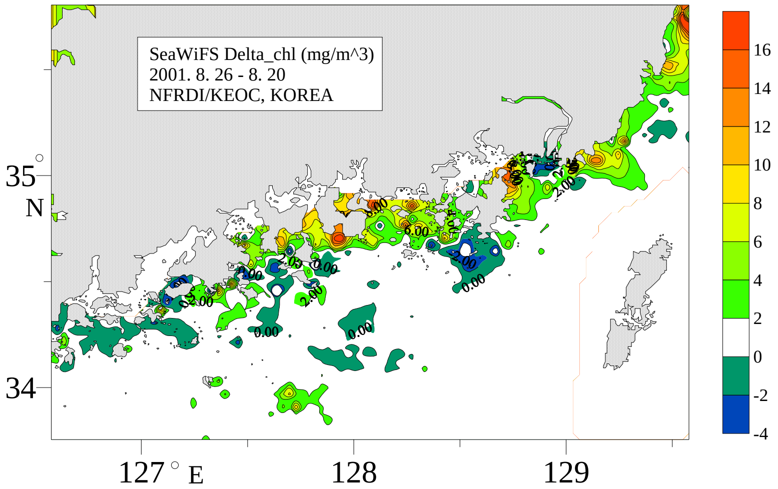
Seasonal and interannual variability of *chlorophyll-a* concentration in the NOWPAP Region was detected spatially by ocean color satellite remote sensing. The starting time of the spring bloom was spatially variable. The spring bloom started from south of the subpolar in March, and moved north of the subpolar front, the Primorye coast and off Hokkaido in April, and into the middle of the Japan Basin in May. The start of the spring bloom showed interannual variability that corresponded to wind speed in the area.

The spring blooms in 1998 and 2002 appeared about 4 weeks earlier than the other spring blooms between 1997 and 2002. These early blooms corresponded to periods of weak winds that led to an early development of the thermocline. The bloom was late in 1999 and 2001 in the Japan Basin and along the Primorye coast. It was also late in the southern area in 2000. It corresponded with stronger than average wind stress that delayed seasonal thermocline formation. The bloom along the Primorye coast appeared later in 1999, corresponding to stronger wind stress, and at the same time seemed to be related to the delay of the melting of sea ice in Mamiya Strait. The fall bloom appeared from early October to early December, and did not have a clear temporal transition. The area where *chlorophyll-a* concentration exceeded 0.8 µg/L was wider in the western area than in the eastern area every year. The magnitude of the fall bloom differed between years, but did not correlate with average wind speed in this season. These results indicate that the timing of the seasonal bloom in the NOWPAP Region is largely affected by the variability in global climate, such as El Nino/Southern Oscillation (ENSO) events (Yamada *et al.*, 2004).

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

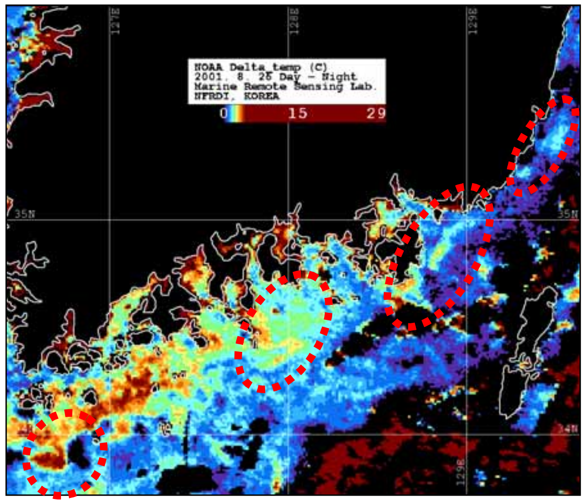
The monitoring activities at NFRDI in Korea have been extended to include all the coastal waters of Korea after the outbreak of *Cochlodinium polykrikoides* blooms in 1995. Several alternative methods were used including climatological analysis, spectral and optical methods which may offer potential 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 SST 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 red tide in August, 2001. The distribution between differences in SST during the day and at night also showed a possibility for red tide detection (Figure 19). Corrected vegetation index (CVI) was used to detect floating vegetation and submerged vegetation containing algal blooms. The results from the optical absorption of *C. polykrikoides* in the ultraviolet band (340nm) showed that if the optical characteristics from each red tide are used, red tide detection will be feasible (Suh *et al.*, 2004b).



(a) Difference in *chlorophyll-a* concentration between before *C. polykrikoides* red tide occurring on August 20 and after one on August 26, 2001

(b) Harmful algal bloom in Korean coastal waters on August 26, 2001



(c) Estimated area of red tide occurrence on the imagery of delta temperature on August 26, 2001

Figure 19. Feasibility of Red Tide Detection around Korean Waters (Suh *et al.*, 2004b)

5.3 Mean Monthly Distributions of Bio-optical Characteristics in the NOWPAP Region

The available data of field measurements show that the operational algorithm OC4 and the simplified algorithm for the particle backscattering coefficient provide quite reasonable results in the NOWPAP Region. Application of OC4 may be explained by the absence of a significant riverine runoff delivering yellow substance and suspended matter.

The semi-analytical algorithm for the yellow substance absorption coefficient used in the Black and Caspian Seas, is not applicable in the NOWPAP Region due to great errors in the atmospheric correction there. The simplified semi-analytical algorithm for this coefficient has been specially developed for the NOWPAP Region.

The prepared colour maps show the mean monthly distributions of *chlorophyll* concentration and of the particle backscattering and the yellow substance absorption coefficients in the NOWPAP Region derived from SeaWiFS data by the above-mentioned algorithms from January 1998 to December 2002 (Figure 20). It can be seen that the most seasonal changes occur in March-June, during the period of the spring phytoplankton bloom, which first covers the southern part of the sea and then the northern part. In October-December, the autumn phytoplankton bloom is observed. The distributions of the particle backscattering and the yellow absorption coefficients change similarly but with no pronounced autumn maxima.

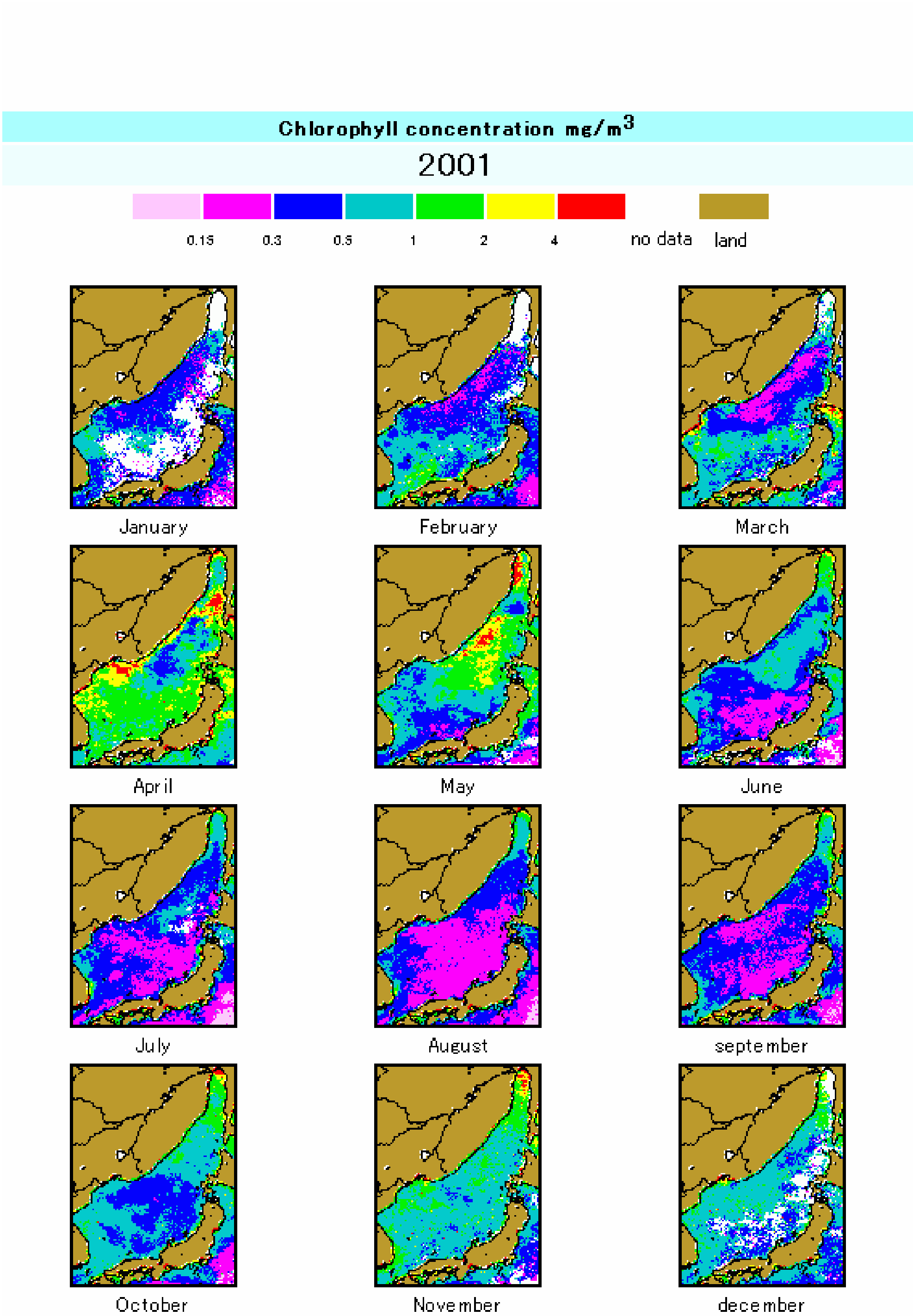


Figure 20. Maps of mean monthly values of *chlorophyll* concentration in 2001
Source: P.P.Shirshov Institute of Oceanology, RAS

6 Strategies/Plans for Remote Sensing related activities

6.1 Satellite data supply and distribution

6.1.1 MODIS Near Real Time Data

EORC, JAXA has been providing higher-level products processed since July 2002 from MODIS observation data through the Internet on a near real-time basis free of charge (MODIS Near Real Time Data, Figure 21, Table 2) After JAXA had set up the new system that receives and processes MODIS and AMSR-E data as an alternative measure for the termination of ADEOS-II in July 2004, time taken for product distribution has been shortened from maximum of one day to an average of about 3 hours. EORC uses the ADEOS-II GLI algorithm which was improved in accuracy by calibration, verification and algorithm development after its launch. This is used instead of the standard NASA algorithm. The use of GLI Version 2 is now under preparation.

Figure 21. MODIS Near Real Time Data
<http://kuroshio.eorc.nasda.go.jp/ADEOS/mod_nrt/>

Table 2. Products in MODIS Near Real Time Data

Spatial Resolution	Product	
	Image	Binary
1 km	Geometrically corrected: Rayleigh corrected reflectance (RcRefl) Normalized water-leaving radiance (nLw) Sea surface temperature (SST) *Chlorophyll-a* concentration (CHLA)	SST CHLA
500 m	Geometrically corrected	-
250 m	Geometrically corrected	-

6.1.2 OrbView-3 and MTSAT

NFRDI is going to set up the new system for analyzing of Orbview-3 and MTSAT in 2004 and 2005.

OrbView-3, launched on 26 June 2003, is among the world's first commercial satellites to provide high resolution imagery from space. OrbView-3 produces 1 m resolution panchromatic and 4 m resolution multi-spectral imagery. 1 m imagery enables the viewing of houses, automobiles and aircraft, and makes it possible to create highly precise digital maps and 3-dimensional fly-through scenes. 4 m multi-spectral imagery provides color and infrared information to further characterize cities, rural areas and undeveloped land from space.

The Multi-functional Transport Satellite (MTSAT) series fulfills two functions: a meteorological function by the Japan Meteorological Agency (JMA) and an aviation control function by for the Civil Aviation Bureau of the Ministry of Land, Infrastructure and Transport. The MTSAT series will succeed the Geostationary Meteorological Satellite (GMS) series as the next generation satellite series covering the East Asia and the Western Pacific regions. On 24 March 2005, the first test images in visible and infrared channels were obtained with MTSAT-1R, launched on 26 February 2005.

6.2 Study Network and Assistance Activity

6.2.1 International Workshop on Remote Sensing of the Marine Environment in the Northwest Pacific Region

‘International Workshop on Remote Sensing of the Marine Environment in the Northwest Pacific Region Workshops’ was organized by the NPEC, the host of the NOWPAP CEARAC since April 1999, aiming to contribute to the development of marine environmental monitoring technologies derived from remote sensing. The first workshop (Toyama, March 2000) recommended that NOWPAP and NPEC should organize regular workshops and training courses, as well as promote the development of real-time information systems of the NOWPAP Region. The second workshop (Toyama, March 2002) focused mainly on ocean color remote sensing, and on importance of Japan’s leadership in this field. The third workshop was held in October 2004 in Beijing.

6.2.2 Red Tide Watcher Project

‘Red Tide Watcher Project’, presented by Japanese scientists, is a 3 year project which started in October 2002. The project’s primary aim is the establishment of red-tide monitoring infrastructure based on the mutual understanding among related countries, including the integration of existing efforts and the latest technology, such as remote sensing. In March 2003, a workshop was held that combined the international ocean-color satellite and red tide symposia, in which researchers of remote sensing and red tides from Asia, Europe and America gathered to share their common understandings, and present conditions and issues regarding the establishment of a red tide monitoring system.

Red tides involve many species of phytoplankton, depending on sea area and season. Thus, wide-area monitoring requires the cooperation of researchers who are studying each area. Also, communication between red tide researchers and remote sensing researchers, which was rare in the past, has become very important. Red Tide Watcher Project initiated an international ocean color observation forum to promote partnership among organizations and specialists relating to red tides along the Asian coast, the marine environment and the remote sensing of ocean color (Red Tide Watcher Project, 2003).

7 Challenges and Prospects

7.1 Real-time Performance and Continuity of Observation

To proceed with the development of algorithms for practical use, infrastructure establishment and subsequent project formation, it is necessary to achieve a real-time performance that provides status and continuity of the observations so that long-term variation can be understood. Real-time performance, such as 'MODIS Near Real Time Data' by JAXA and 'Operation of Application System to Produce Ocean Information derived from Earth Observation Satellites' by NFRDI, is ready for practical use and is expected to provide products in the near future. The continuity will be achieved more than 10 years from now by observation plans such as the Global Change Observation Mission (GCOM) of JAXA, KOMPSAT-II/COMS of KARI, and the National Polar-orbiting Operational Environment Satellite System (NPOESS) Preparatory Project of NASA that follow the presently operating SeaWiFS, OSMI, and MODIS. However, to analyze long-term variations, product compatibility between sensors will be an issue due to the inevitable changes in sensors.

7.2 Ocean Color Remote Sensing in the Coastal area

In ocean color remote sensing by OCTS, SeaWiFS, GLI and MODIS, and OSMI, the estimation algorithm of *chlorophyll-a* concentration that targets the open ocean has almost been established and put into practical use. However, issues still remain for targeting the coast. The relation between ocean color and materials in coastal seawater is not as simple as in the open ocean, due to the influence of SS and CDOM on the optical characteristics of seawater and also to the influence of absorbing aerosols. For example, new algorithm that applies neural networks to in-water algorithm and atmospheric correction is currently under development to solve these issues, and to further increase accuracy, region specific algorithm development should supplement the current practice of using a uniform algorithm.

7.3 Collection of *in situ* data

In developing the algorithm for ocean color remote sensing in the coastal area, it is desirable to have enough *in situ* data to verify/calibrate estimated data obtained from satellites, and to understand optical attributes such as *chlorophyll-a*, SS, and CDOM, etc, of target sea area. However, as the *in situ* data currently available in the NOWPAP Region is very limited in terms of time and space, collection of *in situ* data should be promoted proactively, together with development of algorithms. Also, specification of *in situ* data should be optimized to reflect the operation of satellites installing new types of sensors.

7.4 Improvement of spatial and temporal coverage

Oil spill monitoring by microwave remote sensing still needs much intense spatial and temporal coverage (shorter revisit time) for operational use.

7.5 Continuous development of algorithms and applications of satellite data

Continuous support for research activities for development of algorithms of geophysical parameter retrieval, expansion of satellite data applications and enhancement of collaboration between researchers in NOWPAP countries are necessary.

7.6 Education and public awareness

Education of public about usefulness of remote sensing technology should be encouraged.

7.7 Combined use of satellite data and relevant information

Combined use of satellite observations and relevant data among NOWPAP countries are necessary.

8 Suggested Activities for the NOWPAP Region

NOWPAP, as a project, does not have any plan of new installation of satellite/sensor, observation, and analysis system. NOWPAP Members that have already installed or that are going to introduce such equipment/facility are expected to construct cooperative monitoring network systems by their own equipment/facility. Given, the followings are the proposed future activities for NOWPAP.

8.1 Refinement of guideline being prepared by NPEC for local governments of each country

NPEC has been working on a project called the "Toyama Bay Project" since 2002, in order to evaluates usefulness of coastal zone eutrophication monitoring using ocean color satellite data, recognizing that distribution of chlorophyll-a is a good indicator for eutrophication. It is of great importance to share the result and lessens learned in this project in NOWPAP.

A draft guideline for monitoring of eutrophication in coastal area using satellite data is under development by NPEC, which intends to be a basis for establishing common methods for evaluating and using satellite data for cooperative environmental monitoring in the NOWPAP Region, taking into account the results and issues raised in the "Toyama Bay Project". Review and refine this guideline in WG4 is encouraged towards the establishment of cooperation monitoring, as it is the final goal of NOWPAP WG4.

8.2 Enhancement of the Technical Training Program

In order for the NOWPAP Members to help each other in technical aspects of remote sensing in an effective way, it is necessary to offer a training program on remote sensing data processing and analysis and its application to study marine and coastal environment monitoring. The training program shall be designed for young researcher, students, and local government officers involved in any aspect of marine and coastal environment monitoring.

8.3 Development of Remote Sensing Information Network

During discussions at the first meeting of NOWPAP WG4 and the second CEARAC Focal Points Meeting (FPM), it was pointed out that common understanding and information sharing should be promoted on application and interpretation, the status and future prospects of research and development, and the real use of remote sensing in marine environmental monitoring. Based on such observations, NOWPAP WG4 considered the development of a remote sensing information network and started a portal site on the Internet. However, the portal site's role of navigating locations of scattered information and data is limited in its quality and quantity, and remote sensing information network requires constant updating for its usefulness. Thus, it is necessary to consider step-by-step procedures to develop a remote sensing information network, taking account of realistic limitations, such as development cost, content provision, and so on.

The portal site being developed to construct a remote sensing information network navigates locations of scattered information and datum, however, its role as a useful remote sensing information network will not last long. Thus, it is necessary to consider step-by-step procedures to develop a remote sensing information network. The first step is the development of an ongoing portal site that reviews and provides locations of scattered information and data. The second step is the development of a digital library that also provides the information and data based on the Marine Environmental Watch Project.

8.4 Sustainable ocean observing system and regional cooperation

During the Earth Observation Summit II (Tokyo, April 2004), the Group on Earth Observations

(GEO) adopted the position that observing and understanding the earth more completely and comprehensively will expand worldwide capacity and a means to achieve sustainable development. It will also yield advances in many specific areas of socio-economic benefit, including: (1) reducing loss of life and property from natural and human-induced disasters; (2) understanding environmental factors affecting human health and well being; (3) improving management of energy resources; (4) understanding, assessing, predicting, mitigating and adapting to climate variability and change; (5) improving water-resource management through a better understanding of the water cycle; (6) improving weather information, forecasting and warning; (7) improving the management and protection of terrestrial, coastal and marine ecosystems; (8) supporting sustainable agriculture and combating desertification; and (9) understanding, monitoring, and conserving biodiversity (GEO, 2004). The implementation of NOWPAP activities, including monitoring eutrophication and oil spills, should be made with due consideration of these social benefits.

GOOS has been developed by UNESCO/IOC, United Nations Environment Programme (UNEP), World Meteorological Organization (WMO) and International Council for Science (ICSU). Its coastal module is designed by an advisory group, the Coastal Ocean Observations Panel, and its strategic design plan is now available (UNESCO, 2003). The sustainable coastal observing system should have the ability to rapidly detect and provide timely predictions of changes in a broad spectrum of marine phenomena that affect: (1) the safety and efficiency of marine operations; (2) the susceptibility of human populations to natural hazards; (3) the response of coastal ecosystems to global climate change; (4) public health and well being; (5) the state of marine ecosystems; and (6) the sustainability of living marine resources. Because of these overlapping working areas between GOOS/COOP and NOWPAP, cooperative activities in the development of the regional ocean observing system will be promoted.

The National GOOS Programmes and GOOS Regional Alliances (GRAs) provide the primary venue for identifying user groups, specifying data and information requirements and refining data products over time, based on user feedback and new knowledge. The North-East Asian Regional GOOS (NEAR-GOOS) is one of the GRAs. Because of the overlapping working areas between GOOS and NOWPAP, cooperative activities in the development of the regional ocean observing system need to be promoted.

8.5 Search of other possible usage of the satellite remote sensing for environmental monitoring in the NOWPAP Region

Activities of NOWPAP WG4 have been implemented to the present based on the agreement at the second CEARAC FPM, that was; eutrophication and oil spill to be the main targets of marine and coastal environmental monitoring by remote sensing. National Reports, on the other hand, indicated other serious coastal environmental issues in the NOWPAP Region, such as coastal erosion and discharge of murky waters from rivers. Possibility of monitoring other phenomena by remote sensing is encouraged in the NOWPAP Region.

9 Summary and Recommendation

9.1 Summary

1) Remote sensing technology is feasible for monitoring of eutrophication and oil spill of the NOWPAP Region through the interplay of ship, buoy, air-born, and satellite observations.
2) Previous, present and planned satellite sensors, both from NOWPAP and non-NOWPAP Members, are useful, and continuation of carefully planned satellite programs and programs directed on ground-truth data collection are necessary.
3) *Chlorophyll-a* measured by ocean color remote sensing for open ocean eutrophication monitoring is ready for operational use.
4) *Chlorophyll-a* measured by ocean color remote sensing for coastal eutrophication monitoring is also useful; however, careful evaluation of the quality is required regional basis, and further refinement of algorithm is necessary for some regions.
5) Red tide, suspended matter and organic matter for coastal eutrophication monitoring are promising; however, refinement of algorithms is necessary.
6) Oil spill monitoring by satellite SARs is feasible; however, much intense spatial and temporal coverage is necessary for operational use.
7) Continuous support for research activities for algorithms development, expansion of satellite data applications, and enhancement of collaboration between researchers in NOWPAP Members is needed.
8) Use of satellite data by local governments in each NOWPAP Member should be encouraged. Guidelines for eutrophication monitoring from space, being prepared by NPEC, is useful and should be refined. Information on CEARAC activity associated with environment monitoring and education should be send to local governments and published in local newspapers.
9) Education of public about usefulness of remote sensing technology should be encouraged.
10) Support for integration efforts of satellite and other data between NOWPAP Members are necessary.

9.2 Recommendation of Activity of WG4 for Next Two Years

1) Refinement of guideline being prepared by NPEC for local governments of each country
2) Training of officers of young researcher, students, and officers of local governments, including possible dedicated cruise
3) Further development of portal site, web site on oil spill monitoring by remote sensing and environment watch system, including reference database and digital library
4) Joint activities with IOC/WESTPAC ocean color project.
5) Search of other possible usage of the satellite remote sensing to environmental monitoring in the NOWPAP Region.

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ALOS@EORC <http://www.eorc.jaxa.jp/ALOS/>

EORC <http://www.eorc.jaxa.jp/en/index.html>

JAXA <http://www.jaxa.jp/index_e.html>

JMA <http://www.jma.go.jp/JMA_HP/jma/indexe.html>

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

KORDI <http://www.kordi.re.kr/eng/index.asp>

Marine Environmental Watch Project <http://www.nowpap3.go.jp/jsw/eng/index.html>

Marine Remote Sensing Laboratory, NFRDI <http://www.nfrda.re.kr/korea/mrsl/data_mrsl.htm>

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

New Generation SST for Open Ocean Ver.1.0 Real-time Demonstration Operation <http://www.ocean.caos.tohoku.ac.jp/~merge/sstbinary/actvalbm.cgi?eng=1>

Ocean Home GLI EORC JAXA <http://suzaku.eorc.jaxa.jp/GLI/ocean/>

Oil spill monitoring in the NOWPAP region, POI <http://cearac.poi.dvo.ru/>

ORBIMAGE Inc. <http://www.orbimage.com/>

SOA <http://www.soa.gov.cn> (in Chinese)

List of Acronyms

ADEOS	Advanced Earth Observing Satellite
ALOS	Advanced Land Observing Satellite
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer for Earth Observing System
ASAR	Advanced Synthetic Aperture Radar
AVHRR	Advanced Very High Resolution Radiometers
AVNIR-2	Advanced Visible and Near Infrared Radiometer type-2
CalCOFl	California Cooperative Oceanic Fisheries Investigations
CAS	Chinese Academy of Sciences
CBERS	China Brazil Earth Resources Satellite
CCD	Charge-coupled Device
CDOM	Colored Dissolved Organic Matter
CEARAC	Coastal Environmental Assessment Regional Activity Center
CMODIS	Chinese Moderate Imaging Spectra Radiometer
COCTS	Chinese Ocean Color and Temperature Scanner
COMS	Communication Ocean and Meteorology Satellite
COOP	Coastal Ocean Observations Panel
CVI	Corrected Vegetation Index
CZI	Coastal Zone Imaging
ENSO	El Nino/Southern Oscillation
ENVISAT	Environment Satellite
EOC	Electro Optical Camera
EORC	Earth Observation Research and application Center (Japan)
ERS-1 (2)	European Remote Sensing Satellite-1 (2)
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper Plus
FEB	Far Eastern Branch (Russia)
FPM	Focal Points Meeting
FY-1	Feng Yun-1
GCOM	Global Change Observation Mission
GEO	Group on Earth Observations
GIS	Geographic Information System
GLI	Global Imager
GMS	Geostationary Meteorological Satellite
GOCI	Geostationary Ocean Color Imager
GOES	Geostationary Operational Environmental Satellite
GOOS	The Global Ocean Observing System
GRAs	GOOS Regional Alliances
HY-1 (2, 3)	Hai Yang-1 (2, 3)
ICSU	International Council for Science
IOC	The Intergovernmental Oceanographic Commission
JAXA	Japan Aerospace Exploration Agency
JERS-1	Japanese Earth Resources Satellite-1
JMA	Japan Meteorological Agency
KARI	Korea Aerospace Research Institute
KOMPAST-I (II)	Korean Multi-Purpose Satellite I (II)
KORDI	Korea Ocean Research and Development Institute
MODIS	Moderate Resolution Imaging Spectrometer
MOMAF	Ministry of Maritime Affairs and Fisheries (Korea)
MSC	Multi-spectral Camera
MTSAT	Multi-functional Transport Satellite

MVISR	Multi-channel Visible and IR Scan Radiometer
NASA	National Aeronautics and Space Administration (US)
NASDA	National Space Development Agency of Japan (now JAXA)
NDVI	Normalized Difference Vegetation Index
NEAR-GOOS	North-East Asian Regional GOOS
NFRDI	National Fisheries Research and Development Institute (Korea)
NGSST	New Generation Sea Surface Temperature
NOAA	National Oceanic and Atmospheric Administration
NOWPAP	Northwest Pacific Action Plan
NPEC	Northwest Pacific Region Environmental Cooperation Center (Japan)
NPOESS	National Polar-orbiting Operational Environment Satellite System
OC2 (4)	Ocean Color
OCTS	Ocean Color and Temperature Scanner
OCM	Ocean Colour Monitor
OSMI	Ocean Scanning Multi-spectral Imager
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PAR	Photosynthetically Available Radiation
PI	Principal Investigator
POI	Pacific Oceanological Institute (Russia)
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping
QuikSCAT	Quick Scatterometer
RAR	Real Aperture Radar
RAS	Russian Academy of Sciences
SAR	Synthetic Aperture Radar
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SOA	State Oceanic Administration (China)
SS	Suspended Solid
SST	Sea Surface Temperature
SVISSR	Stretched-Visible Infrared Spin Scan Radiometer
SZ-3 (4)	Shen Zhou-3 (4)
TAO	Tropical Atmosphere Ocean
TM	Thematic Mapper
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
vical coef.	vicarious calibration coefficients
WESTPAC	IOC Sub-Commission for the Western Pacific
WG4	Working Group 4
WMO	World Meteorological Organization