Contents

1. Introduction

The frequent occurrence of large-scale red tides in the coastal areas of China and Korea, apparently induced by eutrophication, is still a serious issue causing an increase in fishery damage, environmental deterioration and food poisoning from the consumption of affected fish. To prevent such damage, it's increasingly important to establish an extensive and continuous monitoring system for observing the emergence of eutrophication (phytoplankton blooms) and red tides. Phytoplankton blooms are sporadic in time and isolated in space, and are therefore hard to monitor by conventional (surface) means. The blooms can color surface waters over large areas and can therefore be detected by satellite remote sensing. However there are currently no methods to determine from satellite data whether a bloom is 'harmful' in its effects on humans, fish or other organisms.

Much of the traffic in the Northwest Pacific Ocean, one of the most crowded sea areas in the world, is tankers and heavy oil cargo vessels. The potential risk of accidental oil spills from these vessels is very high, damaging local fisheries and tourism, and subsequently causing significant degradation to the marine environment. Also, illegal oil dumping is also very important issue taking into account total amount of waste waters. Satellite remote sensing, having wider coverage than conventional methods, high spatial resolution and all-weather capability of a such sensor as Synthetric Aperture Radar (SAR), is expected to detect oil spills resulted both from accidents and from illegal oil damping effectively and accurately with high temporal resolution and fewer false alarms, which is critical to minimize damage and operational expenses.

Consequently, we propose that, for the time being, eutrophication and oil spills should be the main targets of marine environmental monitoring by satellite remote sensing, as both are common environmental issues in the NOWPAP Region and both are expected to be targets for remote sensing applications.

Remote sensing can provide data and information on chlorophyll-*a* concentration, suspended solids (SS), colored dissolved organic matter (CDOM), primary productivity of phytoplankton, red tides, sea surface temperature (SST), sea surface wind speed (SWSS) and precipitation fields. It can also help to analyze the mechanisms of eutrophication and red tides for predicting blooms and providing data on the adaptation and mitigation of eutrophication. With regard to eutrophication monitoring, the target parameters for now should be (1) chlorophyll-*a* concentration, which is already in practical use and is a good indicator of eutrophication, and (2) primary productivity, which is estimated from the observed chlorophyll-*a* concentration, SST and photosynthetically available radiation (PAR). Monitoring red tides by remote sensing will be considered in the mid- and long-term, in accordance with the progress of observation technologies, because there are still many problems to be solved. With regard to oil spill monitoring, remote sensing can provide data and information on the early detection of spills, size estimates, damage assessment, location of oceanic dynamic features (current and river outflow fronts, eddies etc.), and fields of physical oceanic and atmospheric parameters (wind, waves, currents, SST etc.). Such monitoring can also help to identify the pollution source, including accidents and illegal discharge of wastewater from ships, predict the movement and weathering of a spill and possibly determine the nature and thickness of the oil.

The ultimate goal of our activities is to ‘establish cooperative marine environmental monitoring by remote sensing and to contribute to the conservation of the marine environment in the NOWPAP Region’. To achieve this goal, we must thoroughly consider, among other things, the identification and solution of technical issues of marine environmental monitoring by remote sensing, and the technical and financial arrangement in the NOWPAP Region. This Integrated Report aims at sharing a common understanding among the NOWPAP Members on these matters and informing the progress internationally.

2. Sensors and satellites

2.1. China

2.1.1. HY-1B COCTS/CZI

China's second ocean satellite HY-1B, launched on April 2007, carries improved Chinese Ocean Color and Temperature Scanner (COCTS) and the Coastal Zone Imager (CZI) and has been operating stably for four years, one year longer than its designed lifespan. It has been playing a significant role in such fields as the detection of sea surface temperature change, development and utilization of marine bio-resources, marine pollution monitoring and control, and research of global environment changes. COCTS is a 10-channel visible and infrared radiometer while CZI is a 4-channel CCD camera (IOCCG, 2011).

2.1.2. HY-1C/1D COCTS/CZI

HY-1C/1D are the follow-on ocean satellite HY-1B, carried improved COCTS and CZI, scheduled for launch in 2014. HY-1C is AM satellites, HY-1D is PM one, respectively (DRAGONESS, 2008).

Table 1. HY-1C/1D main characteristics (CEOS/ESA, 2011)

Agency	NSOAS/CAST
Status	Planned
Launch Date	01 Jun 2011 (HY-1C), 01 Dec 2011 (HY-1D)
EOL Date	01 Jan 2013
Applications	Detecting ocean colour and sea surface temperature
Instruments	COCTS, CZI
Orbit Details & URL	Type: Sun-synchronous Altitude: 798 km Period: Inclination: 98.6 deg

	Repeat cycle: 7 days LST: 10:30 (HY-1C), 10:31 (HY-1D) Asc/desc: Descending URL: http://www.cast.cn/

2.2. Japan

2.2.1. ALOS PRISM/AVNIR-2/PALSAR

The Advanced Land Observing Satellite (ALOS) followed the Japanese Earth Resources Satellite-1 (JERS-1) and Advanced Earth Observing Satellite (ADEOS) and will utilize advanced land-observing technology. ALOS, launched on January 2006, had been operated for over five years, and completed its operations on May 2011. The three earth observing sensors: the Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM) for digital elevation mapping; the Advanced Visible and Near Infrared Radiometer type 2 (AVNIR-2) for precise land coverage observation; and Phased Array type L-band Synthetic Aperture Radar (PALSAR) onboard ALOS achieved many fruitful results related to earth observations. For oil spill detection, the use of AVNIR-2 and PALSAR contributed to effective surveillance, and thus to the better collection of oil and the reduction of oil spill damage.

2.2.2. ALOS-2 PALSAR

The Advanced Land Observing Satellite-2 (ALOS-2) is a follow-on mission from ALOS, and will be launched in 2013. The state-of-the-art L-band Synthetic Aperture Radar (PALSAR-2) on board ALOS-2, which is an active microwave radar using the 1.2 GHz frequency range, will have enhanced performance compared to ALOS/PALSAR. The PALSAR-2 is capable of observing day and night, and in all weather conditions. PALSAR-2 will have a spotlight mode (1 - 3 m) and a high resolution mode (3 - 10 m). It will allow comprehensive monitoring of disasters by providing users with more detailed data than ALOS/PALSAR. The observation frequency of ALOS-2 will be improved by greatly expanding the observable range of the satellite up to about 3 times, through an improvement in observable areas (870 - 2320 km), as well as giving ALOS-2 a right-and-left looking function, not available on ALOS/PALSAR. It is expected that monitoring of various oceanic phenomena such as wind waves, eddies, currents, upwelling, oil spills and sea ice can be done in details with higher spatial and temporal resolution.

Table 2. ALOS-2 main characteristics (CEOS/ESA, 2011)

Agency	JAXA
Status	Approved
Launch Date	01 Jan 2013
EOL Date	01 Jan 2017
Applications	environmental monitoring, disaster monitoring, civil planning, agriculture and forestry, Earth resources, land surface
Instruments	PALSAR-2
Orbit Details & URL	Type: Sun-synchronous Altitude: 628 km Period: 100 min Inclination: 97.9 deg Repeat cycle: 14 days LST: 12:00 Asc/desc: Descending URL: http://www.jaxa.jp/projects/sat/alos2/index_e.html

2.2.3. ALOS-3 Hyper-/Multi-spectral sensor

ALOS-3 is one of the post ALOS satellites, and will be launched in 2015. ALOS-3 carries the hyper spectral sensor, which is a push broom type imager radiometer with two separate spectral channels: one for the visible to near infrared (VNIR) range and one for the short-wave infrared (SWIR) range. Spatial resolution is 30 m with spatial swath width of 30 km. Number of spectral bands is 57 for the VNIR and 128 for the SWIR. Meanwhile the multispectral sensor has 5 m spatial resolution with 90 km swath width and 4 spectral bands for the VNIR. These spectral bands correspond to the spectral range of LANDSAT ETM+. There is continuity between TERRA/ASTER data and ALOS-3/multispectral sensor data (Tatsumi *et al.*, 2010). With higher temporal and spatial resolution, it is expected that hyper/multi spectra sensor onboard ALOS-3 to be used for monitoring of red tide and coastal landfill or erosion processes.

Table 3. ALOS-3 main characteristics (CEOS/ESA, 2011)

Agency	JAXA
Status	Planned
Launch Date	01 Jan 2014
EOL Date	01 Jan 2018
Applications	Cartography, digital terrain models, environmental monitoring, disaster monitoring, civil planning, agriculture and forestry, Earth resources, land surface
Instruments	Hyper-/Multi-spectral sensor (TBD)
Orbit Details & URL	Type: Sun-synchronous Altitude: 628 km Period: 100 min Inclination: 97.9 deg Repeat cycle: 14 days LST: 12:00 Asc/desc: Descending URL: http://www.jaxa.jp/projects/sat/alos2/index_e.html

2.2.4. GCOM-C1 SGLI

Global Change Observation Mission for Climate monitoring/study (GCOM-C) targets improvement of knowledge and future prediction of the climate system through long-term observations regarding the radiation budget and carbon cycle. GCOM-C1 is the first satellite in the GCOM-C series. GCOM-C1 boards Second-generation Global Imager (SGLI) which has following characteristics:

- 250 m resolution and 1150 km (Visible and Near Infrared Radiometer, VNI) or 1400 km (Infrared Scanner, IRS) swaths for the land and coast observations
- Near-UV and polarization observation for the land aerosol estimation
- Nadir + slant-view observations for the biomass and land cover classification (red and near-infrared bands)

Satellite, sensor and algorithm are developing for the launch in 2014. First version of the standard products will be released to public one year after the launch. GCOM-C products will be free of charge for internet acquisition (Murakami, 2010). It is expected that chlorophyll concentration and sea surface temperature to be observed by SGLI to be used not only for detecting good fishing ground but also for sustainable use of fishery resources.

Table 4. GCOM-C1 main characteristics (CEOS/ESA, 2011)

Agency	JAXA
Status	Approved
Launch Date	01 Feb 2014
EOL Date	01 Feb 2019
Applications	Understanding of climate change mechanism
Instruments	SGLI
Orbit Details & URL	Type: Sun-synchronous Altitude: 800 km Period: 98 min Inclination: 98.6 deg Repeat cycle: LST: 10:30

	Asc/desc: Descending URL: http://www.jaxa.jp/projects/sat/gcom/index_e.html

2.3. Korea

2.3.1. COMS GOCI

In June 2010, Geostationary Ocean Color Imager (GOCI), the world's first geostationary ocean color sensor has been launched on board Communication, Oceanographic, Meteorological Satellite (COMS). GOCI is planned for use in real-time monitoring of the ocean environment around Korean Peninsula by daily analysis of ocean environment measurements of chlorophyll concentration, dissolved organic matter, and suspended sediments taken eight times per day for seven years. GOCI primary data will support ocean environment monitoring, operational oceanographic system, and fishery information service and climate change research. Operational oceanographic system is to provide data and information for ocean and coastal states changes to various users. Basically all research works can belong to the operational oceanographic system. GOCI data can be used for understanding the atmospheric phenomena and land application. The life time of GOCI mission is about 7 years (Ryu *et al.*, 2010).

2.3.2. COMS-2 Advanced GOCI

The Post-GOCI mission was approved by the Korean government in 2010 and is scheduled for launch on board COMS-2 in January 2018. Emphasis will be placed on coastal regions using a multi-sensor approach to include environmental measurements at a high temporal resolution (every hour) to monitor long term global climate change. Key requirements include 13 spectral bands (up from 8 for GOCI) with a spatial resolution of 250 m (cf. 500 m for GOCI). Additional requirements for IR bands are still under examination. Night time observations are also being investigated. (IOCCG, 2011).

Table 5. COMS-2 main characteristics (CEOS/ESA, 2011)

Agency	KARI
Status	Considered
Launch Date	01 May 2017
EOL Date	30 Apr 2024
Applications	Korea's geostationary oceanographic and environmental satellite
Instruments	Advanced GOCI, GEMS
Orbit Details & URL	Type: Altitude: Period: Inclination: Repeat cycle: LST: Asc/desc: URL:

2.4. Russia

2.4.1. Meteor-3M No.1 KMSS

The KMSS, Satellite Multispectral Imagery System, composed of two cameras MSU-100 and MSU-50 was designed for imaging land and water surface in 6 visible and near IR regions within the swath width of about 1000 km, and with 60 - 120 m in spatial resolution, and was launched on board Meteor-3M No.1 in September 2009. KMSS data was delivered to consumers. The objects of departmental monitoring to the benefit of the economy using KMSS data are as follows (Novikova *et al.*, 2008):

- State and forecasting of agricultural crop productivity;
- State and dynamics of forest cover; illegal felling;
- Desertification and deforestation;

- State and dynamics of snow cover;
- Marine optical characteristics, primary productivity and pollution;
- State and dynamics of marine ice cover;
- Geological exploration;
- Cloud cover characteristics;
- Atmospheric aerosol pollution;
- Emergencies and their ecological effect: forest fires, flashes and floods, atmospheric catastrophic phenomena, volcanic eruptions, large-scale man-made disasters.

2.4.2. Meteor-3M No.3 ROSS-1

A first Russian satellite ocean color sensor, ROSS-1, is planned for launch on board Meteor-3M No.3 in 2015. The satellite orbit will be Sun synchronous at 830 km, the swath width is 1150 km, the spatial resolution at nadir at the Earth's surface was about 580 m. ROSS-1 will take measurements by scanning both across the satellite orbit (8 spectral bands) and in the along-track direction (3 spectral bands). The measured data would be used to derive estimates of concentration of chlorophyll and suspended matter in the near-surface ocean, of the solar radiation budget and its volume absorption, of ocean primary production and its effect on the global carbon cycle, to study atmospheric properties (aerosol and clouds). A prototype of the sensor has been produced (Akimov *et al.*, 2009).

Table 6. Meteor-3M No.3 main characteristics (CEOS/ESA, 2011)

Agency	ROSHYDROMET/ROSKOSMOS
Status	Approved
Launch Date	31 Dec 2012
EOL Date	31 Dec 2017
Applications	Oceanography, hydrometeorology, climatology

Instruments	DCS, SAR, Radiomet, OCS, SZS, Scatterometer
Orbit Details & URL	Type: Sun-synchronous Altitude: 835 km Period: 102 min Inclination: 98.7 deg Repeat cycle: 37 days LST: TBD Asc/desc: Ascending URL: http://planet.iitp.ru

2.5. Other countries

2.5.1. Currently-operated/-available satellites and sensors

i. Landsat series

The Landsat series of satellites provides the longest continuous record of satellite-based observations. As such, Landsat is an invaluable resource for monitoring global change and is a primary source of medium spatial resolution Earth observations used in decision-making. Landsat satellites can be classified into three groups, based on sensor and platform characteristics. The first group consists of Landsat 1, Landsat 2, and Landsat 3, with the Multispectral Scanner (MSS) and the Return Beam Vidicon (RBV). The spatial resolution of MSS was approximately 79 m (but often processed to pixel size of 60 m), with four bands ranging VNIR wavelengths. Landsat 3 MSS included a fifth band in the thermal infrared wavelength. The second group includes Landsat 4 and Landsat 5, which carry the Thematic Mapper (TM), as well as MSS. TM has a spatial resolution of 30 m for the six reflective bands and 120 m for the thermal band. The third group consists of Landsat 6 and Landsat 7, which include the Enhanced Thematic Mapper (ETM) and the Enhanced Thematic Mapper Plus (ETM+), respectively. Landsat 6 failed on launch. Landsat 7 ETM+ has a spatial resolution of 30 m for the six reflective bands, 60 m for the thermal band, and includes a panchromatic band with a 15 m resolution. The Landsat data archive at the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center holds an unequaled 36 year record of the Earth's surface and is available at no cost to users via the Internet (http://landsat.usgs.gov/) (Chander *et al.*, 2009).

Landsat archived scenes can be used for change detection algorithm advancement. Also, a spatial resolution of Landsat visible and infrared data and SAR data acquired from the ERS-1, ERS-2, Envisat, RADARSAT-1 and RADARSAT satellites is almost the same that improves understanding of biophysical processes in the upper layer of the sea surface by analysis of correlation of the color, thermal and roughness fields.

ii. Orbview2 SeaWiFS

OrbView-2 is a satellite system developed by Orbital Science Corporation. It carries NASA's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) as its only instrument on August 1997. In the first arrangement of its kind, the U.S. Government procured space-based environmental remote-sensing data for research purposes from a commercial operator. The purpose of SeaWiFS Project is to provide quantitative data on global ocean bio-optical properties to the Earth science community. Subtle changes in ocean color signify various types and quantities of marine phytoplankton (microscopic marine plants), the knowledge of which has both scientific and practical applications as a follow-on sensor to the Coastal Zone Color Scanner (CZCS), which ceased operations in 1986.

iii.Terra/Aqua MODIS

NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument on board the Terra (EOS AM) and Aqua (EOS PM) satellites. Terra MODIS and Aqua MODIS are viewing the entire Earth's surface every 1 - 2 days, acquiring data in 36 spectral bands or groups of wavelengths, at 3 spatial resolutions: 250, 500, and 1000 m. These data will improve our understanding of global dynamics and processes occurring on the land, in the oceans, and in the lower atmosphere. MODIS is playing a vital role in the development of validated, global, interactive Earth system models able to predict global change accurately enough to assist policy makers in making sound decisions concerning the environmental protection (NASA, MODIS Website).

iv. Envisat MERIS

The European Space Agency (ESA) launched the Medium Resolution Imaging Spectrometer (MERIS) on board Envisat in November 2001. The primary mission of MERIS was primarily dedicated to ocean and coastal sea water colour observations. Knowledge of the sea colour can be converted into a measurement of chlorophyll pigment concentration, suspended sediment concentration and of aerosol loads over the marine domain. The instrument could also be used for atmospheric and land surface related studies. MERIS has a high spectral and radiometric resolution and a dual spatial resolution (1200 m and 300 m), within a global mission covering open ocean and coastal zone waters and a regional mission covering land surfaces.

v. Oceansat-2 OCM

The Indian Space Research Organization (ISRO) spacecraft Oceansat-2 was launched in 2009 carrying Ocean Color Monitor (OCM), Scanning Scatterometer (SCAT), and Radio Occultation Sounder for Atmospheric Studies (ROSA). The main objectives of Oceansat-2 are to study surface winds and ocean surface strata, observation of chlorophyll concentrations, monitoring of phytoplankton blooms, study of atmospheric aerosols and suspended sediments in the water. OCM was an improved version of the one on board Oceansat-1.

2.5.2. Scheduled satellites and sensors

i. NPOESS C1/C2 VIIRS

The National Polar-orbiting Operational Environmental Satellite System (NPOESS) is the next generation of low earth orbiting environmental satellites, including only the first two operation satellites (C1 and C2) with an option for their replacements (C3 and C4). The NPOESS will circle the Earth approximately once every 100 minutes. During these rotations, the NPOESS will be providing global coverage, monitoring environmental conditions, collecting, disseminating and processing data about the Earth's weather, atmosphere, oceans, land, and near-space environment. The Visible/Infrared Imager/Radiometer Suite (VIIRS) collects visible/infrared imagery and radiometric data. Data types include atmospheric, clouds, earth radiation budget, clear-air land/water surfaces, sea surface temperature, ocean color, and low light visible imagery. The NPOESS is planned to provide launch readiness capability in FY 2015 and FY 2018.

ii. Sentinels series

ESA is developing five new missions called Sentinels specifically for the operational needs of the Global Monitoring for Environment and Security (GMES) programme. Sentinel-1 with SAR is a polar-orbiting, all-weather, day-and-night radar imaging mission for land and ocean services. The first Sentinel-1 satellite is planned for launch in 2013. Sentinel-2 with Multi Spectral Instrument (MSI) is a polar-orbiting, multispectral high-resolution imaging mission for land monitoring providing, for example, imagery of vegetation, soil and water cover, inland waterways and coastal areas. Sentinel-2 will also deliver information for emergency services. The first Sentinel-2 satellite is planned for launch in 2013. Sentinel-3, with Sea and Land Surface Temperature Radiometer (SLSTR), Ocean and Land Colour Instrument (OLCI), Synthetic Aperture Radar Altimeter (SRAL), is polar-orbiting, multi-instrument mission to measure variables such as sea-surface topography, sea- and land-surface temperature, ocean colour and land colour with high-end accuracy and reliability. The first Sentinel-3 satellite is planned for launch in 2013. The Sentinel-4 and Sentinel-5 missions are dedicated to monitoring the composition of the atmosphere for GMES Atmosphere Services. Both missions will be carried on meteorological satellites operated by European Organization for the Exploitation of Meteorological Satellites (EUMETSAT). Sentinel-4 satellite will be embarked upon a Meteosat Third Generation satellite in geostationary orbit scheduled to be launched in 2019, and Sentinel-5 satellite is expected to be launched in 2020.

3. Data distribution systems

3.1. China

The DRAGONESS project (DRAGON in support of harmonizing European and Chinese marine monitoring for Environment and Security System) was funded by the European Union's (EU) Framework Programme for a 3 year's period running from 2007 to 2010. This project aimed to:

- assess existing Chinese and European information products and services arising from integrated use of remote sensing, *in situ* observations, models and data assimilation methods;
- identify services/data gaps and barriers, such as for instance restrictive data dissemination and availability and reuse policies;
- investigate the possibility for existing and foreseen services to be exchanged between the two continents for necessary regional development and implementation;
- stimulate exchange and initiation of new European-China partnership in Earth observation science and technology in support to global monitoring for environment and security.

DRAGONESS was both benefiting from and complementing the joint ESA and China's Ministry of Science and Technology (MOST) DRAGON collaborative programme that focused on Earth observations from satellites. DRAGON would run until 2012 (Johannessen, 2009).

MAPP, as shown in Figure 1, was a small toolbox developed by the ocean color remote sensing group of the Second Institute of Oceanography (SIO), State Oceanic Administration (SOA), which was released with the multi-satellite data received by the ground station to the scientists in various discipline and the relevant governors. MAPP only focused on the ocean color satellite image viewing, basic data analysis, and the application, especially for the water quality assessment. The target users of MAPP were mainly those who were no major in remote sensing, and those who mainly concerned about the satellite data application, not the data processing, such as atmospheric correction, and algorithms development, etc (Delu, 2007).

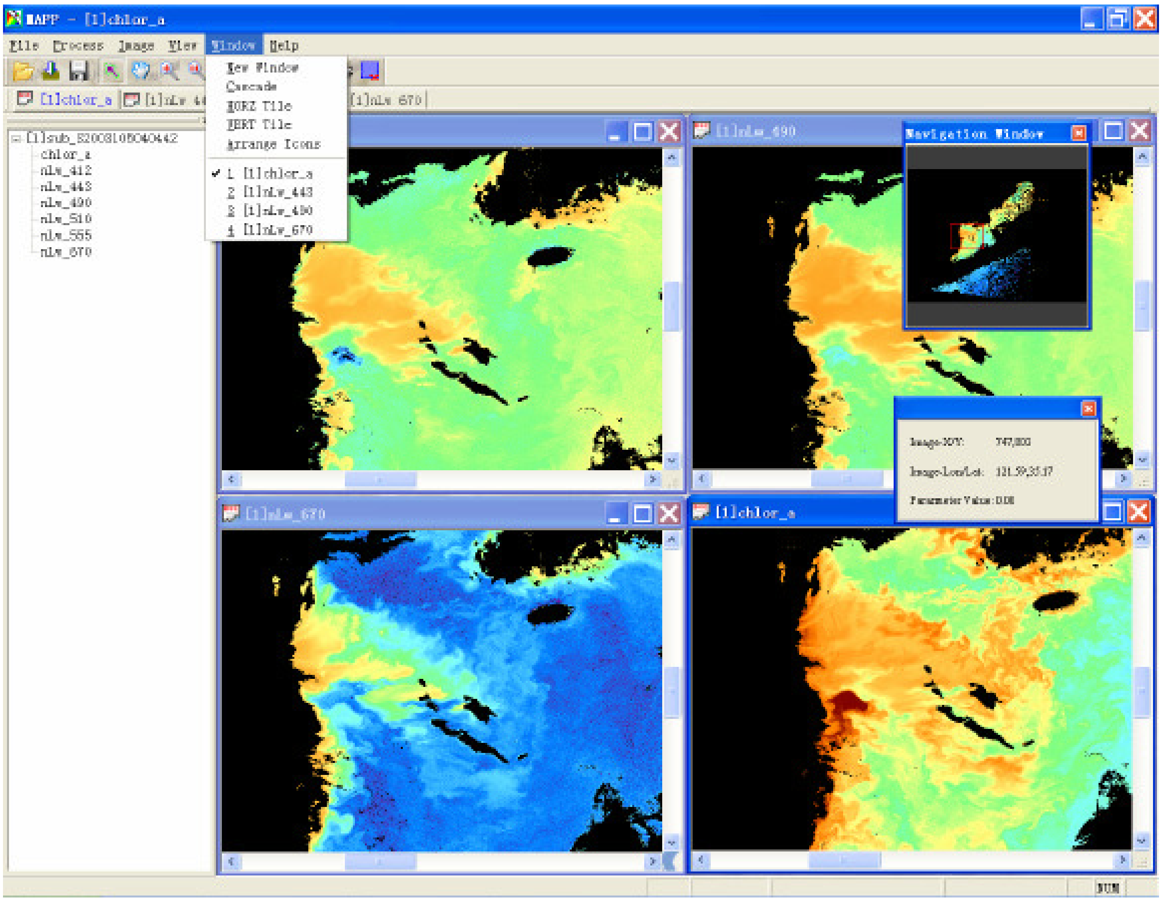

Figure 1. Marine Remote Sensing Data Application and Mapping Toolbox

3.2. Japan

MODIS Near Real Time Data website of JAXA EORC was redesigned in 2006 (Figure 2) and improved reliability of satellite data product through mitigating errors by temporal variation of validation ratio, modification of chlorophyll-*a* estimation algorithm, reduction of strip noise and modification of atmospheric correction algorithm after 2007.

Aerosol optical thickness data with 1km resolution and chlorophyll-*a* concentration data with 500m resolution have been added.

Website of the Marine Environmental Watch Project has been periodically updated and providing SST and chlorophyll-a satellite images over the Northwest Pacific region on a regular basis. Daily mean images of SST and chlorophyll-a have been processed for North sea area in Shandong peninsula, Yangtze River Estuary and adjacent area, Toyama Bay area, Ariake sea area, Northwest Kyushu sea area, Southern Korea area, Jinhae Bay and Peter the Great Bay. Contents to promote use of satellite data for marine environment conservation have been added in data analysis and case study sections. From 2007, the Marine Environmental Watch Project has registered as one of databases of North-East Asian Regional GOOS (NEAR-GOOS), which is one of the regional Global Ocean Observation System (GOOS) sponsored by Intergovernmental Oceanographic Commission of UNESCO (IOC).

Figure 2. MODIS Near Real Time Data (in Japanese)
<http://kuroshio.eorc.jaxa.jp/ADEOS/mod_nrt_new/>

Figure 3. Marine Environmental Protection of North Pacific Region
<http://www.nowpap3.go.jp/jsw/eng/>

3.3. Korea

Korea Ocean Satellite Center (KOSC), the primary data receiving/processing organization for GOCI, had been established at Ansan, Korea during 2005-2010. The KOSC receives the GOCI data every hour during daytime, exactly 8 times hourly. Data processing and archiving steps are taken only 2 hours from the end of reception. The processed GOCI Level 1B and after will be distributed to the users in near-real time. A free application of the GOCI data is available for the public service and research domain. Yet, the commercial application of the GOCI data has to be paid the cost of efforts. Collaborated/pre-registered organizations could utilize the ftp push services to obtain the interesting data as soon as finishing the data registering step. Now, the public researchers could search and download the interested GOCI image in the KOSC website, as shown in Figure 4 (Yoo *et al.*, 2010).

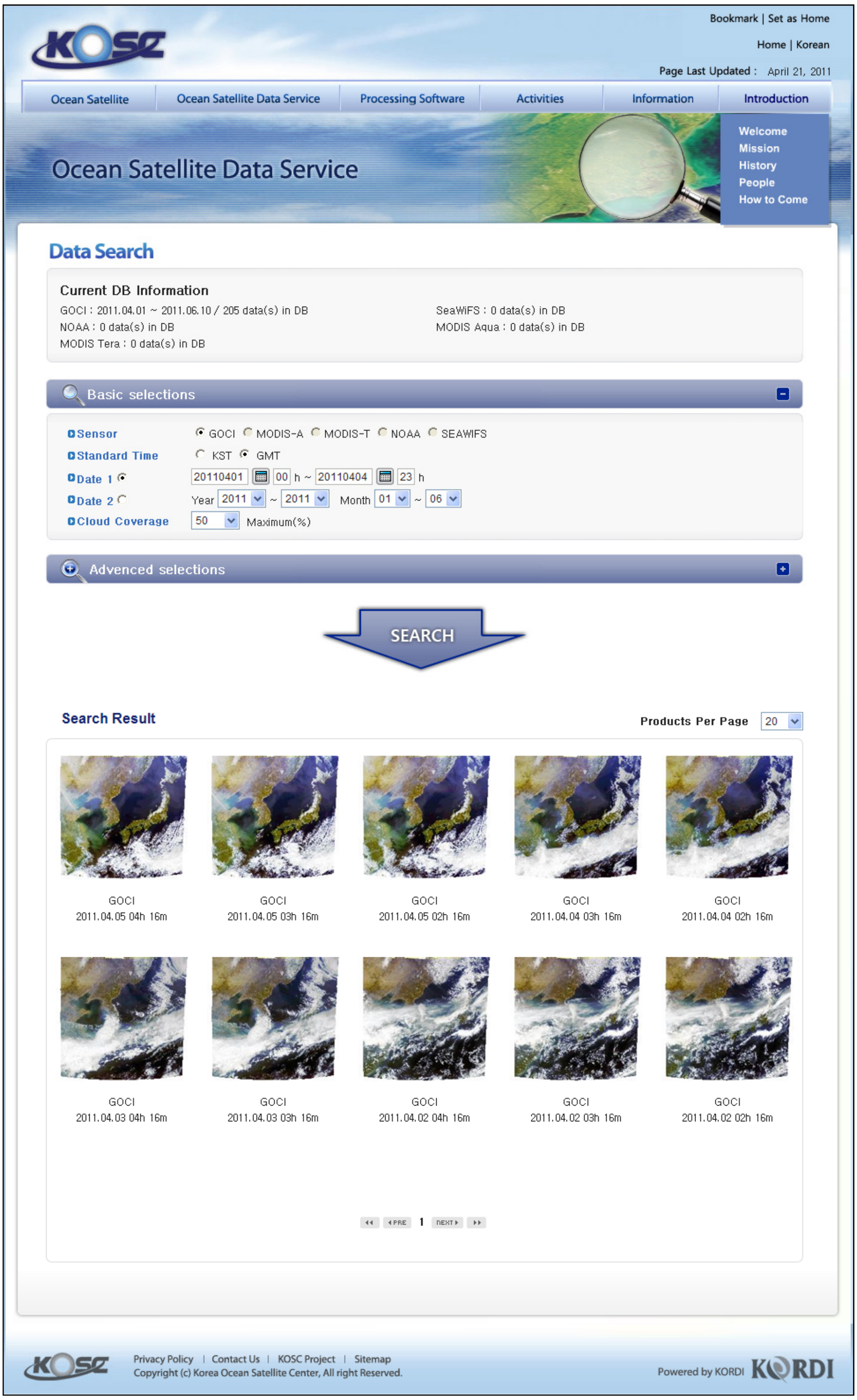

Figure 4. Ocean Satellite Data Service by KOSC
<http://kosc.kordi.re.kr/datasearch/search.kosc>

3.4. Russia

The Shirshov Institute of Oceanology performed to derive a set of bio-optical parameters such as chlorophyll concentration, the particle backscattering and yellow substance absorption coefficients for the seas surrounding Russia with SeaWiFS data since 1998 and later with Aqua MODIS data, as shown in Figure 5. The standard algorithms for processing of satellite ocean color data were based on regression equations, derived mainly from Case-1 waters, and they broke down in optically-complex Case-2 waters. The developed algorithms were only valid in the regions of study and, strictly speaking, in definite areas and seasons (Kopelevich *et al.*, 2005). The statistical homogeneity of the study region to determine the limits of adequacy of the algorithms could be evaluated with satellite data (Kopelevich *et al.*, 2010).

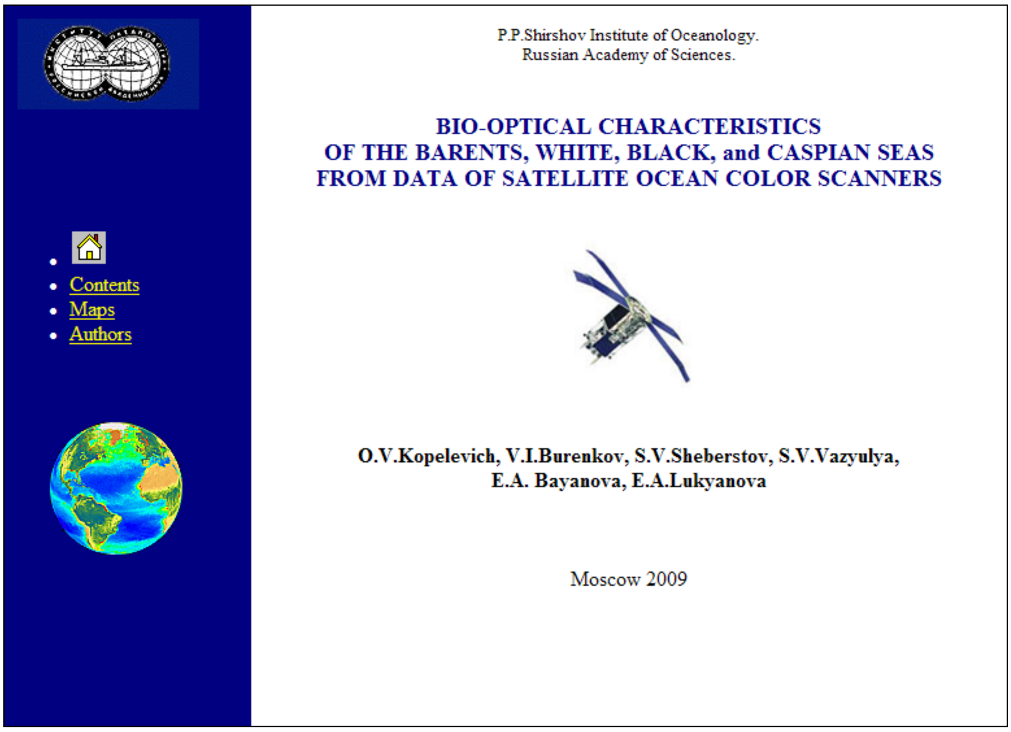

Figure 5. Bio-optical characteristic of the Barents, White, Black, and Caspian Seas from data of satellite ocean color scanners
<http://optics.ocean.ru/>

4. Algorithm development, validation and application for monitoring and assessment of marine and coastal environment

4.1. China

Cui *et al.* (2010) collected an extensive *in situ* data set in the Bohai Sea of China to assess radiometric properties and concentrations of ocean constituents derived from MERIS. These data included spectral normalized water-leaving radiance (nLw) and concentrations of suspended particulate matter (SPM) and chlorophyll-*a*. A strict spatio-temporal match-up method was adopted in view of the complexity and variability of the turbid coastal area, resulting in 13, 48 and 18 match-ups for MERIS nLw, SPM and chlorophyll-*a* estimates, respectively. The band ratio of nLw 490 nm to nLw 560 nm of the satellite data was in good agreement with *in situ* observations. MERIS SPM and chlorophyll-*a* products overestimated the *in situ* values. When match-up criteria were relaxed, the assessment results degraded systematically.

According to Sun *et al.* (2010), Medium Resolution Spectral Imager (MERSI) onboard the second generation of Chinese polar-orbit metrological satellite FY-3A, was a MODIS-like sensor with 20 bands covering VNIR/SWIR/TIR spectral region, and was capable of making continuous global observations, and ocean color application. Onboard absolute radiometric calibration in the reflective solar spectral region was not conduct for MERSI. However, the radiometric sensitivity degradation was monitored using the onboard calibrator, and various calibration techniques were adopted to assure calibration accuracy. Those attempt include absolute calibration using China Radiometric Calibration Site (CRCS) with *in situ* measurements multi-sites calibration tracking and cross calibration with Terra MODIS at CRCS. MERSI ocean color products consisted of water-leaving reflectance retrieved from atmospheric correction algorithm, chlorophyll-*a* concentration and pigment concentration from global empirical models, chlorophyll-*a* concentration, total suspended mater (TSM) concentration and absorption coefficient of CDOM and non algal particle from Chinese regional empirical models.

Chen *et al.* (2007) developed a method of assessing water quality from satellite data. The composite pollution index (CPI) was calculated from measured chemical oxygen demand (COD) and nutrient concentration. The relationships between CPI and 240 band combinations of atmospherically corrected SeaWiFS water-leaving radiance were analyzed and the optimal band combination for estimating CPI was chosen. Furthermore, the CPI value range for each water quality level was determined based on data obtained from 850 samples taken in the Pearl River Estuary. The remotely sensed CPIs were then transferred to water quality levels and appropriate maps were derived. The remotely sensed water quality level maps displayed a similar distribution of levels based on *in situ* investigation issued by SOA (Figure 6).

Hu *et al.* (2010) showed that the green macroalgae *Ulva prolifera* (previously known as *Enteromorpha prolifera*) patches appeared nearly every year between April and July 2000-2009 in the Yellow Sea (YS) and/or East China Sea (ECS), which all originated from the near shore Subei Bank, using a novel index (Floating Algae Index) and multi-resolution remote sensing data from MODIS and LANDSAT (Figure 7). A finite volume numerical circulation model, driven by realistic forcing and boundary conditions, confirmed this finding. Analysis of meteorological/environmental data and information related to local aquaculture activities strongly supports the hypothesis that the recurrent *U. prolifera* in the YS and ECS resulted from aquaculture of the seaweed *Porphyra yezoensis* (or nori) conducted along the 200 km shoreline of the Subei Bank north of the Changjiang (Yangtze) River mouth.

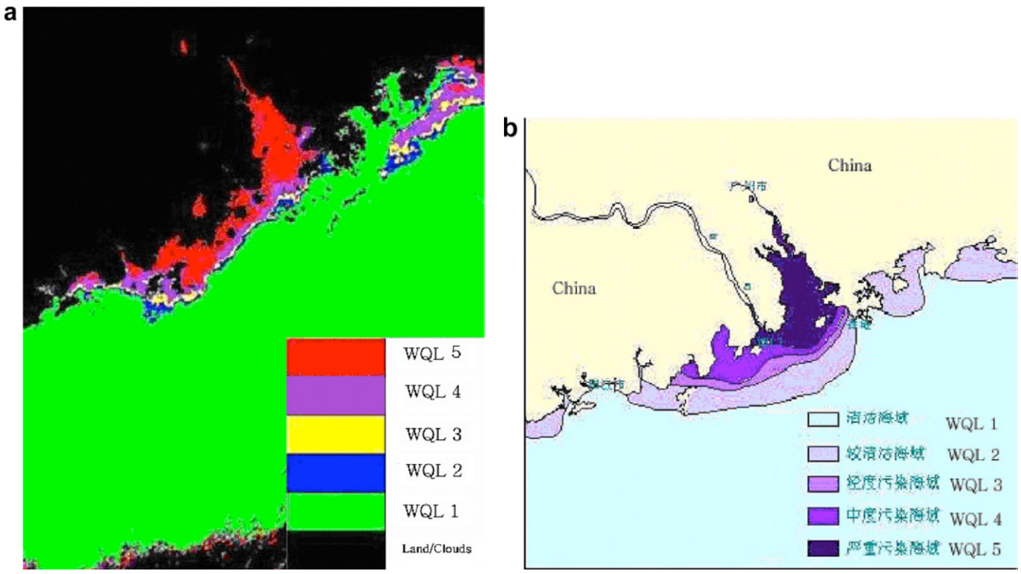

Figure 6. (a) Water quality levels retrieved from SeaWiFS data, (b) Water quality issued by State Ocean Administration, China.

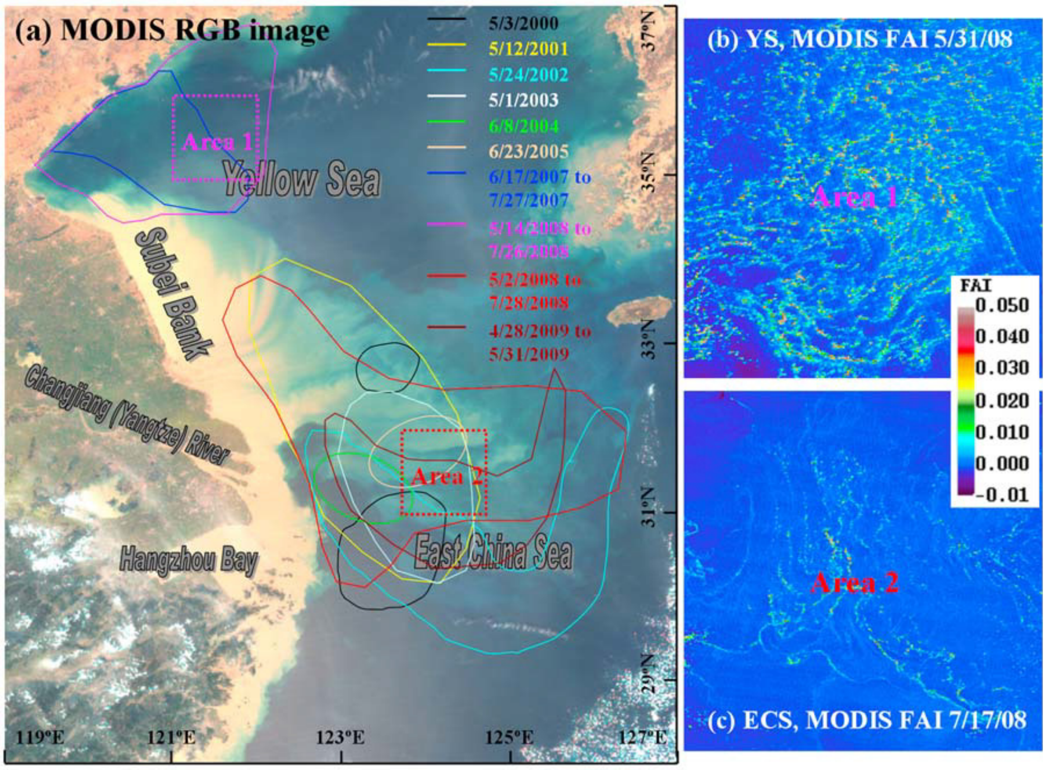

Figure 7. Approximate location and distribution of U. prolifera identified from MODIS FAI imagery between April 2000 and May 2009. The background MODIS RGB image on 5 April 2003 shows the extensive sediment plume from the Subei Shallow Bank to the ECS, (b and c) MODIS FAI images tracing U. prolifera blooms in 1 × 1° areas in the YS and ECS on 31 May 2008 and 17 July 2008.

4.2. Japan

Kawamura *et al.* (2010) developed new SST retrieval method with producing high-quality match-ups coupling the Japanese geostationary satellite, Himawari-6 (H6), and buoy SST observations. The previous version of SST product, called MTSAT SST, left several scientific/technical questions. For solving them, 6,711 algorithm tuning match-ups with precise navigation and 240,476 validation match-ups were generated for covering all seasons and wide ocean coverage. The new version of SST was called H6 SST. The statistical evaluation of H6 SST using the validation match-ups showed the small negative biases and the RMS errors of about 0.74° K for each area.

Saba *et al* (2011) relied on models that estimate marine net primary productivity (NPP) thus it was essential that these models were evaluated to determine their accuracy. To determine global and region specific rates, the skill of 21 ocean color models including Asanuma *et al* (2006) and Kamada and Ishizaka (2005), were assessed by comparing their estimates of depth-integrated NPP to 1156 *in situ* ^{14}C measurements encompassing ten marine regions including the Sargasso Sea, pelagic North Atlantic, coastal Northeast Atlantic, Black Sea, Mediterranean Sea, Arabian Sea, subtropical North Pacific, Ross Sea, West Antarctic Peninsula, and the Antarctic Polar Frontal Zone. The maximum fraction of model skill attributed to uncertainties in both the input variables and *in situ* NPP measurements was nearly 72 %. On average, the simplest depth/wavelength integrated models performed no worse than the more complex depth/wavelength resolved models. Ocean color models were not highly challenged in extreme conditions of surface chlorophyll-*a* and sea surface temperature, nor in high-nitrate low-chlorophyll waters. Water column depth was the primary influence on ocean color model performance such that average skill was significantly higher at depths greater than 250 m, suggesting that ocean color models were more challenged in Case-2 waters than in Case-1 waters. Given that *in situ* chlorophyll-*a* data was used as input data, algorithm improvement was required to eliminate the poor performance of ocean color NPP models in Case-2 waters that are close to coastlines.

Takahashi *et al.* (2009) proposed a multi-spectral classification scheme to identify water with red tide(s) using satellite ocean color imagery obtained by SeaWiFS. The study area was the eastern Seto Inland Sea in Japan, where serious red tides frequently occur. 'Background Ocean Colors' (BOCs), or colors of water around a red tide or those of the water before/after a red tide, were calculated as the monthly climatological average of normalized water-leaving radiances (nLw) with SeaWiFS imagery. Criteria for detecting red-tide pixels were established from analyses of characteristics of the nLw anomalies from BOCs and the nLw spectra together with the red-tide records in Osaka Bay. The proposed scheme could efficiently indicate the presence or absence of red tides for independent match-up with 83% accuracy (Figure 8).

Ishizaka *et al.* (2010a) conducted practical exercise to reduce damage of red tide using remote sensing data in water off Oita prefecture where occurrence of *Karenia mikimotoi* during summer causes most of the problems, and set up website of red tide distribution in this area based on peak shift method from 2010, as shown in Figure 9. There was no serious *K. mikimotoi* bloom occurred in this area in 2010; however, diatom bloom was detected by near real time by satellite, and it was confirmed by ship survey by Oita Prefectural Agriculture, Forestry and Fisheries Research Center. Using MODIS standard ocean color data, a new practical method to discriminate red tide type from non-phytoplankton-dominated waters as well as higher turbid and colored dissolved organic matter was under construction (Siswanot *et al.*, 2010).

Kim *et al.* (2009) analyzed SeaWiFS chlorophyll-*a* distribution in summer in the East

China Sea during 1998-2007 with K-means clustering technique. The proper satellite chlorophyll-*a* concentration indicated the Changjiang Diluted Water (CDW). The spatial distributions of the higher satellite chlorophyll-*a* concentrations (> 0.48 mg/m^3) corresponded well with the distributions of lower salinity CDW (< 30-32) every year. Interannual variation of the CDW area, indicated by the high satellite chlorophyll-*a*, correlated with the interannual variation of the Changjiang summer freshwater discharge. The correlation analysis indicated that the CDW spread eastward in the East China Sea with a time lag of 1 to 2 months after the discharge.

Yamaguchi *et al.* (2011) examined seasonal variability of satellite chlorophyll-*a* (SCHL) in the Yellow Sea and East China Sea (YECS) with 9-year average of monthly data from September 1997 to October 2006, and assessed the interannual variation to understand influence of Changjiang River Discharge (CRD) to YECS during summer. YECS were represented by 12 areas with different seasonal variability of SCHL. Increase of SCHL was observed in large area of YECS during spring, and it was expected as a spring bloom. It was suggested that the interannual variation of SCHL was controlled by the interannual variation of CRD. SCHL during summer in the Yellow Sea gradually increased for the 9 years, and this indicates the possible eutrophication.

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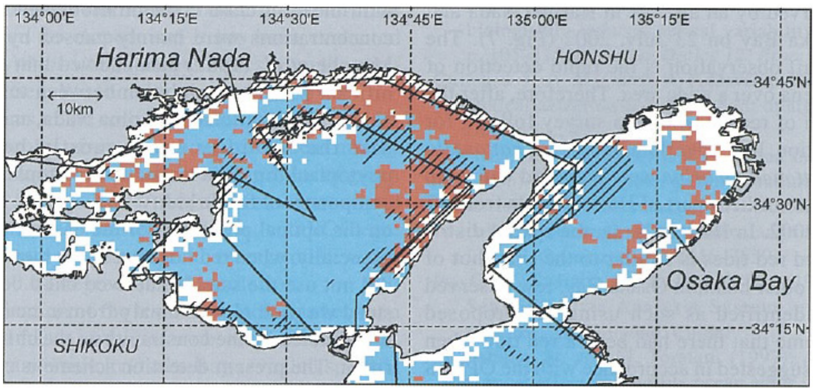

Figure 8. Comparison of the spatial distributions of the detected and observed red tides on 23 July 2002 in Harima Nada and the western Osaka Bay. Black lines indicate the flight routes of aircraft observations, and slashed areas show the observed red-tide areas. Red areas indicate water with a red tide, blue areas refer to water without it, and white areas represent clouds.

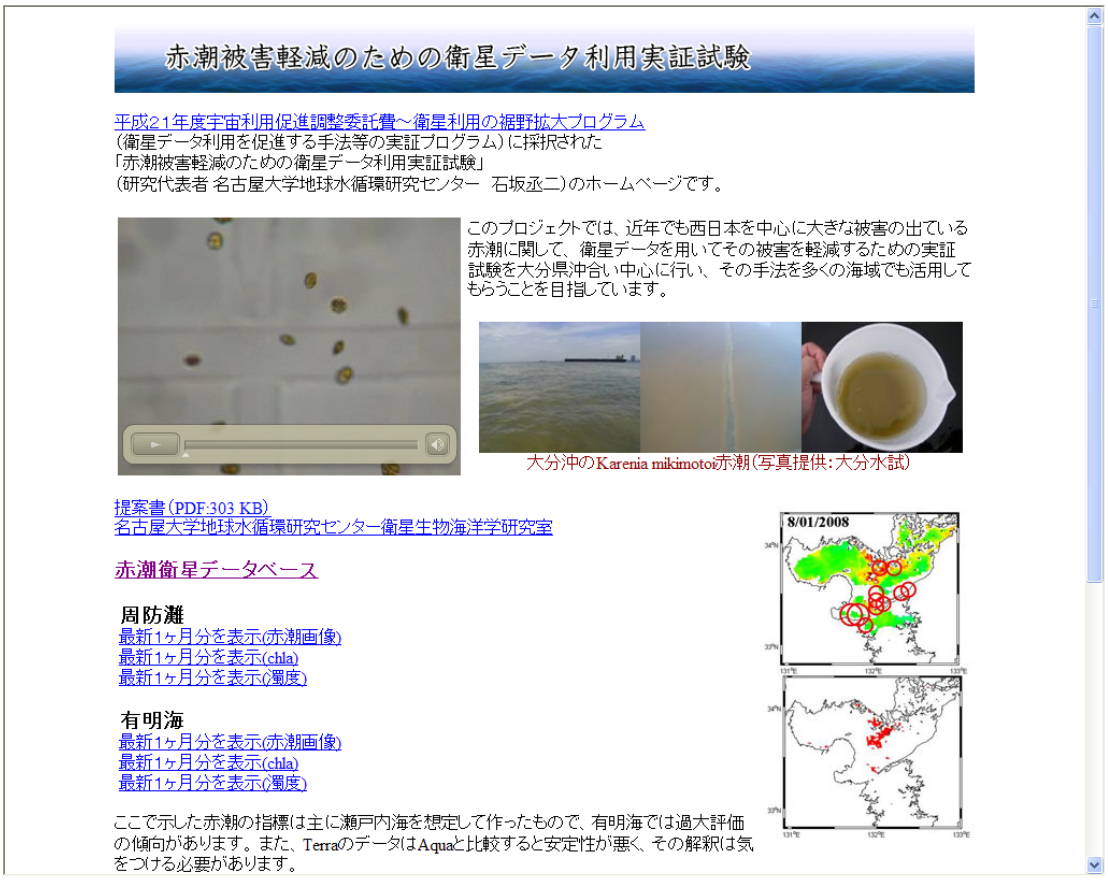

Figure 9. Website of red tide distribution (in Japanese)
http://redtide.hyarc.nagoya-u.ac.jp/

Ishizaka *et al.* (2010b) discussed the possibility of monitoring *Cochlodinium polykrikoides* red tides by satellite-borne ocean color remote sensing. Areas of high concentrations (> 5 mg/m^3) in the daily satellite chlorophyll-*a* distribution corresponded fairly well to areas of *C. polykrikoides* red tides in the south sea of Korea drawn by the Korea National Fisheries Research and Development Institute (NFRDI), as shown in Figure 10. However, satellite chlorophyll-*a* data was missing near the coastal area, possibly because of the influences of clouds, turbid water, brightness of land and other reasons. Interannual variability of monthly composites of maximum satellite derived chlorophyll-*a* concentrations also corresponded to the NFRDI monthly maps during 2000 to 2004 except 2001. Satellite chlorophyll-*a* was high even when there was no *C. polykrikoides* red tide report, possibly because of the influence of turbidity or blooms of other species in the west sea and upwelling area of the east sea. Spectral information could also be used to identify red tides with maximum remote sensing reflectance around 550 nm and a steeper decrease to 500 nm than the shorter wavelength.

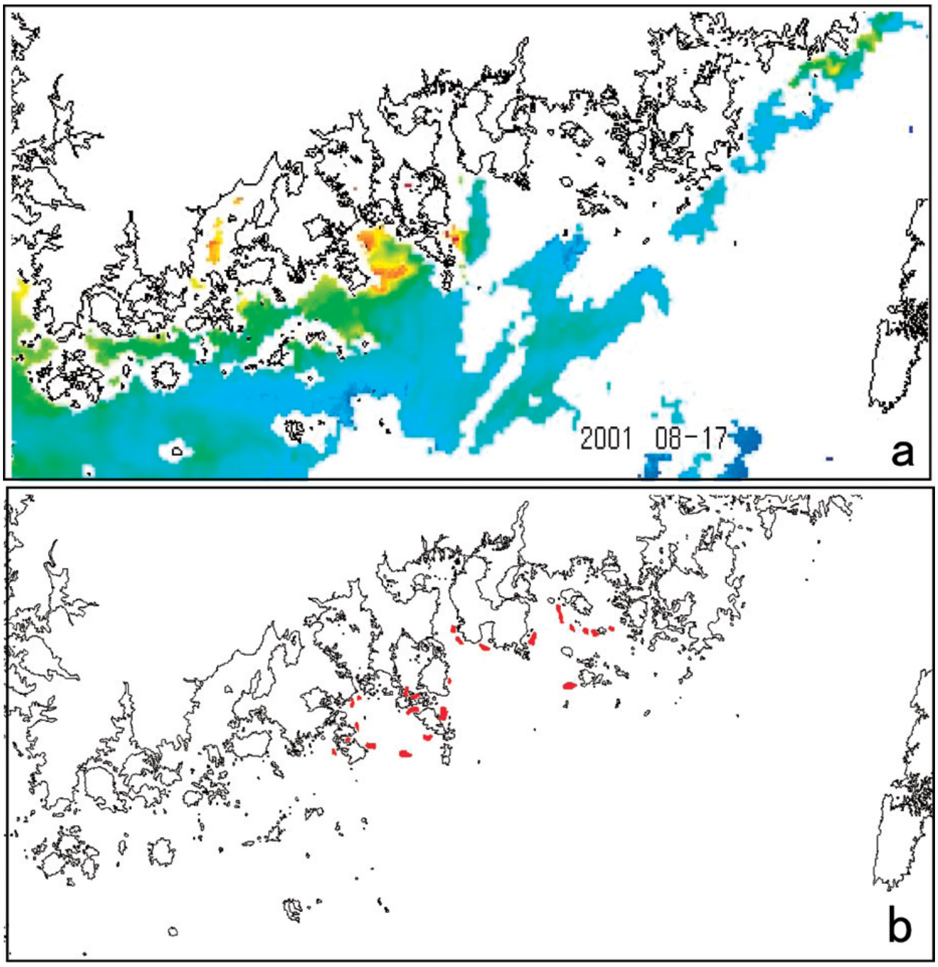

Figure 10. (a) SeaWiFS chlorophyll-a image, (b) C. polykrikoides red tide map of NFRDI on 17 August 2001.

Sasaki *et al.* (2010) investigated distributions of low-salinity water and giant jellyfish (*Nemopilema nomurai*) in the East China Sea during spring-summer, 2003-2008 using ocean-color satellite and *in situ* data. Sea surface salinity was determined from absorption coefficient of colored dissolved organic matter retrieved from the satellite. In July, low-salinity water widely extended from the Changjiang River mouth and moved northeastward to the Cheju Island. It also moved clearly southeastward from the Changjiang River mouth in 2003, 2006 and 2008. It could be considered that these behaviors of low-salinity water were caused by interannual variations of large river discharge from the Changjiang and southerly winds. *N. nomurai* was often found within low-salinity water region by visual observation and/or trawl sampling from July 2004.

The eastward extension (124° -128° E) of low-salinity water approximately corresponded to the distribution of *N. nomurai*. The occurrence of *N. nomurai* was related to the behavior of the Changjiang diluted water.

Terauchi *et al*. (2011) developed a new methodology to assess coastal marine eutrophication preliminary by remote sensing. Time series of chlorophyll-a concentration observed by ocean color satellite from 1997 to 2009 were used to classify eutrophication status of Toyama Bay as a case study. By the combination of chlorophyll-*a* concentration level and its trend, Toyama Bay was then classified into the 6 eutrophication status (High-Increase, High-No Trend, High-Decrease, Low-Increase, Low-No trend and Low-Increase). The results showed that High-Increase and High-No Trend areas were distributed at inner and eastern coast of Toyama Bay, and it was consistent with the increase of riverine input of total nitrogen from the Jinzu River (Figure 11). The suggested methodology in other area could be applied through further tunings in determination of reference condition level of satellite chlorophyll-*a* concentration and improving its accuracy in turbid waters.

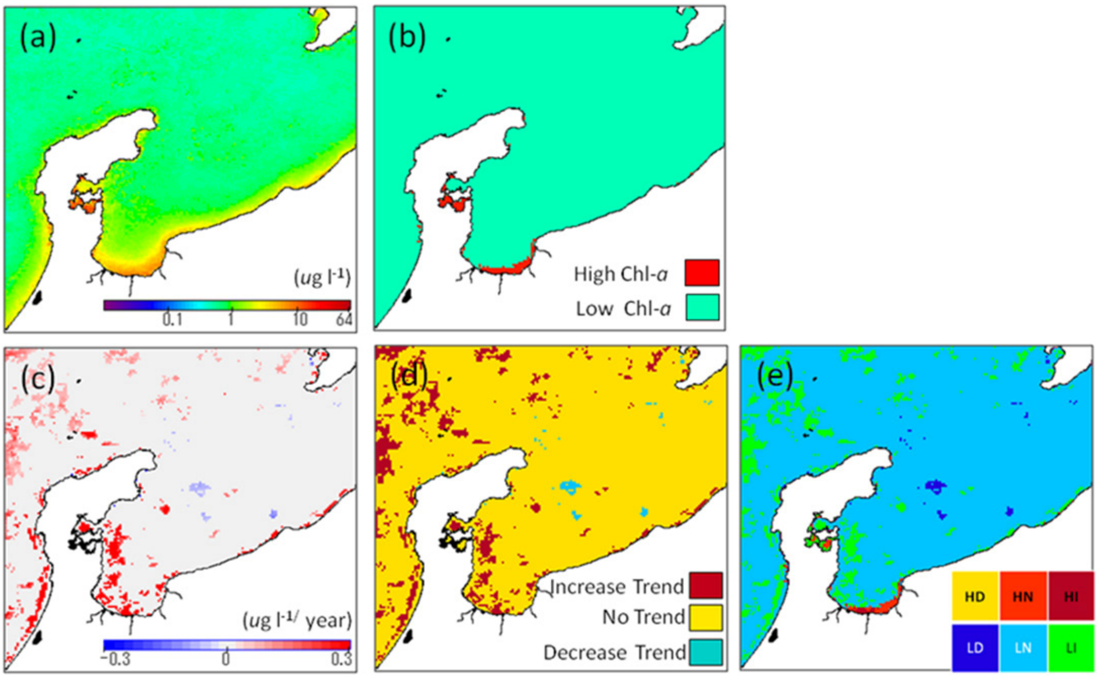

Figure 11. Result of preliminary eutrophication assessment by remote sensing in Toyama Bay by the combination of level and trend in chlorophyll-*a* concentration (Chl-a). (a) 13-years (1997-2009) overall mean of satellite Chl-a. (b) High and Low Chl-a area determined by the criteria of 5 μg/L referring to the lowest limit of the Medium Chl-a condition suggested by Bricker et al. (2003). (c) Pixel wise trend detected by annual Chl-a maximum in monthly mean Chl-a from 1997 to 2009. The significance of trend was estimated at pixel wise by the Sen Slope test at 90 % confidence level. (d) Increase Trend, No Trend and Decrease Trend area divided. (e) Toyama Bay was classified into 6 eutrophication status; HI (High-Increase), HN (High-No Trend), HD (High-Decrease), LI (Low-Increase), LN (Low-No Trend) and LI (Low-Increase), by the combination of the level and the trend of satellite Chl-a.

4.3. Korea

Son *et al.* (2010) would compare radiometric, atmospheric, and bio-optical parameters between *in situ* measurements and GOCI data in order to provide quantitative control of the GOCI standard products. The calibration/validation for radiometric, atmospheric, and bio-optical data of GOCI were determined from the platform systems (Ieodo and Gageocho ocean research stations), buoy systems (a reference target site around Dokdo and Eocheongdo), and periodic ocean environmental data (IOPs, AOPs, temperature, salinity, ocean optics, fluorescence, and turbidity data sets). Several ocean color algorithms had been developed for GOCI using *in situ* measurements. These data sets collected around the Korean Peninsula included chlorophyll-*a*, suspended sediment, particulate organic carbon concentration, and absorption coefficient of dissolved organic matter as well as *in situ* radiance data.

Shanmugam *et al.* (2008) developed RCA-chlorophyll (red tide index chlorophyll-algorithm - RCA) estimates from the SeaWiFS, sea surface height variations/geostrophic currents from the multi-satellite altimeters, sea surface temperature from NOAA AVHRR, and wind speed/direction from the QuikSCAT (Figure 12). RCA-chlorophyll were used in conjugation with field observation data to first describe comprehensively the occurrences of various harmful algal blooms and their underlying mechanisms and link to nutrient enrichment during the summer (June-September) in shelf-slope waters off the Northwest Pacific covering China, Korea, Japan and Russia.

In 1991, South Korea embarked on an ambitious project to reclaim nearly 401 km^2 of land and tidal flats from the Yellow Sea by building a system of two dikes extending 33 km across the mouths of the Dongjin and Mangyeong rivers, offshore of the Saemangeum district. The construction of the Saemangeum Reclamation Project's northern dike was completed in June 2003; the southern dike was finished in April 2006. Since the dikes have been constructed, satellite-derived images have been used to demonstrate marine environmental responses observed from ocean color data inside and outside the dikes during and after the dike construction. Son and Menghua (2009) showed that after closure of the dikes, water transparencies drastically increased and the amount of suspended sediments in the region decreased (Figure 13). The changes may reflect the significantly diminished tidal currents in the Saemangeum region.

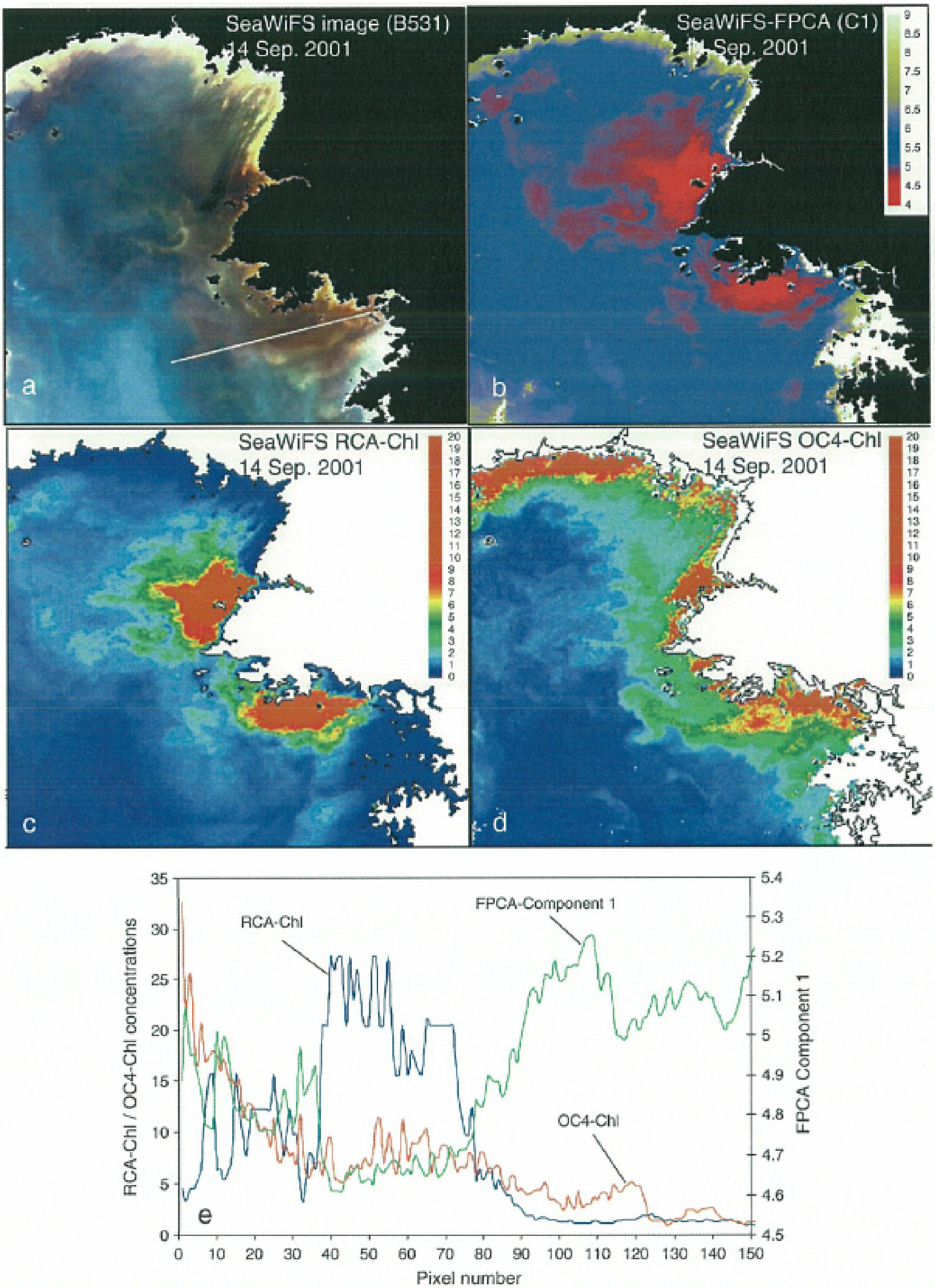

Figure 12. (a) SeaWiFS color composite image of 14 September 2001. (b) SeaWiFS-FPCA(Forward Principal Component Analysis) image from the component 1 (C1)

which comprises nearly 98% of the critical data contained in the 8 bands. (c) SeaWiFS RCA-Chl image from the SSMM scheme, (d) SeaWiFS OC4-Chl image(mg/m^3) from the generic atmospheric correction algorithm, and (e) Profiles of SeaWiFS OC4-Chl, RCA-Chl and FPCA-C1 from a transect running across the bloom from the coastal areas to its offshore (transect in (a)).

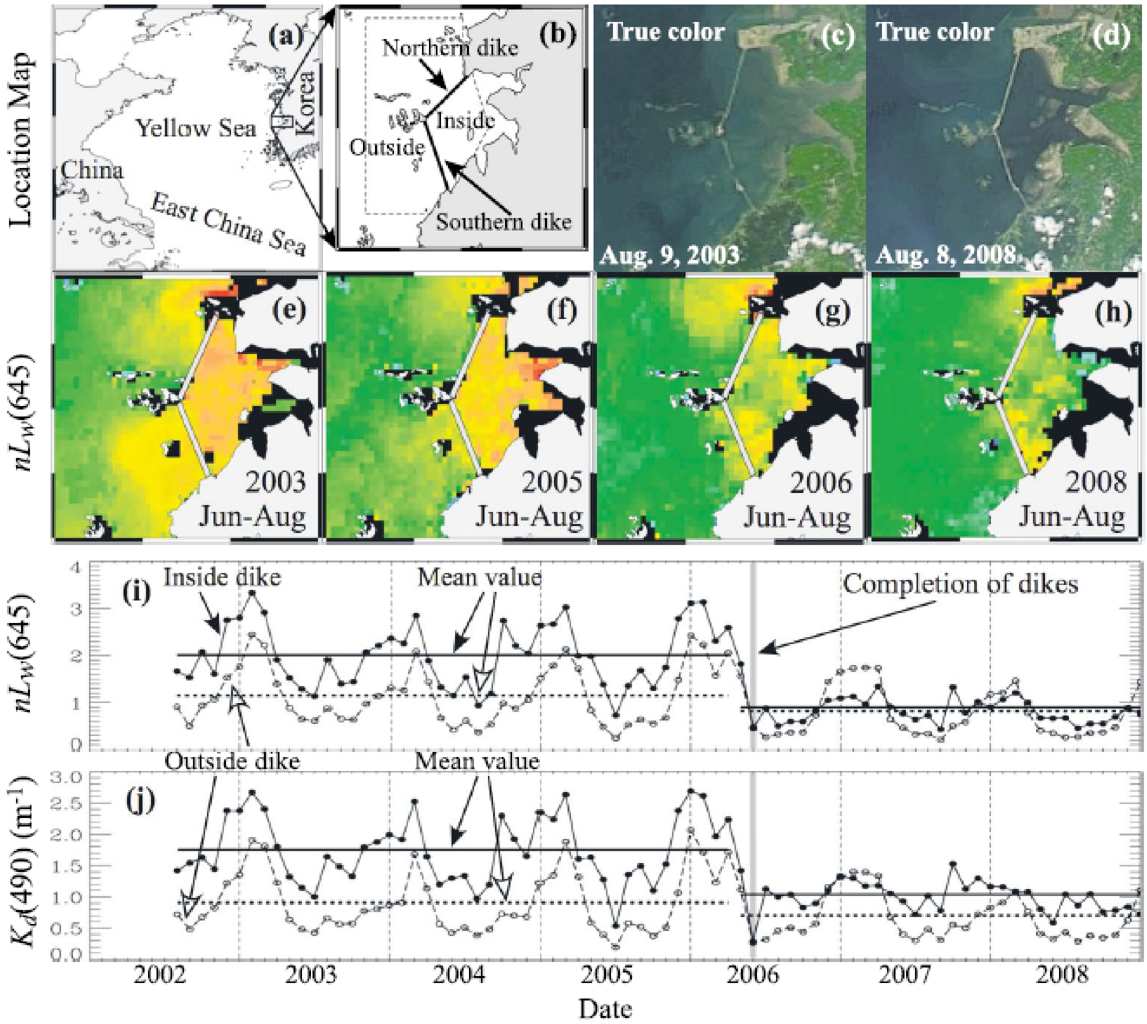

Figure 13. (a and b) Maps of the Saemangeum reclamation area on the middle west coast of Korea. (c and d) MODIS true color images. (e-h) MODIS derived normalized water- leaving radiance at a wavelength of 645 nm, nLw (645), for the summers (June-August) of 2003, 2005, 2006, and 2008, respectively. (i and j) MODIS derived time series (July 2002 to December 2008) for nLw (645) and the diffuse attenuation coefficient at a wavelength of 490 nm, Kd (490), for the region inside (solid curve) and outside (dashed curve) the dikes, respectively.

4.4. Russia

Satellite ocean color sensors are providing data to study various biological and ecological issues. For quantitative use of the data, the algorithms and products need to be evaluated in varied atmospheric and oceanic regimes. Current evaluation programs are limited (a couple of fixed buoys, a few dedicated cruises). Insufficient measurements are made, especially in the open sea. The remote sensing of sea coastal waters is widely used in different applications of ecological monitoring, climate modeling, fishing and many others for the retrieval of parameters characterizing the content of particulate and dissolved substances. The spectral remote sensing reflectance measured by satellite instruments is used as an input parameter in solving the related forward and inverse problems of radiative transfer for the system 'sea water – atmosphere'. The volume scattering function (VSF) is one of the basic inherent optical properties influencing the flux of radiation upwelling from the water surface. Presently the most advanced algorithms for the processing and the interpretation of satellite imagery employ VSF to solve radiative transfer equation. On the other hand, the measurements reveal the high variability of VSF for different types of sea water, especially in coastal areas. Thus, the case specific VSF modeling is needed.

Mitnik *et al.* (2008) monitored the mesoscale (50 m - 20 km) oceanic phenomena in Peter the Great Bay by analysis of multisensory satellite datasets. The datasets consisted of ERS-1/2 SAR, Envisat ASAR and ALOS PALSAR images, LANDSAT TM/ETM+, NOAA AVHRR and Terra/Aqua MODIS visible and infrared images, QuikSCAT-derived sea surface winds and ocean color data (SeaWiFS, MODIS), as well as of the weather maps, ship surveys and ground truth data acquired in 1991-2008. Spatial resolution of SAR images was in the range of 10 -150 m and a swath width changes from about 70 till 400 km. This combination was unique and allowed revealing the synoptic-scale, mesoscale and fine-scale features of the surface circulation, oceanic dynamic phenomena, wind field and oil spills independently on sun illumination and cloudiness. Measurements of the SST and wind speed and direction were carried out at POI Marine Stations and at several coastal points during the ASAR and SAR data acquisitions. Characteristics of the sea surface roughness were determined by processing of time series of images of a system of small floats and thin disc floats of various sizes as well as by analysis of images of the sea recorded by a polarization video system.

5. Regional activities on monitoring and assessment of marine and coastal environment by remote sensing

Several regional activities have been conducted under the network of internal collaboration in the NOWPAP region.

Pacific Oceanological Institute of the Far Eastern Branch of Russian Academy of Sciences and NOWPAP CEARAC updated website on oil spill monitoring by remote sensing on a regular basis, as shown in Figure 14. The provided satellite images were used as reference information to help assess damages of marine environment by oil spill especially for severe cases such as the Hebei Sprit incident in Korea in 2007 and the Peng Lail 19-3 incident in 2011.

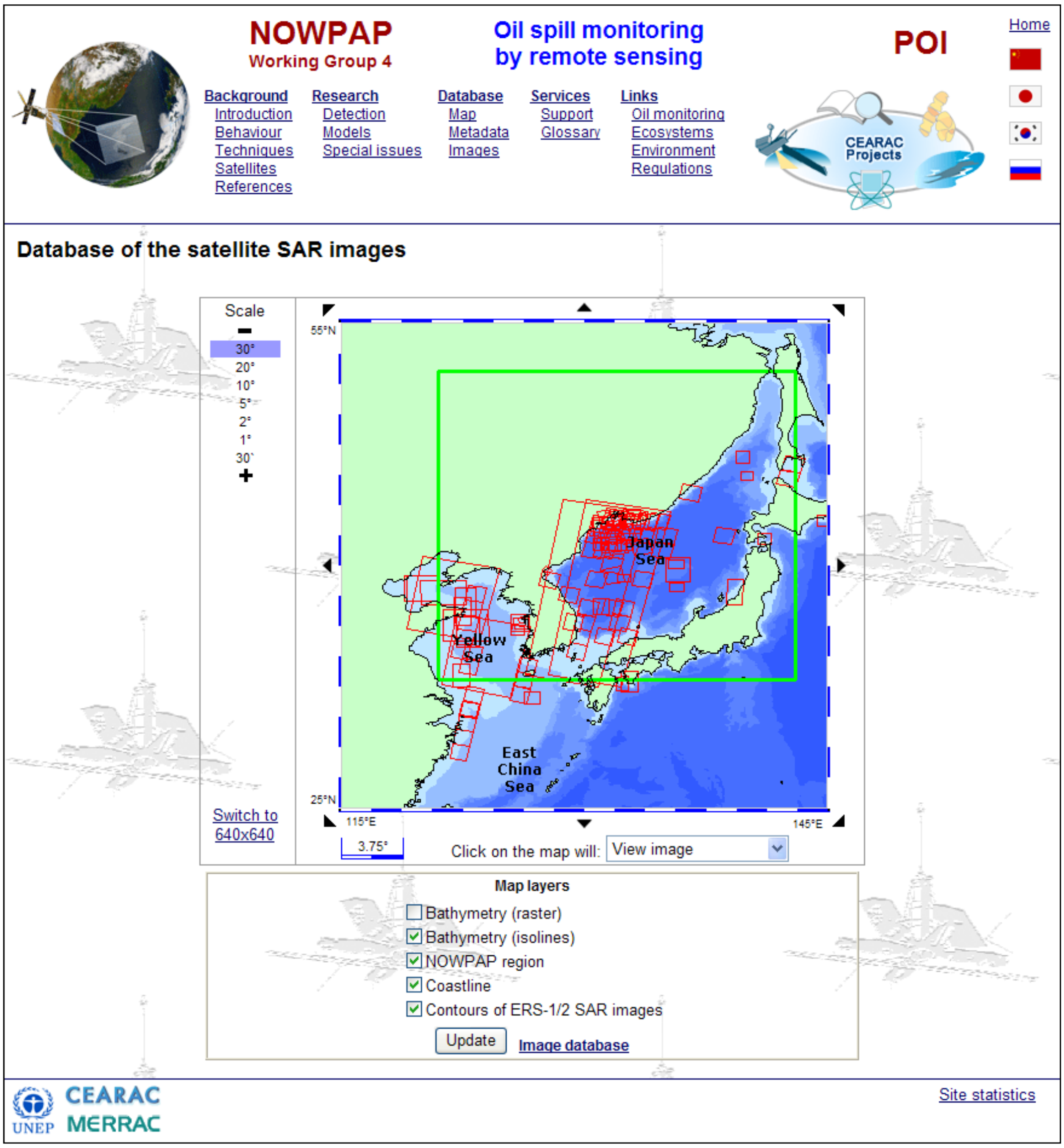

Figure 14. Website on oil spill monitoring by remote sensing
http://cearac.poi.dvo.ru/

The UNDP/GEF project ‘Reducing environmental stress in the Yellow Sea Large Marine Ecosystem’ (YSLME) organized the workshop ‘YSLME Ocean Color Workshop I’ for consulting to develop regional ocean color algorithm for the Yellow Sea. The task of the formed scientist team was to develop (or refine any existing) operational regional algorithm for ocean color that works for turbid Case-2 waters. Siswanto *et al.* (2011) published outcome of this project and the developed algorithm in GOCI data processing for better assessment and future monitoring of primary productivity in the Yellow Sea.

IOC/WESTPAC and CEARAC conducted the 1st NEAR-GOOS - NOWPAP joint training course on remote sensing data analysis at Nagasaki, Japan on September 2007. The 2nd NOWPAP training course on remote sensing data analysis was organized by the Korea Ocean Research & Development Institute (KORDI) and CEARAC at Jeju, Korea on November 2008. The course consisted of lectures by specialists and hands-on practical sessions on analysis of remote sensing data. The training course was targeted at postgraduate students, professional researchers and local government officers working in the fields of marine sciences and coastal-zone management. In collaboration with the North Pacific Marine Science Organization (PICES) and IOC/WESTPAC, CEARAC will conduct the 3rd training course at Vladivostok, Russia on October 2011 (NOWPAP CEARAC).

The 3rd PICES international summer school entitled 'Satellite Oceanography for the Earth Environment' was held at Seoul, Korea on August 2009. The summer school was sponsored by PICES, the Scientific Committee on Oceanic Research (SCOR), Research Institute of Oceanography at Seoul National University, East Asian Sea Time-series (EAST-1) project of the Ministry of Land, Transport and Maritime Affairs (MLTM) of the Republic of Korea, 'Brain Korea 21' Program, Korea Ocean Research and Development Institute (KORDI), Pukyung National University, NOWPAP CEARAC and so on. The objective of the summer school was to help and motivate postgraduate students, early-career scientists, and other professionals, including those who are new to satellite oceanography, by providing a basic concept and knowledge of remote sensing for advanced applications (PICES, 2010).

The 7th Korean-Japan Workshop for Ocean Color (KJWOC) was held on December 2010 in Hakodate, Japan. The aim of these workshops was to exchange scientific knowledge between Korea and Japan and to promote capacity building. The 2010 workshop was expanded and co-held with another Asian ocean color workshop, namely the 1st Asian Workshop for Ocean Color research (AWOC) with participation from China, Japan, Korea, Taiwan, Thailand, USA and Vietnam. The importance of collaborative work in ocean color research was discussed and there was community consensus regarding the further need for community development in Asia (KJWOC, 2010).

IOC/WESTPAC organized the 8th IOC/WESTPAC International Scientific Symposium entitled Ocean Climate and Marine Ecosystems in the Western Pacific, at Busan, Korea on March 2011. The symposium had attracted wide attention from ocean communities within and outside the region with more than 400 participants expected to share their knowledge on various topics such as Coastal Acidification, Climate Modeling and Prediction, Marine Remote Sensing, Paleoclimatology (Corals and Monsoon) and more. In parallel to the symposium, IOC/WESTPAC Workshop on Remote Sensing for Coastal Habitat Mapping (WESTPAC-ORSP) took place as one of the many workshops (IOC/WESTPAC International Scientific Symposium).

6. Challenges and prospects

6.1. Continuous of observations

Satellite remote sensing is capable of providing information of marine environment over wider area without interference of national boundaries and it is helping to understand various oceanic phenomena can't be observed only with conventional ship observations. With its repeatability of observation, satellite remote sensing has been used to detect long term changes on a global scale such as climate changes. Therefore, it is ideal that same series of quality controlled observation data be maintained for longer and continuous period on a regular basis. Periodical and continuous ship observation is also necessary for calibration and validation of satellite data.

6.2. Improvement of spatial and temporal resolution and increase in number of spectral bands

Phenomena such as eutrophication, red tide, HAB and oil spill which may deteriorate marine environment occurs at various spatio-temporal scales. Big scale phenomena often start from small scale or is an aggregation of those small phenomena. Marine environment in coastal area is dynamically changing because of complex physical process due to intensive use in fishing and tourism. Thus, it is necessary to develop new sensors and satellites that have higher spatial (100 - 250 m) and temporal (1 - 2 per hour) resolution to observe these small phenomena.

The increased number of spectral bands of the satellite spectroradiometers in the nearest future will allowed to solve the task of algal species identification. The approach should be based on hyper-spectral data analysis. The approach realization is need in a database of absorption and reflectance coefficients of the most 'popular' harmful algal species. The database should be created with *in situ* measurements or/and laboratory ones. The laboratory measurement is need in technologies of algal species growing.

6.3. Ocean color remote sensing in coastal areas

The main task is bio-optical algorithms development for Case-2 waters. The coastal areas are areas of turbid waters usually. And the atmosphere correction of radiance measured by satellites over the turbid is not satisfactory now (Moses *et al.*, 2009). As the result, regional algorithms are widely used. NIR bands procedure is used now for atmosphere correction of MODIS data, for example. It leads to overestimation of chlorophyll-*a* concentration in some times usually. Shallow waters problem is existed too in the coastal areas due to the bottom reflectance.

6.4. Education and capacity building

Although, satellite remote sensing data has been used widely among professional researchers and scientists, data use by the local government or the public who face marine environmental problems has just started recently. To promote operational use of satellite remote sensing, it is essential to provide capacity building opportunities such as organization of series of training course, workshop and enhancement of information network on remote sensing of marine environment.

7. Suggested activities for NOWPAP Region

7.1. Organization of the technical training course

Training courses organized by NOWPAP, PICES and IOC/WESTPAC have been playing important role for promoting use of remote sensing data for marine environment conservation in the NOWPAP region. It is expected that these courses to be continuously conducted and highly-sophisticated. Follow-up of past trainees are also important to help monitor marine environment problems in the NOWPAP region by remote sensing.

7.2. Cooperation with other international organizations

There have been many activities and programs being implemented world widely by international organizations on remote sensing of marine environment. Building cooperative partnership with these activities and programs is a key for effective and efficient implementation of CEARAC activities.

The CoastColour project aims to increase global user uptake of advanced products from ESA's MERIS mission by developing, demonstrating and validating the latest techniques for monitoring water constituents in coastal zones around the world. In particular, the project will be developed according to the needs of the user community, including scientists studying bio-geochemical and physical processes in coastal waters, and companies and government agencies who specialize in providing water quality information to various users such as the aquaculture industry, local authorities responsible for maintaining water quality and others (ESA, 2010). East China Sea, Yellow Sea, a part of eastern NOWPAP sea area is registered as one of the test sites and subset for surface reflectance, inherent optical properties, water constituent concentrations, water transparency/turbidity information and chlorophyll indices are available.

The ChloroGIN project aims to deliver products, namely ocean maps of chlorophyll and sea surface temperature, as indicators of the state of the ecosystem needed for ecosystem and fisheries management, and at some sites, a measure of light penetration into the ocean, which is needed, along with the other two variables, to calculate plankton primary production. The project builds up with the six nodes, i.e. ChloroGIN-Europe, ChloroGIN-Indian Ocean, ChloroGIN-Antares, ChloroGIN-Africa, ChloroGIN-Canada, ChloroGIN-Asia as well as Global ChloroGIN (Figure 15). ChloroGIN-Asia is divided in two regions, Northeast Asia and Southeast Asia. JAXA and NPEC, which distributes near real time MODIS data of Northeast Asian area, function as the Northeast Asia node of ChloroGIN (PML, ChloroGIN Earth).

Ocean color radiometry offers considerable potential for the observation of HABs. However, this potential has not been fully realized for several reasons: the sizable uncertainties associated with ocean color applications in the optically-complex coastal zone; observation systems not fully cognizant of the ecological role of the wide variety of potentially harmful algal blooms across global coastal ecosystems; and a lack of consolidated information regarding the suitability of available ocean color techniques for HAB application to different ecosystems. The ocean color and harmful algal bloom scientific communities would gain a great deal by identifying and addressing these issues. The combined IOCCG and GEOHAB Working Group, aims to produce a highly approachable ‘consumer's guide’ to ocean color-based harmful algal bloom methods. The ecosystem-specific nature of optimal ocean color based HAB observations, the technical difficulties of using ocean color in the optically-complex coastal zone, and the need to understand the limitations of ocean color for deriving phytoplankton community composition will be primary focus areas (IOCCG, Harmful Algal Blooms and Ocean Colour).

The IOCCG, in conjunction with the EU PRESPO Project for sustainable development of the artisanal fisheries in the Atlantic area has prepared a handbook of satellite remote sensing image interpretation, with a focus on applications for marine living resources conservation and management. This handbook is intended as a web-based educational/training document oriented towards the interpretation of satellite images derived from data freely available (for the most part) from various space agency archives (IOCCG, 2010). The IOCCG has also been contributing to NOWPAP through advertising and sponsoring the past NOWPAP training course on remote sensing data analysis.

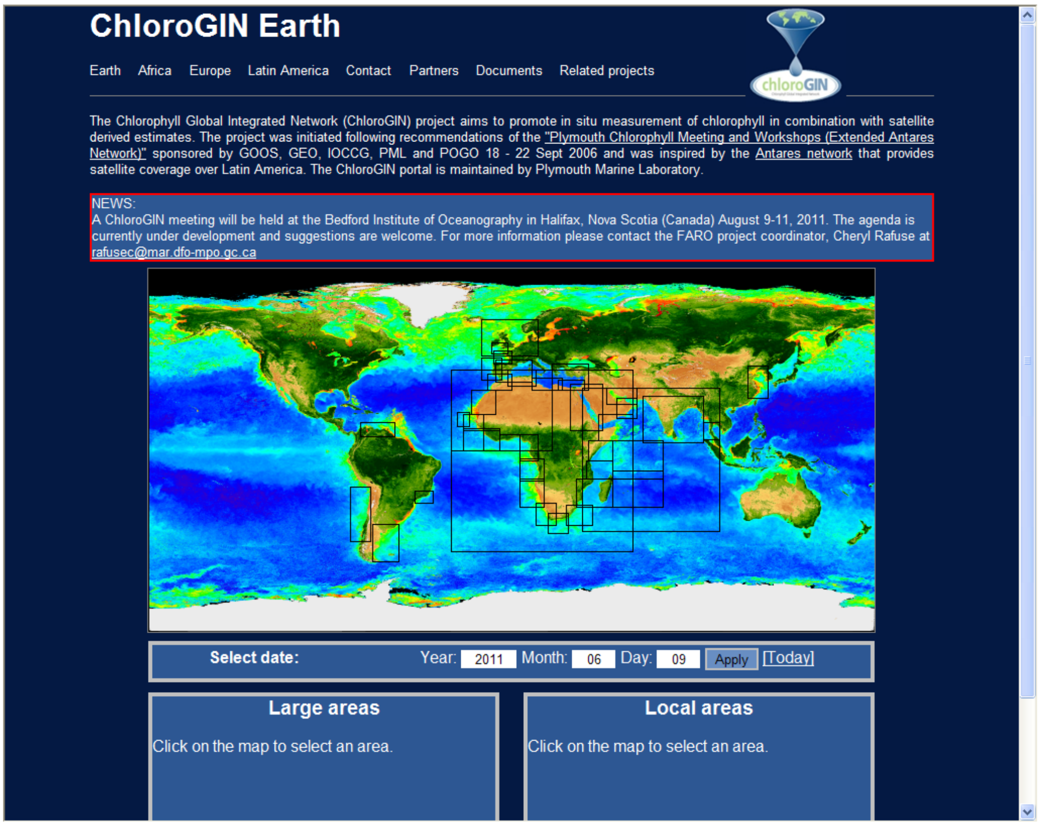

Figure 15. ChlorOGIN Portal
<http://www.chlorogin.org/world/>

7.3. Maintaining and enrichment of remote sensing information network

CEARAC has set up information network on remote sensing of marine environment. Information in the following websites of CEARAC should be continuously updated on a regular basis and providing up-to-date information for user in the NOWPAP region.

- NOWPAP Ocean Remote Sensing Portal
- Website on oil spill monitoring by RS
- Marine Environmental Watch

The following information is expected to be added to the above existing websites.

- Latest references relates to ocean remote sensing in the NOWPAP region
- Latest educational materials on ocean remote sensing in the NOWPAP region
- Latest satellite images on oil spills
- New satellite data set such as chlorophyll-a concentration in turbid water and spectral parameters of harmful algal species
- Time series plot of satellite derived SST and chlorophyll-a

7.4. Support of research and development

There are ongoing activities on research and development in the field of satellite remote sensing of marine environment in various institutions and organizations world widely. Especially, coordinated research arrangement for atmospheric correction problems on the base of *in situ* measurements in the Case II waters is necessary to develop better algorithm for turbid waters. While outcomes from these research and development activities should be open to the user in the NOWPAP region, researchers and scientists need feedbacks from the end users to develop successful outcomes. Therefore, it is necessary to organize workshops or symposiums that enhance information on wide variety of topics from the state-of-the-art techniques to operational use of remote sensing data.

8. Summary and recommendations

8.1. Summary

8.2. Recommendations

References

7th Korean-Japan Workshop for Ocean Colour (KJWOC) and 1st Asian Workshop for Ocean Colour (AWOC)

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Acronyms

ADEOS	Advanced Earth Observing Satellite
ALOS	Advanced Land Observing Satellite
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	AMSR for Earth Observing System
ASAR	Advanced Synthetic Aperture Radar
AVHRR	Advanced Very High Resolution Radiometers
AVNIR	Advanced Visible and Near Infrared Radiometer type
CAS	Chinese Academy of Sciences
CAST	China Association for Science and Technology
CCD	Charge Coupled Device
CDOM	Colored Dissolved Organic Matter
CEARAC	Coastal Environmental Assessment Regional Activity Center
CEOS	Committee on Earth Observation Satellites
CMODIS	Chinese Moderate Imaging Spectra Radiometer
COCTS	Chinese Ocean Color and Temperature Scanner
COD	Chemical Oxygen Demand
COMS	Communication, Ocean, and Meteorological Satellite
CZI	Coastal Zone Imaging
CZCS	Coastal Zone Color Scanner
Envisat	Environment Satellite
EORC	Earth Observation Research and application Center (Japan)
ESA	European Space Agency
ETM+	Enhanced Thematic Mapper plus

EUMETSAT European Organization for the Exploitation of Meteorological Satellites

GCOM-C Global Change Observation Mission for Climate monitoring/study

GEOHAB IOC-SCOR Research Programme on the Global Ecology and Oceanography of Harmful Algal Blooms

GLI Global Imager

GOCI Geostationary Ocean Color Imager

GOOS Global Ocean Observing System

HAB Harmful Algal Bloom

IOC Intergovernmental Oceanographic Commission of UNESCO

IOCCG International Ocean Colour Coordinating Group

ISRO Indian Space Research Organization

JAXA Japan Aerospace Exploration Agency

JERS-1 Japanese Earth Resources Satellite-1

KARI Korea Aerospace Research Institute

KORDI Korea Ocean Research and Development Institute

KOSC Korea Ocean Satellite Center

LANDSAT Land Remote Sensing Satellite

MERIS Medium Resolution Imaging Spectrometer

MERSI Medium Resolution Spectral Imager

MODIS Moderate Resolution Imaging Spectrometer

MOST China's Ministry of Science and Technology

MSI Multi Spectral Instrument

MTSAT Multi-functional Transport Satellite

NASA National Aeronautics and Space Administration (USA)

NEAR-GOOS North-East Asian Regional - GOOS

NFRDI National Fisheries Research and Development Institute (Korea)

NOAA National Oceanic and Atmospheric Administration

NOWPAP Northwest Pacific Action Plan

NPEC Northwest Pacific Region Environmental Cooperation Center (Japan)

NPOESS National Polar-orbiting Operational Environmental Satellite System

NPP Net Primary Productivity

NSOAS National Satellite Ocean Application Service (China)

OCM Ocean Colour Monitor

OLCI Ocean and Land Colour Instrument

PALSAR Phased Array type L-band Synthetic Aperture Radar

PAR Photosynthetically Available Radiation

PML Plymouth Marine Laboratory (UK)

PICES North Pacific Marine Science Organization

POI Pacific Oceanological Institute (Russia)

PRESPO Sustainable Development of the Artisanal fisheries in the Atlantic Area (Pesca RESPOnsável; in Portuguese)

PRISM Panchromatic Remote-sensing Instrument for Stereo Mapping

QuikSCAT Quick Scatterometer

ROSHYDROMET Federal Service for Hydrometeorology and Environmental Monitoring (Russia, ROSHYDROMET; in Russian)

ROSKOSMOS Russian Federal Space Agency (ROSKOSMOS; in Russian)

SAR Synthetic Aperture Radar

SCOR Scientific Committee on Oceanic Research

SeaWiFS Sea-viewing Wide Field-of-view Sensor

SGLI Sencond-generation GLI

SIO	Second Institute of Oceanography (China)
SLSTR	Sea and Land Surface Temperature Radiometer
SOA	State Oceanic Administration (China)
SPM	Suspended Particulate Matter
SRAL	Synthetic Aperture Radar Altimeter
SS	Suspended Solid
SST	Sea Surface Temperature
SWIR	Short Wavelength Infrared
TIR	Thermal Infrared
TM	Thematic Mapper
TSM	Total Suspended Mater
UNDP/GEF	United Nations Development Programme/Global Environment Facility
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
VIIRS	Visible/Infrared Imager/Radiometer Suite
VNIR	Visible to Near Infrared
WESTPAC	Sub-Commission for the Western Pacific
YSLME	Reducing environmental stress in the Yellow Sea Large Marine Ecosystem