Annex X
Workplan of NOWPAP WG4 (RS) for the 2006-2007 Biennium

1 Objective and background

The role of CEARAC is to coordinate with the NOWPAP Members for establishing a collaborative, regional monitoring programme for the marine and coastal environment using remote sensing techniques. To play this role, CEARAC has been working with experts in NOWPAP Members under the framework of NOWPAP Working Group 4 (WG4).

As one of the highest priority of WG4 activity during 2004 to 2005, National Reports on Ocean Remote Sensing in the NOWPAP Region was prepared by each NOWPAP Members. CEARAC secretariat then compiled those National Reports and published an Integrated Report on Ocean Remote Sensing for the NOWPAP Region in 2005. The work plan of WG4 for 2006-2007 was prepared by the CEARAC secretariat on the basis of suggestions proposed in the Integrate Report and WG4 work plan reviewed in the previous FPMs.

This document describes WG4 workplan in details for 2006-2007 based on the approved CEARAC work plan of 2006-2007 at the 10th Intergovernmental meeting (IGM) of NOWPAP in 2005.

2 Work plan of WG4 for 2006-2007

The work plan of WG4 for 2006- 2007 is summarized in Table 1 below.

Table 1. Work plan for 2006-2007.

Activities		2006 (FPM 4th, WG4 3rd)	2007 (FPM 5th)
Planning & Coordination of Eutrophication /Oil spill monitoring in the NOWPAP Region	Refinement of guideline being prepared by NPEC for local governments of each country	Review of NPEC guideline; Publication of NOWPAP version	Publication of NOWPAP version
	Training of officers of young researcher, students, and officers of local governments	Planning/Coordination	Implementation
Development of remote sensing information network system	Integration of new function to search related publication		
	Establishment of Digital Library	Design	Establishment
Joint activities with IOC/WESTPAC ocean color project		Workshop on Ocean RS	
Search of other possible usage of the satellite remote sensing to environmental monitoring in the NOWPAP Region		Feasibility study	Feasibility study

2.1 The Refinement of NPEC Eutrophication Monitoring Guidelines by the NOWPAP Members

2.1.1 Objective and Background

The NPEC has been working on a project called the 'Toyama Bay Project' since 2002, in order to evaluate the usefulness of coastal zone eutrophication monitoring using ocean color satellite data, recognizing that the distribution of *chlorophyll-a* is a good indicator of eutrophication. It is of great importance to share results and lessons from the project toward the establishment of cooperation monitoring, as it is the final goal of NOWPAP Working Group 4 (WG4).

A draft guideline for the monitoring of eutrophication in coastal areas using satellite data (Appendix 9) is under development by the NPEC (NPEC Guidelines), which is intended 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'.

2.1.2 Details of the Guidelines Refinement

A 'NPEC Guidelines' is written in English. It is not, however, suitable to be used as guidelines for all of the NOWPAP Members as it is, since it does not sufficiently take into account the differences in surrounding among the NOWPAP Members. Therefore, a guideline that can apply to address local situations in each Member country (NOWPAP Guidelines) is needed. These refinement activities will be conducted by the experts of the NOWPAP Members, mainly CEARAC and WG4 members.

- ✓ Review of the Monitoring Items and the Observation/Analysis Methods for Satellite and in situ Monitoring

  As 'NPEC Guidelines' was developed based on the results from the 'Toyama Bay Project', peculiar circumstance for each NOWPAP Member is not fully considered. Therefore, the monitoring items and the observation/analysis methods for satellite and in situ monitoring are to be reviewed and localized/revised as appropriate for each region.

- ✓ Case Studies

  At least one case study targeting on a sea area in the NOWPAP Region shall be added by each Member. The case study on the Toyama Bay attached as Annex1 of Appendix 9 in the 'NPEC Guidelines' will be referred as an example.

- ✓ Translation

  The 'NOWPAP Guidelines' will be translated as much as possible into the languages used in each NOWPAP Member to make it readily understandable to the local government officers, researchers, and students in each country.

- ✓ Approval from the Governments of the NOWPAP Members

  To promote the practical use of the 'NOWPAP Guidelines' in the NOWPAP Region, it is of importance to received endorsement of the government of each NOWPAP Member. Therefore, procedures to obtain governments' approval of the NOWPAP Member are to be considered.

2.1.3 Schedule

Future schedule is shown in Fig. 1. The draft NPEC Guidelines is to be submitted at the 4th CEARAC FPM in March 2006, then the necessary refinement to make it useful for each Member will be discussed by CEARAC and WG4. At the 3rd CEARAC WG4 meeting which is scheduled in the summer of 2006, interim review of the NPEC Guidelines by the experts will be discussed in details, and the contents will be finalized by the end of 2006 as the guidelines for eutrophication monitoring using satellite data in the NOWPAP Region.

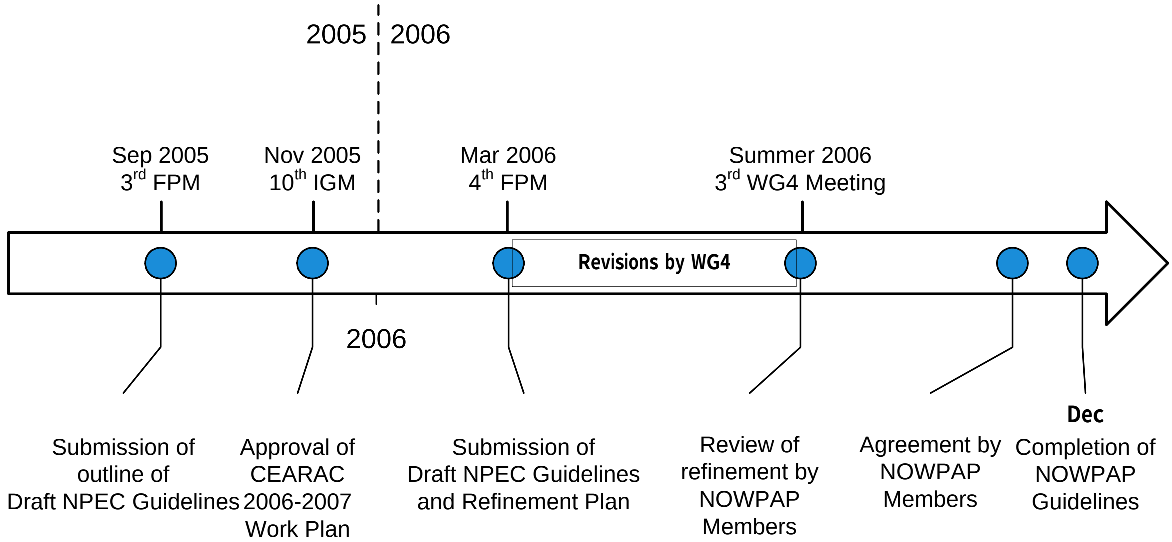


Fig. 1. Schedule for the refinement of NPEC Guidelines.

2.2 Outline of RS Training program on data analysis

2.2.1 Objective and Background

At the 1st CEARAC FPM held in February 2003, the capacity building on ocean remote sensing technology in the NOWPAP Region was accepted as one of the important issues to be discussed. Also, in the National Reports compiled in 2005, China and Russia have expressed the needs of the training programs on ocean remote sensing.

The objectives of this training program are to establish the framework that would enables mutual technical assistance for the marine environmental monitoring by remote sensing, and to provide capacity building assistance to improve technical capability in ocean remote sensing in the NOWPAP Region.

2.2.2 Details of the Training Program

✓ Expected participants

The training program will be open to the following groups of people in the NOWPAP Region.

- Local government officers serving in environmental protection
- Young researchers
- Students

✓ Contents

The training program will consist of lectures and practice sessions, both conducted in English. At the end of the training program, participants will be requested to write an analysis report on a target sea area in the NOWPAP Region based on knowledge and skills obtained during the training program. The report will be submitted to CEARAC and will be used to publicize CEARAC activities, etc.

- Lectures - Satellite Oceanography, Sensor Characteristics
- Practice Sessions - Operation of remote sensing and GIS software, Case studies on open ocean and coastal environmental monitoring

By the end of the training, participants will acquire the following knowledge and skills.

- Utilization methods for the remote sensing data in the open ocean and coastal environmental monitoring
- Benefits and limits of the use of remote sensing in the open ocean and coastal environmental monitoring
- Utilization methods for the remote sensing data in GIS

✓ Duration of the Training
Duration of the training will be 5 days.

✓ Venue
The training will be held in one of the NOWPAP Members.

✓ Class Capacity
The maximum number of the trainee will be around twelve.

✓ Cost Tuition
Training will be provided free of charge, however, the cost for the transportation and the accommodation will borne by participants.

✓ Application Procedure

Application procedure for the training will be as follows to ensure that the course meets the expectation s of the prospective applicants.

(1) Applicant submits a document explaining future goals and expectations from the course.
(2) CEARAC Secretariat goes over the application documents, and selects the candidates.

2.2.3 What CEARAC will provide

✓ Training program
A Training plan that is suitable to build technical capability for ocean remote sensing will be developed by the Secretariat in conjunction with the WG4 members. The plan would also consider the efficiency of the training; i.e., possibility of joint activity with other organizations, etc. In the course of preparation and finalization of training program, sufficient discussion is to be conducted among the WG4 members.

✓ Preparation
The following will be arranged by the Secretariat as preparation for the training.

- Trainer
Trainer(s) will be selected based on the discussion by the WG4 members and experts.
- Equipments/Materials
Textbooks and computers will be prepared as required.
- Training room
Training rooms that satisfy the training requirements will be coordinated and secured in conjunction with the FP of the host country and the WG4 members.

✓ Public relations activity
When all details of the program details are determined, the secretariat will notify the training program to the related organizations to invite applicants.

✓ Implementation Management
While the training program is underway, the secretariat will support the trainers and the trainees to smoothly implement the training.

2.2.4 Schedule

Fig. 2 shows the future schedule of organizing the training program. Implementation plan of the training program will be discussed at the 3rd WG4 meeting schedule in summer 2006. Then, the targeting course will be organized in 2007.

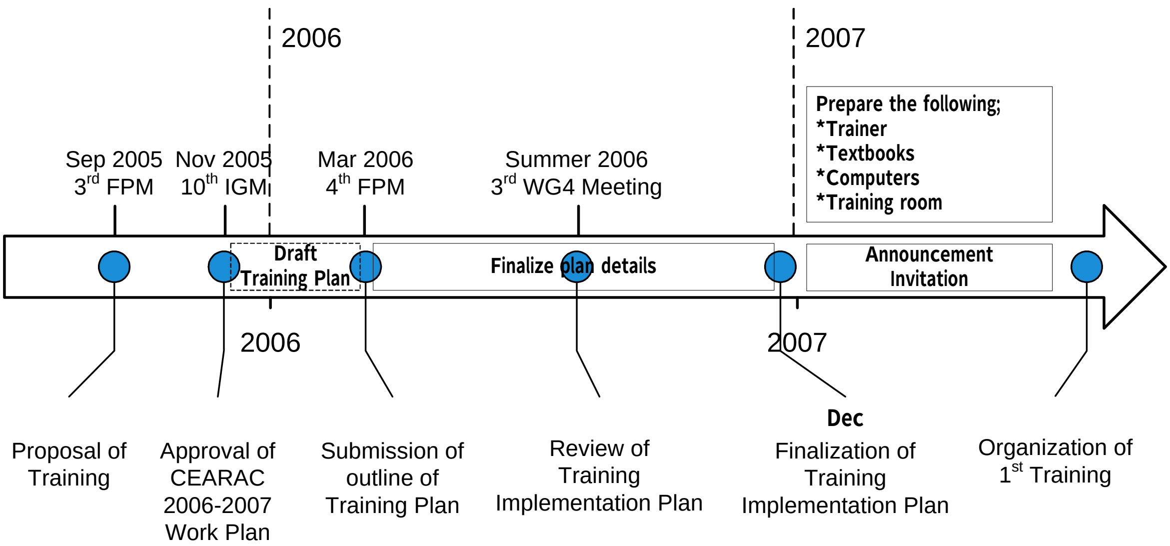


Fig. 2. Schedule for RS Training.

2.3 Further development of RS Information Network*

**This activity will be conducted under the NPEC's own budget to support WG4 activity.*

2.3.1 Objective and Background

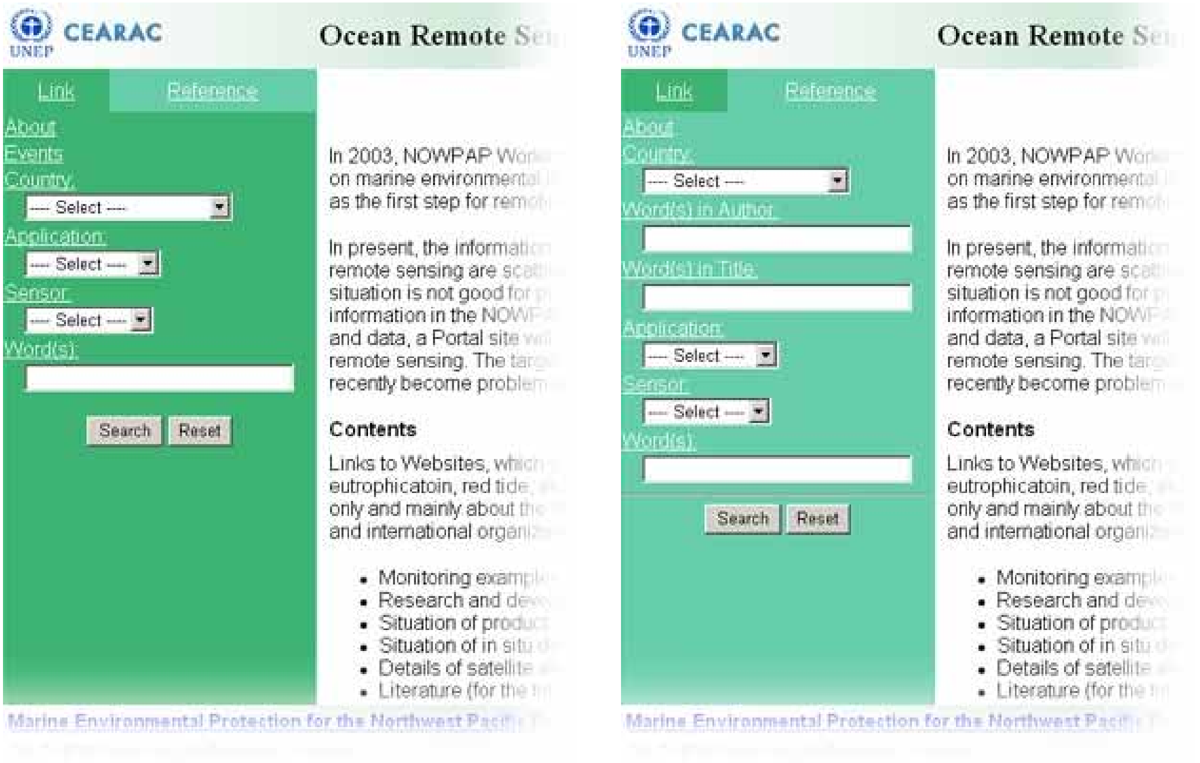
Since information/data on marine environmental monitoring exists in a number of organizations, information sharing on the status of studies/researches in the NOWPAP Region has not been easy. As the first step to improve the situation, a portal site has been developed in April 2005 to introduce the links to related websites.

To promote the use of the information network and to disseminate the knowledge on marine environmental monitoring by remote sensing, upgrading of the portal site functions, namely the addition of the links to the related websites and also the search function for reference literatures, were recommended and approved at the 3rd CEARAC FPM held on September, 2005.

2.3.2 Search function for reference literatures

The current portal site only contains links to the related websites ('Link' search). To promote increase use of it and disseminate knowledge on marine environmental monitoring by remote sensing, it is desirable to construct more sufficient functions such as collecting and offering the latest information on reference literature. Consequently, the function to locate papers/literatures that have high degree of technical usability was added to the portal site as 'Reference' search, as an aim to provide the information on the latest findings to the users.

- ✓ Overview of the functions
  Reference search and Link search are presented as parallel functions on the website, and can be switched easily by selecting the tabs, as shown in Fig. 3. Queries on references can be conducted on 'Country', 'Author', 'Title', 'Application', and 'Sensor'.



Link Search(existing function) Reference Search(added function)

Fig. 3. Selection Menu for Reference Search.

- ✓ Collection of reference information

  References that satisfy the following conditions as much as possible will be collected from the materials listed in Table 2. Information on each reference will then be summarized and categorized as listed in Table 3. The most important factor in terms of maintaining the quality of the reference database is the selection of the references to be searched, and therefore will be collected based on the ‘Reference Collection Rules’ listed below.

  < Reference Collection Rules >

(1) References on eutrophication monitoring or oil spill detection by remote sensing technology.
(2) References on the NOWPAP Region, or references that are considered highly applicable to the NOWPAP Region.
(3) References written in English.
(4) For collection, references listed in Table 2 are to be used.
(5) Information on the collected references will be categorized by items listed in Table 3.

Table 2. Materials to be used to collect the references.

Remote Sensing of Environment
International Journal of Remote Sensing
Journal of Oceanography
Journal of Geophysical Research
Applied Optics

Table 3. Summary of Reference Information.

Item *：mandatory	Contents
Country*	Country (China, Japan, Korea, Russia)
Authors*	Name of the author
Year*	Year of publication
Title*	Title of reference
Source*	Source, etc
Sensor	Sensors used
Application	Application
Keyword	Keyword

2.3.3 Schedule

Initial setting for the links to the related websites has been completed. Literature search function is now being tested using the reference literature information collected from the National Reports and the Integrated Report. As the next step shown in Fig. 4, test operation is to be conducted by the 4th CEARAC FPM, and the official operation is scheduled to commence on April 2006.

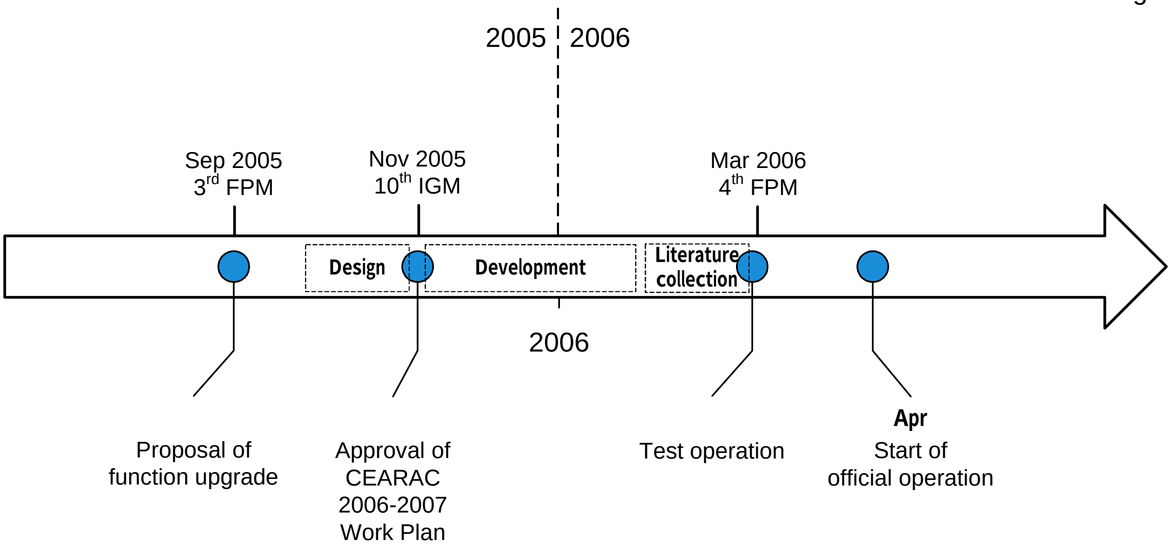


Fig. 4. Schedule for further development of RS Information Network.

2.4 Joint activities with IOC/WESTPAC ocean color project*

**This activity will be conducted under the NPEC's own budget to support WG4 activity.*

WG4 has been implementing activities related to marine and coastal environment monitoring with remote sensing from the perspective of its utilization in the intergovernmental framework, while IOC/WESTPAC makes efforts on Ocean Color Remote Sensing as a scientific activity. Because both groups partly cover the same geographic areas and subject, it is considered to work together through co-organizing workshop and training activity to achieve their own goals.

NPEC has been organizing International Workshops on Remote Sensing of the Marine Environment in the Northwest Pacific Region since 1999. The aim is to contribute to the development of marine environmental monitoring technologies derived from remote sensing. NPEC is now planning to organize its 4th workshop in summer 2006 and considers the possibility of joint hosting of workshops with other organization such as IOC/WESTPAC and PICES.

2.5 Search of other possible usage of the satellite remote sensing to environmental monitoring in the NOWPAP Region

**This activity will be conducted under the NPEC's own budget to support WG4 activity.*

Activities of WG4 have been implemented to the present based on the agreement at the 2nd CEARAC FPM. They are 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.

In accordance with such background, NPEC will consider possibility of monitoring other phenomena by remote sensing, which might be useful to decide the future activities of WG4.

A guideline for monitoring of eutrophication
in coastal area using satellite data

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I. Purpose and background of the project

Northwest Pacific Region Environmental Cooperation Center (NPEC) is designated as Special Monitoring and Coastal Environmental Assessment Regional Activity Center (CEARAC) and is working on development of evaluation method for marine and coastal environment using satellite remote sensing.

In the NOWPAP Region, red tide and eutrophication are becoming major problems, calling for joint monitoring as preventive measure. NPEC, recognizing that distribution of Chl-a is a good indicator for eutrophication, has commenced a project called the “Toyama Bay Project”, which evaluates usefulness of monitoring of eutrophication in coastal area using satellite data.

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 evaluation and using satellite data for cooperative environmental monitoring in the NOWPAP Region, taking into account of the results and issues raised in the “Toyama Bay Project”.

It, however, may be difficult to utilize this guideline as it is, because of large differences in surroundings in each county. Therefore, it is necessary to have experts from the NOWPAP Region to review and refine the guideline prepared by NPEC so that it would match the situation in each region, and to have individual guidelines developed for the NOWPAP region. As a result, it is desirable that the use of satellite data for eutrophication monitoring in the NOWPAP countries and regions will be actively promoted in the future.

II. Eutrophication and satellite remote sensing

1. Introduction

- Understanding marine environment with focus on eutrophication, and corresponding research

Environmental indicators to confirm the level of eutrophication are; Nitrogen (NO3-N, NH4-N, etc) and Phosphate (PO4-PM, etc) (nutrients for phytoplankton), Chl-a (indicator for red tide and eutrophication), Suspended Solid and Transparency (indicator for Turbidity), and COD (indicator for organic pollution).

- Advantage of eutrophication monitoring using satellite remote sensing

Satellite data can be obtained and utilized by any person and any place. Compared to the in situ monitoring data, it is often superior in terms of ranges covered, continuity, and irrelevance to national boundaries. Combined with the in situ data, satellite data can be utilized beneficially as monitoring information. The level of Chl-a, which strongly correlate to eutrophication level, can be estimated from the Ocean Color Satellite data.

- Disadvantage of eutrophication monitoring using satellite remote sensing

Accuracy of satellite data needs to be validated for each sea area, as there could be substantial margin of errors in data taken from coastal areas where there are high concentration of colored dissolved organic materials and suspended inorganic materials. This disadvantage can be supplemented by in situ data.

- Usefulness of eutrophication monitoring by satellite remote sensing

Satellite remote sensing makes it possible to estimate spatio-temporal Chl-a concentrations. Also, the usefulness of satellite monitoring can be further improved when correlation between Chl-a concentration and organic pollution indicator such as COD is found. There is an algorithm reported, although data are taken from the outer ocean (northern North Pacific Ocean), that enables estimation of the concentration of nitrate in sea surface currents. Nitrate is one of the major constituents of nutrient, it can be estimated from water temperature and Chl-a concentration obtained from satellite monitoring (Goes, J.I. et al.1999).

This guideline gives methodology on how to obtain and analyze satellite data, analysis of in situ data for validating the accuracy of satellite data and integrated evaluation of satellite data with other environmental data.

2. Satellite Data

1) Monitoring variables

a. Chl-a

Chl-a is contained in all species of phytoplankton, and it can be regarded as total amount of phytoplankton that is the base element of biological production of the ocean. In other words, measuring the level of Chl-a enables monitoring of mass generation by phytoplankton. If eutrophication proceeds, Chl-a concentrations become abnormally high and it often result increase of red tide.

Satellite remote sensing allows the estimation of the oceanic Chl-a by measuring water-leaving visible radiation of each wavelength of sea surface. Chl-a concentration can be determined by the color of the water leaving light; greener is higher, hence Chl-a present in water absorbs blue light.

b. Sea Surface Temperature

Satellite remote sensing allows the measurement of sea surface temperature using infrared and/or microwave ranges of electromagnetic waves. Seasonal change in meteorology and basic information such as current rip can be obtained from data on water temperature of ocean current.

c. Turbidity (K490)

The water clarity is a measure of “turbidity” and it can be obtained by a specific property of K490 (diffuse attenuation coefficient) which indicates how visible light in the blue.

d. Other monitoring variables are summarized in 5. Appendix.

2) Sensors

a. Chl-a

Satellite observation of ocean color began in 1978 with the launch of the Coastal Zone Color Scanner (CZCS) instrument on the NIMBUS-7 satellite (Mitchell, 1994). CZCS was a demonstration mission to establish the technological and scientific feasibility of mapping ocean phytoplankton pigment concentrations from satellite and its observation continued through about June 1986, although with problems caused by sensor degradation in its later years (Evans and Gordon, 1994.) After about 10 years of blank period, NASDA (predecessor of JAXA (Japan Aerospace Exploration Agency)) launched the Japanese Ocean Color and Temperature Sensor (OCTS) on the ADEOS satellite that operated from August 1996 to June 1997. NASA subsequently launched the Sea-Viewing Wide Field-of–view Sensor (SeaWiFS) in August 1997, which has a five-year design life and continues to operate in 2005, and the Moderate Resolution Imaging Spectroradiometer (MODIS) launched on TERRA in December 1999 and on AQUA in May 2002. JAXA then launched Global Imager (GLI) on the ADEOS-II satellite. It enabled frequent, accurate and global observations of various geo-physical parameters in the ocean (Ishizaka *et al*., 2004). However, operation ceased due to mechanical trouble in October 2003, 10 months after its launch. NASA have been maintaining time series of the aforementioned data, it is necessary, however, to ensure the compatibly of each data for time series analysis.

SeaWiFS (Sea-viewing Wide Field-of-view Sensor) and MODIS (The Moderate Resolution Imaging Spectro-radiometer) are the ocean color sensors currently in operation that monitors Chl-a concentrations and these monitored data are open to the public via the Internet.

SeaWiFS Chl-a concentration data from September 1997 (right after its launch) to December 2004, can be obtained for free of charge by submitting user application to NASA. Methods for acquiring SeaWiFS data depend on the purpose (research or commercial). MODIS data is received at many organizations, and is open to the public via the Internet.

b. Sea Surface Temperature

Sea Surface Temperature is estimated by processing of NASA AVHRR (Advance Very High Resolution Radiometer) and NASA MODIS data. The data are received by many organizations and transmitted to the public via the Internet.

c. Turbidity (K490)

SeaWiFS and MODIS provide data set of K490 that is useful to detect turbidity in the water.

3) Obtaining data

a. Chl-a

<SeaWiFS>

If SeaWiFS Chl-a data are used for research, they can be obtained free of charge, under conditions that NASA authorizes the purpose of data use. Process for user registration is described in detail on 'SeaWiFS Project Information' site in SeaWiFS Project Homepage (http://oceancolor.gsfc.nasa.gov/SeaWiFS/).

SeaWiFS Chl-a data can be obtained via the Internet from NASA Goddard Distributed Active Archive Center. NASA provides SeaWiFS data products in different spatial resolution, either in GAC (Global Area Coverage) or in LAC (Local Area Coverage). Both GAC and LAC data can be utilized for monitoring of coastal areas.

<MODIS>

MODIS data that had been received by ground station of JAXA and processed by JAXA GLI algorithm can be downloaded from the Northwest Pacific Region Marine Environment Watch Homepage (the Marine Environment Watch Homepage). To download, user registration is necessary, which can be done on the website below.
URL for user registration: http://www.nowpap3.go.jp/jsw/eng/search/regist.html

Method to download MODIS Chl-a concentration data is described in the website below: http://www.nowpap3.go.jp/jsw/eng/software/

b. Sea Surface Temperature

AVHRR data can also be downloaded from the Marine Environment Watch Homepage. The method for user application is the same as for MODIS data.

c. Turbidity

SeaWiFS K490 data also can be obtained via the Internet from NASA Goddard Distributed Active Archive Center. NASA provides SeaWiFS data products in different spatial resolution, either in GAC (Global Area Coverage) or in LAC (Local Area Coverage). Both GAC and LAC data can be utilized for monitoring of coastal areas.

4) Processing Method

a. Setting up of Processing Systems

SeaDAS (SeaWiFS Data Analysis System), a free software developed by NASA, is the most suitable choice for processing and analyzing Chl-a and K490 data from SeaWiFS SeaDAS may be run on PC-Linux, which enables the construction of processing environment at low cost.

For processing and analyzing Chl-a data from MODIS and Sea Surface Temperature data from AVHRR, Excel program from Microsoft may be used.

b. Extraction of Data

i. Chl-a

<SeaWiFS>

To extract Chl-a data, L1A level data need to be obtained from NASA DAAC, and atmospheric correction and geometric correction need to be conducted.

<MODIS>

MODIS Chl-a data retrieved by application of JAXA GLI algorithm can be obtained from the Marine Environment Watch Homepage.

ii. Sea Surface Temperature

AVHRR-derived SST data can be processed data by the Marine Environment Watch Homepage.

iii. Turbidity

To extract K490 data, L1A level data need to be obtained from NASA DAAC, and atmospheric correction and geometric correction need to be conducted.

3. In Situ Data

To maximize the usefulness of satellite monitoring, it is essential to obtain in situ data coinciding in time and space with satellite data. Match up data set is used for calibration and validation.

1) Monitoring Items and Measuring Method

a. Chl-a concentration

In situ measurements of Chl-a concentration are used for calibration and validation of satellite data. They are also a good indicator of eutrophication and correlate with organic pollution level, such as COD, etc.

b. Suspended Solid (SS) and Chromatic Dissolved Organic Material (CDOM)

SS and CDOM are measured as they influence on errors of satellite-derived Chl-a concentration. It is recommended to compare the measured SS and CDOM values with satellite data and with Water-Leaving Radiance,

c. Water-Leaving Radiance

In situ Water-Leaving Radiance of sea surface can be monitored by measuring profile of reflectance in water. The data are used to calibrate and validate in-water algorithms.

d. COD and Nutrient

COD is an indicator of organic pollution. If they are measured simultaneously, it may be useful to develop further understanding of the behavior of eutrophication and organic pollution process. This will make it possible satellite remote sensing function as a monitoring tool of organic pollution that is leading to eutrophication for local use.

e. Sea Surface Temperature and Salinity

In situ SST measurements are used to evaluate the errors of satellite-derived SST fields. They are also used to calculate growth rate of phytoplankton. Measurements of surface salinity make it possible to estimate how much fresh water due to river outflow and precipitation are flowing into the target area.

f. Transparency

Transparency can be used to grasp a rough figure on average turbidity in the surface seawater. Measurement method is simple. There are plenty of data in the past, which can be used for comparison with the present data in particular in the NOWPAP Region.

g. Other items

Other items that can be measured are vertical distribution of water temperature and salinity. It is also advisable to keep records of the weather conditions including atmospheric temperature, cloudiness, wind speed and direction, waves and wave undulation, etc. during satellite sensing.

h. Measurement method

Please refer to Manual for oceanographic observation (Japan Meteorological Agency) and Marine Monitoring Guideline for the Correction and Validation of Satellite Sea Color Data (Earth Science and Technology Forum/Earth Monitoring Committee, Marine Environment Science Team 2001) for the detailed measurement methods and notes to be taken care of the measurements of Chl-a, Suspended Solid, Chromatic Dissolved Organic Material, and Water-Leaving Radiance.

2) Determining Sampling Points

a. Number of Sampling Points and Spatial Scales

About 10 in situ sampling points (the more the better) are desirable per 1 measurement from satellite. It is necessary to set the sampling points in coastal area, outer sea and also at the border, to obtain wider range of in situ data. Due to limited spatial resolution of satellite data, sampling points need to be set at least 1 km apart from each other.

b. Distribution of Sampling Points

It is desirable to set fixed points if continuous in situ monitoring is possible; however arbitrary points are acceptable for a single-shot measurement. Coastal topography and sea bathymetry as well as the location of river outflow need to be considered when sampling points are determined.

3) Monitoring Frequency and Timing

When monitoring frequency and timing are determined, climatic (less cloud coverage is preferable) and oceanographic conditions (times when river waters flow in and growth of phytoplankton is active should not be missed) need to be considered. Regular monitoring (once a month, for example) is necessary if temporal variations of water quality need to be captured by in situ monitoring. However, if more match-up data set is needed, the monitoring shall be specialized in obtaining more sea truth data, and the monitoring timing could be focused on short terms under good conditions.

4) Requisites for Monitoring and Analysis

Vessels used for monitoring need to have enough seaworthiness and speed to implement what is laid out in the monitoring plan. Positioning system (e.g. GPS) and navigation system are also required.

Participation of organization that holds necessary capability and equipments for analyzing Chl-a, COD, SS, CDOM and other nutrient salts is essential.

It is desirable to obtain Water-Leaving Radiance data to verify in-water Algorithm.

4. Overall Evaluation

1) Accuracy Evaluation

a. Evaluation of Underwater Algorithm (Analysis of Profiling Reflectance)

Correlation shall be analyzed between in situ Chl-a concentration and satellite-derived Chl-a concentration (satellite Chl-a concentrations), calculated from Water-Leaving Radiance using the underwater algorithm. This analysis can clarify if there are any discrepancies, wether in atmosphere or underwater part in the estimation algorithm of Chl-a concentrations by satellite. It is essential to improve the accuracy of satellite monitoring

b. Analysis of correlation between in situ and satellite Chl-a concentration

Correlation between in situ and satellite Chl-a concentration shall be analyzed. It is more preferable to look into differences between in situ and satellite chlorophyll a concentration depending on levels of CDOM and SS. If there are many sets of satellite and in situ data and certain correlation is observed between these data, the correlation can be applied to bring satellite data close to in situ data through calibration and validation. It is also useful to confirm if satellite data can be used as relative data.

In general, the data from satellite is often overestimated in comparison with in situ data when the concentration of SS and CDOM become higher. Thus, its comparison with in situ data is required when satellite Chl-a data is to be used as absolute value. When SS and CDOM are considered to be high, e.g. after heavy rain and inflow of turbid water, it is recommended not to use satellite Chl-a concentration data, as it is likely to be strongly affected by high SS and CDOM.

2) Integration with the Existing Monitoring System

a. Understanding spatio-temporal variations of eutrophication by Ocean Color Satellite

If no substantial temporal differences are observed in differences between satellite data and in situ data, satellite data can be used for analyzing time-series behavior of eutrophication penomenon. As many data can be obtained from one measurement in satellite monitoring, averaging these data will balance out errors from each value. Also, satellite monitoring can help understand spatial characteristics of eutrophication, as data can be obtained to cover wide range of area. The usefulness of satellite monitoring is expected to increase when accuracy of satellite Chl-a concentration data is improved.

b. Evaluation of Eutrophication

If COD or concentration of various nutrient salt (e.g. Phosphorus, Nitrogen, etc.) is measured at the same time, understanding on the relationship with Chl-a concentration and causes of eutrophication may be further developed.

c. Comparison of existing data (Chl-a, COD) to satellite data and Data Complementation

By comparing of spatio-temporal variation of satellite Chl-a concentration data to the existing water quality data for the target sea area, variation patterns and reproducibility of satellite data may be evaluated.

5. Appendix

1). Table of satellite data product for eutrophication monitoring

Below are the table of satellite data products for marine environmental monitoring which is provided from NASA.

The data are categorized in starndard and evaluation product.

In this guideline, all these products are prioritized by the importance for eutrophication monitoring.

NASA Standard Products

Product Name	Description		Units	Priority
Chlor_a	Sensor default Chlorophyll a concentration (OC4 for SeaWiFS, OC3 for MODIS)	Index of the total amount of phytoplankton in surface layer.	mg·m-3	A
SST	Daytime Sea Surface Temperature	Temperature of Sea Surface layer.	degrees Celsius	A
K490	Diffuse attenuation coefficient at 490nm	Index of the turbidity of the water colum - how visible light in the blue- green region of the light penetrates within the colum.	m-1	B
PAR	Photosynthetically active radiation	PAR is the amount of visible light available for photosynthesis.	E/m^2/day	B
nLw_nnn	Normalized water-leaving radiance	The normalized water-leaving radiances are the upwelling radiance just above sea surface, in the absence of an atmosphere, and with the sun directly overheadphysical values, such as cholorphyll concentration.	mW·cm-2·µm-1·sr-1	B

NASA Evaluation Products

Product Name	Description		Units	Priority
chl_oc2	Chlorophyll-a concentration, OC2 algorithm	Index of the total amount of phytoplankton in surface layer.	mg·m-3	C
chl_oc3	Chlorophyll-a concentration, OC3 algorithm		mg·m-3	C
chl_oc4	Chlorophyll-a concentration, OC4 algorithm		mg·m-3	C
chl_octsc	Chlorophyll-a concentration, OCTS-C algorithm		mg·m-3	C
chl_ndpi	Chlorophyll-a concentration, Normalized Difference Pigment Index algorithm		mg·m-3	C
chl_carder	Chlorophyll-a concentration, Carder bio-optical model		mg·m-3	C
chl_clark	Chlorophyll-a concentration, Clark algorithm		mg·m-3	C
chl_gsm01	Chlorophyll-a concentration, Garver-Siegel-Maritorena-2001 bio-optical model		mg·m-3	C
poc_clark	Particular Organic Carbon (D.Clark)	Index of the total amount of Particular Organic Carbon in surface layer.	mg·m-3	C
tms_clark	Total suspended matter(D.Clark)	Index of the total amount of suspended matter in surface layer.		C
calcite	Default Calcite Concentration (calcite_3b)	Index of the total amount of detached Coccolith in surface layer.	moles/m^3	C
calcite_2b	Calcite concentration, 2-band algorithm (Gordon and Balch)		moles/m^3	C
ipar	Instantaneous photosynthetically available radiation	Instantaneous degree of the amount of visible light available for photosynthesis.		C
flh	Fluorescence line height	Index of radiance of leaving sea surface, which is presumably a result of chlorophyll fluorescence.		C
cfe	Chlorophyll fluorescence efficiency	Efficiency of the conversion of absorbed solar radiation into fluorescence by phytoplankton.		C
arp	Instantaneous absorbed radiation by phytoplankton	Number of phtons absorbed by phytoplankton.		C

Annex 1

A case study in Toyama Bay

1. Objective and Background

In order to evaluate the effectiveness of remote sensing techniques as a monitoring tool for the marine and coastal environment, a case study was conducted in Toyama Bay. In this study, MODIS Chl-a was analyzed with sea-truth data for validating in-water algorithms for estimating Chl-a concentration.

In addition, SeaWiFS Chl-a concentration data were analyzed to understand spatio-temporal variation of water quality in Toyama Bay. The correlation between phytoplankton and seawater pollution (COD; Chemical Oxygen Demand, classified phosphate) was studied to understand the process of pollution.

2. Method

1) Monitoring survey of Toyama Bay

a.Observed variables with vessel

pH, temperature, salinity, water color, transparency, underwater radiances (measured by Profiling Reflectance Radiometer (PRR) 600)

Temperature and salinity (measured by CTD)

b.Analyzed variables in lab

DO(Dissolved Oxygen), Chl-a, SS(Suspended Solid), CDOM(Colored dissolved organic matter), classified phosphate, silicate, total nitrogen, COD etc.

2) Obtaining ocean color satellite data

MODIS Chl-a data was obtained through Marine Environmental Watch System. The data was processed based on the algorithm, which was developed by JAXA for GLI, a sensor on board on ADEOS-II satellite.

SeaWiFS Chl-a data of Toyama Bay from 1998 to 2003 was also obtained and processed for the coverage from longitude 136.5 to 138.5 degrees east and latitude 36.5 to 38.0 degree north. (Fig. 1)

Fig.1 Location of study area.

3. Analysis and discussion

1) Analysis of time series satellite Chl-a concentration

a. Analysis of daily Chl-a concentration image

Chl-a concentration patterns of Toyama Bay in May 2003 were observed (Fig.2). As described later, satellite Chl-a concentration tended to be over estimated than in-situ Chl-a concentration data, when high concentration of SS and CDOM caused by discharge of murky waters was detected. Few rainfall and river discharge, however, was measured in studied period shown in Fig.2, and it was considered that high Chl-a concentration was moved with the anti-clockwise flowage pattern, which was previously suggested in Toyama Bay (Uchiyama 1993).

By this means, remotely sensed Chl-a images are useful but not limited to detect its concentration and its transition pattern with the flowage pattern.

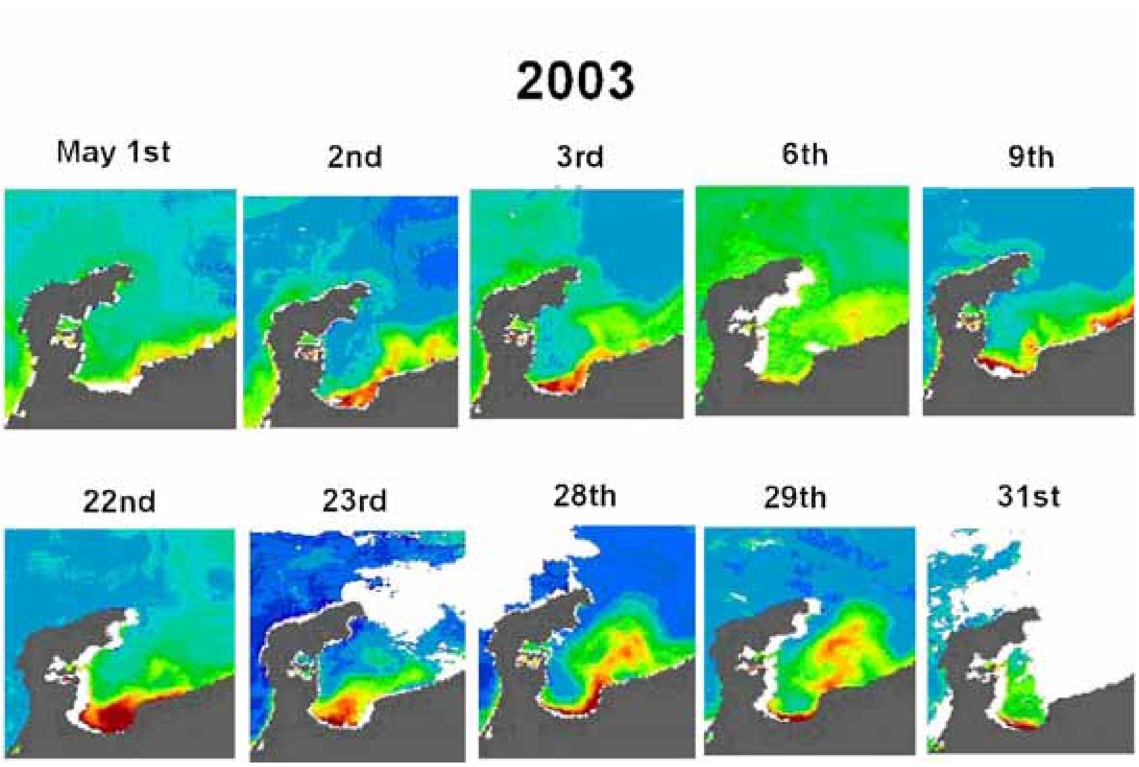

Fig. 2 Chl-a concentrations pattern of May 2003 observed by MODIS in Toyama Bay

b. Analysis of monthly Chl-a concentration image

The monthly average SeaWiFS Chl-a concentration image below indicates two peaks of Chl-a concentration every year, one in early spring (March and April) and the other in fall (October and November). It also shows that the Chl-a concentration of the inner area of the bay is higher every summer (June, July and August) and fall (September and October) than in the other seasons (Fig. 3).

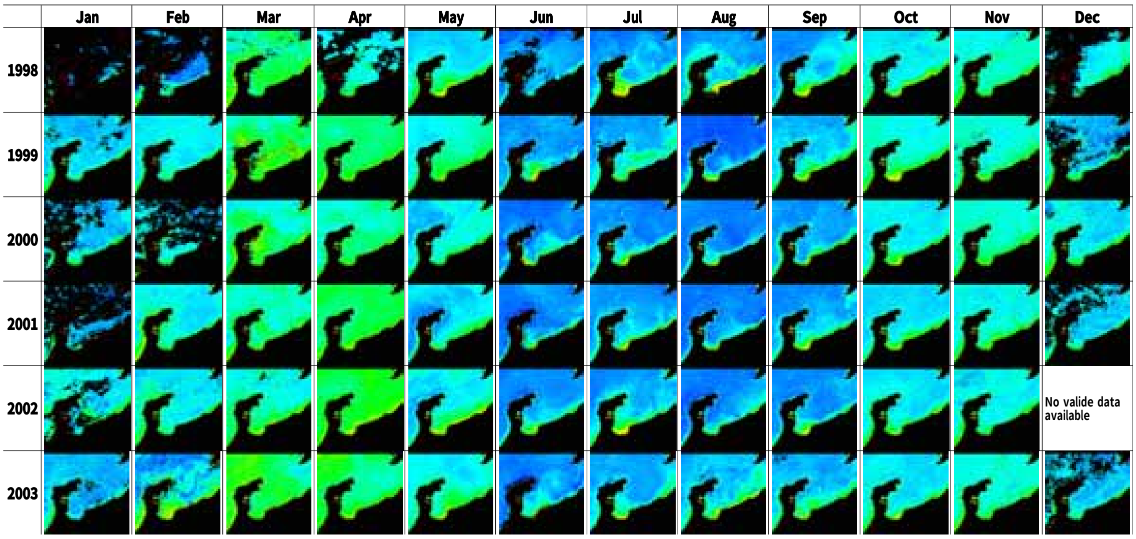

Fig. 3 Monthly average SeaWiFS Chl-a image of Toyama Bay.

c. Seasonal variability of Chl-a concentration in three different areas

Time series of daily SeaWiFS Chl-a concentration in three different areas showed different characteristic of seasonal variation (Fig. 4). There were two apparent peaks of Chl-a concentration in spring and fall every year in outer area. This corresponds to the timing of seasonal phytoplankton bloom offshore or in the NOWPAP Region (excluding the Yellow Sea) (Yamada 2004), and it is expected that the land source nutrient input is minimum. On the other hand, Chl-a concentration in inner area was higher in summer and fall and radically changed in a short period of time. This may be caused by nutrient input from river, and possible eutrophication by human activity is suspected. It is clear that the middle part of the bay is also influenced by river discharge but the influence is relatively smaller than the inner part.

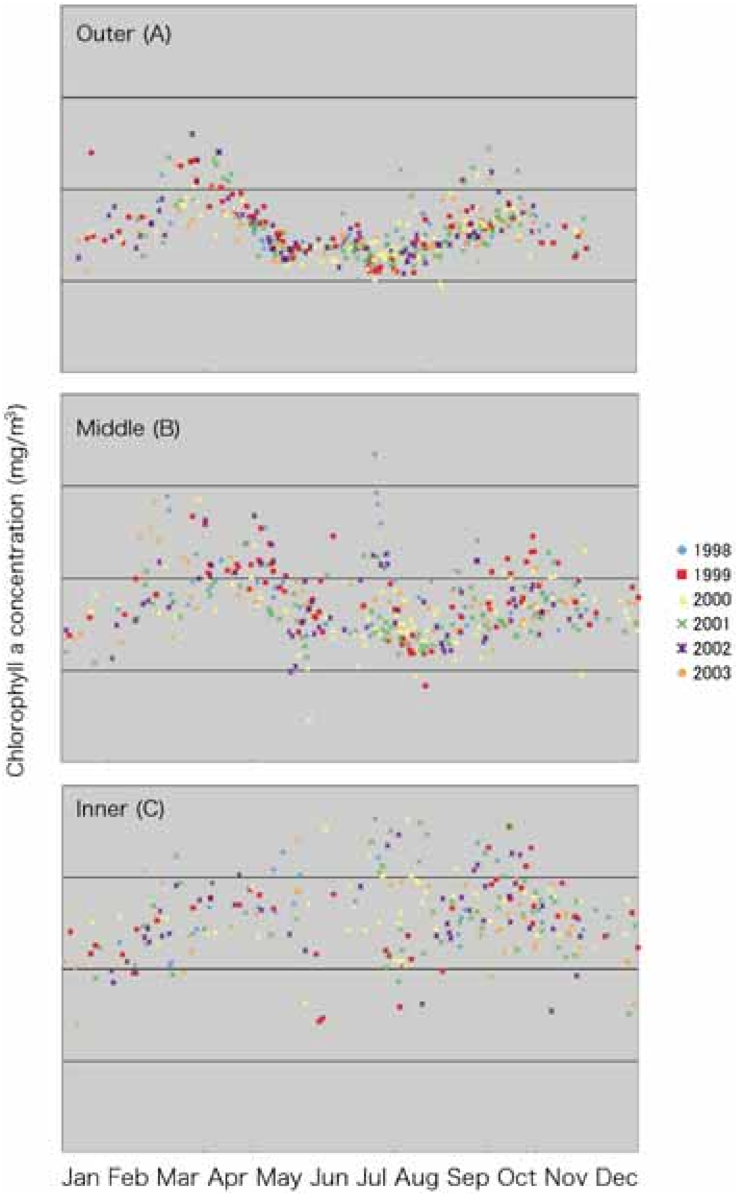

Fig. 4 Seasonal variability of Chl-a concentration in three different areas. Each area, outer (A), middle (B) and inner (C), is corresponding to the location in Fig. 1.

2) Validation of satellite Chl-a concentration

a. Validation of in-water algorithms

The correlation between in situ Chl-a concentrations and one derived from three existing in-water algorithms of SeaWiFS, MODIS and GLI were investigated, using data observed in Isahaya, Ariake (Kyushu Region), East China Sea (ECS), Wakasa Bay (Japan sea) and Toyama Bay (Fig. 5). The results showed strong relationship in ratio 1:1, varying coefficient of correlation 0.85 to 0.88 and square error of 0.015 to 0.016 in all data. When investigating data of Toyama Bay solely, the coefficient of correlation varied 0.55 to 0.58, however square error was 0.052 to 0.057. The above results indicate that there is no unique characteristic in Toyama Bay, thus, existing in-water algorithms can be applied to estimate Chl-a concentration in Toyama Bay. It is also suggested that there might be a problem in atmospheric correction.

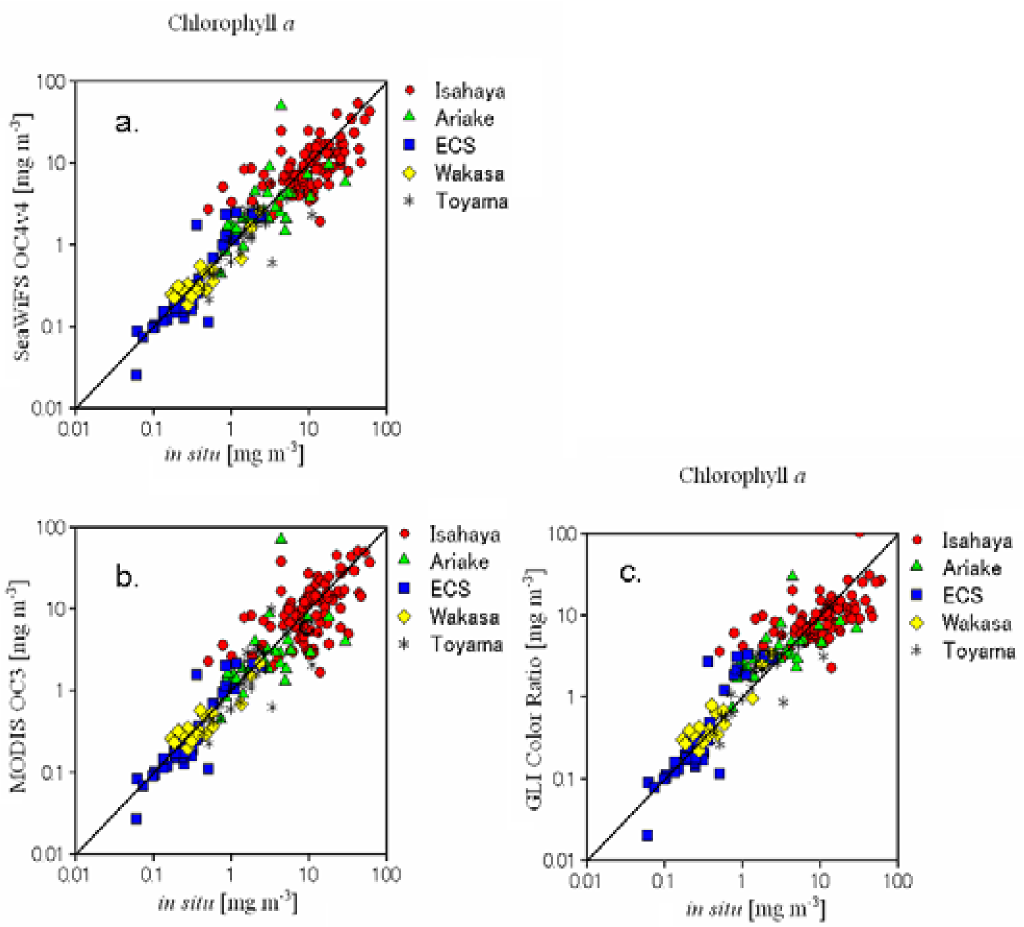

Fig. 5 Relationships in situ Chl-a and one derived from three existing in-water algorithms SeaWiFS, MODIS and GLI

b. Correlation of Chl-a concentration between in situ and MODIS

The correlation between in situ and MODIS Chl-a concentration processed by JAXA GLI algorithm was investigated using match up data of 4 cruises (Fig. 6). Liner regression was found in all cases. MODIS Chl-a concentration was slightly underestimated in one case (July 23, 2004), while strong positive correlation (R = 0.88 **, N=9) was found. In contrast, MODIS Chl-a concentrations for other three cases tended to be overestimated. It was suggested that the underestimation of MODIS Chl-a concentration of July 23, 2004 be affected by anomaly of mirror on MODIS instrument, which was reported by NASA.

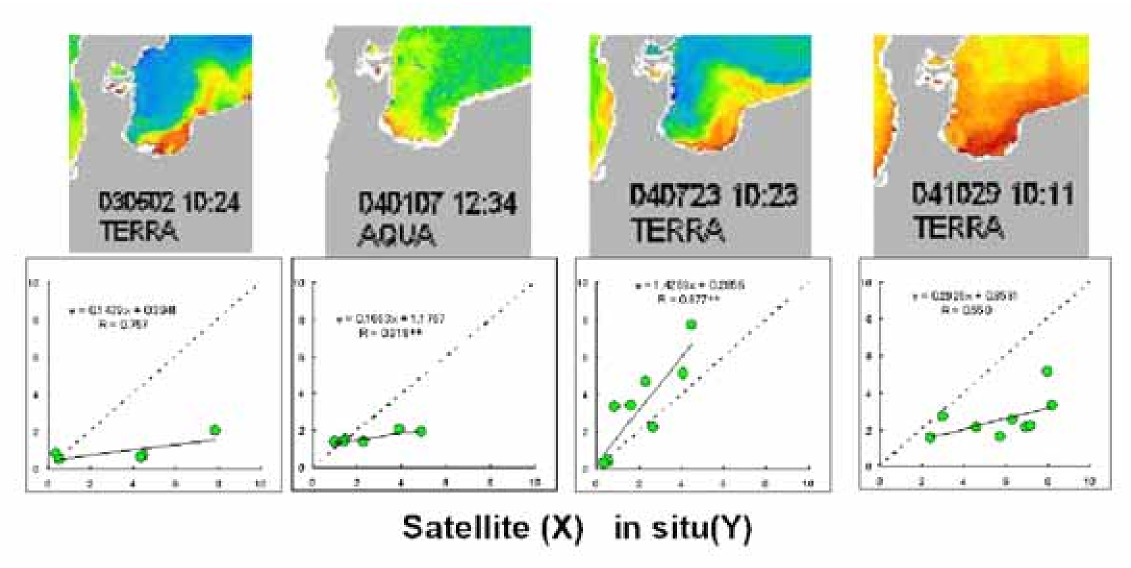

Fig. 6 Relationship between satellite and in situ Chl-a.

c. Analysis of MODIS Chl-a concentration with SS and CDOM

The difference between in situ and MODIS Chl-a concentration and its relationship with SS and CDOM was studied. It was found that MODIS Chl-a concentration tends to be overestimated when the concentration of SS and CDOM become higher (Fig. 7).

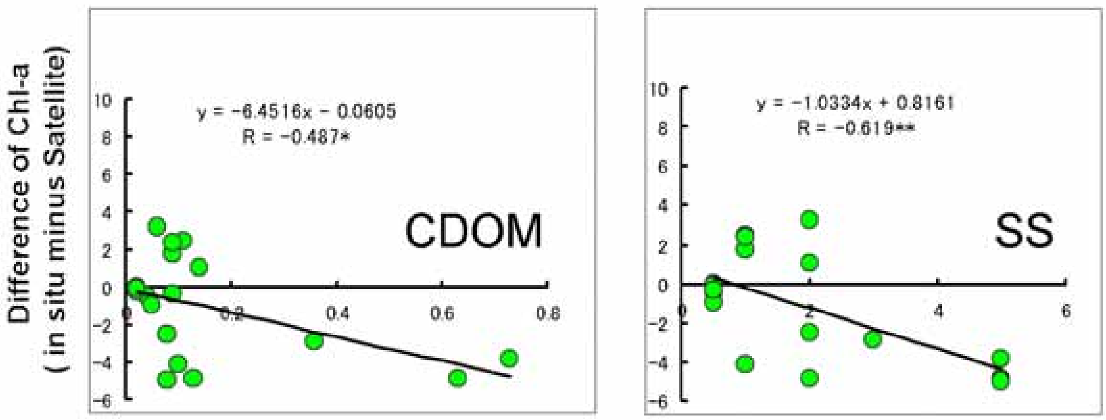

Fig. 7 Analysis of MODIS Chl-a concentration with SS and CDOM.

3) Correlation between in situ Chl-a concentration and COD

Strong positive correlation (R = 0.87, N = 86) was found between in situ Chl-a and COD (Fig. 8). Less variability was found especially in spring and summer, when seasonal stabilization of upper water layer is promoted. This result suggested that the satellite monitoring of Chl-a concentrations can be possible for monitoring of organic pollution indicated COD.

It was considered that the section of regression formula is indicating the whole organic matter other than phytoplankton, such as detritus, dissolved organic matter and zooplankton. Further analysis of the constituent of the section is necessary to understand the process of organic pollution.

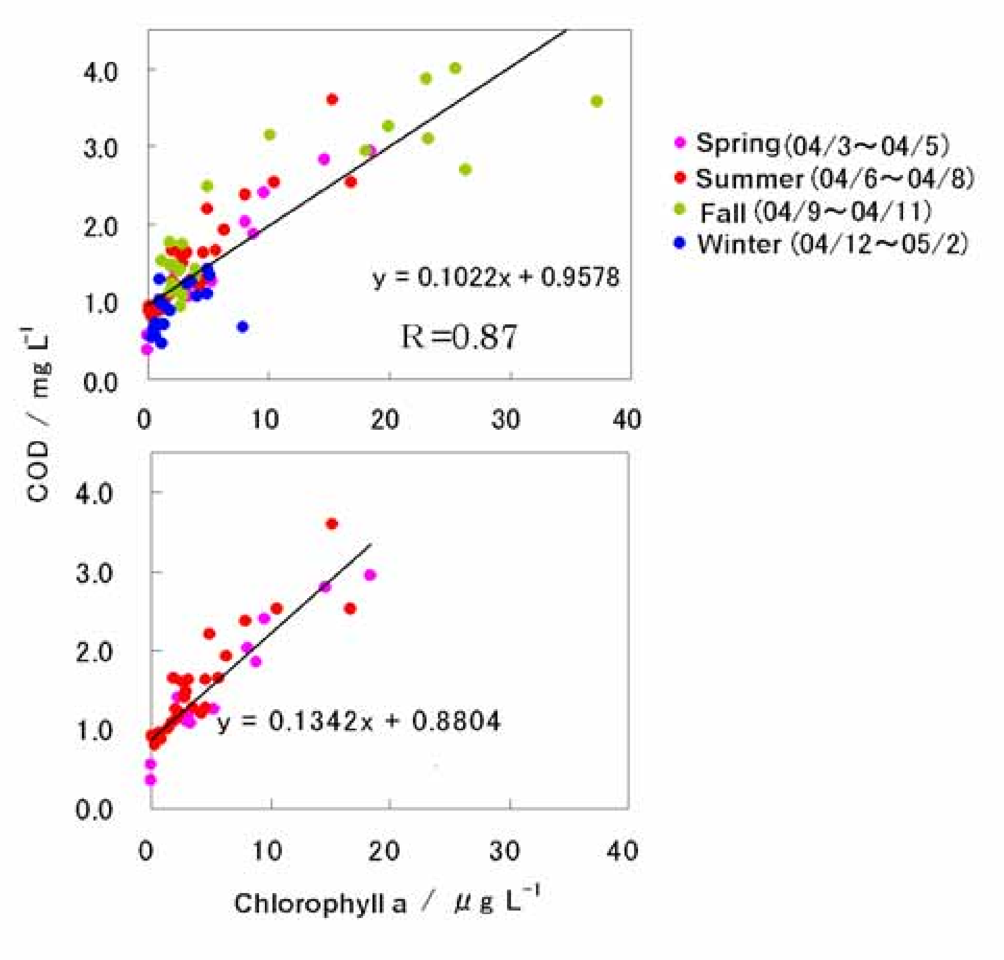

Fig. 8 Correlation between Chl-a concentration and COD in Toyama Bay

4. Overall evaluation of remote sensing as monitoring tool

1) Detecting spatio-temporal variation of eutrophication by ocean color satellite

Liner regression was found in relationship between in situ and MODIS Chl-a concentration data (Fig. 5). The characteristics of variation pattern were represented well, as Chl-a concentration in inner area of the bay is higher every summer and fall, through analyzing of time series of satellite Chl-a concentration data (Fig. 2). Thus, it is possible to detect eutrophication by using ocean color satellite data as relative value in Toyama Bay.

2) Evaluation of eutrophication from in situ investigation

Since strong positive correlation ($R = 0.87$, $N = 86$) was found between in situ Chl-a concentration and COD, as an indicator of eutrophication, monitoring of Chl-a concentration by satellite may be useful to find the characteristics of eutrophication and organic pollution in coastal area.

3) Others

Monitoring by satellite is more economical than vessel survey, and it also can estimate the conditions regularly even when there is no vessel survey. In addition, we can discuss the characteristics of eutrophication further through analyzing satellite Chl-a concentration data with other environmental elements such as river discharge or sea temperature and salinity.