Annex VI-2

Draft National Report on Ocean Remote Sensing in Japan

(Reviewed by the Second Meeting of NOWPAP WG4)

Contents

1. Status of Remote Sensing utilization in marine environment monitoring

To contribute to conservation of global environment which provides common basis for human living, Japan so far has been developing and operating two earth observing satellites of ADEOS and ADEOS-II (both suspended the operation due to mechanical trouble) by NASDA (present JAXA), taking advantage of remote sensing by satellite enabling cross border, wide, uniform, and frequent observation of global phenomenon.

The first earth observing satellite by Japan, ADEOS, was launched in August 1996. OCTS on ADEOS, taking over observation mission of NIMBUS-7 CZCS launched by US in 1978, enabled global observation of ocean color and SST and contributed to understand conditions of *chlorophyll-a*, dissolved matter, and SST in the ocean. Data obtained by OCTS were used for: understanding of ocean primary production and carbon circulation; acquisition of information on fishing and oceanographic conditions; and environmental monitoring, etc. Unfortunately, it suspended its operation due to mechanical trouble in June 1997, however, the obtained data until then resulted in the establishment of estimation algorithm for *chlorophyll-a* concentration and contributed to ocean environmental monitoring by ocean color as well as OrbView-2 SeaWiFS launched by US in 1997 (Saino, 1998; Kawamura and the OCTS-team, 1998; Shimada *et al.*, 1998).

ADEOS-II was launched in December 2002, taking over the observation mission of ADEOS, to clarify mechanisms of long-term climate change such as global warming and to be used for weather information and fishing, etc. ADEOS-II was equipped with GLI of high resolution and multiple wavelength channel based on the OCTS development. It enabled frequent, global, and accurate observation of various geo-physical parameters in the ocean (Ishizaka *et al.*, 2004). However, the operation was given up due to mechanical trouble in October 2003, ten months after its launch. Although the originally planned long-term and continuous monitoring of global environment was not achieved, the data obtained by GLI until then resulted in products including *chlorophyll-a* concentration (an important indicator of carbon circulation) and SST (an indicator of climate change) that are available since December 2003 (see section 5.1.2). GLI calibration/validation (see section 3.3.1) and results of estimation algorithm development of various geo-physical parameters are applied also to MODIS Near Real Time Data by EORC, JAXA which provides MODIS higher-level products targeting surrounding sea area of Japan (see section 3.2.2.1 and 5.1.1).

Products of *chlorophyll-a* concentration and SST by MODIS Near Real Time Data, as well as SST by NOAA AVHRR, have been actively used for monitoring projects such as Marine Environmental Watch Project (see section 2.1) and monitoring of sea areas that have frequent damages by red tide. More accurate product development has been tried by case study in each coast (see section 2.3, 3.2.2.2) because products of *chlorophyll-a* concentration targeting coasts do not have enough accuracy at present. In open ocean where estimation of *chlorophyll-a* concentration have achieved accuracy for practical use, estimation model of primary productivity have been considered by using *chlorophyll-a* concentration. Seasonal- and interannual variation of primary productivity in global scale is about to be clarified (see section 3.2.3). However, *in situ* data necessary to validate the model absolutely lack and a system to efficiently obtain such data is under development (see section 3.3.2).

While OCTS and GLI are optical sensors, Japan has a plan to launch ALOS equipped with PALSAR, which is upgraded from SAR of JERS-1. PALSAR is expected to contribute to study dynamics of various marine phenomenon (see section 3.1). In addition, AMSR-E developed by Japan and installed in Aqua has been successfully conducting its observation since its launch and its higher-level products have been opened since September 2003. Among them, SST has been used in the development of New Generation SST in open ocean participated by domestic and foreign researchers (see section 3.2.1).

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 and CHLA shows *chlorophyll-a* concentration.

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
SeaWiFS	OrbView-2	CHLA	1 day	• Understanding of red tide
MODIS	Terra/Aqua	SST CHLA	(2 times /day)	• Monitoring for water quality • Understanding of red tide • Understanding of ocean dynamics
AMSR-E	Aqua	SST	1 day	• Understanding of ocean dynamics

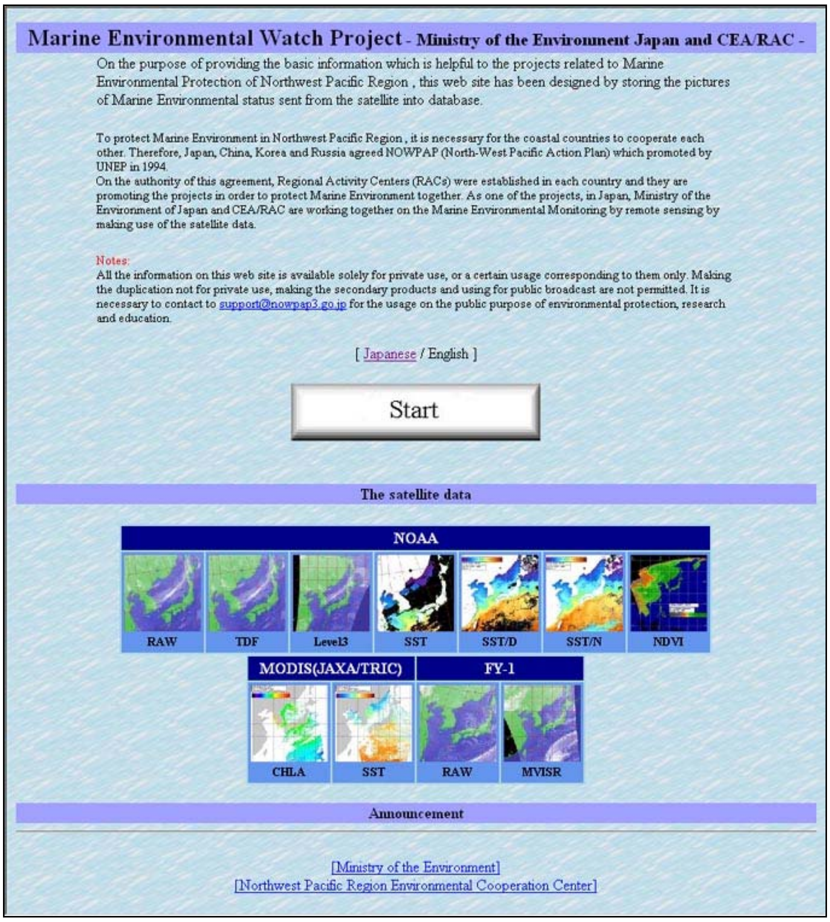
2 Case examples of RS application in marine environmental monitoring

2.1 Marine Environmental Watch Project

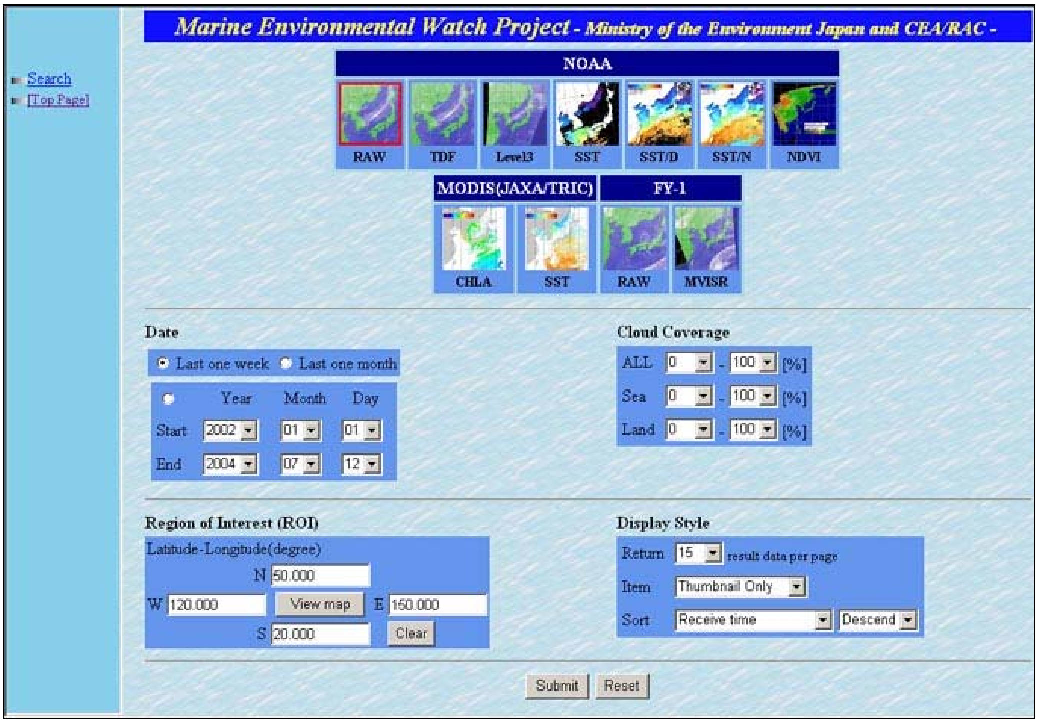
Ministry of Environment of Japan contracted with Northwest Pacific Region Environmental Cooperation Center (NPEC) to prepare Marine Environmental Watch Project since 2000 as a NOWPAP promotion project to provide useful basic information for marine environmental conservation, utilizing remote sensing by satellite; and started operation of its receiving ground station since March 2002. Receiving targets are NOAA AVHRR and FY-1 MVISR that are expected for marine monitoring use.

Measured data obtained by the receiving ground station are automatically processed for NOWPAP region and saved as database expecting future study use because there is no other source for the measured data in the past. The contents are widely opened through the Internet (Figure 1) providing: distribution image of cloud, SST, and NDVI by search condition of measurement date, cloud cover, and region; and 10-day composite images of SST for day and night.

In addition to the above-mentioned data, MODIS *chlorophyll-a* concentration and SST products distributed by EORC, JAXA are provided since July 2004 to further assist and promote marine environmental conservation. Previous data delivery by regular mail has been shifted to unmanned distribution technologies including online order, FTP, etc, resulting in quick data delivery to domestic and foreign users.



(a). Main



(b). Data search

Figure 1. Marine Environmental Watch Project
<http://www.nowpap3.go.jp/jsw/index.php?lang=en>

2.2 Coastal Information System of Ehime Prefecture

In coastal area of Uwajima Sea, water temperature drastically changes due to the intrusion of Kuroshio system from the Pacific. To quickly provide such information on the water temperature change, Ehime prefecture and Center for Marine Environmental Studies of Ehime University collaboratively operate the Coastal Information System (Figure 2). The system broadcasts water temperature data of 5 m depth at 8 stations established in Uwajima Sea coast through the Internet by automatic updating every 2 hours transmitted through a Low Earth Orbit satellite (Orbcomm) with about 30 minutes delivery time after the measurement.

These sea temperature data, combined with SST image of Uwajima Sea obtained by Ehime Chuyo Fisheries Experimental Station from NOAA AVHRR and ocean color image by MODIS, are provided as comprehensive marine information. The ocean color image by MODIS is adopted from higher-level products provided by EORC, JAXA.

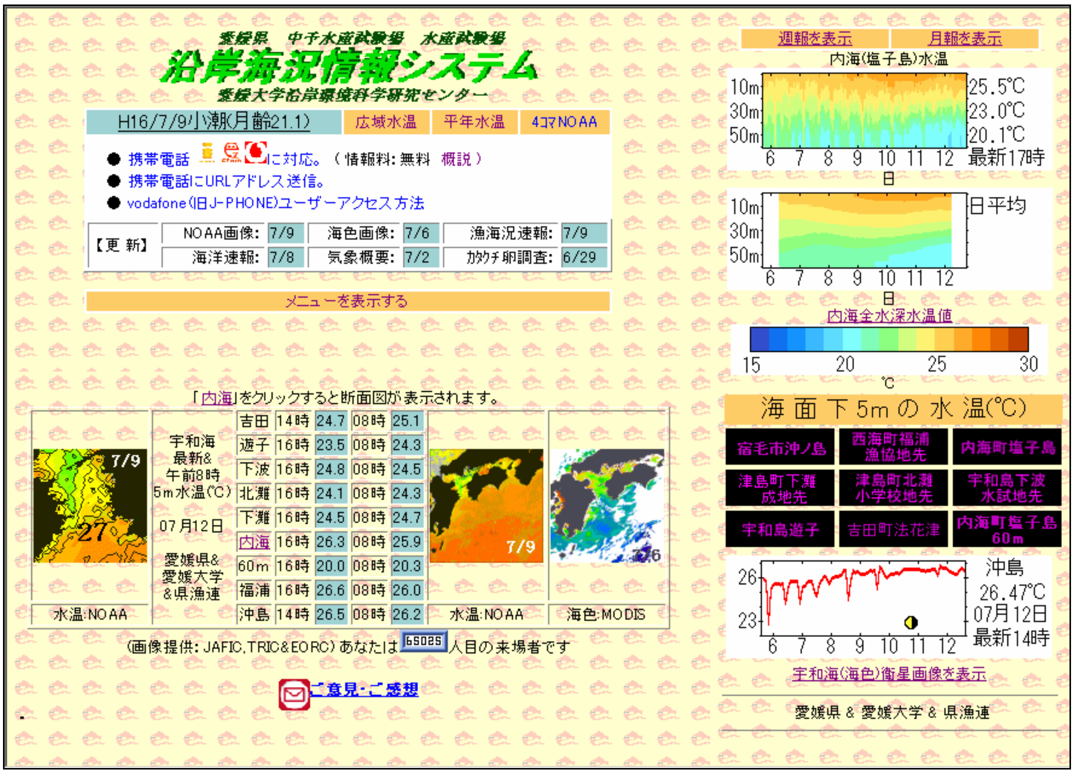


Figure 2. Ehime Prefecture Coastal Information System
<http://www8.ocn.ne.jp/~ehchusui/>

2.3 Ariake Sea Project

Ariake Sea is a representative shallow coastal area in west Japan that has been known as a place full of marine life resources for a long time. In recent years, however, fishes and shellfishes including short-necked clam and pen shell have rapidly decreased. Red tides with its increasing frequency and scale have caused serious damages by color fading of laver (Nakata, 2003).

To tackle the issue, researchers of faculty of fisheries, Nagasaki University, organized a project of "Research and study on changes of environment, ecosystem, and fisheries in Ariake Sea". As its core project, "Comprehensive study on the impact on fishery resources caused by the environmental change in Ariake Sea" has been conducted since 2001 for five years. The final goal of the project is to provide concrete proposals on expected future conservation and utilization of the environment and fishery resources in Ariake Sea by systematically clarifying the process of the change and transition of the environment and fishery production regarding Ariake Sea as one material cycling system. To achieve the goal, researchers are studying characteristics and changing process of the environment and ecosystem of Ariake Sea such as physical environment, sedimentation process at the bottom of the sea, oxygen depleting process, impacts of artificial chemicals, plankton production including red tide, and long-term change of benthic life in tidal flats (Nakata, 2003).

According to Ariake Sea Project, One of the studies headed by Professor Joji Ishizaka, faculty of fisheries, Nagasaki University is conducting the following activities to clarify dynamics and processes of low-level production by phytoplankton and zooplankton in Ariake Sea.

1) Collection of existing knowledge of the past red tides, etc
2) Monthly survey in Isahaya bay of standing crops of phytoplankton and zooplankton, taxonomical composition, environmental conditions including sea temperature, salinity, transparency, and nutrients concentration; and several times surveys a year in Ariake Sea of phytoplankton, zooplankton, etc
3) Study on estimation method by remote sensing of phytoplankton (*chlorophyll-a*), suspended solids (SS), transparency, SST, etc
4) Continuous monitoring of chlorophyll fluorescence by mooring system

Ishizaka (2003) considered the cause of red tide by reviewing *chlorophyll-a* concentration images in Ariake Sea from 1998 to 2001 processed from SeaWiFS data together with *in situ* data, etc by Nagasaki University. The obtained image shows red tide occurrence, growth, and end since December 2000 that damaged laver. It also shows seasonal trend of *chlorophyll-a* that peaked from June to July and in November from 1998 to 2001 not only in Isahaya bay but also in whole Ariake Sea. The result shows observation of *chlorophyll-a* concentration by satellite remote sensing is effective in red tide observation. The remaining issue is the overestimation and lack of *chlorophyll-a* concentration in the head of Ariake Sea.

Currently, efforts have been made to accumulate Ariake Sea area image clipped from *chlorophyll-a* concentration image in MODIS higher-level products distributed by EORC, JAXA day-by-day aiming at clarifying red tide dynamics by analyzing the data (Figure 3).

Figure 3. *Chlorophyll-a* Image of Ariake Sea by MODIS
<http://w3.fish.nagasaki-u.ac.jp/FISH/KYOUKAN/ISHIZAKA/MODIS/>

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

3.1 Sensor and Satellite

ALOS

The Japanese Earth observing satellite program consists of two series: satellites mainly for atmospheric and marine observation, and the ones mainly for land observation. ALOS, the Advanced Land Observing Satellite, aims the following objectives by improving land observing technologies of JERS-1 and ADEOS and by collecting global land observation data with high resolution. Also, ALOS May exhibit a possibility of application for marine environment.

1) Providing maps for Japan and other countries including those in the Asian-Pacific region (Cartography)
2) Performing regional observation for "sustainable development", harmonization between Earth environment and development (Regional Observation)
3) Conducting disaster monitoring around the world (Disaster Monitoring)
4) Surveying natural resources in domestic and foreign countries (Resources Surveying)
5) Developing technology necessary for future Earth observing satellite (Technology Development)

ALOS, as shown in Figure 4 and Table 2, has three earth observing sensors: 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 Phased Array type L-band Synthetic Aperture Radar (PALSAR) for day-and-night and all-weather land observation. In order to utilize fully the data obtained by these sensors, ALOS was designed with two advanced technologies: the former is the high speed and large capacity mission data handling technology, and the latter is the precision spacecraft position and attitude determination capability. They will be essential to high-resolution remote sensing satellites in the next decade.

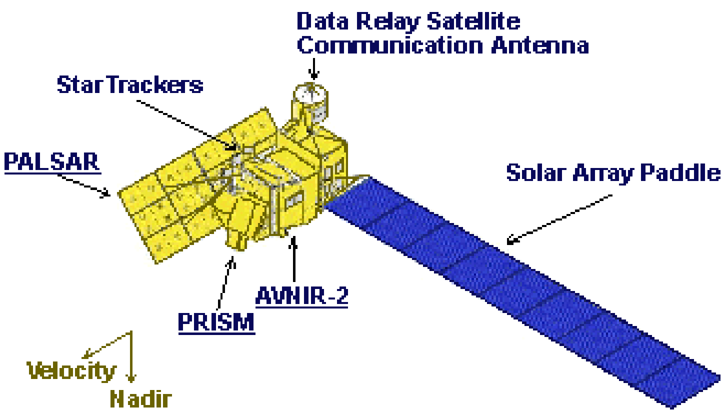


Figure 4. ALOS - Overview -
Source: ALOS@EORC

Table 2. ALOS Characteristics
Source: ALOS@EORC

Date	2004-
Launch Vehicle	H-IIA
Launch Site	Tanegashima Space Center
Spacecraft Mass	Approx. 4 tons
Generated Power	Approx. 7 kW (at End of Life)
Design Life	3 -5 years
Orbit	Sun-Synchronous Sub-Recurrent Repeat Cycle: 46 days Sub Cycle: 2 days Altitude: 691.65 km (at Equator) Inclination: 98.16 deg.
Attitude Determination Accuracy	2.0×10^{-4} deg. (with GCP)
Position Determination Accuracy	1 m (off-line)
Data Rate	240 Mbps (via Data Relay Technology Satellite) 120 Mbps (Direct Transmission)
Onboard Data Recorder	Solid-state data recorder (90Gbytes)

Various products derived from ALOS are expected to contribute widely to the advancement of science as well as to application fields such as natural resource management, disaster monitoring and damage mitigation, and regional development and planning. The ALOS science program seeks to promote both "scientific" and "application" researches. Application researches are expected to provide data products and algorithmic products for near-term practical uses. The ALOS science program sets research development targets as follows for ALOS data utilization and its algorithm development for data products.

1) Land Use and Land Cover Research
2) Topography and geology
3) Terrestrial (Vegetation) Ecosystem, Agriculture and Forestry Research
4) Climatic System, Hydrological Processes, and Water Resources Related Research
5) Oceanography and Coastal Zone Related Research
6) Disasters and Earthquakes
7) Resource Exploration
8) Development of Spatial Data Infrastructure
9) Basic Studies on Scattering and Interferometric Characteristics
10) Basic studies for accurate observation with high resolution optical sensors

In Oceanography and Coastal Zone Related Research, the program aims to provide information to assist economic activities including sea traffic, pollution control, and fisheries in coastal areas. For this purpose, it is necessary to develop an algorithm for products from PALSAR data such as: sea surface wind and wave height datasets; sea ice datasets; oil spill datasets; etc. It is also necessary to extract high resolution DEM combined with the existing depth data.

Especially in the oil spill detection, if it is possible to identify the spilled area by PASLAR and AVNIR-2 with pointing function which can change its observation area, information on oil spill condition and its dispersion will be widely and immediately available. It is expected to contribute to effective survey, collection, and reduction of the damage. PALSAR ScanSAR mode data will be used to extract information on large-scale ocean currents (Kuroshio, etc), cold and warm water masses, coastal water currents, and internal waves. In addition to the above-mentioned developing datasets, they are expected to largely contribute to studies on air-sea interaction, sea waves, and dynamics of various ocean phenomena in coastal zones and the open ocean. Once ocean dynamics is understood more in detail, it is expected to accelerate clarification of the mechanisms and modeling of eutrophication and related red tide resulting in the damage prevention in fisheries.

Ocean phenomena like surface wind wave, internal wave, sea surface roughness, and other features are dependent on characteristics of synthetic aperture radar including observation frequency, polarization, and off nadir angle. Table 3 shows major characteristics of ALOS PALSAR and JERS-1 SAR. J-ERS-1 continued its observation mission from 1992 to 1998 with providing observation data over the land mainly. The off nadir angle of JERS-1 SAR was set to 35 deg., which was the moderate angle between the land observation and marine one. The lower off nadir angle is sensitive to land features and the higher off nadir angle is sensitive to ocean phenomena. Although the off nadir angle was set to 35 deg., JERS-1 SAR provided many unique images over the ocean and provided information on the ocean including surface wind wave, eddies, current shares, and surface roughness which is dependent on micro films (Asanuma *et al.*, 2003b). It is expected that ALOS PALSAR may exhibit its possibilities to apply observation data for marine applications judging from its characteristics as well as JERS-1 SAR. Especially, the higher off nadir angle of 51 deg. may provide more sensitive image to ocean phenomena.

Table 3. Major characteristics of SAR

	ALOS PALSAR		JERS-1 SAR
Major observation mode	High resolution	ScanSAR	-
Observation frequency	L-band (1.27GHz)		L-band (1.275GHz)
Polarization	HH, VV, HH&HV, VV&VH	HH, VV	HH
Spatial resolution	10 m	100 m	18 m
Number of looks	2	8	3
Scan width	70 km	250-350 km	75 km
Off nadir angle	10-51 deg.		35 deg.

Symposiums and workshops were organized by JAXA as follows to promote an international- and interdisciplinary community of researchers on data use ready for ALOS launch after 2004.

March 2000	ALOS Data Use International Symposium 2000
March 2001	ALOS Data Use Industrial Symposium 2001
February 2003	ALOS Data Use Symposium 2003
January 2004	ALOS PI Workshop and Report on Public Subscription Results of JERS-1 Research

3.2 Algorithm for Geo-physical Parameters

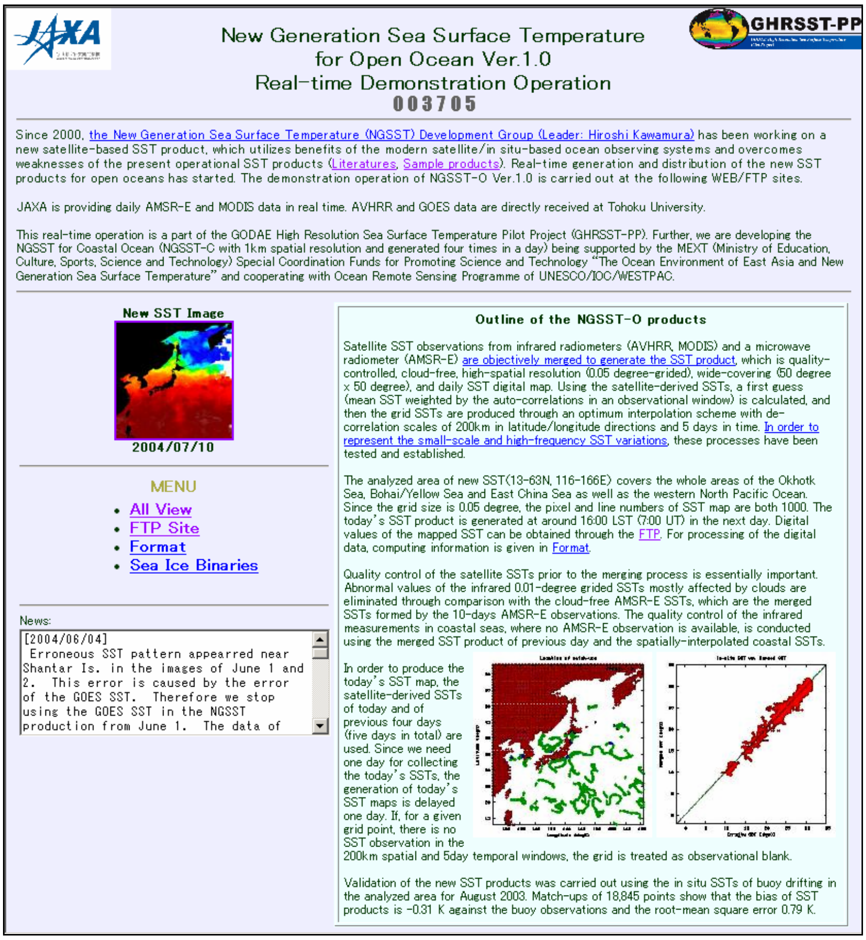
3.2.1 Sea Surface Temperature

New Generation Sea Surface Temperature for Open Ocean Ver.1.0 Real-time Demonstration Operation

Since 2000, the New Generation Sea Surface Temperature (NGSST) Development Group represented by Professor Hiroshi Kawamura, Center for Atmospheric and Ocean Studies, Tohoku University, has been working on a new satellite-based SST product, which utilizes benefits of both modern Satellite and *in situ*-based ocean observing system; and overcome 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 and started real-time generation and distribution of the NGSST products for open oceans (Figure 5). This real-time operation is a part of the GODAE High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP).

The new SST product, "Merged SST", is generated from objectively merged SST obtained by AVHRR, MODIS, and AMSR-E. Using these SST, a first guess (mean SST weighted by the auto-correlations) is calculated, and then the final product is produced through a simple optimum interpolation scheme (Guan and Kawamura, 2004). This method enables to provide proper SST of relatively small scale and quick change. Also, it requires severe quality control of SST data to be merged. Abnormal values of SST from AVHRR and MODIS are eliminated through comparison with the 10-day composite SST (AMSR-E Merged SST) prior to the generation of Merged SST. The quality control, where no AMSR-E SST observation is available, is conducted using the Merged SST of previous day or the spatially interpolated values. Merged SST generation 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 targeting coastal area with spatial resolution of 1 km and distribution frequency of 4 times a day, which is NGSST project of Ocean Remote Sensing Programme of UNESCO/IOC/WESTPAC and supported by IOC and Special Coordination Funds for Promoting Science and Technology "New Generation Sea Surface Temperature".



New Generation Sea Surface Temperature
for Open Ocean Ver.1.0
Real-time Demonstration Operation
003705

Since 2000, the New Generation Sea Surface Temperature (NGSST) Development Group (Leader: Hiroshi Kawamura) has been working on a new satellite-based SST product, which utilizes benefits of the modern satellite/in situ-based ocean observing systems and overcomes weaknesses of the present operational SST products (Literatures, Sample products). Real-time generation and distribution of the new SST products for open oceans has started. The demonstration operation of NGSST-O Ver.1.0 is carried out at the following WEB/FTP sites.

JAXA is providing daily AMSR-E and MODIS data in real time. AVHRR and GOES data are directly received at Tohoku University.

This real-time operation is a part of the GODAE High Resolution Sea Surface Temperature Pilot Project (GHRSST-PP). Further, we are developing the NGSST for Coastal Ocean (NGSST-C with 1km spatial resolution and generated four times in a day) being supported by the MEXT (Ministry of Education, Culture, Sports, Science and Technology) Special Coordination Funds for Promoting Science and Technology "The Ocean Environment of East Asia and New Generation Sea Surface Temperature" and cooperating with Ocean Remote Sensing Programme of UNESCO/IOC/WESTPAC.

New SST Image

2004/07/10

MENU
- All View
- FTP Site
- Format
- Sea Ice Binaries

News:
[2004/06/04]
Erroneous SST pattern appearred near Shantar Is. in the images of June 1 and 2. This error is caused by the error of the GOES SST. Therefore we stop using the GOES SST in the NGSST production from June 1. The data of

Outline of the NGSST-O products

Satellite SST observations from infrared radiometers (AVHRR, MODIS) and a microwave radiometer (AMSR-E) are objectively merged to generate the SST product, which is quality-controlled, cloud-free, high-spatial resolution (0.05 degree-grided), wide-covering (50 degree x 50 degree), and daily SST digital map. Using the satellite-derived SSTs, a first guess (mean SST weighted by the auto-correlations in an observational window) is calculated, and then the grid SSTs are produced through an optimum interpolation scheme with de-correlation scales of 200km in latitude/longitude directions and 5 days in time. In order to represent the small-scale and high-frequency SST variations, these processes have been tested and established.

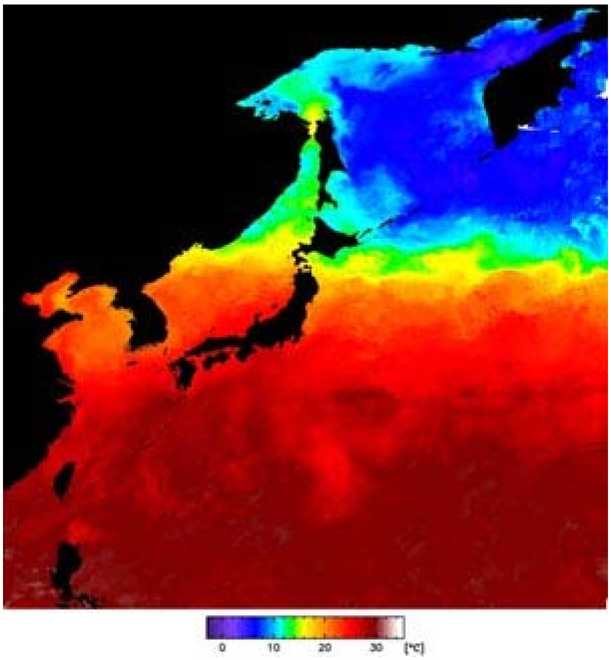
The analyzed area of new SST(13-63N, 116-166E) covers the whole areas of the Okhotk Sea, Bohai/Yellow Sea and East China Sea as well as the western North Pacific Ocean. Since the grid size is 0.05 degree, the pixel and line numbers of SST map are both 1000. The today's SST product is generated at around 16:00 LST (7:00 UT) in the next day. Digital values of the mapped SST can be obtained through the FTP. For processing of the digital data, computing information is given in Format.

Quality control of the satellite SSTs prior to the merging process is essentially important. Abnormal values of the infrared 0.01-degree grided SSTs mostly affected by clouds are eliminated through comparison with the cloud-free AMSR-E SSTs, which are the merged SSTs formed by the 10-days AMSR-E observations. The quality control of the infrared measurements in coastal seas, where no AMSR-E observation is available, is conducted using the merged SST product of previous day and the spatially-interpolated coastal SSTs.

In order to produce the today's SST map, the satellite-derived SSTs of today and of previous four days (five days in total) are used. Since we need one day for collecting the today's SSTs, the generation of today's SST maps is delayed one day. If, for a given grid point, there is no SST observation in the 200km spatial and 5day temporal windows, the grid is treated as observational blank.

Validation of the new SST products was carried out using the in situ SSTs of buoy drifting in the analyzed area for August 2003. Match-ups of 18,845 points show that the bias of SST products is -0.31 K against the buoy observations and the root-mean square error 0.79 K.

(a). Web site



Produced by NGSST Development Group.

(b). Merged SST on July 12, 2004

Figure 5. New Generation Sea Surface Temperature
<http://www.ocean.caos.tohoku.ac.jp/~merge/sstbinary/actvalbm.cgi?eng=1>

3.2.2 *Chlorophyll-a* Concentration

3.2.2.1 Improvement of algorithm for Near Real-time MODIS Processing

For the estimation of physical quantities, EORC, JAXA has not been using standard algorithm provided by NASA since 2002 when the center started near real-time processing of MODIS data but been using an algorithm prepared for ADEOS-II GLI. After the launch of ADEOS-II at the end of 2002, GLI had calibration, verification, and algorithm development, and then in 2004, such results were applied to MODIS higher-level products to improve their accuracy.

According to Murakami *et al*. (2004), Major changes of the algorithm for ADEOS-II before and after the launch are in the atmospheric correction and in-water algorithm. In the atmospheric correction algorithm, MODIS specific Look Up Table (LUT) was applied because conversion from MODIS radiance to GLI radiance could have errors due to the conditions of land surface or atmosphere. In addition, aerosol model was selected for in-water optical model (Tanaka *et al*., 2004) in the iteration process to improve atmospheric correction in coastal turbid water. Data-lack area and outlier data problems in coastal areas are expected to improve as a result. On the other hand in the in-water algorithm, empirical equation coefficients on *chlorophyll-a* concentration were adjusted in accordance with the adoption of LUT. The empirical equations used in in-water algorithm are shown in Table 4.

Table 4. In-water algorithms used in the MODIS NRT processing (Murakami *et al*., 2004)

Parameter	Equation nlwX: Normalized water-leaving radiance at Xnm
CHLA: *Chlorophyll-a* concentration	CHLA = 10^(0.36786 -2.3450*r +1.0645*r2 -0.53167*r3) -0.035 r = log10(max(nlw443,nlw470,nlw490)/nlw551)
SS: Suspended solid concentration	SS = 10^(-0.2977 -1.5537*r +0.42439*r2) r = log10(nlw443/nlw551)
CDOM: Colored dissolved organic matter absorption at 440nm	CDOM = 10^(-1.4952 -1.5020*r) r = log10(nlw443/nlw531)

The improved algorithm was verified in ocean color observation by Kaiyo, the marine observation vessel of JAMSTEC, in East China Sea from February to March 2004 (Figure 6 and Figure 7). As a result, the estimated radiance spectrum and *chlorophyll-a* concentration by both Terra and Aqua MODIS met with *in situ* data well. Some discrepancy between the estimated values and *in situ* data, which would have been due to atmospheric correction error by aerosol absorption, was found and it would be a future research topic.

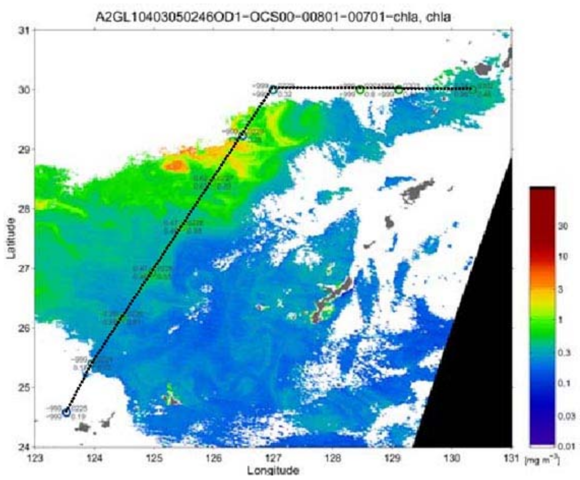
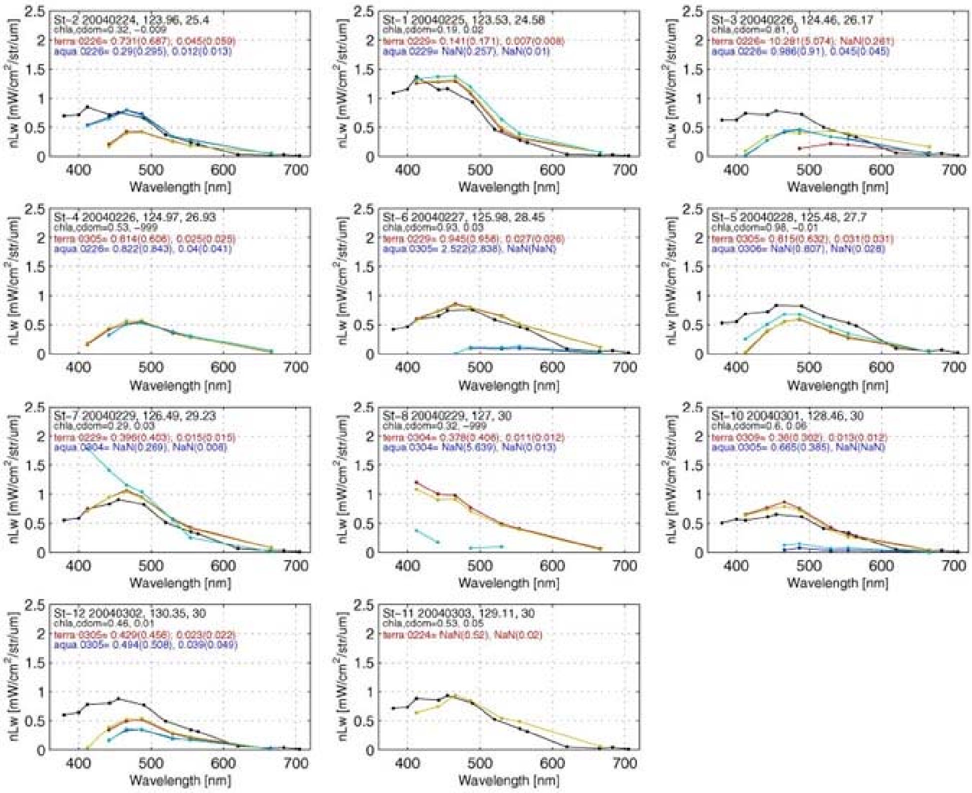
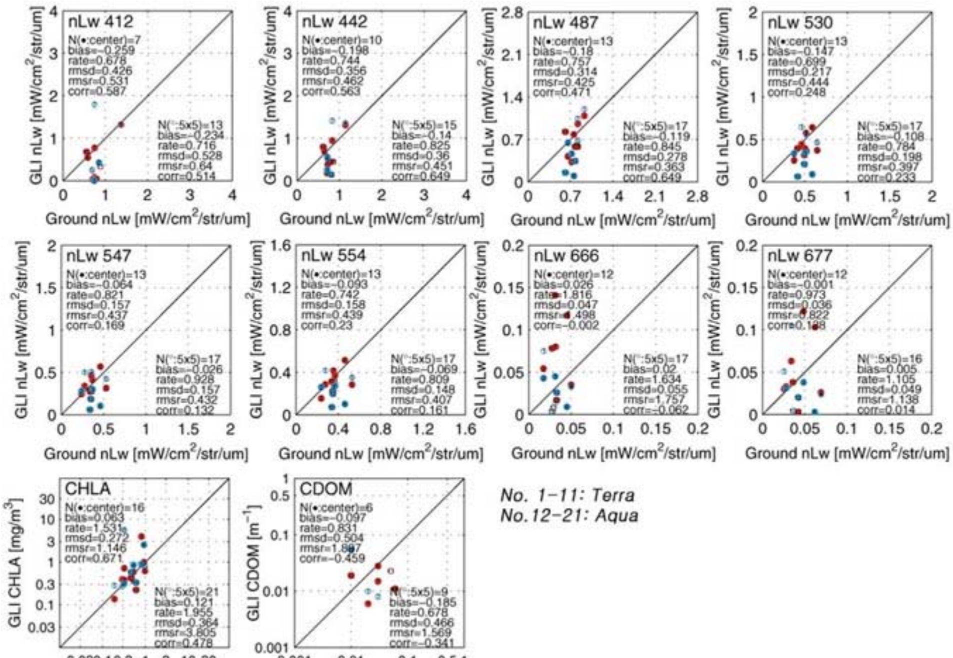


Figure 6. Navigation Route and *Chlorophyll-a* Image on March 5, 2004
(Murakami *et al*., 2004)



(a). Spectrum

Black lines in the graphs show the *in situ* data; red and yellow lines show recent observation data by Terra and their 5x5 spatial average respectively; and blue and sky blue lines show recent observation data by Aqua and their 5x5 spatial average respectively. Black characters show *in situ* observation points, date, longitude/latitude, CHLA, and CDOM respectively; red characters show Terra observation date, CHLA, and CDOM respectively; and blue characters show Aqua observation date, CHLA, and CDOM respectively.



(b). nLw, CHLA, CDOM

x-axis shows *in situ* data; y-axis shows estimated data by MODIS; red dots show Terra; and blue dots show Aqua.

Figure 7. Comparison between *in situ* data and estimated data (Murakami *et al*., 2004)

3.2.2.2 Toyama Bay Project

The project aims at developing algorithm for conducting a precise measurement of *chlorophyll-a*, SS, and CDOM in Toyama Bay as a model area. Also it aims at showing the effectiveness of remote sensing as a monitoring technique of the marine environment to NOWPAP Members (China, Korea, and Russia). The project is to be conducted over three years (starting in 2003) with the cooperation of NPEC, Nagasaki University, Toyama University, Toyama Prefectural Fisheries Experimental Station, and Toyama Prefectural Environmental Science Research Center. In the fiscal year 2003, the following studies were conducted in Toyama Bay for water quality characteristics; and for estimation method of SST and *chlorophyll-a* concentration by remote sensing.

1) Marine monitoring survey

   To monitor currents and water quality of Toyama Bay, monthly regular sampling and *in situ* survey were conducted at 9 stations (7 coastal stations, bay central station, and outside station). The outline of the findings on water quality in Toyama Bay is as follows.

   - *Chlorophyll-a* concentration showed relatively high negative correlation with DO (Dissolved Oxygen) and positive correlation with pH, SS, and SST.
   - Phosphorus had large influence on increase and decrease of phytoplankton while silicic acid had little influence.
   - Increase of phytoplankton related to increase of COD (Chemical Oxygen Demand).

2) Environmental monitoring survey by satellite

   To develop and validate in-water algorithm to estimate *chlorophyll-a* and SS concentration in the coastal area of Toyama Bay, SeaWiFS and MODIS data were acquired and analyzed. Also, accuracy verification was conducted for SST and *chlorophyll-a* concentration of AVHRR and MODIS provided by Marine Environmental Watch Project. The outline of the results is as follows.

   - The water with high *chlorophyll-a* concentration was observed along the coast of Toyama Bay and carried out of the bay by the counterclockwise current (Figure 8).
   - Accuracy of SST estimated by AVHRR was high even in the coastal area.
   - Estimated *chlorophyll-a* concentration by GLI algorithm did not meet well with *in situ* data in Toyama Bay although a good correlation with *in situ* data was observed in other areas as a whole.
   - Reverse computation algorithm of radiative transfer model by neural network did not have enough accuracy to estimate *chlorophyll-a* concentration at the moment.

In the fiscal year 2004, the project will continue the same surveys and obtain more *in situ* data to improve the in-water algorithm to estimate *chlorophyll-a* and SS concentration, etc, that did not have enough accuracy. Also, in order to demonstrate the effectiveness of remote sensing, the project will attempt to develop a more accuracy in-water algorithm with combining past SeaWiFS data.

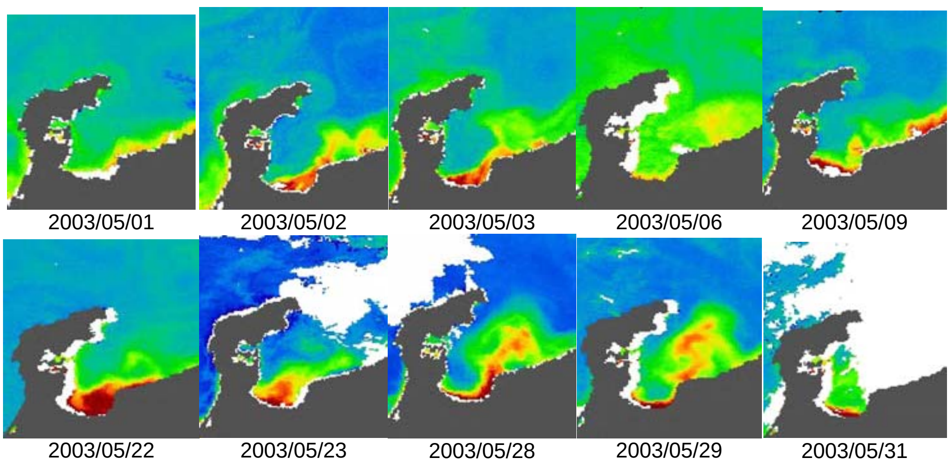


Figure 8. Continuous Images of Ocean Color in Toyama Bay

3.2.3 Primary Productivity

3.2.3.1 Algorithm to estimate primary productivity by using two community phytoplankton model

Kameda and Ishizaka (2000) reconsidered Depth-Integrated algorithm of Behrenfeld and Falkowski (1997) by adding observation data in the coast of Japan and showed that primary productivity was overestimated in high *chlorophyll-a* concentration area and underestimated in low *chlorophyll-a* concentration area. They also showed that P^B_{opt}, the maximum photosynthesis rate per unit *chlorophyll-a,* depends not only on SST but also on *chlorophyll-a* concentration. P^B_{opt} was expressed as a function of SST and *chlorophyll-a* concentration assuming that there are two types of phytoplankton: one that largely changes its biomass with slow primary productivity and large size; and the other that has small biomass with fast primary productivity and small size. Global primary production was estimated with applying this algorithm to OCTS/SeaWiFS data. As a result, 1) the overestimation in high *chlorophyll-a* concentration area was corrected; 2) the yearly total of primary production obtained from monthly *chlorophyll-a* concentration met with existing knowledge; and 3) the underestimation in low *chlorophyll-a* concentration area such as west equatorial Pacific Ocean was not corrected. It was due to that surface value estimated from observation data by satellite was used although vertical distribution of *chlorophyll-a* should have been used.

These algorithms have been developed targeting ocean area basically. In coast, sea surface *chlorophyll-a* concentration estimated from ocean color remote sensing still has large error even now due to SS and CDOM that disturb optical properties rather than phytoplankton. In addition, a difficulty still remains in the assumption's applicability in ocean area that phytoplankton concentration determines photosynthetically available radiation (Ishizaka, 2002).

3.2.3.2 Depth and Time Resolved Primary Productivity Model

Asanuma *et al.* (2000) proposed a depth and time resolved primary productivity model taking account of: vertical distribution of photosynthetically available radiation and *chlorophyll-a* concentration; and time varying carbon fixation rate. This model provided vertical distribution of photosynthetically available radiation and *chlorophyll-a* concentration as an empirical equation, resulting in fairly good agreement between its estimated values and *in situ* data of primary production in equatorial area and in pacific coast of Japan. However, in its validation process, overestimation in case II water was confirmed. It was pointed out that the main reason of the overestimation was due to vertical estimates of photosynthetically available radiation solely based on surface *chlorophyll-a* concentration estimated from observation data by satellite.

To improve the accuracy in case II water, Asanuma *et al.* (2003a) introduced a concept of diffused attenuation coefficient corresponding to *chlorophyll-a* concentration taking account of optical attenuation by SS and CDOM. As a result, the estimated values and *in situ* data had good agreement as a whole and its practical use is about to realize although with some exceptions in singular points where *in situ* data exceeded the estimated values (Matsumoto and Asanuma, 2003). A part of these studies is the result of comprehensive study, "Cooperative research on the global mapping of carbon cycle and its advancement", funded by Special Coordination Funds for Promoting Science and Technology.

Figure 9 shows the global distribution of ocean primary productivity that was estimated through applying the model to GLI data. It was characteristic that the ocean primary productivity was estimated relatively high in the middle-to-high latitude coastal regions and equatorial area where photosynthesis by phytoplankton is active.

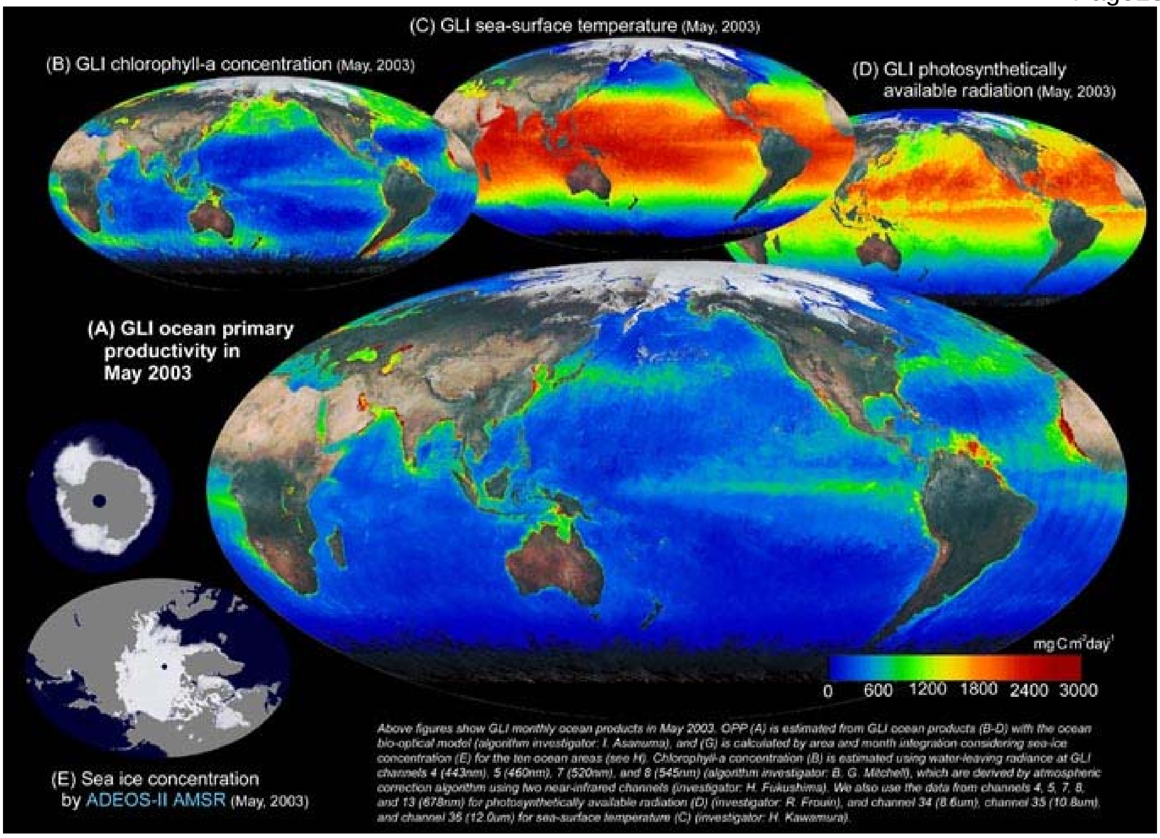


Figure 9. GLI Ocean Primary Productivity in May 2003
Source: EORC, JAXA

3.3 Validation of Geo-physical Parameters

3.3.1 GLI Match-up Analysis

JAXA/EORC GLI ocean group has been validating various physical quantity estimated from GLI data by match-up data set since GLI was launched. Match-up data set consists of *in situ* data and clipped data of GLI observed in the same position, same time, or nearby time. By comparing both data, efforts have been made: to recognize high level product's error; to adjust parameters in high level processing; and to improve algorithms in high level processing.

In situ data to be used in validation are collected through two approaches, one from the global level, and the other from Asian area where users are concentrated. In the global level, data are collected from wide area such as offshore California and Hawaii where atmospheric and oceanographic conditions are good, other Atlantic ocean, etc, making the best use of international cooperation with Principal Investigator (PI), SIMBIOS, etc.

In Asian ocean, data of East China Sea, Ariake Sea, Offshore Sanriku, Tokyo Bay, Toyama Bay, etc, are maintained by Field campaign and cooperative observation of Nagasaki University, Tokyo University of Fisheries (present Tokyo University of Marine Science and Technology), Hokkaido University, Fisheries Agency, Japan Coast Guard, and NPEC. These data are managed by JAXA and part of them can be used only for calibration/validation or algorithm development. Figure 10 shows all locations where *in situ* data were obtained.

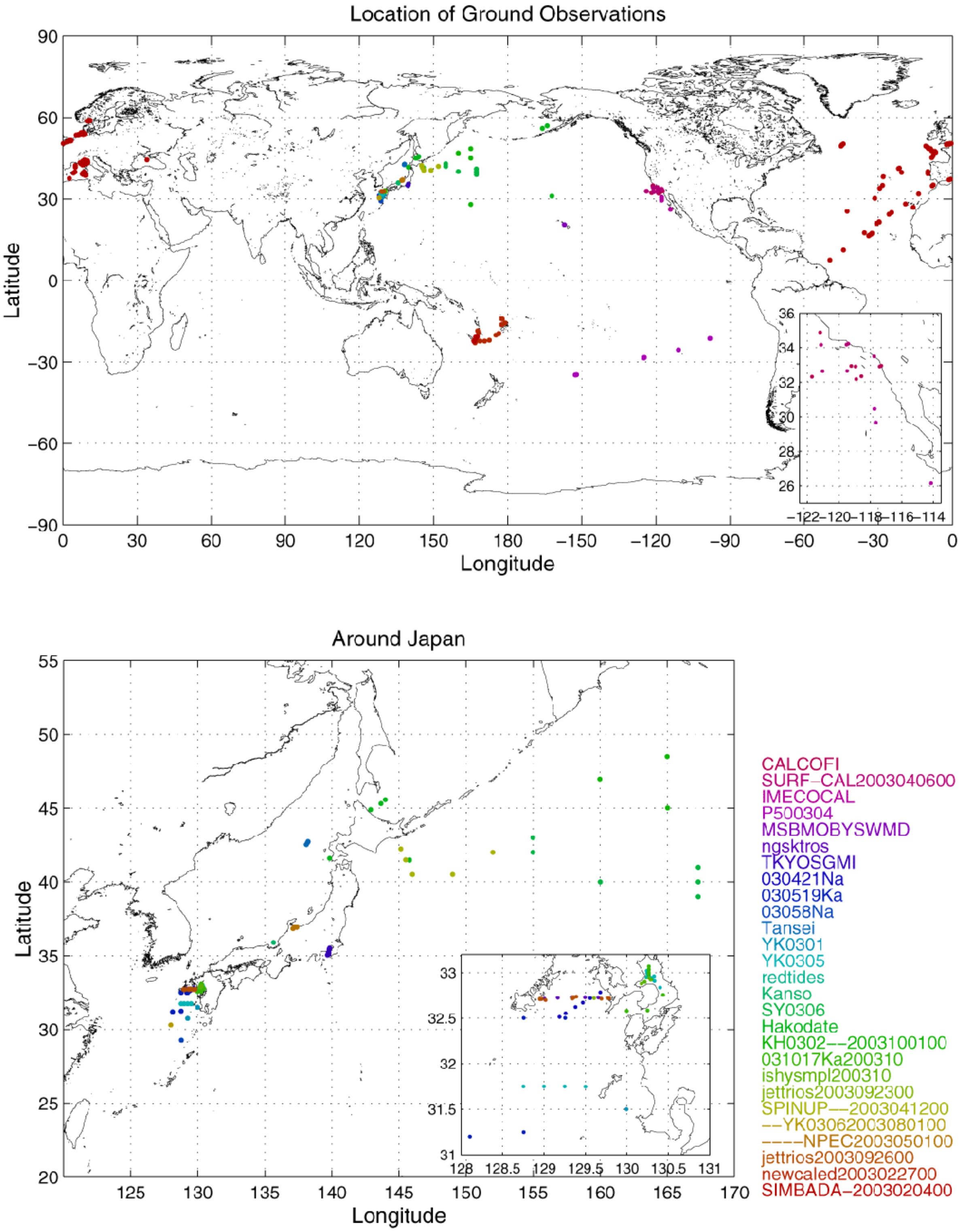


Figure 10. All Locations of the ground observations
Source: Ocean Home GLI EORC JAXA

Validated results of the product by match-up data is shown in Table 5. The results suggested that the accuracy of *chlorophyll-a* concentration is good as a whole while it is not good enough in coasts. They also suggested the underestimation of CDOM that is considered due to the difference of target area in the algorithm development and in the validation. In addition, it was confirmed that the distribution and values of each product generally have good agreement with validated products of SeaWiFS and GMS.

Table 5. Summary of GLI Validation (version 1 products)
(JAXA/EORC GLI Ocean Group, 2004)

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 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% (10km/monthly)	11%	- agree well with SeaWiFS PAR and 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 440nm	-50～+100%	(82%)	- insufficient data number (now increasing)
SS	suspended sediment concentration	-50～+100%	(34%)	- insufficient data number
K490	attenuation at 490nm	-35～+50%	(78%)	- insufficient data number (now increasing)
SST	bulk sea surface temperature	0.6K	0.6K	- cloud detection problem - Electric noise on MTIR image

3.3.2 Project on Ocean Productivity Profiling System

To understand material cycling in ocean, it is necessary to clarify geographic distribution and variation of Biological Pump activity. For the clarification, measurement of phytoplankton quantity and primary production by ocean color remote sensing is expected to be a practical method of the observation. However, present data are not enough to validate the phytoplankton quantity and primary production estimated by the ocean color remote sensing. Especially, lack of primary production data is serious because they are measured by on site experiment by vessels.

"Project on Ocean Productivity Profiling System" represented by Professor Toshiro Saino, Hydrospheric Atmospheric Research Center, Nagoya University, aims at providing data for real time validation of estimated primary productivity by ocean color remote sensing (Saino, 2001). The project started as a five-year plan (November 1999 to October 2004) and will continue as a new five-year plan, "Ocean Primary Productivity Monitoring by Satellite" from November 2004. Japan Science and Technology Agency supports these projects as Core Research for Evolutional Science and Technology.

As shown in Figure 11, the underwater automatic escalation buoy is composed of underwater winch below the euphotic zone and measurement buoy that escalate from the winch to water surface. The measurement buoy has sensors such as Fast Repetition Rate Fluorometer (FRRF) and Profiling Reflectance Radiometer (PRR) providing vertical profiles. The system can keep calm depth so that it can reduce the influence by waves and attached organisms. It can also transfer the measured data in real time and can remote control the winch by acoustic and radio communication function. Currently, the model 1 has been repeatedly tested in the sea for putting it to practical use.

Regarding validation methods for primary production estimated by ocean color remote sensing, daily and depth integrated net primary production is necessary as a fundamental data. Further accurate algorithms development have been tried to estimate daily and depth integrated total primary production, making the best use of total primary production of phytoplankton by FRRF, phytoplankton quantity estimated from PRR measurement, and time series of solar radiation estimated from GMS data.

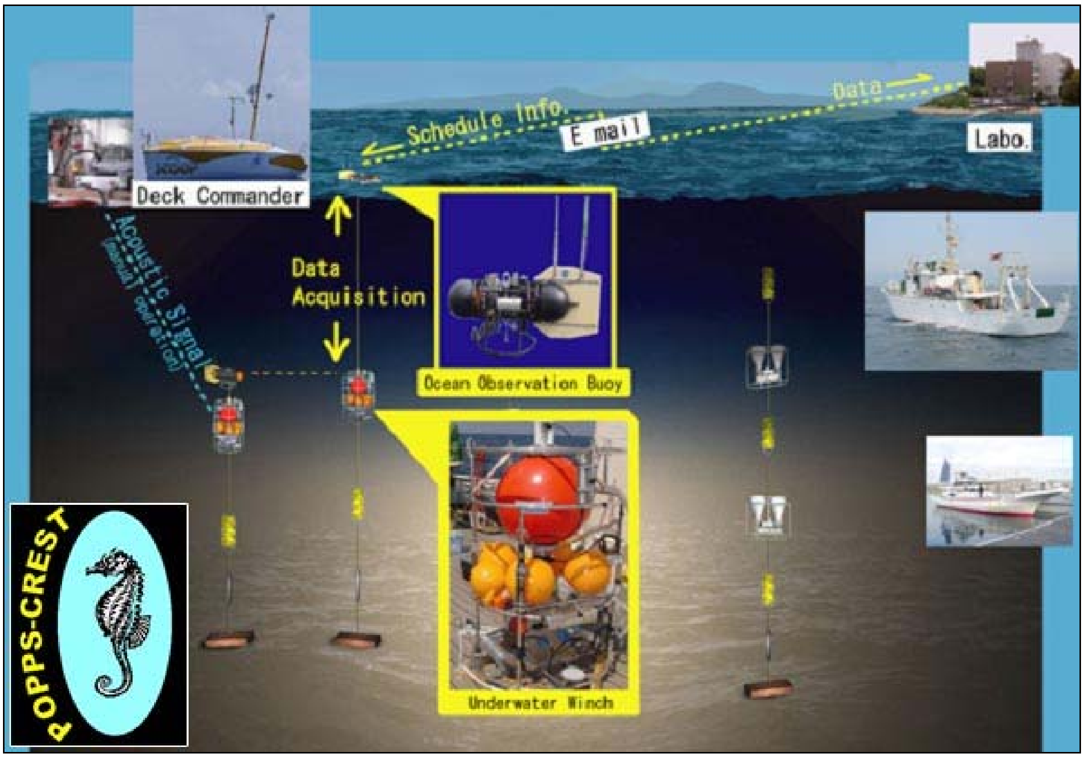


Figure 11. Project on Ocean Productivity Profiling System (POPPS)

4 Introduction of latest findings

4.1 Remote sensing oceanography of a harmful algal bloom off the coast of southeastern Vietnam

Harmful algal blooms (HABs) in the southeastern Vietnamese coastal waters have caused large economic losses in aquacultured and wild fisheries in recent years; however, there have been few oceanographic studies on these HAB events. The present study reports an extensive HAB off southeastern Vietnamese waters during late June to July 2002 with in situ observations and analyzes the oceanographic conditions using satellite remote sensing data. The HAB had high *chlorophyll-a* concentrations (up to 4.5 mg/m^3) occurring ~200 km off the coast and ~200 km northeast of the Mekong River mouth for a period of ~6 weeks. The bloom was dominated by the harmful algae haptophyte *Phaeocystis* cf. *globosa* and caused a very significant mortality of aquacultured fish and other marine life. In the same period, SST imagery showed a cold water plume extending from the coast to the open sea, and QuikScat data showed strong southwesterly winds blowing parallel to the coastline. This study indicated that the HAB was induced and supported by offshore upwelling that brings nutrients from the deep ocean to the surface and from coastal water to offshore water and that the upwelling was driven by strong wind through Ekman transport when winds were parallel to the coastline. This study demonstrated the possibility of utilizing a combination of satellite data of *chlorophyll-a* concentration, SST, and wind velocity together with coastal bathymetric information and *in situ* observations to give a better understanding of the biological oceanography of HABs (Tang *et al.*, 2004).

4.2 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. Start timing of the spring bloom was different spatially. The spring bloom started subpolar front and southward in March, northward of subpolar front, the Primorye coast and off Hokkaido in April and in the middle of Japan Basin in May. The start of the spring bloom showed interannual variability that corresponded with the wind speed in the area.

The spring bloom in 1998 and 2002 appeared about four weeks earlier between 1997 and 2002, and it corresponded with weak winds that can lead to an early development of the thermocline. The bloom was late in 1999 and 2001 in the Japan Basin and along the Primorye coast, and in the southern area in 2000. It corresponded with stronger wind stress that delayed seasonal thermocline formation. The bloom along the Primorye coast appeared later in 1999, and it corresponded with stronger wind stress, and at the same time, it seemed to be related with the delay of melting of sea ice in Mamiya Strait. The fall bloom appeared from early October to early December, and it did not have a clear temporal transition. The area where *chlorophyll-a* concentration exceeded 0.8μg/l was wider in the western area than in the eastern area every year. The magnitude of the fall bloom was different between years, but it did not show a correlation with average wind speed in fall. Those results indicated that the timing of the seasonal bloom in the NOWPAP Region is largely affected by the variability of global climate such as ENSO events (Yamada *et al*., in press).

4.3 Wind jets and wind waves off the Pacific coast of northern Japan under winter monsoon captured by combined use of scatterometer, SAR and altimeter

Wind jets and wind waves off the Pacific coast of northern Japan under the East Asian winter monsoon are investigated using scatterometer, SAR, and altimeters. This study indicates important role of coastal topography in air-sea interaction by taking wind wave developments for instance. Under the monsoon outbreaks, strong winds blow through over the Japanese archipelago toward the Pacific Ocean and form distinguished wind jets and wakes over the ocean. First, we depict two prevailing wind flow patterns associated with the northwesterly winter monsoon. They are derived by averaging QuikSCAT wind vectors when the 850-hPa pressure level wind directions are within and , respectively. In the two wind flow patterns, wind jets and wakes are formed in different regions in connection with the line of strike of the topography. Then, using high-resolution satellite observations of QuikSCAT and ERS-2 SAR for wind, and TOPEX/Poseidon and ERS-2 RA for significant wave height, we present two case studies corresponding to the two prevailing wind flow patterns in order to investigate wind wave development under topographically modified winds. Combined use of QuikSCAT and ERS-2 SAR allow us to capture the surface wind transition from the shore to the offshore. The SAR-derived wind fields reveal smaller-scale wind jets and lower wind regions in near shore regions. They verify that the wind jets and wakes are extensions of terrestrial gaps and blockages. The coastal wind jets extending from Uchiura Bay and Mutsu Bay and the Tsugaru Straits are noticeable. Variations of significant wave height observed by TOPEX/Poseidon and ERS-2 RA are compared with those of surface winds derived from QuikSCAT and ERS-2 SAR along the altimeter ground tracks. As a result, the positions of local maximum and minimum of significant wave height and squares of wind speeds coincide with each other. This demonstrates the important role of coastal topography in wind modification and the resulting offshore wind wave development (Shimada and Kawamura, in press).

5 Strategies/Plans for RS related activities

5.1 Satellite data supply and distribution

5.1.1 MODIS Near Real Time Data

EORC, JAXA has been providing Higher-level products including *chlorophyll-a* concentration and SST processed from MODIS observation data through the Internet by near real-time basis since July 2002 (Figure 12). Tokai University Space Information Center receives MODIS observation data, Tokai University Research & Information Center processes Level 1B files, and then EORC estimates physical quantity. This procedure took half to one day to provide products to users due to data transmission time among stations. In July 2004, JAXA developed a new system that EOC receives data and conducts Level 1B processing and started its operation in parallel with the existing system. This is a part of alternatives to provide products of Terra/Aqua MODIS and Aqua AMSR-E with the users who were going to use ADEOS-II GLI/AMSR products which suspended its operation at the end of October 2003 due to mechanical troubles. In the new system, transmission line with huge capacity has been prepared between EOC and EORC, enabling product distribution in about 4 hours as an average.

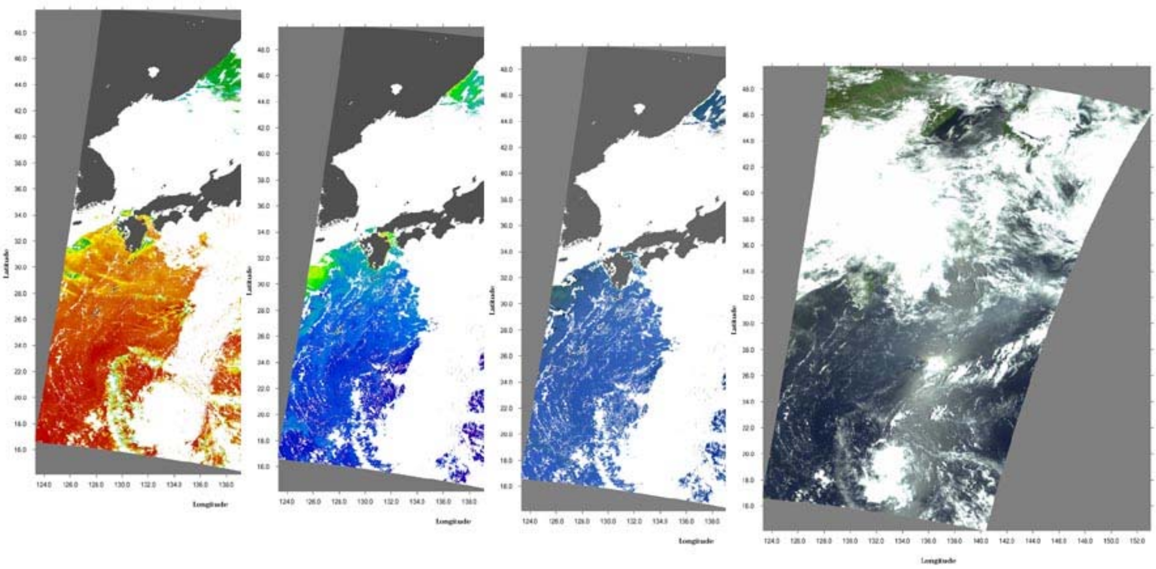
EORC uses ADEOS-II GLI algorithm which was improved its accuracy by calibration/verification and algorithm development after its launch rather than NASA standard algorithm. Use of GLI Version 2 is now under preparation.

Currently available high order products are shown Table 6 and Figure 13. All products are free of charge. Simple registration including user name, organization, etc is necessary when using Binary Data.

Figure 12. MODIS Near Real Time Data
<http://kuroshio.eorc.nasda.go.jp/ADEOS/mod_nrt/>

Table 6. 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), and Chlorophyll-a concentration (CHLA).	SST CHLA
500 m	Geometrically corrected	-
250 m	Geometrically corrected	-



Courtesy of JAXA/TOKAI UNIVERSITY

Figure 13. Sample of 1 km Images Supplied by MODIS Near Real Time Data: SST, CHLA, nLw, RcRefl on July 12, 2004.

5.1.2 RESTEC

The Remote Sensing Technology Center of Japan (RESTEC) was established in August 1975 to promote social economy and the well being of the nation's citizenry. To these ends, RESTEC utilizes satellites and conducts basic and general research development related to remote sensing. Remote sensing encompasses Earth resources and phenomena investigation. Furthermore, RESTEC promotes the diffusion and development of remote sensing and other space development utilization.

RESTEC provides various satellite data and has its institutional frame to continuously provide the data including the past observation data. Table 7 shows part of the provided data that Japan is involved in its development and operation. Various products of Aqua AMSR-E have been provided since September 2003; and those of ADEOS-II AMSR and GLI have been provided since December 2003. Regarding ALOS, which is planned to launch 2004, “ALOS use committee” was established to promote data use and dissemination and to conducts various activities towards data supply.

Table 7. Satellite data provided by RESTEC related to Japan

Satellite	Sensor	Operational period
MOS-1, 1b	MESSR VTIR MSR	1987/02-1996/04
JERS-1	VNIR SWIR SAR	1992/09-1998/10 1992/09-1993/12 1992/09-1998/10
ADEOS	AVNIR (Multi-Band) AVNIR (Panchromatic-Band) OCTS	1996/10-1997/06
TRMM	PR VIRS TMI	1997/11-
Aqua	AMSR-E	2002/05-
ADEOS-II	GLI VNIR SWIR MTIR AMSR	2002/12-2003/10
ENVISAT	ASAR	2002/03-
ALOS	PRISM AVNIR-2 PALSAR	(Plan)

Users need to submit order forms to RESTEC to obtain satellite data shown in Table 7. To fill up the order forms, users should obtain necessary information from EOC operated by JAXA. Earth Observation data and Information System (EOIS) is a comprehensive online information service (Figure 14) integrated as a common interface for various services including scene search, data set search, etc provided by JAXA and NASA. Users can consider whether they order them or not by confirming the search results of detailed information and sample image of the target satellite by inputting observation date, cloud amount, etc to EOIS.

Users, who are permitted by EOC, JAXA, can directly order data through EOIS without submitting order forms to RESTEC.

Figure 14. Earth Observation Data and Information System
<https://isswww.eoc.jaxa.jp/iss/en/index.html>

5.1.3 Agropedia-SIDaB

Satellite Image Database System in AFF (SIDaB) is operated by Computer Center for Agriculture, Forestry and Fisheries Research of the Ministry of Agriculture, Forestry and Fisheries of JAPAN since 2000. The system accumulates universal observation data such as NOAA, DMSP, GMS, etc, and provides products processing, search functions, and data. SIDaB is widely opened through the Internet as a content of "Agropedia", an agricultural information resource system that intends effective use of research results. The system newly began to receive MODIS data since December 2002, and provides products of Level 1B, Level 3B, and NDVI as of February 2003 (Figure 15). Product of *Chlorophyll-a* concentration is now under consideration for distribution.

Users can obtain target products by search conditions of observation date, cloud amount, and region. Furthermore, users can obtain products with specific processing such as area request, format specification, etc, with free of charge. User registration in “Agropedia” is required for the use.

Figure 15. Agropedia - SIDaB
<http://rms1.agsearch.agropedia.affrc.go.jp/menu_en.html>

5.1.4 WebPaNDA/WebMODIS

Institute of Industrial Science of University of Tokyo, the earliest adopter in Japan, has been receiving NOAA AVHRR observation data since 1984 and has been operating an online distribution system (WebPaNDA) for Level 1B data and Quicklook images by using FTP since February 2002. PaNDA, which stands for Package for NOAA Data Analysis, is a software package that has functions of format conversion, radiation correction, atmospheric correction, precise geometric correction by GCP, etc. While it is often the case that costly commercial software is used for the processing of AVHRR data, PaNDA is a freeware to realize precise geometric correction that is considered to be the most difficult processing (Takeuchi *et al*., 2002).

In parallel with receiving AVHRR data, the Institute started to receive Terra MODIS observation data since May 2001 and has been operating WebMODIS since September 2002 which pre-processes MODIS data by HDFLook and distribute them to users like WebPaNDA. In 2003, the Institute also started to receive Aqua MODIS observation data and now is working on adding functions including atmospheric correction, BRDF correction, and radiation correction by 6S. The institute set the final goal as providing high order products such as NDVI, land surface temperature, SST, and LAI (Takeuchi *et al*., 2003).

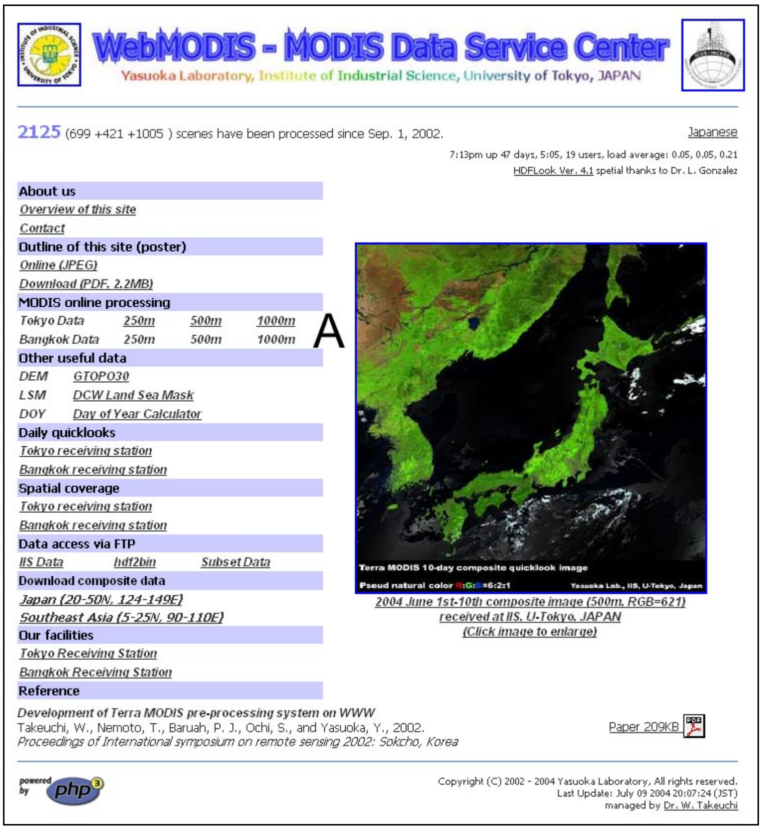
Both WebPaNDA and WebMODIS provide data for free of charge. Sample using method of WebMODIS is shown as follows. Table 8 shows the available data.

1) Select special resolution from 250 m, 500 m, or 1000 m (Figure 16-(a)-A).
2) Select necessary date of the data by file name (Figure 16-(b)-A).
3) Input longitude and latitude of the necessary area (Figure 16-(b)-C) or select from prepared options (Figure 16-(b)-B).
4) Input e-mail address to receive the information on data processing completion and download procedure (Figure 16-(b)-C).
5) Receive the e-mail informing FTP site about 20 minutes after completing procedures from 1) to 4). Download data from the FTP site. The data will be deleted 72 hours after the e-mail notice.

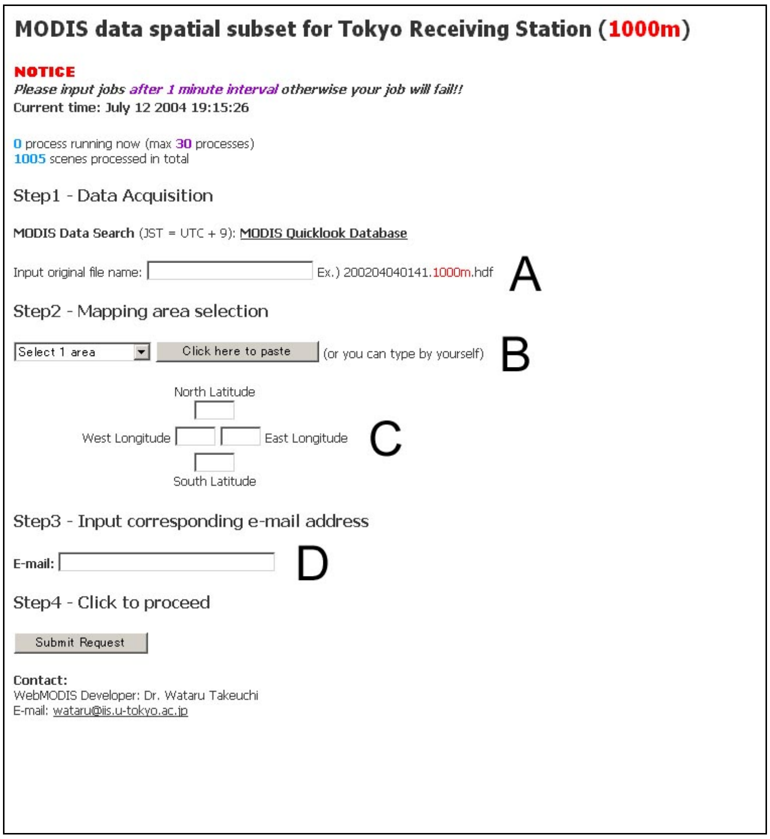
Table 8. Available file list processed on WebMODIS in terms of spatial resolution (Takeuchi *et al*., 2003)

FNAME expresses the data acquisition date in the form of YYYYMMDDHHMM (Year, Month, Day, Hour and Minute in UTC). Reflectance values are in radiance, thermal values in brightness temperature (celsius degree) and zenith/azimuth angles in radian. HDF data are in 32-bit floating values.

Spatial Resolution	File	Note
250 m (QKM)	FNAME QKM RefSB.hdf	Image of Visible and Near-infrared (channel 1, 2)
	FNAME QKM QuickLook.jpg	Quicklook image of Visible and Near-infrared
	FNAME QKM.met	Meta-information (ASCII)
500 m (HKM)	FNAME QKM AggrHKM RefSB.hdf	Image of Visible and Near-infrared (channel 1, 2)
	FNAME HKM RefSB.hdf	Image of Visible and Near-infrared (channel 3-7)
	FNAME HKM QuickLook.jpg	Quicklook image of Visible and Near-infrared
	FNAME HKM.met	Meta-information (ASCII)
1000 m (1KM)	FNAME QKM Aggr1KM RefSB.hdf	Image of Visible and Near-infrared (channel 1, 2)
	FNAME HKM Aggr1KM RefSB.hdf	Image of Visible and Near-infrared (channel 3-7)
	FNAME 1KM RefSB.hdf	Image of Visible and Near-infrared (channel 8-9 and 26)
	FNAME 1KM Emissive.hdf	Image of Thermal Infrared (channel 20-25 and 27-36)
	FNAME SensorAzimuth.hdf	Sensor Azimuth Angle
	FNAME SensorZenith.hdf	Sensor Zenith Angle
	FNAME SolarAzimuth.hdf	Solar Azimuth Angle
	FNAME SolarZenith.hdf	Solar Zenith Angle
	FNAME 1KM QuickLook.jpg	Quicklook image of Visible and Near-infrared
	FNAME 1KM.met	Meta-information (ASCII)



(a). Main



(b). Data Search

Figure 16. WebMODIS
<http://webmodis.iis.u-tokyo.ac.jp/>

5.2 Study Network and Assistance Activity

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

The workshop is organized by NPEC that was designated as the Special Monitoring and Coastal Environmental Assessment Regional Activity Center (CEARAC) based on NOWPAP in April 1999 aiming at contributing to the development of marine environmental monitoring technologies by remote sensing. In the workshop, relating countries (Japan, China, Korea, and Russia) including NOWPAP Working Group 4 (NOWPAP WG4) members attend to make presentation on remote sensing application examples of marine environmental monitoring, research and development trend, etc, and to exchange information.

The first workshop held in Toyama from March 31 to April 1 in 2000 recommended that NOWPAP and NPEC should organize regular workshops and training courses; and promote development of real-time information system of the NOWPAP Region (NPEC, 2000).

The second workshop held in Toyama from March 25 to 26 in 2002 mainly focused on ocean color remote sensing that was different from general argument as in the first workshop. Reports were presented on ocean color remote sensing in each country; general argument was done on atmospheric correction and in-water algorithm; and the framework was presented relating to marine environmental remote sensing in Asia. Asian researchers expressed their expectation that Japan should take the leadership and establish cooperation system in Asia for the use of ocean color remote sensing based on the experience through ADEOS OCTS for coastal environmental monitoring. The workshop obtained the following discussion results (NPEC, 2000; NPEC, 2003). The third workshop is going to be held in October 2004 in Beijing.

1) It is very important to continue survey and monitoring by using CZCS, OCTS, FY-1, and SeaWiFS.
2) *In situ* survey is necessary to improve in-water algorithm and atmospheric algorithm.
3) It is important to research cooperatively to collect *in situ* observation data for the improvement of model, calibration, and validation.
4) Regular data collection by each regional organization is useful to accumulate data.
5) Quality control of *in situ* data is important and has to be carried out always. Establishment of standardized protocols is necessary to accurately accumulate quality data from different organizations and projects.
6) Consideration of land-ocean system is important for monitoring, modeling, and reducing pollution in NOWPAP area. Specifically, coastal- and river basin monitoring are necessary.
7) NOWPAP is expected to have cooperative activities with international marine environmental monitoring programs including IOC, GOOS, etc.
8) It was proposed that workshops and training courses should be continued and their results and satellite data managed and operated by NPEC should be widely opened.

5.2.2 Red Tide Watcher Project

In Asian coast, large-scale red tides have frequently occurred, resulting in social issues including increase of fishery damage, deterioration of tourism resources, and poisoning due to polluted fishes and shellfishes. To prevent such damages, it is necessary to have regular- and large scale monitoring program. However, in Asian coastal countries, collection of red tide occurrence information still relies on survey vessels mainly. The establishment of monitoring system is expected due to the spreading of red tide occurrence. Red Tide Watcher Project has started since October 2002 for three years aiming mainly at the establishment of red tide monitoring infrastructure based on the mutual understanding among related countries including integration of existing efforts and the latest technology, ocean color remote sensing by satellite.

Red tide species include lots of phytoplankton depending on sea area and season. Thus, wide area monitoring requires 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. Based on such observations, Red Tide Watcher Project initiated an international ocean color observation forum to promote partnership among organizations and specialists relating to red tides in Asian coast, marine environment, and remote sensing of ocean color. The outlines of the activities are as follows (Red Tide Watcher Project, 2003).

1) Monitoring red tides that spread widely in Asian coasts
   Establishing an international ocean color observation forum of organizations and researchers in Asia relating to red tides, marine environment, and remote sensing of ocean color. Initiating a wide area red tide monitoring system, Red Tide Watcher, that integrates the forum activities; and database development and operation of red tide occurrences.
2) Ecology of red tides
   Reviewing ecological information by studying red tide plankton classification and ecology as well as by collecting information from each country's researchers through holding a red tide ecology symposium.
3) Ocean color observation by satellites
   Establishing an algorithm estimating *chlorophyll-a* quantity from highly turbid water which is dominant in Asian coast by studying optical characteristics of seawater. Also, investigating efficient operation of red tide monitoring system by ocean color remote sensing thorough observation satellite workshop.
4) Asian I-LAC database
   Taking a role of basic infrastructure development including Asian I-LAC database, its maintenance, and its operation system.

In March 2003, a workshop was held entitled both international ocean color satellite and red tide symposium in which about 30 researchers of remote sensing and red tide from Asia, Europe, and America gathered to share the common understandings, present conditions, and issues towards the establishment of red tide monitoring system (Red Tide Watcher Project, 2003).

This project is supported by Special Coordination Funds for Promoting Science and Technology "Red-Tide Watcher"

6 Challenges and Prospects

6.1 Real-time Performance and Continuity of the Observation

To proceed algorithm development for practical use, infrastructure arrangement, and project formation afterwards, it is necessary to achieve: real-time performance that provides status; and continuity of the observation that provides long-term variations. The real-time performance, as shown in 5.1.1, has already been ready for practical use and expected to provide products in shorter time in future. The continuity will be achieved more than 10 years from now by observation plans such as Global Change Observation Mission of JAXA and NPOESS Preparatory Project of NASA that follow presently operating SeaWiFS and MODIS. However, to analyze long-term variations by using products of OCTS, SeaWiFS, MODIS, and GLI that range 8 years, product compatibility between sensors would be an issue due to inevitable differences between sensors.

Global Change Observation Mission

To systematically observe global environmental variations in time and space, JAXA is considering a long-term earth observation program, called Global Change Observation Mission (GCOM), for necessary parameters starting from ADEOS-II for 15 years. The program plans to launch two earth observation satellites based on Integrated Global Observing Strategy (IGOS). One is GCOM-A1 satellite that observes ozone and greenhouse gases and the other is GCOM-B1 satellite that observes material and energy cycle. GCOM-B1 will be equipped with Second generation GLI (SGLI), which has multiple wavelength-channel as a successor of GLI, aiming that Japan should take a leading role in the observation of ocean color and marine primary production.

It is very important to conduct such coastal monitoring for understanding and predicting impacts of human activities on marine environment especially for Japan which has long coast line as a topographic feature and experiences concentration of population and industries with rapid development in coast. S-GLI is a sensor that is expected to contribute to it. Frequent observation of once in a day, high resolution observation by 250m, and high SNR (signal to noise ratio) ocean color observation, etc are considered although they are still in the preliminary stage. The final goal is as follows.

Understanding of coastal-area processes
- Income and expenditure of materials (carbon, soil, pollutant...) and heat.
- Process of primary production (contribution in the carbon cycle)
- Interaction between coast and open ocean.

Coastal area monitoring
- Pollution of material and heat due to urbanization and industrialization
- Eutrophication (e.g., red tide) in the coastal and in-land waters
- Natural disasters (abnormal wind, rain, influence of an earthquake...)
- Estimation of productivity (fishery locations and a catch of fish)
- High resolution sea-ice position and displacement
- Near real-time inputs of high resolution numerical (physical, biological and chemical) models in the coastal area.

In addition, based on the experience of ADEOS-II which suspended its operation due to mechanical troubles, it is now under consideration to launch a sensor S-GLI ALOHA version (ALOHA: Atmosphere, Land and Ocean Harmonized Answer) in 2008 as S-GLI prior mission.

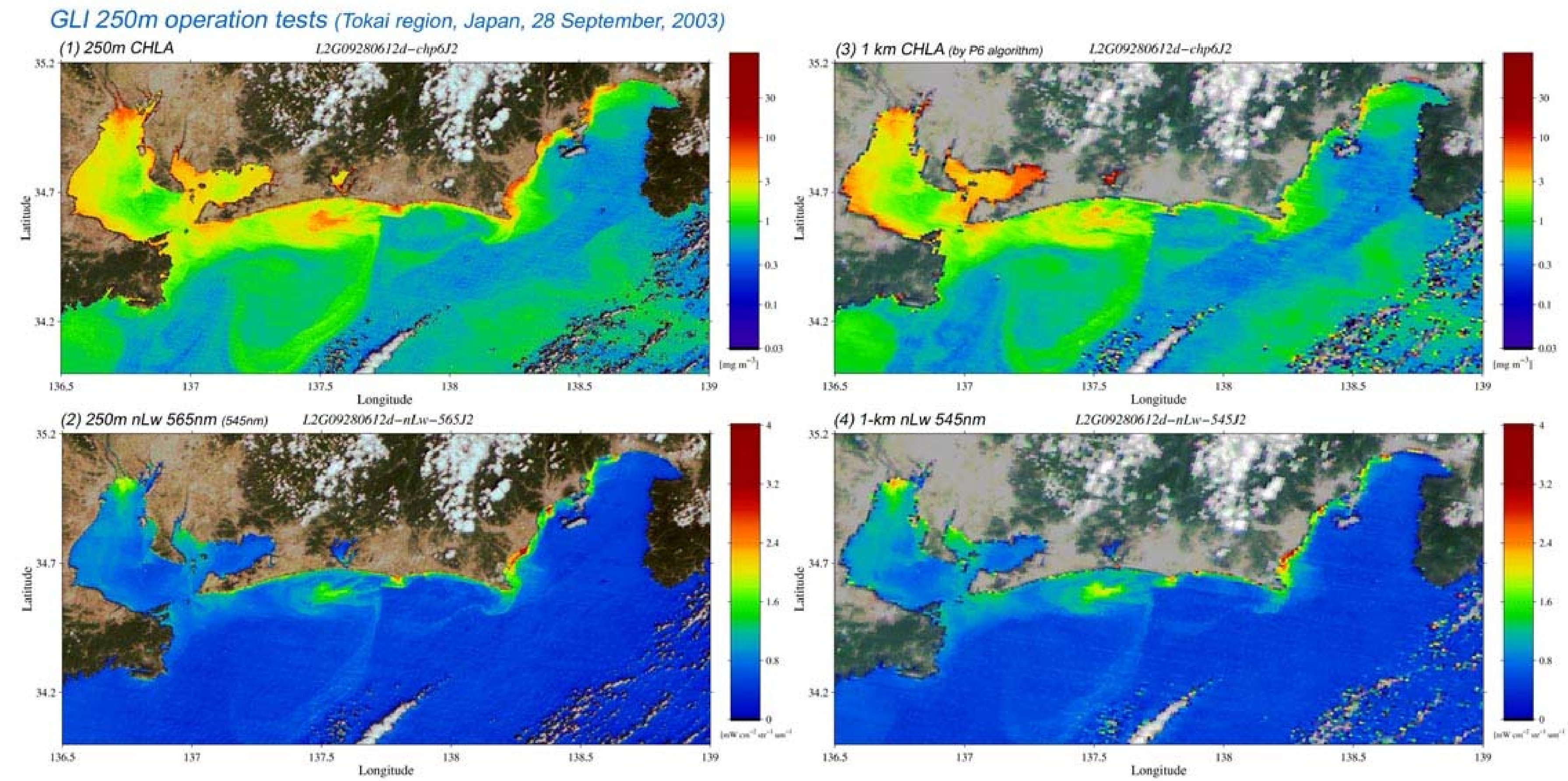
6.2 Practical Use of Ocean Color Remote Sensing in Coast

In the ocean color remote sensing by OCTS, SeaWiFS, GLI, and MODIS, the estimation algorithm of *chlorophyll-a* concentration targeting open ocean has been almost established and in practical use. However, issues still remain if targeting coast. The relation between ocean color and materials in coastal seawater is not such simple like in open ocean due to: influence to optical characteristics of seawater by SS, CDOM, etc; and influence by absorbing aerosol which is supposed to be man-made. In addition, an assumption used in open ocean that water-leaving radiance in the near infrared is negligible is not applicable to coast due to its probable high turbidity.

Presently, new algorithms are under development to solve these issues. Regarding atmospheric correction, neural network use was proposed for in-water algorithm (described later) to estimate water-leaving radiance by analytical method taking account of absorption coefficients of *chlorophyll-a*, SS, and CDOM rather than the use of empirical method by regression formula. The method is expected as an effective approach even in absorbing aerosol correction due to the advantage that can treat optical interaction between air and water. Such optical interaction was difficult to identify by the existing algorithm that uses in-water algorithm after atmospheric correction. Regarding in-water algorithm, a reverse computational method by neural network is under study. It first analyzes water-leaving radiance of *chlorophyll-a*, SS, and CDOM by the radiative transfer model. Then, the neural network reversely computes *chlorophyll-a*, SS, and CDOM. To practically use the algorithm, it is important to develop and validate the radiative transfer model based on the enough *in situ* data set of water-leaving radiance, *chlorophyll-a*, SS, CDOM, etc (Ishizaka, 2001). For further accuracy challenge, region specific algorithm development is considered in stead of uniform algorithm.

Another issue is coarse special resolution of existing observed data of 1 km when estimating distribution in coast that has more complicated topography than open ocean. To tackle the issue, the processing methods are under study on GLI products with special resolution of 250 m as a combination of 250 m and 1 km resolution (Figure 17) and MODIS products with special resolution of 500 m as a combination of 500 m and 1 km resolution (Sakuno, 2004).

At the end of October 2003, ADEOS-II terminated its operation due to mechanical troubles. Although the available period was short, valuable observation data of high resolution image and multi wavelength has made great progress in ocean color remote sensing in coast towards practical use. Utilizing the results, it is highly probable that ocean color remote sensing by MODIS as a leading sensor would enter into practical use in near future depending on *in situ* data arrangement as a key.



Produced by EORC, JAXA.

Figure 17. GLI 250m operation tests #3 (Tokai region, Japan, 26 September, 2003)

7 Suggested activities for the NOWPAP Region

7.1 Remote Sensing Information Network in Future

It has been pointed out through the argument in the first meeting of NOWPAP WG4 and the second CEARAC FPM that common understanding and information sharing should be promoted on usefulness, status-and-future prospects of research-and-development, and real use of remote sensing in marine environmental monitoring. Based on such observation, NOWPAP WG4 considered the development of remote sensing information network and started Portal site development in the Internet. However, the Portal site's role of navigating locations of scattered information and data has its limitation in quality and quantity and its role as useful remote sensing information network will not last long. Thus, it is necessary to consider step-by-step procedure to develop remote sensing information network, taking account of realistic limitation such as development cost, providing contents, etc. Figure 18 shows an illustration of the concept to develop remote sensing information network step-by-step.

The step-by-step development has two steps depending on target information, accumulated data quantity, and sharing level. The first step is a Portal site development (ongoing) that reviews and provides locations of scattered information and data. The second step is a Digital Library development that provides not only locations of information and data but also information and data themselves. Marine Environmental Watch Project, which is currently expanding its functions, is worth notice as a basis of Digital Library.

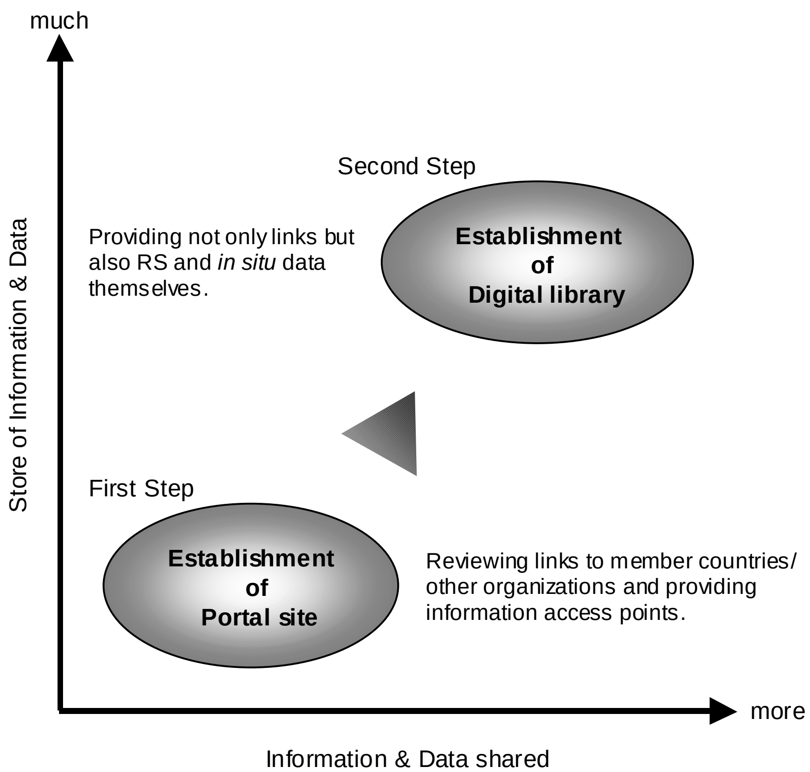


Figure 18. Step for Development of Remote Sensing Information Network System

7.2 Sustainable ocean observing system and regional cooperation

The Global Ocean Observing System (GOOS) has been developed by UNESCO/IOC, UNEP, WMO and 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 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 developments of the regional ocean observing system is to be promoted.

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. North-East Asian Regional GOOS (NEAR-GOOS) is one of GRAs formed in the world coastal seas. Its region is almost the same as that of NOWPAP, and its member countries are also the same. In order to promote the space-based monitoring systems of NOWPAP and achieve its goals, close collaborations with NEAR-GOOS may be important and necessary.

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EOIS <https://isswww.eoc.jaxa.jp/iss/en/index.html>

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

ESA ENVISAT <http://envisat.esa.int/>

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

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NPOESS <http://www.ipo.noaa.gov/>

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/>

RESTEC < http://www.restec.or.jp/restec_e.html>

WebMODIS <http://webmodis.iis.u-tokyo.ac.jp/>

WebPaNDA <http://webpanda.iis.u-tokyo.ac.jp/>

List of Acronyms

6S	Second Simulation of the Satellite Signal in the Solar Spectrum
ADEOS	Advanced Earth Observing Satellite
ALOS	Advanced Land Observing Satellite
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	Advanced Microwave Scanning Radiometer for EOS
ASAR	Advanced synthetic aperture Radar
AVHRR	Advanced Very High Resolution Radiometers
AVNIR-2	Advanced Visible and Near Infrared Radiometer type-2
BRDF	Bidirectional Reflectance Distribution Function
CCMA	Center for Coastal Monitoring and Assessment
CEARAC	Coastal Environmental Assessment Regional Activity Center
CZCS	Coastal Zone Color Scanner
DEM	Digital Elevation Model
DMSP	Defense Meteorological Satellite Program
ENSO	El Nino/Southern Ocillation
ENVISAT	Environment Satellite
EOC	Earth Observation Center
EOIS	Earth Observation Data and Information System
EORC	Earth Observation Research and application Center
EOS	Earth Observing System
ERS-2	European Remote Sensing Satellite-2
ESA	European Space Agency
FPM	Focal Points Meeting
FRRF	Fast Repetition Rate Fluorometer
FTP	File Transfer Protocol
GCOM	Global Change Observation Mission
GCP	Ground Control Point
GHRSST-PP	GODAE High Resolution Sea Surface Temperature Pilot Project
GLI	Global Imager
GMS	Geostationary Meteorological Satellite
GODAE	Global Ocean Data Assimilation Experiment
GOOS	The Global Ocean Observing System
GRAs	GOOS Regional Alliances
HABs	Harmful Algal Blooms
ICSU	International Council for Science
IGOS	Integrated Global Observing Strategy
IOC	The Intergovernmental Oceanographic Commission
I-LAC	Intensive Local Area Coverage
JAMSTEC	Japan Marine Science and Technology Center
JAXA	Japan Aerospace Exploration Agency
JERS-1	Japanese Earth Resources Satellite-1
JMA	Japan Meteorological Agency
LAI	Leaf Area Index
LUT	Look up Table
MI	Microwave Imager
MODIS	Moderate Resolution Imaging Spectrometer
MVISR	Multi-channel Visible and IR Scan Radiometer
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan (present JAXA)
NDVI	Normalized Difference Vegetation Index
NEAR-GOOS	North-East Asian Regional GOOS

NGSST	New Generation Sea Surface Temperature
NOAA	National Oceanic and Atmospheric Administration
NOWPAP	Northwest Pacific Action Plan
NPEC	Northwest Pacific Region Environmental Cooperation Center
NPOESS	National Polar-orbiting Operational Environment Satellite System
NPP	NPOESS Preparatory Project
OCTS	Ocean Color and Temperature Scanner
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PaNDA	Package for NOAA Data Analysis
PAR	Photosynthetically Available Radiation
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping
PRR	Profiling Reflectance Radiometer
QuikSCAT	Quick Scatterometer
RA	Radar Altimeter
RESTEC	Remote Sensing Technology Center of Japan
S-GLI	Second generation-GLI
S-VISSR	Stretched-Visible Infrared Spin Scan Radiometer
SAR	Synthetic Aperture Radar
SeaWiFS	Sea-viewing Wide Field-of-view Sensor
SIDaB	Satellite Image Database System in AFF
SIMBIOS	Sensor Intercomparison and Merger for Biological and Interdisciplinary Oceanic Studies
SST	Sea Surface Temperature
TAO	Tropical Atmosphere Ocean
TRMM	Tropical Rainfall Measuring Mission
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VIIR	Visible Infrared Imaging Radiometer Suite
VIRS	Visible and Infrared Scanner
WESTPAC	IOC Sub-Commission for the Western Pacific
WG4	Working Group 4
WMO	World Meteorological Organization