# Annex X - 1

## Refinement of "NPEC Guideline for Eutrophication Monitoring by Remote Sensing" by the NOWPAP Members

## 1 Objective and Background

Northwest Pacific Region Environmental Cooperation Center (NPEC) has been working on a project called the ‘Toyama Bay Project’ since 2002, in order to evaluate the usefulness of remote sensing data for coastal zone eutrophication monitoring, recognizing that the distribution of *chlorophyll-a* is a good indicator of eutrophication.

Taking into account the results and lesson learned from the Toyama Bay Project, a Guideline for Eutrophication Monitoring by Remote Sensing (Appendix A) was prepared by the NPEC (NPEC RS Guideline) and submitted to the 4th CEARAC Focal Point Meeting (FPM) took place in Toyama 8-9 March 2006, which intended to be a basis for establishing common methods for evaluation and use of satellite data for cooperative environmental monitoring in the NOWPAP Region.

Following the decision at the 4th CEARAC FPM, refinement of ‘NPEC Guideline for Eutrophication Monitoring by RS’ by the NOWPAP Members was adopted at a main activity of NOWPAP WG4 in 2006.

## 2 Details of the Guidelines Refinement

‘NPEC RS Guidelines’, is not yet 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, refinement of NPEC RS Guideline is required in order to fit in situations in each NOWPAP Member and to have one consolidated guideline (NOWPAP RS Guideline). These refinement activities will be conducted by the experts of the NOWPAP Members, mainly CEARAC and WG4 experts, under MOU being prepared by CEARAC. The following tasks will be included in the MOU that is under preparation. US$3,000 will be allocated to China, Korea and Russia respectively for reviewing and refining of the NPEC RS Guideline and US$6000 will be allocated to Japan for harmonizing information and printing of the NOWPAP RS Guideline.

✓ Review of the Monitoring parameters and the Observation/Analysis Methods for Satellite and *in situ* Monitoring

As ‘NPEC RS Guideline’ was developed based on the results from the ‘Toyama Bay Project’, peculiar circumstance for each NOWPAP Member is not fully considered. Therefore, the monitoring parameters and the observation/analysis methods for satellite and in situ monitoring are to be reviewed and localized/revised as appropriate for each region. Checklist for reviewing and refining the guideline will be prepared by CEARAC and interim review will be reported from each NOWPAP Member (excluding Japan) voluntary.

✓ Case Studies

At least one case study targeting on a sea area in the NOWPAP Region shall be added by each NOWPAP Member. The case study on the Toyama Bay attached to in the ‘NPEC RS Guideline’ will be referred as an example.

✓ Approval from the Governments of the NOWPAP Members

To promote the practical use of the ‘NOWPAP RS Guideline’ in the NOWPAP Region, it is important to receive endorsement of the government of each NOWPAP Member. Therefore, a procedure to obtain governments’ approval of the NOWPAP Member is requested.

✓ Translation

The ‘NOWPAP RS Guideline’ will be translated as much as possible into the languages used in each NOWPAP Member to make it easy understandable to local government officers, researchers, and students in the NOWPAP Region.

## 3 Draft table of contents of NOWPAP RS Guideline

Draft table of contents of the NOWPAP RS Guideline was prepared based on the NPEC RS Guideline (Appendix B). Considering the differences of situation in each NOWPAP Member, region-specific issues are added.

## 4 Schedule

Future schedule is shown in Fig. 1. The draft NPEC RS Guideline was submitted at the 4th CEARAC FPM in March 2006, and then the necessary refinement to make it useful for each Member will be discussed at the 3rd CEARAC WG4 Meeting, based on interim review of the NPEC RS Guideline by the experts in each NOWPAP Member. The guideline will be finalized by the end of 2006 as a guideline for eutrophication monitoring using satellite data for the NOWPAP Region (NOWPAP RS Guideline).

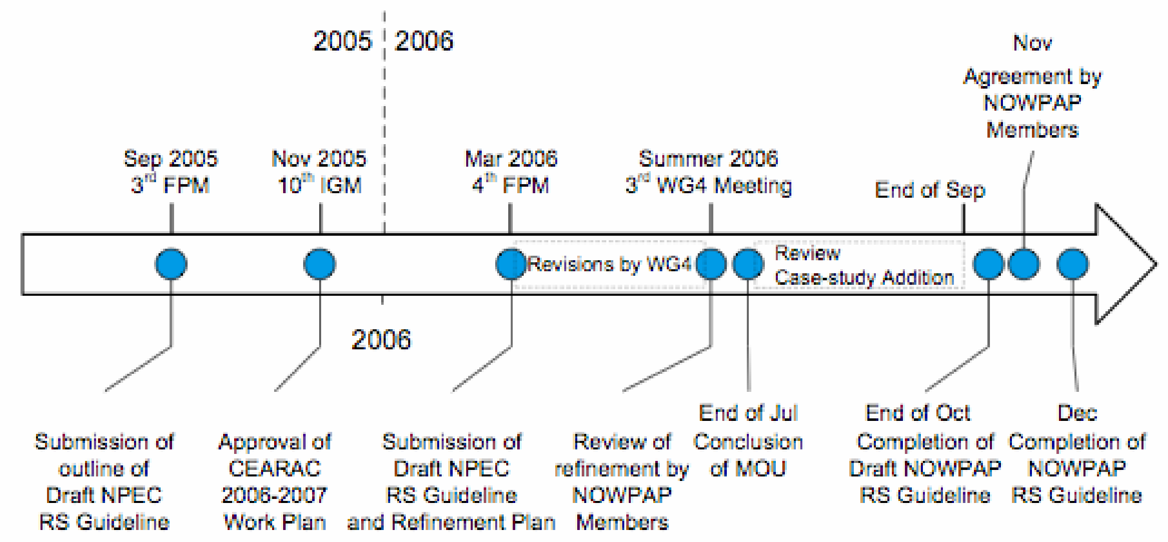


Figure 4.1 Schedule for the refinement of NPEC RS Guideline.

## 5 Budget

The budgets for the RS guideline refinement are summarized in Table 5.1.

Table 5.1 Budgets for RS guideline refinement.

| Item | Budget US$ |
|---|---|
| Refinement | |
| China | 3,000 |
| Korea | 3,000 |
| Russia | 3,000 |
| Harmonization (Japan) | 3,000 |
| Print | 3,000 |
| TOTAL | 15,000 |

**Appendix A**

## NPEC Guideline for Eutrophication Monitoring by Remote Sensing

**Table of Contents**

## I. Background and purpose

The Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Northwest Pacific Region (NOWPAP) was adopted in September 1994 as a part of the Regional Seas Programme of the United Nations Environment Programme (UNEP). In order to support the implementation of the action plan, a network of Regional Activity Centres (RAC) was established in each Member country (NOWPAP Member) in pursuit of the chosen goals and objectives. Among these RACs, Special Monitoring and Coastal Environmental Assessment Center (CEARAC) was established in Japan and Northwest Pacific Region Environmental Cooperation Center (NPEC) was designated as the hosting body of CEARAC in 1999.

Under the CEARAC, two working groups, namely WG3 and WG4, comprised of national experts from each NOWPAP Members were established with the responsibility to implement activities related to HAB including red tides (WG3) and remote sensing of marine environment (WG4).

This, Guideline for Eutrophication Monitoring by Remote Sensing, was prepared by NPEC to support activities of WG4, which intends to be a basis for establishing common methods for evaluation and using satellite data for cooperative environmental monitoring in the NOWPAP Region, referring to the results and lessons learned from a case study conducted in Toyama Bay. To share this guideline in the NOWPAP Region, national experts of NOWPAP WG4 are going to cooperate in reviewing and refining the guidelines in order to fit in the situation in each region, and to have one integrated guidelines suitable for the NOWPAP Region.

This guideline was made for coastal managers in local government aiming at making the best use satellite remote sensing for the monitoring and assessment of eutorophication which represents one of the most sever and widespread environmental problems in the NOWPAP Region. We hope this guideline will contribute to proper use of satellite data for monitoring and assessment of eutrophication then, as a result, to capacity building of the NOWPAP Member countries and regions.

## II. Eutrophication and satellite remote sensing

### 1. Introduction

Eutrophication is the phenomenon of enrichment of aquatic ecosystem through increasing loads of nutrients.

Eutrophication is often caused by human activities, such as inputs from extra fertilizer from agriculture farming, food for aquaculture, untreated and/or treated sewage and industrial wastewater, and it deteriorates coastal environment. Harmful algal (phytoplankton) bloom is typically caused by the eutrophication and induce fish kill, damage to ecosystem, and sometimes direct human health problems. Eutrophication degrades the water quality by accelerating organic matter decomposition and decreasing light availability in the coastal water body. All these problems are common in the NOWPAP region.

In order to assess eutrophication, there are several indicators presently used. Phosphate, ammonia and nitrate, in both river and coastal waters are the major constituents of nutrients. Chlorophyll-a (Chl-a) is an indicator of phytoplankton biomass and its concentrations increase with the growth of phytoplankton as a result of eutrophication. Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) are used to quantify the magnitude of organic pollution inducing depletion of oxygen in aquatic ecosystem. Suspended solid(SS) and transparency are used for the indicator of turbidity. All these indicators can be measured directly by water sampling of ship observation.

While collecting information from water sampling by ship observation in marine waters is often costly and limited in space and time, satellite remote sensing can cover large area (up to global) with relatively high resolution (250 m - 1 km) without restriction of national boundaries. It also covers long time (nearly 10 years) with frequent (several days) and consistent data. Recently, remote sensing can provide data and information on Chl-a concentration, SS, Colored dissolved organic matter (CDOM), primary productivity of phytoplankton, red tide and sea surface temperature (CEARAC, 2005.). Thus, it is reasonable to complement the conventional method of ship observation monitoring with satellite remote sensing techniques.

Moreover, with regular ship monitoring data, remote sensing data is able to provide broad visual image of oceanic phenomena to help understand the process of eutrophicaion that is useful for assessment of coastal environment.

## 2. Satellite Data

Among the parameters measured by satellite, ocean color may be the most useful information for monitoring eutrophication. Ocean color is the measure of spectral characteristics of water leaving radiance and comparable to the visible inspection of the watercolor. Chlorophyll-a concentration and turbidity can be calculated from the ocean color data and the method is fairly well established in the open ocean and less accurate in the coastal area where other materials influence to the water color. Sea Surface Temperature (SST) can also be measured by remote sensing using infrared and/or microwave ranges of electromagnetic wave.

### 2.1 Monitoring parameters

a. Chl-a concentration

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 of phytoplankton. If eutrophication proceeds, Chl-a concentrations become abnormally high and it often results degradation of water quality such as increase of red tide and so on.

Satellite remote sensing allows the estimation of the oceanic Chl-a concentrations 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. SST

SST is the water temperature at the sea surface. Seasonal change in meteorology and basic information such as water mass can be detected by SST image.

c. Turbidity (K490)

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

d. Other parameters provided by space agency are summarized in 5. Appendix as an example and other possible products may also be available.

## 2.2 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. 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 the frequency is limited (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 also launched Global Imager (GLI) on the ADEOS-II satellite. However, operation ceased due to mechanical trouble in October 2003, 10 months after its launch.

NASA is maintaining the quality and consistency among each data for all the period and providing those data via the Internet.

SeaWiFS Chl-a concentration data from September 1997 (right after its launch) can be obtained for free of charge by submitting user application to NASA, Methods for acquiring SeaWiFS data depends on the purpose (research or commercial).

b. Sea Surface Temperature

Sea Surface Temperature is estimated by processing of NOAA 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 and it is useful to detect turbidity in the water.

**2.3 Obtaining satellite data**

Satellite data can be obtained from many organizations. This guideline introduces some examples for monitoring of the NOWPAP Region. Data format specifications are to be referred to each data provider.

a. Chl-a

<CZCS>

CZCS Chl-a concentration data from November 1978 through June 1986 can be obtained from the Ocean Color Web (http://oceancolor.gsfc.nasa.gov/). NASA is classifying these data as evaluation products since improvement of accuracy is still on going.

<OCTS>

OCT Chl-a concentration data from November 1996 through June 1997 can be obtained from the Ocean Color Web via the Internet. NASA is classifying these data as evaluation products. products since improvement of accuracy is still on going.

<SeaWiFS>

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 depends on the purpose (research or commercial). SeaWiFS Chl-a data can be obtained for free of charge for research purposes, under the conditions that NASA authorizes the purpose of data use. Procedure for becoming NASA authorized user is described in details on 'SeaWiFS Project Information' site in SeaWiFS Project Homepage (http://oceancolor.gsfc.nasa.gov/SeaWiFS/).

SeaWiFS Chl-a data can be obtained from the Ocean Color Web. NASA provides SeaWiFS Chl-a data products in different spatial resolution.

<MODIS>

MODIS data is received at many organizations, and is open to the public via the Internet. MODIS Chl-a data from June 2002 can be obtained from the Ocean Color Web of NASA.

JAXA also provide MODIS Chl-a data that had been received by the Earth Observation Center and processed by JAXA GLI algorithm. The Subset of these processed data are geometrically corrected for the NOWPAP Region by the Northwest Pacific Region Marine Environment Watch and it can be downloaded from its website (the Marine Environment Watch Homepage). User registration is required to obtain the data (http://www.nowpap3.go.jp/jsw/eng/search/regist.html).

b. SST
<AVHRR>

NOAA AVHRR from Feb 2002 can be obtained from the Marine Environment Watch Homepage. The data is geometrically corrected for the NOWPAP Region and merged by day and 10 days.

<MODIS SST>

MODIS SST data from June 2002 can be obtained from the Ocean Color Web via the Internet with LAC spatial resolution. The Marine Environment Watch Homepage also provides MODIS SST data processed by JAXA GLI algorithm from August 2002.

c. Turbidity (K490)

SeaWiFS and MODIS provide K490 data set that could be used as an indicator of turbidity and it can be obtained from the Ocean Color Web.

**2.4 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 concentrations, SST and turbidity (K490) data from SeaWiFS SeaDAS may be run on PC-Linux, which enables the construction of processing environment at reasonable cost. WIM is also suitable software for analyzing satellite images. WIM works on Microsoft Windows operating system and its evaluation version and be obtained via the Internet (http://www.wimsoft.com).

Excel program from Microsoft may be used for processing and analyzing Chl-a concentration and Sea Surface Temperature data provided from the Marine Watch Homepage.

Other suitable software's are introduced on the Marine Watch Homepage.

b. Extraction of physical values

Physical values for each sensor can be extracted from the following satellite date product.

(1) Chl-a concentration data

<CZCS>

Data Product Name: CZCS Level 2 data

Data source: Source: Ocean Color Web

Recommended software application: NASA SeaDAS, WIM

<OCTS>
Data Product: OCTS Level 2 data
Data Source: Ocean Color Web
Recommended software application: NASA SeaDAS, WIM

<SeaWiFS>
Data Product: SeaWiFS Level 2 data
Data Source: Ocean Color Web
Recommended software application: NASA SeaDAS, WIM

<MODIS>
Data Product: MODIS Level 2 data
Data Source: Ocean Color Web
Recommended software application: NASA SeaDAS, WIM

<MODIS processed by JAXA>
Data Product: JAXA GLI MODIS
Data Source: Marine Watch Homepage
Recommended software application: NASA SeaDAS, WIM, Microsoft Excel

(2) Sea Surface Temperature
<AVHRR>
Data Product: AVHRR SST
Data Source: Marine Watch Homepage
Recommended software application: NASA SeaDAS, WIM, Microsoft Excel

<MODIS >
Data Product: MODIS SST
Data Source: Ocean Color Web
Recommended software application: NASA SeaDAS, WIM

(3) Turbidity (k490)
<SeaWiFS>
Data Product: SeaWiFS Level 2 data
Data Source: Ocean Color Web
Recommended software application: NASA SeaDAS, WIM

<MODIS>
Data Product: MODIS Level 2 data
Data Source: Ocean Color Web
Recommended software application: NASA SeaDAS, WIM

## 3. In Situ Data

To maximize the usefulness of satellite data for eutrophication monitoring monitoring, it is essential to obtain in situ data. Match up data set can be used for calibration and validation. Conversely, satellite data can help in better interpretation of in situ data with providing large spatio-temporal coverage image of oceanic phenomena, which in situ data cannot cover.

### 3.1 Monitoring Parameters and Measuring Method

a. Chl-a concentration

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

b. Nutrients

Eutrophication is often caused by direct nutrient load from land. Nutrients control phytoplankton growth and change the taxonomic composition.

c. Temperature and Salinity

Temperature is a good indicator of water mass and vertical mixing condition. It can be also used to estimate growth rate or primary production of phytoplankton. Measurements of surface salinity make it possible to estimate how much fresh water due to river outflow and precipitation is flowing into the target area.

d. 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.

e. COD

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.

f. Suspended Solid (SS)

SS is an indicator of sediment loads from river and/or resuspension from bottom, also considered as an indication for turbidity.

This may influence on errors of satellite-derived Chl-a concentration.

g. Chromatic Dissolved Organic Material (CDOM)

CDOM is a part of the dissolved organic mater, sometimes important for oxygen consumption loaded from land and/or produced by biological activity in the coastal area. This may influence on errors of satellite-derived Chl-a concentration.

h. 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.

i. 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.

j. Measurement methods

Measurement methods are explained in details in NASA SeaWiFS Technical Report Series, which are available at SeaWiFS Project Information Homepage.

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) also describes the details of measurement methods (Japanese only) and notes to be taken care of the measurements of Chl-a, Suspended Solid, Chromatic Dissolved Organic Material, and Water-Leaving Radiance

**3.2 Determination of Monitoring site and sampling points**

a. Criteria for selecting monitoring site

The following criteria should be considered for selecting monitoring site for the purpose of this guideline, in order to a monitor and assess eutrophication. .

(1) Receiving nutrients loads from rivers, direct discharges of domestic and industrial wastes, loads from mariculture activities and/or diffuse sources

(2) Being sensitive to eutrophication phenomena (enclosed coastal bay and estuaries, shallowness, limited water recycling, etc.).

(3) Having historical records of accumulated data of water quality in the past.

b. 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.

c. 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 determining the sampling points.

### 3.3 Monitoring Frequency and Timing

When determining monitoring frequency and timing, 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.

### 3.4 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 is also required.

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

## 4. Monitoring and assessment of eutrophicaion

### 4.1 Accuracy Evaluation

a. 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.

The data from satellite ~~is~~ often contains error in comparison with in situ data when the concentration of SS and CDOM become higher. Thus, its comparison to 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.

b. Evaluation of Underwater Algorithm

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

**4.2 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. 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.

b. Evaluation of Eutrophication

If COD or concentration of various nutrients (e.g. Phosphorus, Nitrogen, etc.) is measured at the same time, understanding on the relationship with Chl-a 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.

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**NASA Evaluation Products**

| Product Name | Description | | Units | Priority |
|---|---|---|---|---|
| chl_oc2 | Chlorophyll-a concentration, OC2 algorithm | Index of total amount of phytoplankton in the 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 total amount of Particular Organic Carbon in the surface layer. | mg·m-3 | C |
| tms_clark | Total suspended matter(D.Clark) | Index of total amount of suspended matter in the surface layer. | | C |
| calcite | Default Calcite Concentration (calcite_3b) | Index of total amount of detached Coccolith in the 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 leving the 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) were studied to understand the process of pollution.

**2. Method**

**2.1 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.

**2.2 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)

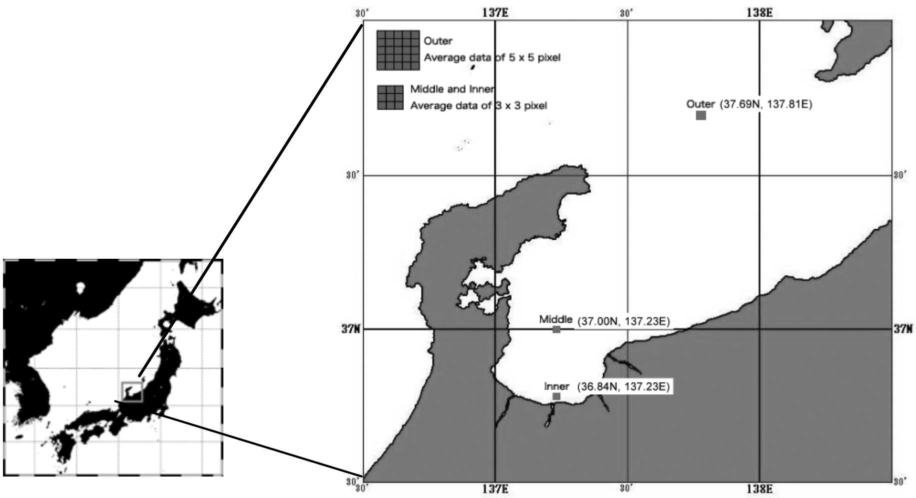


**Fig.1 Location of study area.**

## 3. Analysis and discussion

### 3.1 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.1). 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.

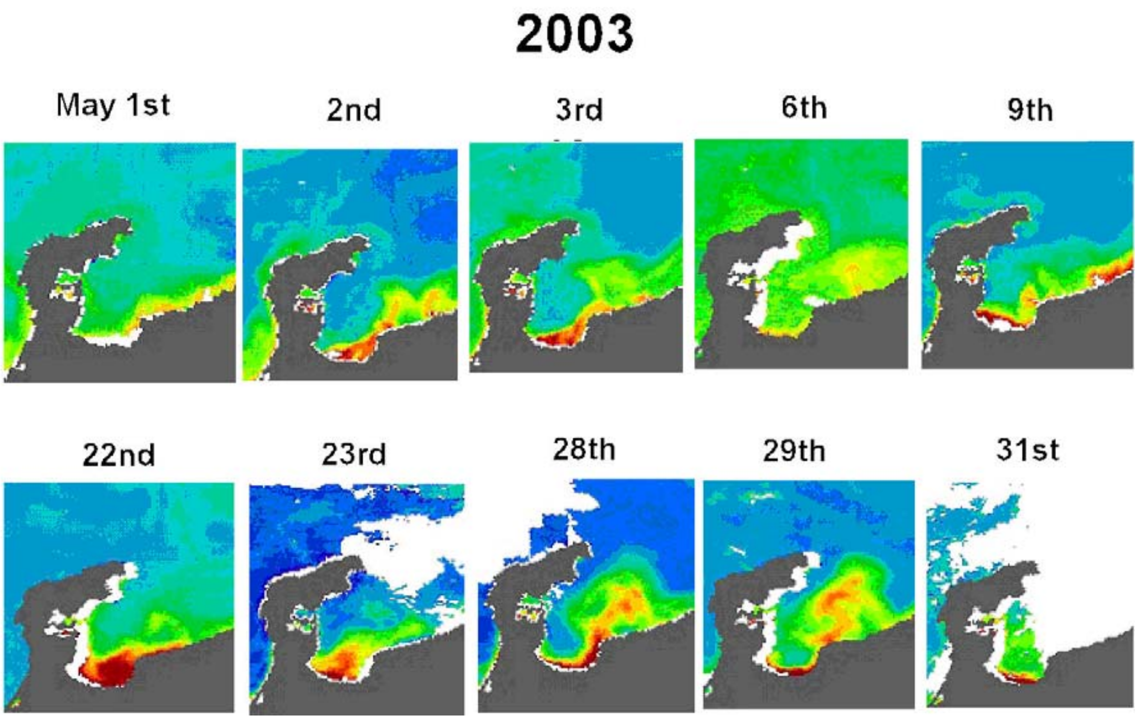


**Fig. 2 Chl-a concentrations pattern of May 2003 observed by MODIS in Toyama Bay**

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).

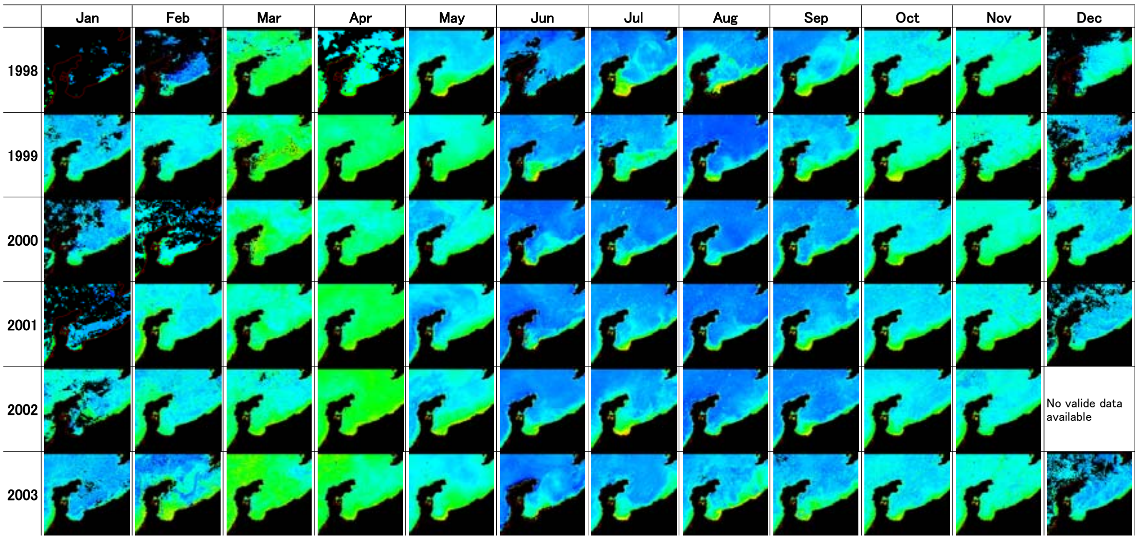


**Fig. 3 Monthly average SeaWiFS Chl-a image of Toyama Bay.**

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 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 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.

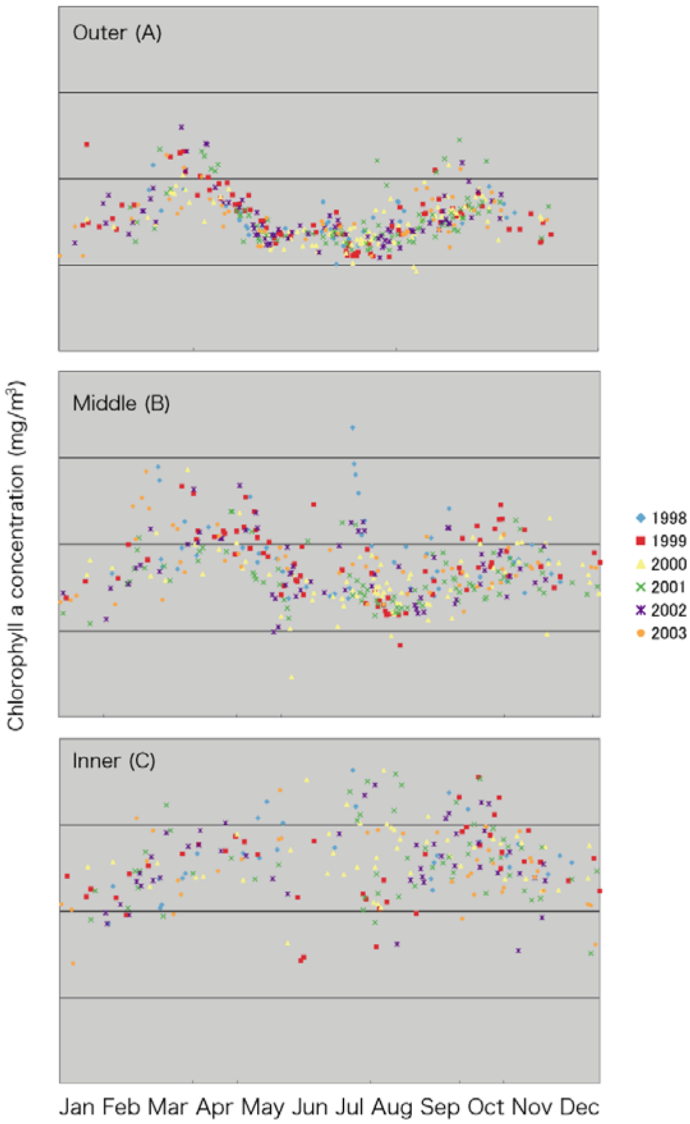


**Fig. 4 Seasonal variability of Chl-a concentration in three different areas. Each area, outer (A), middle (B) and inner (C), is corresponding to the location in Fig. 1.**

### 3.2 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 correction, 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 also suggested that there might be a problem in atmospheric correction.

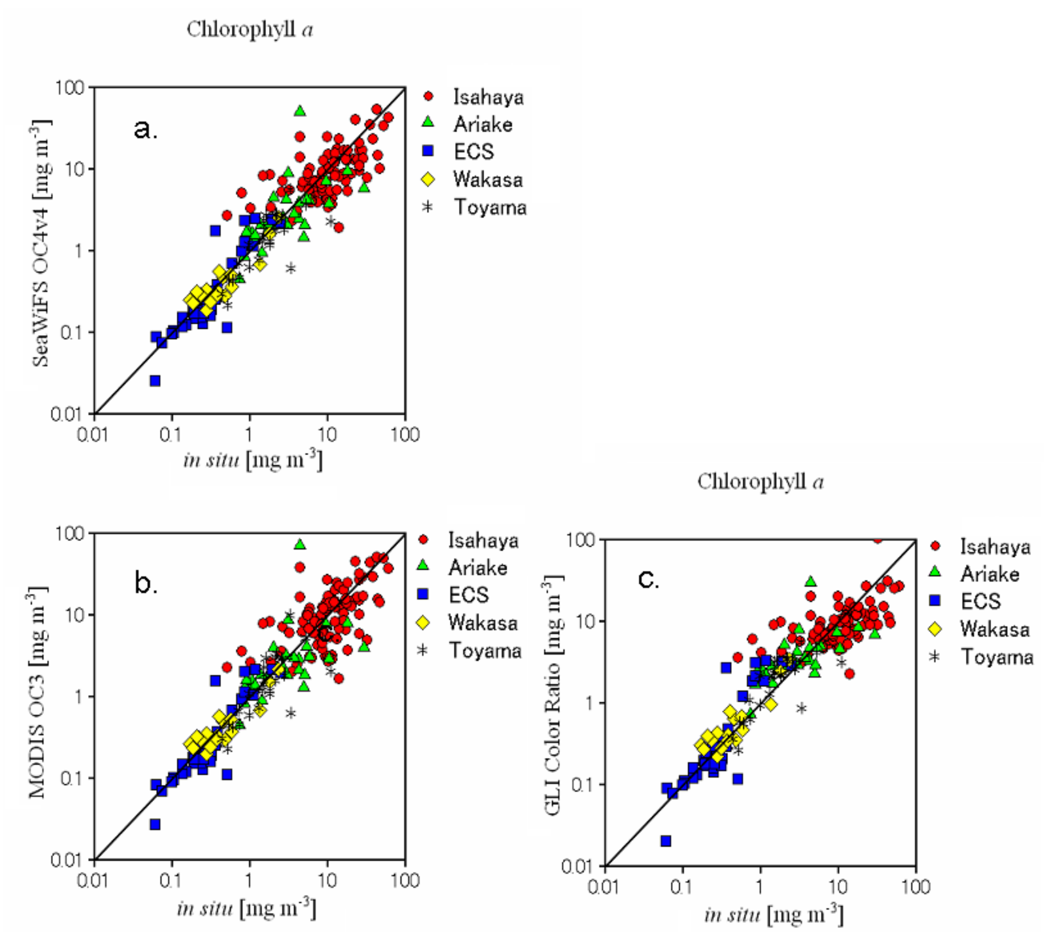


**Fig.5 Relationships in situ Chl-a and one derived from three existing in-water algorithms SeaWiFS, MODIS and GLI**

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 may be affected by anomaly of mirror on MODIS instrument, which was reported by NASA.

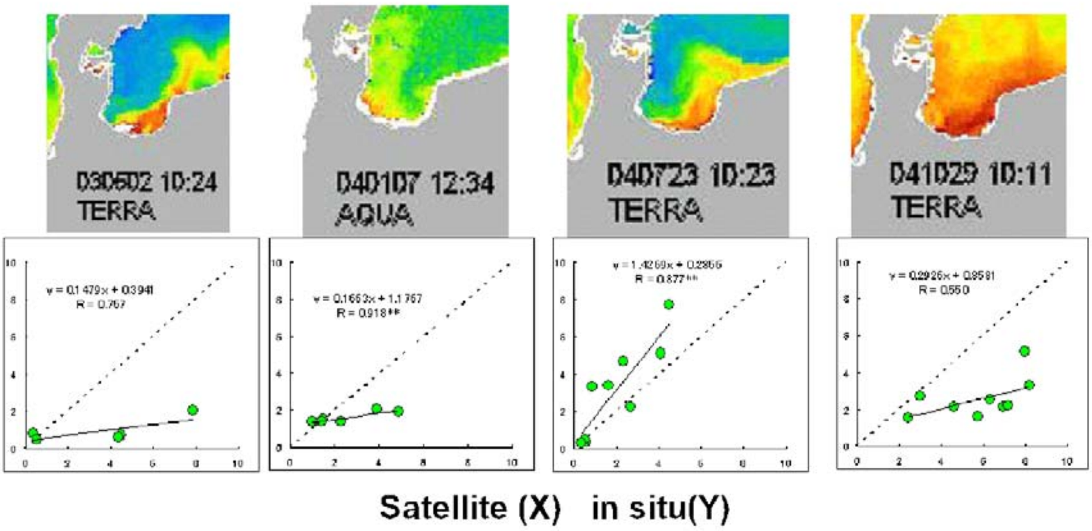


**Fig.6 Relationship between satellite and in situ Chl-a**.

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 were studied. It was found that MODIS Chl-a concentration tends to be overestimated when the concentration of SS and CDOM become higher (Fig. 7).

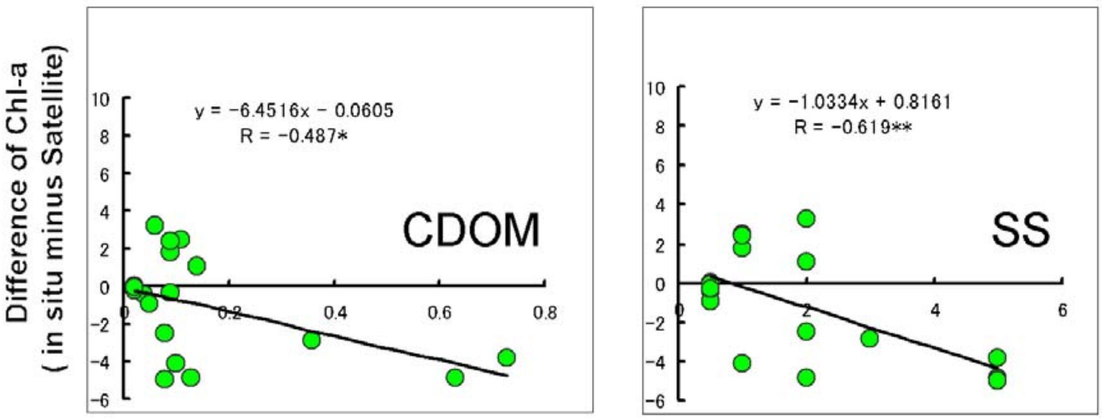


**Fig.7 Analysis of MODIS Chl-a concentration with SS and CDOM.**

**3.3 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 is possible for monitoring of organic pollution indicated COD.

It was considered that the section of regression formula is indicating 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.

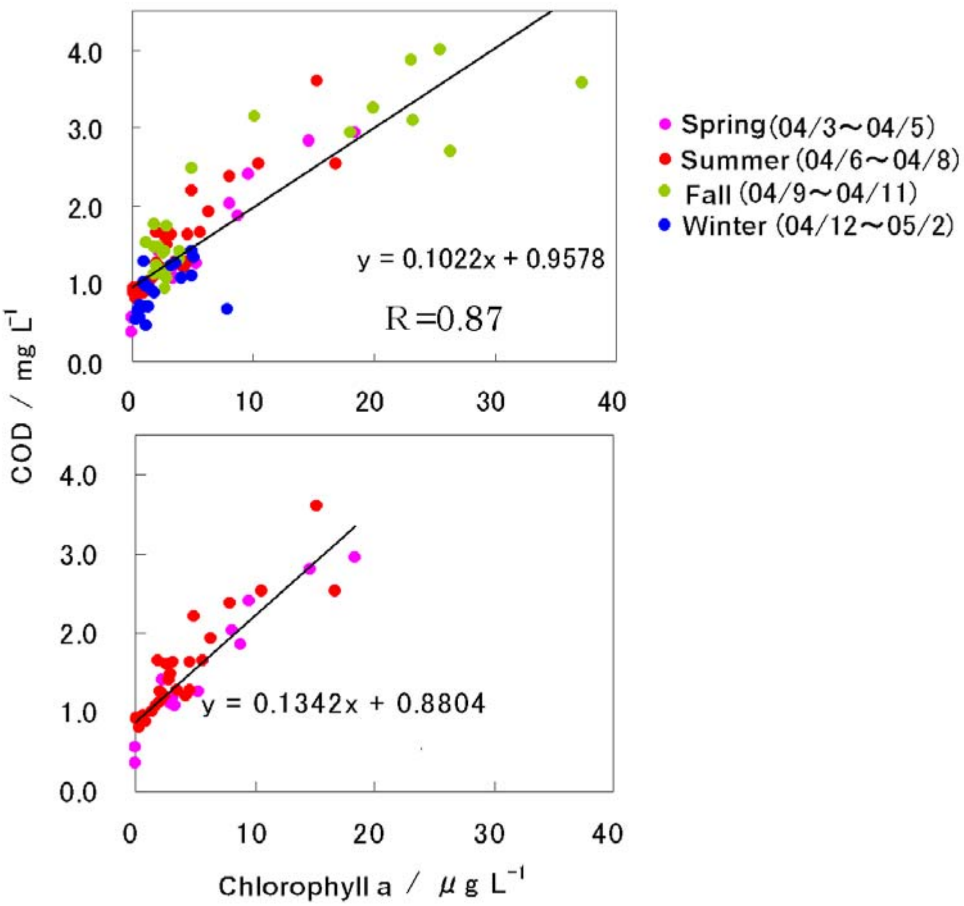


**Fig.8 Correlation between Chl-a concentration and COD in Toyama Bay**

## 4. Assessment of eutrophication with remote sensing

### 4.1 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.

### 4.2 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.

### 4.3 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.

**Appendix B**

## Draft Table of Contents of Guideline for Eutrophication Monitoring by RS

**I. Background and purpose**

Describe background and purpose of this project such as outline of NOWPAP, WG4 and intended use.

**II. Eutrophication and satellite remote sensing**

1. Introduction

Describe the definition of "eutrophication" used in the NOWPAP Guidelines, and the advantage/disadvantage of remote sensing technology for the monitoring of eutrophication.

2. Satellite data

2.1 Monitoring parameters

Describe remote sensing data products that can be applied to the monitoring of eutrophication.

2.2 Sensors

Describe remote sensing sensor names with their brief explanation..

2.3 Obtaining data

Describe availability of the above mentioned satellite date products and explain how to obtain those data.

2.4 Data processing method

Describe computational requirement and necessary data processing methods for analyzing the above mentioned data.

2.5 Region-specific issues

Describe the region-specific issues based on the differences come out of the result of the review by each country.

- China
- Japan
- Korea
- Russia

3. In situ data

3.1 Monitoring parameters and measurement method

Describe field observation parameters can be applied to the monitoring of eutrophication with the measurement method.

3.2 Determination of sampling points

Describe the factors to be considered for the determination of sampling points in filed observation.

3.3 Monitoring frequency and timing

Describe the factors to be considered for determination of monitoring frequency and timing.

3.4 Requisites for monitoring and analysis

Describe the requirement for monitoring and analysis

3.5 Region-specific item/issue

Describe the region-specific issues based on the differences come out of the result of the review by each country.

- China
- Japan
- Korea
- Russia

4. Monitoring and assessment of eutrophication
   4.1 Accuracy evaluation
   Describe the factors to be considered when analyzing the relationship between the satellite and *in situ* data.

   4.2 Integration with the existing monitoring system
   Describe methods necessary for understanding the eutrophication status and its cause.

5. Appendix
   5.1 Table of satellite data product for marine environmental monitoring
   Describe the satellite data product suitable for marine environmental monitoring provide by space agencies.

**Annex 1**
**A case study in China**

**Annex 2**
**A case study in Japan**
1. Objective and background
2. Method
   2.1 Monitoring survey of Toyama Bay
   2.2 Obtaining ocean color satellite data
3. Analysis and discussion
   3.1 Analysis of time series of satellite chlorophyll a (Chl-a) concentrations
   3.2 Validation of satellite Chl-a concentration
   3.3 Correlation between in situ Chl-a concentration and COD
4. Monitoring and assessment of eutrophicaiton with remote sensing
   4.1 Detecting spatio-temporal variation of eutrophication by ocean color satellite
   4.2 Evaluation of eutrophication from in situ investigation
   4.3 Others

**Annex 3**
**A case study in Korea**

**Annex 4**
**A case study in Russia**

Appendix C

Introduction to activities against eutrophication in other regions

| Area | Mediterranean | The North Sea | National Estuarine in USA |
|---|---|---|---|
| Lead organization | UNEP MAP (MED POL) | OSPAR | NOAA |
| Program | Eutrophication Monitoring Strategy (2003) | Common Procedure for Identification of Eutrophication Status (2002) | National Estuarine Eutrophication Assessment (2004) |
| Intended user | Member states of MAP | Member states of OSPAR | Coastal Managers in each state |
| Parameters and Eutrophication determination criteria | <Parameters><br>Temperature, pH, Transparency/Secchi depth, Salinity, Orthospehate, Total phoshorus, Silicate, Dissolved Oxygen, Chlorophyll, Total Nitrogen, Nitrate, Ammonium, Nitrate, Phytoplankton<br><br><Eutrophication determination criteria><br>Trophic Index : TRIX (Volluenweider et al. 1998)<br>TRIX = (log10[ChA*aD%O*DIN*TP]+k]*m<br><br>Where:<br>ChA = Chlorophyll a concentration as ug/L;<br>aD%O = Oxygen as absolute % deviation from saturation;<br>DIN = Dissolved Inorganic Nitrogen, N-(NO3+NO2+NH4) as ug/L;<br>TP = Total Phosophorus as ug/L.<br>k = 1.5<br>m = 10/12 = 0.833<br>The parameters k and m are scale coefficients necessary to fix the lower limit value of the Index and the extension of the related Torphic Scale, i.e. from 0 to 10 TRIX units. | <Parameters><br>-Category1-<br>Total N/P inputs and direct discharges, Winter DIN/DIP, Increased winter N/P ration<br>-Category2-<br>Maximu and mean chl a concentration, Region/area specific phytoplankton indicator species, Macrophytes including macroalge<br>-Category3-<br>Degree of oxygen deficiency<br>Changes/kills in Zoobentohs and fish kills, Organic Carbon/ Organiz Matter<br>-Category4-<br>Algal toxins incidence<br><br><Eutrophication determination criteria><br>Different set of parameter categories will be applied to assess the eutrophic sattus of diffferent region.<br>For example, only parameters in category 1 and 2 are used for Belgian waters, since the other categories are not applicable. | <Parameters><br>Salinity, Temperature, Meteorological data, Water residence time, Turbidity, Chl-a, Seagrass, Macrophytes, Bentihic alge, Phytoplankton, Dissolved Oxygen, Sediment organic content, Dissolved nutrient, N:P:Si ration, Freshwater Flow, nutrient concentration, load, Seawater exchange, nutrient concentration, load, Anthoropogenic and natural nutrient loads, Ponit Sources, Nonpoint sorces<br><br><Eutrophication determination criteria><br>Classify eutrophication into 9 patterns by phenomena |

| Area | Mediterranean | The North Sea | National Estuarine in USA |
|---|---|---|---|
| Features | Creating TRIX Map with remote sensing data | Implmentation management is strict under the convension framework. | Typology concept for classifiing charateristic of monitoring site is under development to determine the thresholds for eutrophication in each type. |
| Goal | <Short term><br>Obligate the member states to conducte sea truth monitoring by the mandatory parameters. Evaluate pilot parameters such as Dissolved Oxygen, Phytoplankton, Benthos and water residence time.<br><br><Mid term><br>Development of new indicator and model for Eutrophication with utlizing remote sensing and buoy data.<br><br><Long term><br>Establishment of indicator system based | <Long term><br>Terminate occurrence of eutrophication by 2010 | – |
| Challenges | – | – | Translation and integration of science into information and tools that are useful to managers.<br>Report of result to the public and Congreass to leverage action anf funding for management and related research. |