NOWPAP CEARAC

Northwest Pacific Action Plan
Special Monitoring and Coastal Environmental Assessment
Regional Activity Centre

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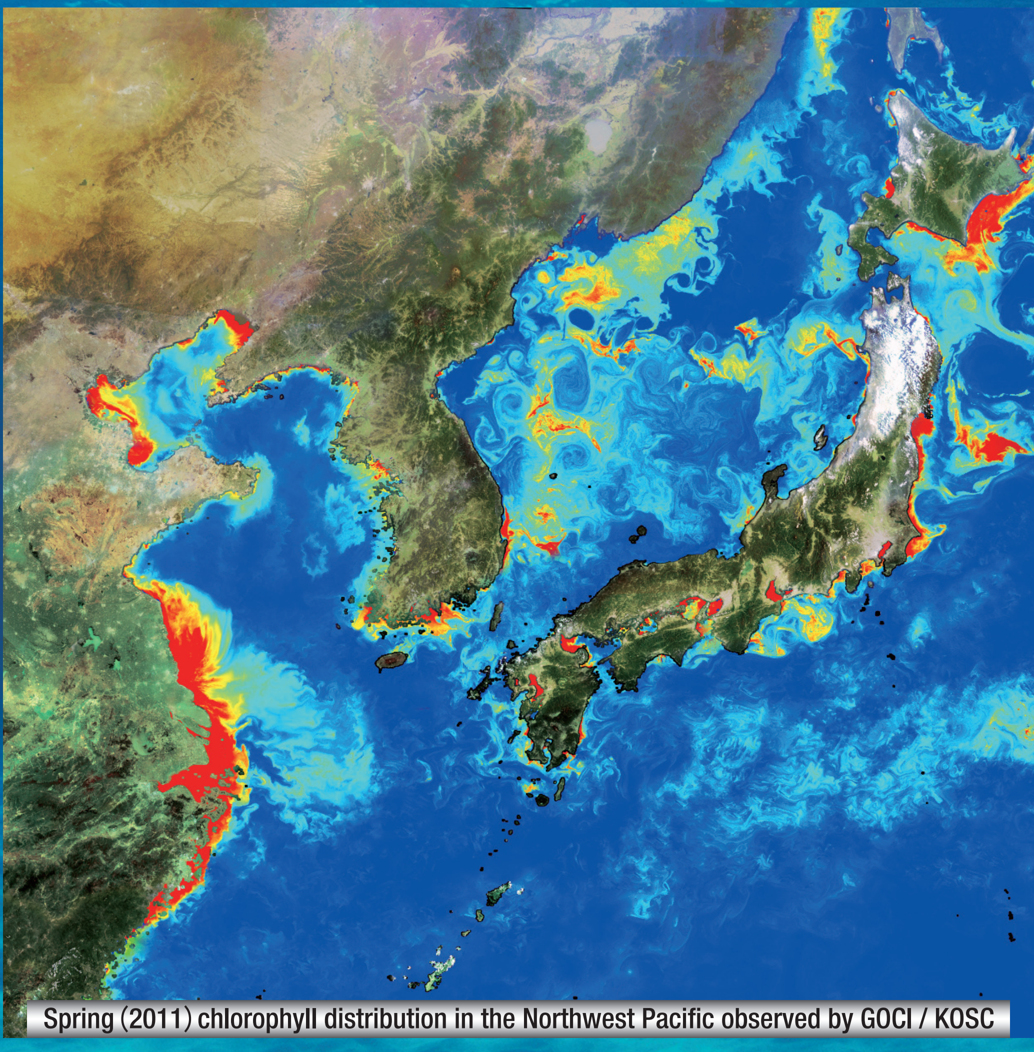
Integrated Report on Ocean Remote Sensing for the NOWPAP Region : Towards Assessment of the Marine and Coastal Environment



Spring (2011) chlorophyll distribution in the Northwest Pacific observed by GOCI / KOSC

CEARAC Report 2011

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established at the Northwest Pacific Region Environmental Cooperation Center (NPEC)

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Cover Photo

Image is used by kind permission of the Korea Ocean Satellite Center. Several images of different dates were mosaicked to realize this cloud-free picture and the numerical signals of the Northwest Pacific were differently processed to maintain a balanced tone throughout the whole coverage of GOCI. More information about GOCI is described in chapter 2.3 of this report.

Preface

As part of the Regional Seas Programme of the United Nations Environment Programme (UNEP), the Northwest Pacific Action Plan (NOWPAP) was adopted in September 1994 by the People's Republic of China, Japan, the Republic of Korea and the Russian Federation. There are four Regional Activity Centres (RACs) responsible for carrying out individual NOWPAP activities and projects approved at NOWPAP Intergovernmental Meetings (IGMs).

In 1999, the Special Monitoring and Coastal Environmental Assessment Regional Activity Centre (CEARAC) was established as a RAC. CEARAC is hosted by the Northwest Pacific Region Environmental Cooperation Center (NPEC), established in 1998 in Toyama, Japan, under the auspices of the Ministry of Environment in Japan. CEARAC is responsible for coordinating the regional assessment of marine, coastal and associated freshwater environments, and developing tools for environmental planning and management based on these assessments. CEARAC has two working groups: Working Group 3 (WG3) is responsible for the monitoring and assessment of harmful algal blooms (HABs) and Working Group 4 (WG4) is responsible for the development of new monitoring tools using remote sensing techniques. In recent years, WG3 and WG4 have worked on a joint assessment of the eutrophication status in the NOWPAP region.

The 'Integrated Report on Ocean Remote Sensing for the NOWPAP Region' was first published in 2005 to provide information on the status of ocean remote sensing in the NOWPAP region and to address issues identified by WG4. Based on suggestions made in the Integrated Report, CEARAC has organized three training courses on ocean remote sensing for young researchers in the region. CEARAC also improved the availability of internet content by establishing a new portal site on ocean remote sensing and a new webpage on oil-spill monitoring. CEARAC has further worked towards strengthening the cooperation, coordination and sharing of information between relevant organizations.

Over the past five years, new satellites and sensors have been deployed and more frequent and detailed observation data have been collected. The reanalysis of past observation data has helped improve the databases used to identify long-term trends in phenomena such as climate change. Further studies have led to progress in applying remote sensing techniques in order to conserve the marine environment.

A proposal to update the 2005 'Integrated Report on Ocean Remote Sensing for the NOWPAP Region' was approved at the 14th NOWPAP IGM (Toyama, Japan, 8-10 December 2009). CEARAC updated this report based on the work plan approved at the 8th NOWPAP CEARAC Focal Points Meeting (Toyama, Japan, 13-15 September 2010). CEARAC expects that this latest report will contribute to a common understanding among NOWPAP member states on the state of remote sensing of the marine environment in the NOWPAP region.

The CEARAC Secretariat would like to thank all of the CEARAC Focal Points, as well as the WG4 experts and Dr. Yu-Hwan AHN, for their great contributions to this publication.

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Contents

1. Introduction

The NOWPAP was adopted by China, Japan, Korea and Russia at the first IGM (Seoul, Korea, 14 September 1994). Among the three resolutions adopt at the first NOWPAP IGM, Resolution 1 identified five areas of priority for the action plan, one of which was NOWPAP/3, that outlined the establishment of a collaborative, regional monitoring program.

During the 'Expert Workshop on Establishment of a Collaborative, Regional Monitoring Programme' in July 1998, the proposal for NOWPAP/3 on the 'use of remote sensing data' as one of the new monitoring techniques/approaches was evaluated. The 1st Meeting of the Coordinating Committee for NOWPAP/3 (Beijing, China, 21-22 May 2001) and the 7th IGM (Vladivostok, Russia, 20-22 March 2002) prioritized remote sensing of the marine environment in NOWPAP. Subsequently, CEARAC was assigned the responsibility of implementing these activities under WG4.

In order for CEARAC to implement activities related to the development of new marine environmental monitoring tools by remote sensing, WG4 was formed with experts on remote sensing of the marine environment from each NOWPAP member state. With the consensus of the NOWPAP members, activities on remote sensing applications that focus on eutrophication and oil spills have been ongoing since 2003.

In 2005, CEARAC requested WG4 experts from the NOWPAP members (China, Japan, Korea and Russia) to prepare national reports on the status of ocean-remote sensing on the marine environment. From these reports was published the 'Integrated Report on Ocean Remote Sensing for the NOWPAP Region' The Integrated Report included recommendations on capacity building through training courses, improved information networks and closer cooperation among relevant regional and international organizations and programs to facilitate further utilization of ocean-remote sensing to monitor marine environment. Since then, CEARAC has organized three training courses on ocean-remote sensing for young researchers in the region. CEARAC has also focused on enhancing web content by establishing a new portal site on ocean-remote sensing and a new webpage on oil-spill monitoring, and has strengthened cooperation, coordination and information sharing among relevant organizations.

In recent years, new satellites and sensors have been deployed, and more frequent and detailed observation data have been collected. Reanalysis of past observation data has also helped to improve databases for identifying long-term trends on phenomena such as climate change. As further studies are been undertaken, progress has been made in applying remote sensing for conservation of the marine environment.

Despite increasing knowledge of the NOWPAP sea area and continued development of monitoring techniques by remote sensing, the status of the marine environment remains critical. Eutrophication, red tides and oil spills, identified as main targets of ocean-remote sensing in the Integrated Report, have not been mitigated or prevented, and their status is becoming ever-more serious.

The frequent occurrence of large-scale red tides in the coastal areas of the Northwest Pacific region, apparently induced by eutrophication, remains a serious issue. Red tides have resulted in increased fishery damage, environmental deterioration and food poisoning in humans from the consumption of affected fish. While satellite data can be used to identify blooms, there are no current methods to determine whether a bloom is harmful to humans, fish or other organisms. Nevertheless, ocean-color remote sensing techniques have advantages over conventional in-situ methods when monitoring sea surfaces with wide spatial scales (from tens of meters to a few thousand kilometers) and high temporal resolution (several times a day under cloudless or partly cloudy conditions).

Much of the traffic in the Northwest Pacific Ocean, one of the most crowded sea areas in the world, comprises tankers and heavy oil cargo vessels. The potential risk of accidental oil spills from these vessels remains very high, damaging local fisheries and tourism, and subsequently causing significant degradation to the marine environment. Also, illegal oil dumping is a very serious issue depending on the amount of waste water. Satellite-remote sensing via a sensor such as the Synthetic Aperture Radar (SAR), has wider coverage than conventional methods, as well as has high spatial resolution and all-weather capability. Such remote sensing is expected to detect oil spills, both from accidents and illegal oil dumping, effectively and accurately with high temporal resolution and fewer false alarms than other methods, and this is critical for minimizing damage and operational expenses. Consequently, CEARAC continuously proposes that eutrophication and oil spills should be monitored by satellite-remote sensing, as both environmental concerns are common and widespread in the NOWPAP region.

The ultimate goal of CEARAC 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, NOWPAP members must thoroughly consider, among other things, the identification and solution of technical issues related to marine environmental monitoring by remote sensing, and the technical and financial arrangements in the NOWPAP region. This Integrated Report aims to document common understandings among NOWPAP members on these matters and to inform the international community of such progress in the Northwest Pacific region.

2. Sensors and satellites

2.1. China

2.1.1. HY-1B COCTS/CZI

China's second ocean satellite, HY-1B, was launched in April 2007 and carries an improved Chinese Ocean Color and Temperature Scanner (COCTS) and Coastal Zone Imager (CZI). The satellite has been operating stably for 4 years, 1 year longer than its designed lifespan. It has been playing a significant role in such fields as the detection of sea surface temperature (SST) 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-ons to the ocean satellite HY-1B. They are scheduled for launch in 2014 and will carry the improved COCTS and CZI. HY-1C is on an AM orbit, whereas HY-1D is on a PM orbit (IOCCG, 2010b; IOCCG, 2011). Table 1 summarizes the main characteristics of the HY-1C/1D ocean satellites.

Table 1. Main characteristics of HY-1C/1D (CEOS/ESA, 2011; IOCCG, 2011)

Agency	National Satellite Ocean Application Service (NSOAS)/ China Association for Science and Technology (CAST)
Status	Planned
Launch Date	2014
EOL Date	TBD
Applications	Detecting ocean color and sea surface temperature
Instruments (Resolution)	COCTS (1100 m), CZI (250 m)
Orbit Details & URL	Type: Sun-synchronous Altitude: 798 km Period: TBD Inclination: 98.6 deg Repeat cycle: 7 days LST: 10:30 (HY-1C), 13:30 (HY-1D) Asc/Desc: Descending (HY-1C), Ascending (HY-1D) 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 in January 2006, operated for over 5 years, and completed its operations in 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 the Phased Array type L-band Synthetic Aperture Radar (PALSAR) onboard ALOS, collected many important earth observations. For example, the use of AVNIR-2 and PALSAR contributed to effective surveillance for oil-spill detection, 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, 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 under 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 expanding the observable range of the satellite up to about three times, with an improved observable area of 870 to 2320 km, as well as giving ALOS-2 a right-and-left looking function, which is 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 detailed with higher spatial and temporal resolution. Table 2 summarizes the main characteristics of the ALOS-2 satellite.

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

Agency	Japanese Aerospace Exploration Agency (JAXA)
Status	Approved
Launch Date	Jan 2013
EOL Date	Jan 2017
Applications	Environmental monitoring, disaster monitoring, civil planning, agriculture and forestry, Earth resources, land surface
Instruments (Resolution)	PALSAR-2 (1-100 m)
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 2014. 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 and the spatial swath width is 30 km. The number of spectral bands is 57 for the VNIR and 128 for the SWIR. Meanwhile, the multi-spectral sensor has a 5 m spatial resolution, a 90 km swath width and 4 spectral bands for the VNIR. These spectral bands correspond to the spectral range of the Landsat ETM+ (section 2.5.1). There is continuity between Terra ASTER data and ALOS-3 multi-spectral sensor data (Tatsumi *et al.*, 2010). With higher temporal and spatial resolution, it is expected that the hyper/multi spectra sensor onboard the ALOS-3 will be used for monitoring red tides and coastal-landfill or erosion processes. Table 3 summarizes the main characteristics of the ALOS-3 Satellite.

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

Agency	JAXA
Status	Planned
Launch Date	2014
EOL Date	2018
Applications	Cartography, digital terrain models, environmental monitoring, disaster monitoring, civil planning, agriculture and forestry, Earth resources, land surface
Instruments (Resolution)	Hyper-spectral sensor (30 m), Multi-spectral sensor (5 m), Panchromatic sensor (0.8 m)
Orbit Details & URL	Type: Sun-synchronous Altitude: TBD Period: TBD Inclination: TBD Repeat cycle: TBD LST: 13:30 Asc/Desc: Descending URL: http://www.jaxa.jp/projects/sat/alos2/index_e.html

2.2.4. GCOM-C1 SGLI

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

- 250 m resolution and 1150 km Visible and Near Infrared Radiometer, or 1400 km Infrared Scanner, swaths for land and coastal observations
- Near-ultraviolet and polarization observations for land-aerosol estimation
- Nadir + slant-view observations for biomass and land-cover classifications (red and near-infrared bands)

Satellites, sensors and algorithms are being developed for the launch in 2014. The first version of the standard products will be released to the public 1 year after the launch. GCOM-C products will be free of charge for internet acquisition (Murakami, 2010). It is expected that chlorophyll concentration and SST will be observed by SGLI, which will be used to identify good fishing grounds and provide data for the sustainable use of fishery resources. Table 4 summarizes the main characteristics of the GCOM-C1.

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

Agency	JAXA
Status	Approved
Launch Date	Feb 2014
EOL Date	Feb 2019
Applications	Understanding of climate change mechanism
Instruments (Resolution)	SGLI (250-1000 m)
Orbit Details & URL	Type: Sun-synchronous Altitude: 800 km Period: 98 min Inclination: 98.6 deg Repeat cycle: TBD 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, the world's first geostationary ocean-color sensor, the Geostationary Ocean Color Imager (GOCI), was launched onboard the Communication, Oceanographic and Meteorological Satellite (COMS). The GOCI is planned for use in the real-time monitoring of the ocean environment around the Korean Peninsula by taking measures of oceanic chlorophyll concentration, dissolved organic matter, and suspended sediments eight times per day for 7 years. The GOCI primary data will support ocean environment monitoring, operational oceanographic systems, and fishery information service and climate-change research. The operational oceanographic system will provide data and information on ocean and coastal-state changes to various users. Basically, all research work can belong to the operational oceanographic system. GOCI data can be used for understanding atmospheric phenomena and land applications. The lifetime of the GOCI mission is about 7 years (Ryu *et al.*, 2010).

2.3.2. GeoKOMPSAT-2B Advanced GOCI

The satellite name COMS has been changed to GeoKOMPSAT. In the GeoKOMPSAT-2A satellite, only meteorological payload will be loaded. The post-GOCI mission was approved by the Korean government in 2010 and is scheduled to launch on board the GeoKOMPSAT-2B in 2018 (Ahn *et al.*, 2010). 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 360 m (cf. 500 m for GOCI). Additional requirements for infrared (IR) bands have been dropped due to budget restrictions and the limited size of the main bus. The possibility of night-time observations is also being investigated. Table 5 summarizes the main characteristics of the GeoKOMPSAT-2B.

Table 5. Main characteristics of GeoKOMPSAT-2B (Ahn *et al.*, 2010)

Agency	Korea Aerospace Research Institute (KARI)
Status	Approved
Launch Date	2018
EOL Date	2025
Applications	Korea's geostationary oceanographic and environmental satellite
Instruments (Resolution)	GOCI-II (250 x 250 m) for local coverage, 1 x 1 km for full disk coverage), Geostationary Ocean Color Imager
Orbit Details & URL	Type: Geostationary Altitude: 357000 km Period: every 1 hour & 1-2 time per day Inclination: 0 Repeat cycle: TBD LST: TBD Asc/Desc: TBD URL: TBD

2.4. Russia

2.4.1. Meteor-M No.1 KMSS

The KMSS Satellite Multispectral Imagery System, composed of the two cameras MSU-100 and MSU-50, was designed for imaging land and water surface in six visible and near-IR regions within the swath width of about 1000 km and spatial resolution of 60 to 120 m. It was launched on board Meteor-M No.1 in September 2009 and has since been delivering KMSS data to users. The objects of monitoring by KMSS are to benefit the economy in the following fields (Novikova *et al.*, 2008):

- State and forecasting of agricultural crop productivity
- State and dynamics of forest cover, including 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, floods, including flash flooding, atmospheric catastrophic phenomena, volcanic eruptions, large-scale man-made disasters.

2.4.2. Meteor-M No.3 CZS/OCS

The Meteor-M satellite series is designed for operational provision of global hydrometeorological data for weather forecasts, ozone layer dynamics, assessment of radiation fields, and monitoring marine environments and ice cover in polar regions. Meteor-M No.1 carries multi-spectral scanning devices for studying marine productivity. Meteor-M No. 2 (replica of No. 1) will continue the series of multi-purpose satellites and is scheduled for launch in 2012. Meteor-M No. 3 is intended to complement data provided by Nos. 1 and 2 to extend the range of environmental applications, and is scheduled for launch in 2015. Meteor-M No. 3 will carry a Coastal Zone Scanner (CZS) (6 channels, 410-786 nm) to monitor shelf and near-coastal areas, and an Ocean Color Scanner (OCS) for open waters (8 channels, 402-885 nm) (IOCCG, 2011). Table 6 summarizes the main characteristics of the Meteor-M No. 3.

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

Agency	ROSHYDROMET/ROSKOSMOS
Status	Approved
Launch Date	2015
EOL Date	2020
Applications	Oceanography, hydrometeorology, climatology
Instruments (Resolution)	CZS-Coastal Zone Scanner (80 m), OCS-Ocean Color Scanner (1000 m), SAR-Synthetic Aperture Radar X band (1-500 m), Scatterometer (25 km)
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. The Landsat data archive at the U.S. Geological Survey (USGS) Earth Resources Observation and Science Center holds an unequaled 36-year record of the Earth's surface and is now available at no cost to users via the Internet (http://landsat.usgs.gov/) (Chander *et al.*, 2009). As such, Landsat is an invaluable resource for monitoring global change and is a primary source of medium spatial resolution observations of Earth that are 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. The spatial resolution of MSS was approximately 79 m (but often processed to a pixel size of 60 m), with4 bands in the VNIR wavelength. Landsat 3 MSS included 5 bands in the Thermal Infrared (TIR) wavelength. The second group includes Landsat 4 and Landsat 5, which carries 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 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.

Landsat archived data can be used for change detection algorithm advancement and understanding land-ocean interactions in the coastal areas. Also, a spatial resolution of Landsat visible, IR data and SAR data acquired from the European Remote Sensing Satellites (ERS-1 and ERS-2), Envisat, RADARSAT-1 and RADARSAT-2 satellites is almost the same in that it improves understanding of biophysical processes in the upper layer of the sea surface by correlative analysis of color, temperature and roughness fields.

The Landsat Data Continuity Mission (LDCM) is a collaboration between NASA and the USGS that will provide moderate resolution measurements of the Earth in the VNIR, SWIR and TIR. The LDCM satellite payload consists of two scientific instruments: the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS). These two sensors will provide images at a spatial resolution of 30 m (VNIR, SWIR), 100 m (TIR) and 15 m (panchromatic). The OLI provides two new spectral bands, one tailored to detect cirrus clouds and the other for coastal zone observations. The TIRS will collect data for two other narrow spectral bands in the thermal region formerly covered by one wide spectral band on Landsats 4-7. The LDCM scene size will be 185 km cross-track by 180 km along-track. The nominal spacecraft altitude will be 705 km, with cartographic accuracy of 12 m or better. LDCM is scheduled to launch in December 2012.

ii. Orbview2 SeaWiFS

OrbView-2 is a satellite system developed by Orbital Science Corporation. It carried NASA's Sea-viewing Wide Field-of-view Sensor (SeaWiFS) as its only instrument in August 1997, and the satellite terminated operation in July 2010. 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 the SeaWiFS Project is to provide quantitative data on global ocean bio-optical properties to the Earth Sciences community. Subtle changes in ocean color signify various types and quantities of marine phytoplankton (microscopic marine algae), 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.

To redefine the archive product suite as more useful data products, SeaWiFS reprocessing was successfully completed in November 2009 and again in September 2010. NASA maintains the quality and consistency of SeaWiFS data for all periods of operation and provides the data products (chlorophyll-*a* concentration, diffuse attenuation coefficient, photosynthetically available radiation, etc.) at a different spatial resolution on NASA's OceanColor Web (http://oceancolor.gsfc.nasa.gov/). The data products can be obtained free of charge by submitting an application to NASA. Methods for acquiring SeaWiFS data depend on the intended use of the data, i.e. research or commercial.

The OceanColor Web was opened by the NASA Ocean Biology Processing Group in February 2004 to serve as the entry point into all of NASA's ocean-color activities. The site offers access to datasets from NASA's ocean-color missions as well as many other useful links and services.

iii. Aqua/Terra MODIS

NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) is a key instrument on board the Aqua and Terra satellites. Both MODIS radiometers view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands or wavelength groups at 3 spatial resolutions: 250, 500 and 1000 m. These data products will improve understanding of global dynamics and processes occurring on the land, in the oceans and in the lower atmosphere.

Aqua MODIS reprocessing was completed in April 2010, and there is a much improved agreement between MODIS and SeaWiFS data products. Terra MODIS reprocessing was completed in January 2011, resulting in good agreement with SeaWiFS and Aqua MODIS, but the required corrections were very large, so its data products should be used with caution (IOCCG, 2011). These reprocessings enabled long-term trend analyses covering SeaWiFS, MODIS and NASDA/JAXA's Ocean Color and Temperature Scanner. As well as SeaWiFS data products, NASA maintains and provides data products for chlorophyll-*a* concentration, SST, diffuse attenuation coefficient, photosynthetically available radiation, etc. on their OceanColor Web. The data products can be obtained free of charge.

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 ocean and coastal seawater-color observations. MERIS has a high spectral and radiometric resolution with dual spatial resolution (1200 and 300 m). The Spectrometer has a global mission covering open ocean and coastal areas, and a regional mission covering land surfaces. For the interpretation of MERIS measurements, ESA developed an inverse modeling technique, and it is used to derive data products. The MERIS data products are provided free of charge using Earth Observation Link, which is the ESA's client for Earth Observation Catalogue and Ordering Services. Some MERIS data products limited to the sea area around the U.S. are also provided in NASA's OceanColor Web.

ESA's CoastColour project is helping scientists develop techniques to take full advantage of the unique capabilities of MERIS. The sharpest view of coastal waters to date is provided by MERIS, which includes spectral bands specifically designed to characterize the complex mixing of pollutants, suspended sediments and phytoplankton typically found in coastal areas. Part of the NOWPAP region is registered as one of the test sites.

The ESA's BEAM is an open-source toolbox and development platform for viewing, analyzing and processing of remote sensing data. Originally developed to facilitate the utilization of MERIS data, BEAM now supports data from MODIS, Advanced Very High Resolution Radiometer (AVHRR), AVNIR, PRISM, and so on. Various data and algorithms are supported by dedicated extension plug-ins.

v. Oceansat-2 OCM

The Indian Space Research Organization (ISRO) spacecraft Oceansat-2 was launched in 2009, carrying an Ocean Color Monitor (OCM), a Scanning Scatterometer and a Radio Occultation Sounder for Atmospheric Studies. 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 its predecessor on Oceansat-1. The OCM data products are available at 360 m spatial resolution, which are also called Local Area Coverage products. The Global Area Coverage (GAC) products are available at 4 km spatial resolution, covering the NOWPAP region.

An Announcement of Opportunity (AO) call inviting proposals from international Principal Investigators (PIs) opened in 2008. ISRO provided OCM data to all AO PIs after the initial calibration/validation activities were over and data were formally released for public use. They also provided the GAC products through a web-based data dissemination system.

2.5.2. Scheduled satellites and sensors

i. NPOESS/NPP mission

The tri-agency Integrated Program Office (IPO) includes the Department of Commerce, Department of Defense and NASA. The IPO plans the National Polar-orbiting Operational Environmental Satellite System (NPOESS) to monitor global environmental conditions, and collect and disseminate data related to weather, atmosphere, oceans, land and near-space environment. The first NPOESS satellite is planned for launch in 2013. The NPOESS Preparatory Project (NPP) was conceived to systematically reduce the risk of NPOESS and maintain continuity of certain environmental datasets that were initiated with Terra and Aqua.

The NPP satellite was launched in October 2011, and carried the following primary NPOESS sensors: Advanced Technology Microwave Sounder; Cross-track Infrared Sounder; Ozone Mapping and Profiler Suite; and Visible Infrared Imager Radiometer Suite. These sensors collect data on atmospheric and SSTs, humidity soundings, land and ocean biological productivity, and cloud and aerosol properties.

ii. Sentinels series

ESA is developing five families of Sentinel missions specifically for the Global Monitoring for Environment and Security (GMES) program, ensuring continuity with the Envisat mission. GMES Marine Services will deliver information on the state and dynamics of the ocean and coastal areas to help protect and manage the marine environment and resources more effectively, and will also focus on marine safety and the monitoring of pollution such as oil spills.

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, i.e. vegetation, soil and water cover, inland waterways and coastal areas, and emergency services. The first Sentinel-2 satellite is planned for launch in 2013. Sentinel-3, with a Sea and Land Surface Temperature Radiometer (SLSTR), Ocean and Land Color Instrument (OLCI) and Synthetic Aperture Radar Altimeter (SRAL), is a polar-orbiting, multi-instrument mission to measure variables such as sea-surface topography, sea- and land-surface temperature, ocean color and land color with high-end accuracy and reliability. The first Sentinel-3 satellite is planned for launch in 2013.

3. Data distribution systems

3.1. China

NSOAS provides paid observation data off-line. The data are obtained by COCTS and CZI on board the HY series satellites. Utilization of the data in foreign countries is limited to ocean research institutions/organizations (Figure 1).

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 period (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 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 a new European-China partnership in Earth observation science and technology to support global monitoring for environment and security

DRAGONESS benefits from and complements the joint ESA and China's Ministry of Science and Technology DRAGON Collaborative Programme that focuses on Earth observations from satellites. DRAGON runs until 2012 (Johannessen, 2009).

A Marine Remote Sensing Data Application and Mapping Toolbox (MAPP), as shown in Figure 2, was developed by the ocean color remote sensing group of the State Key Laboratory of Satellite Ocean Environment Dynamics (SOED), the Second Institute of Oceanography (SIO), and the State Oceanic Administration (SOA). The toolbox was released with multi-satellite data, received by the ground station at SOED, to scientists from various disciplines and relevant governors. The first version of MAPP focused solely on ocean-color satellite-image viewing, basic data analyses, and various applications, particularly water-quality assessment. The target users of MAPP are mainly those without extensive remote sensing capability, and those concerned with satellite data application rather than data processing (e.g. atmospheric correction and algorithm development) (Delu, 2007).

Figure 1. National Satellite Ocean Application Service (in Chinese)
<http://www.nsoas.gov.cn/>

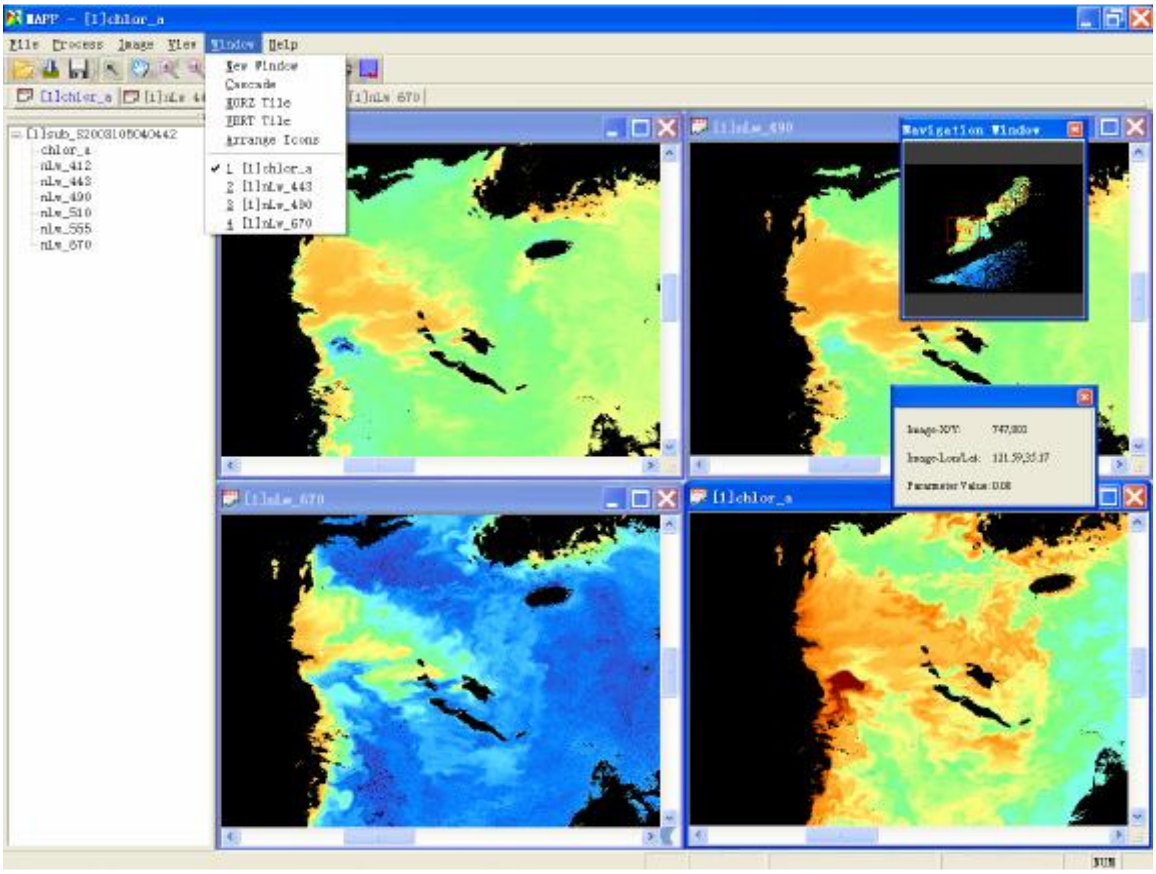

Figure 2. Marine Remote Sensing Data Application and Mapping Toolbox

3.2. Japan

MODIS Near Real Time Data website of JAXA's Earth Observation Research Centre was redesigned in 2006 (Figure 3). The reliability of the satellite data product was improved after 2007 through mitigating errors by temporal variation of validation ratio, modification of chlorophyll-*a* estimation algorithms, reduction of strip noise and modification of atmospheric correction algorithms. Aerosol optical thickness data with 1 km resolution and chlorophyll-*a* concentration data with 500m resolution have also been added.

The website of the Marine Environmental Watch Project has been periodically updated, and regularly provides SST and chlorophyll-*a* satellite images over the Northwest Pacific region (Figure 4). Daily mean images of SST and chlorophyll-*a* have been processed for the 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 the use of satellite data for marine environment conservation have been included for data analysis and case study sections. From 2007, the Marine Environmental Watch Project has been registered as one of the databases of the North-East Asian Regional GOOS (NEAR-GOOS), which is a regional Global Ocean Observing System (GOOS) sponsored by the Intergovernmental Oceanographic Commission (IOC) of UNESCO.


The Moderate Resolution Imaging Spectroradiometer

MODIS

Near Realtime Data

JAXA EORC

Documents | Browse images | Binary data | Topics | FAQ | History

About MODIS Near real time homepage

このホームページは、NASA地球観測衛星TERRA/AQUA搭載センサMODISによって観測されたデータを、東海大学情報技術センター(TRIC)および宇宙航空研究開発機構(JAXA 地球観測センター(EOC)が 受信・輝度/幾何変換処理(Level 1B)処理し、そのデータをJAXA/地球観測研究センター(EORC)が 準リアルタイム処理して公開しているものです。

公開画像は、1km分解能のクロロフィルa濃度画像、海面水温画像、海面放射輝度画像、簡易大気補正済み輝度画像、エアロゾルの光学的厚さと、500m分解能のクロロフィルa濃度画像、250m 及び 500m分解能 の幾何補正済み画像です。

バイナリデータは1km分解能のクロロフィルa濃度と海面水温のものを公開しています。

公開期間は以下の通りです。
TRIC受信 ：2001年4月4日以降
EOC受信 ：2004年6月28日以降

また、光合成有効放射量(PAR)及び積雪分布を以下のページで公開しております。
>>JASMES :
JAXA Satellite Monitoring for Environmental Study

JASMES

なお、バイナリデータのご利用には、E-Mailでの利用者登録が必要となります。詳細は こちら をご覧ください。

Information

[2011.5.18]
アルゴリズム改善に関するお知らせ

以下の点についてアルゴリズムを改善し、2011年5月25日の観測データ処理より反映します。

・250m/500m処理において校正係数の時間変動についての修正
・250m/500m処理において「Tokara」領域を追加
・日本周辺の500mHDFデータに新規パラメータを追加

[2011.3.1]
サービス一時停止のお知らせ

EORCの設備メンテナンスに伴い、下記期間において準リアル処理およびバイナリデータ提供サービスを一時停止させて頂きます。
なお、停止期間の観測データについては、再開後に処理する予定です。

停止期間：2011年3月4日18:00～3月7日12:00(JST)

[2011.2.14]
サービス一時停止のお知らせ

EORCの設備メンテナンスに伴い、下記期間において準リアル処理およびバイナリデータ提供サービスを一時停止させて頂きます。
なお、停止期間の観測データについては、再開後に処理する予定です。

停止期間：2011年2月18日18:00～2月21日12:00(JST)

Monthly search

・年月を指定することで、公開画像を一覧表示することが出来ます。また、表示されたサムネイル画像をクリックすることで、その拡大画像を閲覧することが出来ます。

[Monthly Searchの使用方法]

- 年と月を選択します(受信局毎の公開期間に注意)。
- 受信局(TRICまたはEOC)を選択します。
- 次に、画像の種類を選択します(1km：日中プロダクト画像、Night SST：夜間海面水温画像、500m[RGB]：500mRGB画像、250m：250m画像)。
- 最後に[View list]ボタンを押すと画像一覧が表示されます。

2011 / 6
TRIC EOC
1km Night SST
500m[RGB] 500m[Chla]
250m
View list

Latest image

・現在の最新画像をランダムで表示しています。
(EOC受信処理データ・低解像度)

tau_865 [1km] 2011/06/17 00:34

Funka_chla [500m] 2011/06/17 00:34

Okhot [250m] 2011/06/17 00:34

sst [Night SST] 2011/06/16 16:45

宇宙航空研究開発機構 地球観測研究センター
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Figure 3. MODIS Near Real Time Data (in Japanese)
<http://kuroshio.eorc.jaxa.jp/ADEOS/mod_nrt_new/>

Figure 4. Marine Environmental Protection of North Pacific Region
<http://www.nowpap3.go.jp/jsw/eng/>

3.3. Korea

The Korea Ocean Satellite Center (KOSC) in the Korea Ocean Research and Development Institute (KORDI), the primary data receiving/processing organization for GOCI, was established at Ansan, Korea, between 2005 and 2010 (Ahn *et al.*, 2010). The KOSC receives the GOCI data eight times a day during the daytime. Data processing and archiving steps are taken 2 hours from the end of reception. The processed GOCI Level 1B and after is distributed to users in near-real time. A free charge of the GOCI data is available for the public service and research domain. However, the commercial application of the GOCI data has to cover the costs of data distribution. Collaborating and pre-registered institutions can utilize the ftp push services to obtain their data of interest after all of the processing is done. Public researchers can search and download the GOCI images of interest on the KOSC website (http://kosc.kordi.re.kr), as shown in

Figure 5. It is expected that GOCI data products will be used actively in the NOWPAP region from now on.

The National Fisheries Research and Development Institute (NFRDI) under the Ministry for Food, Agriculture, Forest & Fisheries has developed a satellite remote sensing system to derive information on oceanic fields since 1989. This system has provided satellite-based information that is useful for finding fishing ground formation and monitoring marine environmental variation. The system provides satellite data observed by NOAA AVHRR (1989-), MODIS (2002-), Defense Meteorological Satellite Program (DMSP) Optical Linescan System (OLS) (1995-), and Archiving Validating and Interpretation of Satellite Oceanographic data (AVISO) (2011-). SST charts with isotherms and 7-day composite color SST images, MODIS derived charts of chlorophyll-a concentration, DMSP OLS derived charts of nighttime light related to the fishing activity and AVISO derived charts of ocean current have been available in the NFRDI website, as shown in Figure 6.

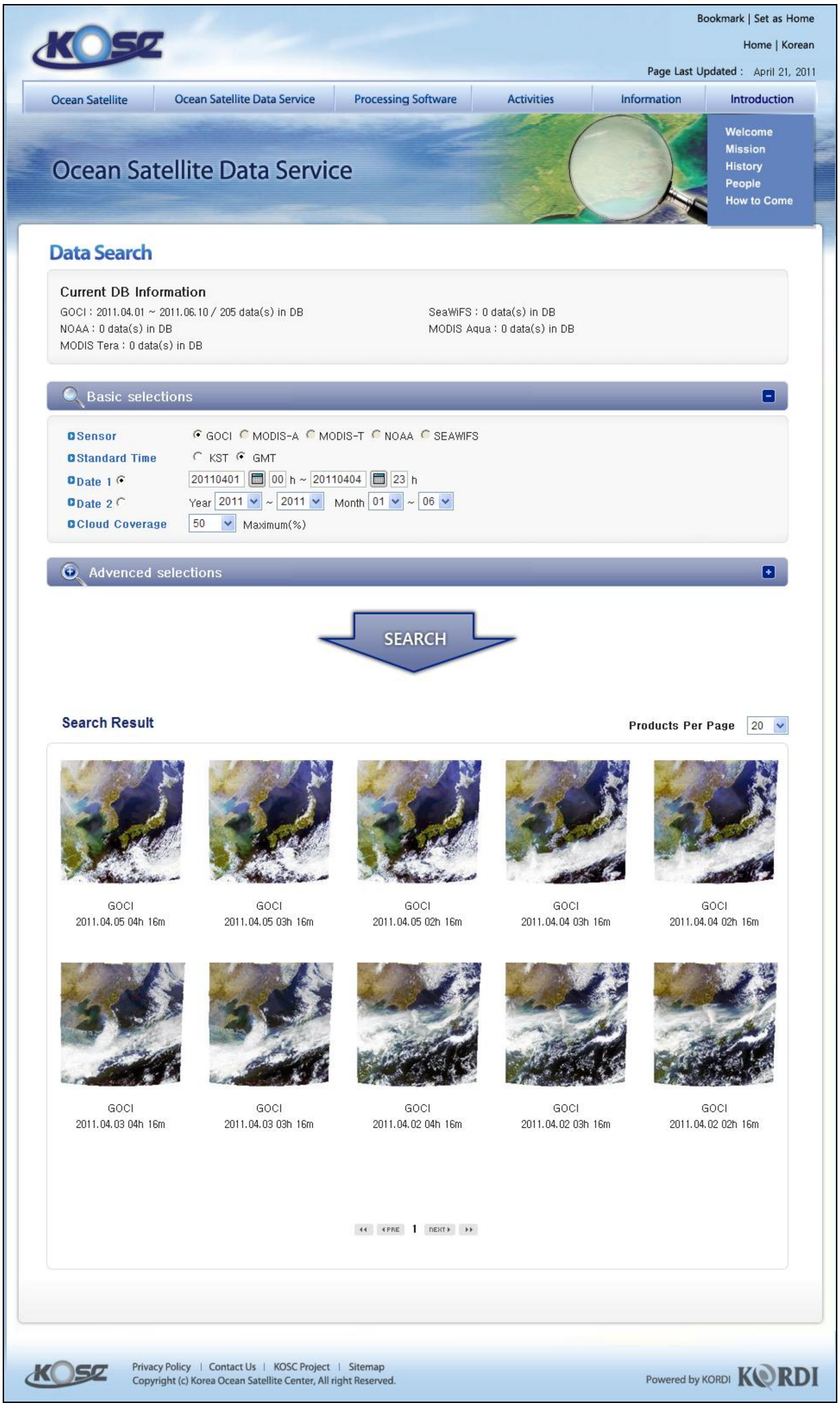
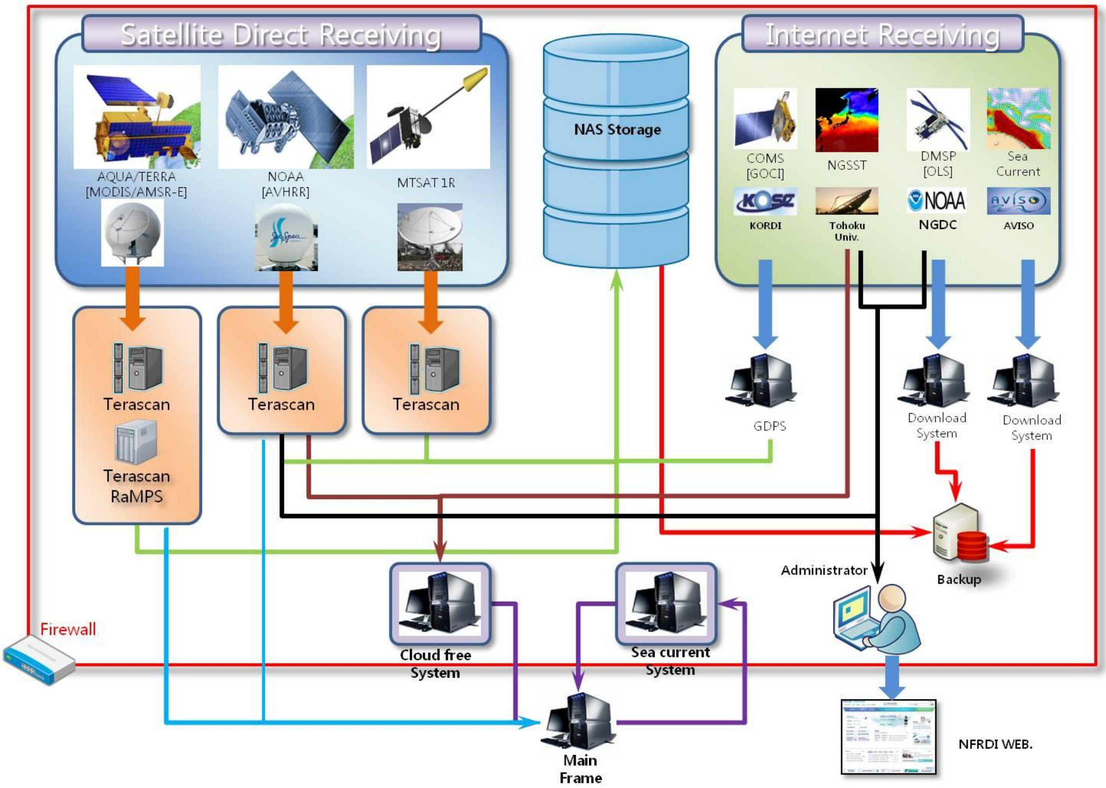
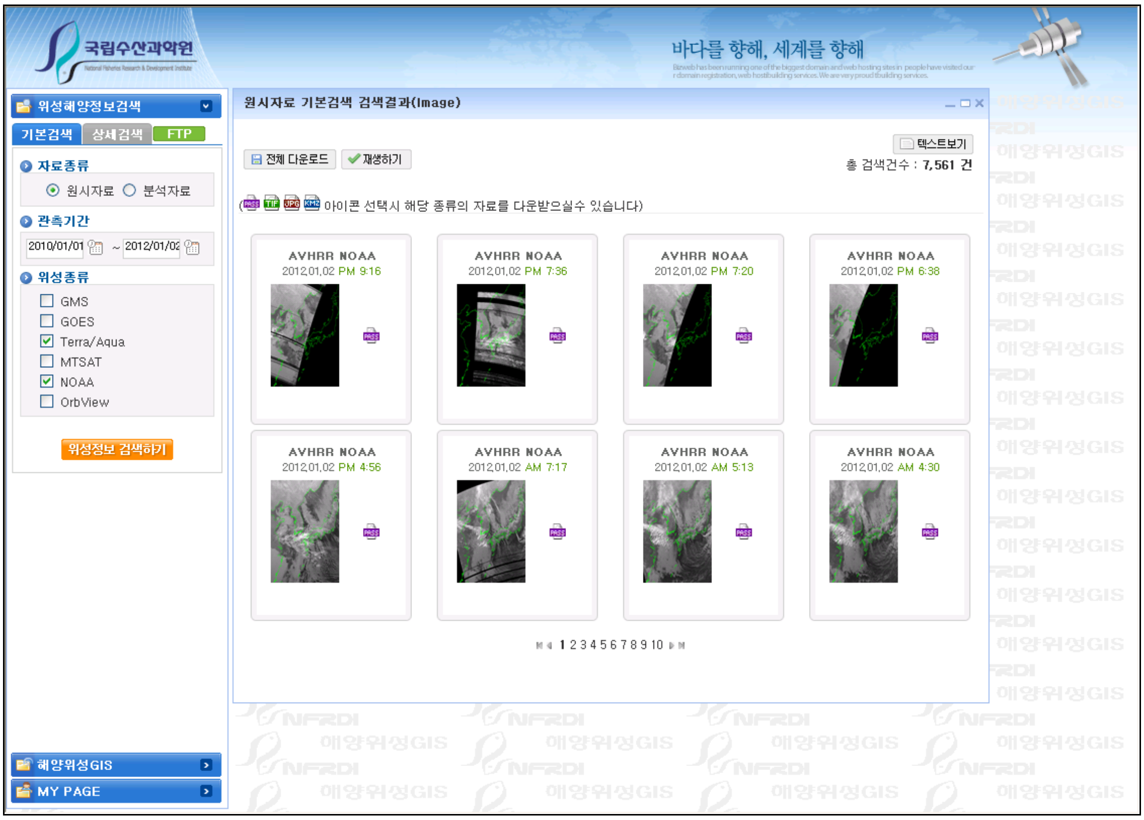


Figure 5. Ocean Satellite Data Service by KOSC
<http://kosc.kordi.re.kr/datasearch/search.kosc>



Satellite data acquisition using direct receiving and internet receiving



Satellite data distribution service (in Korean)
<http://portal.nfrdi.re.kr/sois>

Figure 6. Satellite based ocean information system in NFRDI

3.4. Russia

The Shirshov Institute of Oceanology derived a set of bio-optical parameters, including chlorophyll concentration, particle backscattering and yellow substance-absorption coefficients for the seas surrounding Russia. This was done using SeaWiFS data from 1998, and sometime later using Aqua MODIS data (Figure 7). The standard algorithms for the processing of satellite ocean-color data were based on regression equations, derived mainly from Case-1 waters, and they were broken down into optically-complex Case-2 waters. These algorithms were only valid in the regions of study and, strictly speaking, in specific areas and seasons (Kopelevich *et al.*, 2005). The statistical homogeneity of the study region could be evaluated with satellite data to determine the limits of adequacy of the algorithms (Kopelevich *et al.*, 2010).

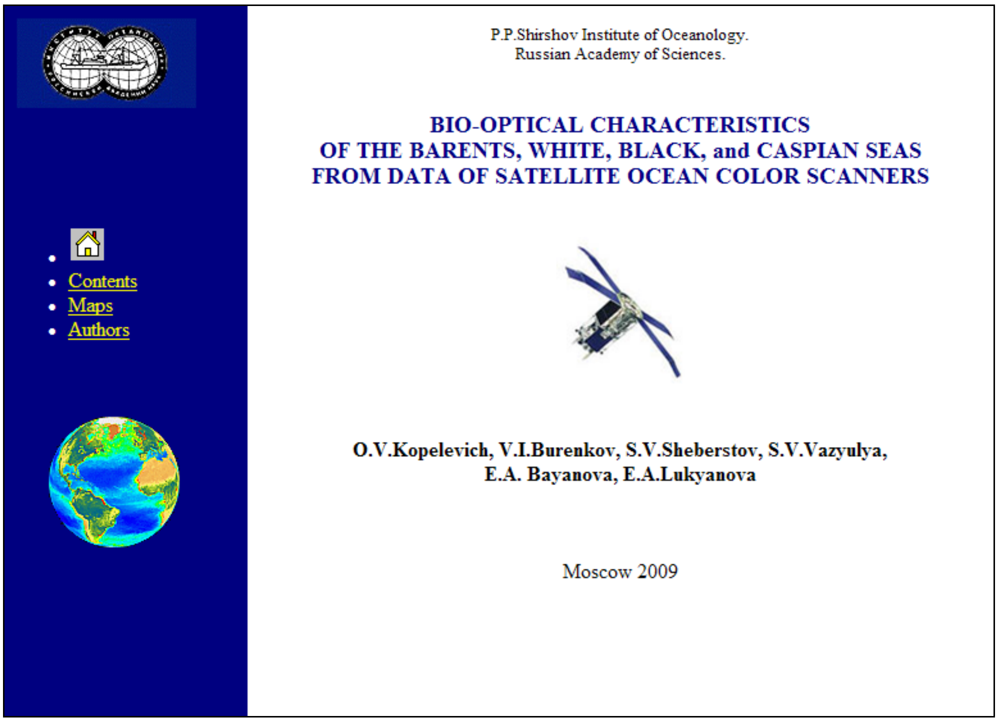


Figure 7. Bio-optical characteristic of the Barents, White, Black, and Caspian Seas from data of satellite ocean color scanners
<http://optics.ocean.ru/>

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

4.1. China

Cui *et al.* (2010) collected extensive in-situ data 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 to 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), the Medium Resolution Spectral Imager (MERSI) on board the second generation Chinese polar-orbit meteorological satellite FY-3A, was a MODIS-like sensor with 20 bands covering the VNIR/SWIR/TIR spectral region. The sensor was capable of making continuous global observations and had ocean-color application. Onboard absolute radiometric calibration in the reflective solar-spectral region was not conducted for MERSI. However, radiometric sensitivity degradation was monitored using the onboard calibrator, and various calibration techniques were adopted to assure calibration accuracy. Those techniques included absolute calibration using the China Radiometric Calibration Site (CRCS) with in-situ measurements, multi-site calibration tracking and cross calibration with Terra MODIS at CRCS. MERSI ocean-color products consisted of water-leaving reflectance retrieved from an atmospheric correction algorithm, chlorophyll-*a* concentration and pigment concentration from global empirical models, and chlorophyll-*a* concentration, total suspended mater (TSM) concentration, absorption coefficient of color dissolved-organic matter (CDOM) and non-algal particle matter 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 nLw 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 8).

Hu *et al.* (2010) showed that green macroalgae *Ulva prolifera* (previously known as *Enteromorpha prolifera*) patches appeared nearly every year between April and July from 2000 to 2009 in the Yellow Sea (YS) and/or East China Sea (ECS), all of which originated from the near shore of Subei Bank. This was done using the novel Floating Algae Index and multi-resolution remote sensing data from MODIS and Landsat (Figure 9). 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* (nori) conducted along the 200 km shoreline of the Subei Bank north of the Changjiang (Yangtze) River mouth.

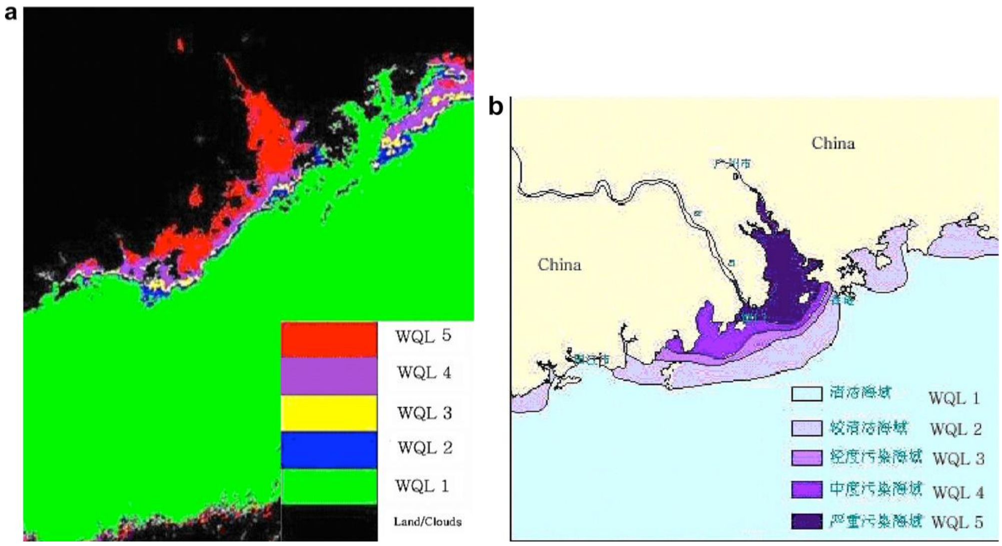


Figure 8. (a) Water-quality levels retrieved from SeaWiFS data, (b) Water quality issued by the State Ocean Administration, China.

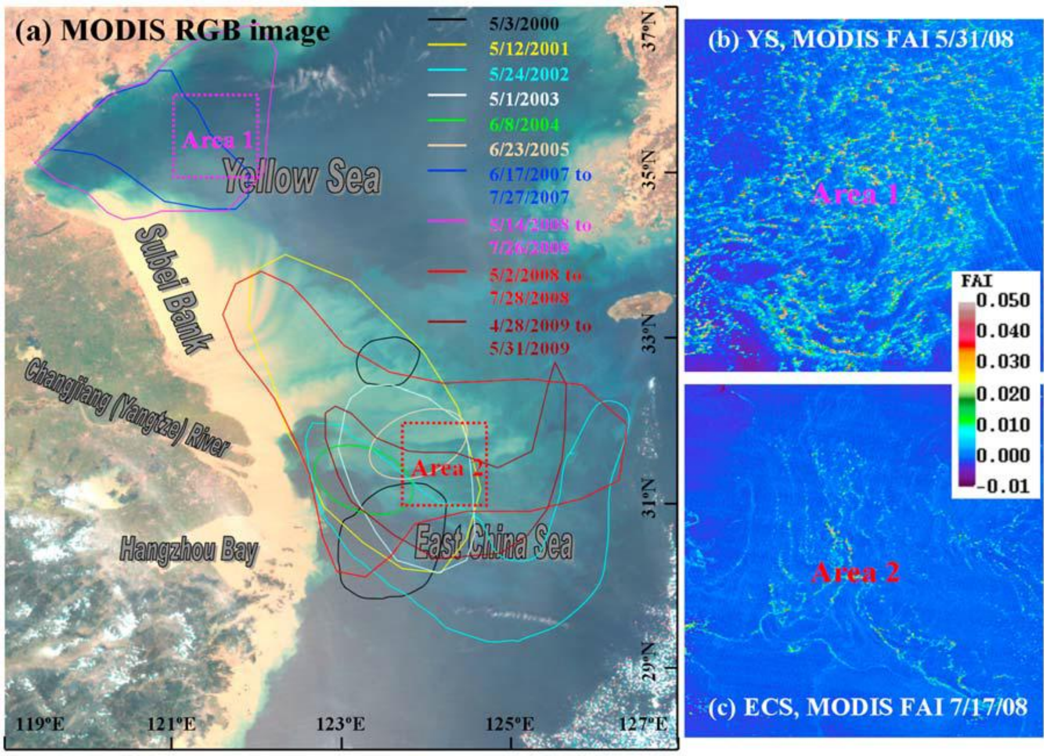


Figure 9. Approximate location and distribution of *U. prolifera*, identified from MODIS FAI (Floating Algae Index) imagery between April 2000 and May 2009. The background MODIS RGB image on 5 April 2003 shows the extensive sediment plume from the Subei Shallow Bank to the ECS, (b) and MODIS FAI images tracing *U. prolifera* blooms in 1 × 1° areas in the YS and ECS on 31 May 2008 and 17 July 2008 (c).

4.2. Japan

Kawamura *et al.* (2010) developed a new SST retrieval method and produced high-quality match-ups by 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. To address them, 6,711 algorithm tuning match-ups with precise navigation and 240,476 validation match-ups were generated covering all seasons and with wide ocean coverage. The new version of SST is called H6 SST. The statistical evaluation of H6 SST, using the validation match-ups, showed small negative biases and RMS errors of about 0.74° K for each area.

Saba *et al.* (2011) evaluated 21 models, including two Japanese models. Of these models, Kameda and Ishizaka (2005) and Asanuma *et al.* (2006), estimate marine Net Primary Productivity (Net PP) using ocean-color data. To determine global and region-specific rates, the skill of those models was assessed by comparing their estimates of depth-integrated Net PP to 1156 in-situ ^{14}C measurements encompassing 10 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 Net PP 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 SST, 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. This suggests that ocean-color models were more challenged in Case-2 waters than in Case-1 waters. Given that in-situ chlorophyll-*a* data were used as input data, algorithm improvement was required to eliminate the poor performance of ocean-color Net PP models in Case-2 waters close to coastlines. Among the models tested in this research, performance of the Kameda and Ishizaka (2005) models are the best for areas with a water depth shallower than 250 m.

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), the 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 nLw with SeaWiFS imagery. The 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 10).

Ishizaka *et al.* (2010) conducted practical exercises to reduce damage of red tides by using remote sensing data in water off Oita prefecture where the occurrence of *Karenia mikimotoi* during summer is the cause of most HABs. These researchers set up a website of red-tide distribution off Oita Prefecture based on a peak shift method from 2010 (Figure 11). There were no serious *K. mikimotoi* bloom occurrences in this area in 2010, but a diatom bloom was detected using near real-time satellite data and confirmed with a ship survey by the Oita Prefectural Agriculture, Forestry and Fisheries Research Center. Siswanto *et al.* (2010) improved on a practical method to discriminate red-tide from non-phytoplankton-dominated waters, as well as higher turbid and CDOM, using MODIS standard ocean color data.

Kim *et al.* (2009) analyzed SeaWiFS chlorophyll-*a* distribution over summer in the ECS from 1998 to 2007 using a K-means clustering technique. The proper satellite chlorophyll-*a* concentration indicated the Changjiang Diluted Water (CDW) area. The spatial distributions of the higher satellite chlorophyll-*a* concentrations (> 0.48 mg/m^3) corresponded well with the distribution of lower salinity CDW (< 30-32) every year. Interannual variation in the CDW area, indicated by the high satellite chlorophyll-*a*, correlated with the interannual variation in the Changjiang summer freshwater discharge. The correlation analysis indicated that the CDW spread eastward in the ECS 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 YS and ECS, with a 9-year monthly average from September 1997 to October 2006, and assessed the interannual variation to understand the influence of the Changjiang River Discharge (CRD) to the YS and ECS during summer. The YS and ECS was represented by 12 areas of different seasonal variability in SCHL. The increase of SCHL was observed in large area of the YS and ECS during spring, and it was expected to be a spring bloom. It was suggested that the interannual variation in SCHL was controlled by the interannual variation in CRD. The SCHL during summer in the YS gradually increased over the 9-year study period, indicating possible eutrophication.

Sasaki *et al.* (2008) measured the absorption coefficients of CDOM and derived a relationship with salinity in the East China Sea during summer when the amount of CRD was large. Low salinity CDW was observed widely in the shelf region and was considered to be the main origin of CDOM, resulting in a strong relationship between salinity and absorption coefficients of CDOM. The error in satellite-derived absorption coefficients of CDOM estimated by the present ocean-color algorithm could be corrected by satellite-retrieved chlorophyll data. Satellite-retrieved salinity could be predicted with about ±1.0 accuracy from satellite-derived absorption coefficients of CDOM. Satellite-derived absorption coefficients of CDOM could be an indicator of low salinity CDW during summer.

Ohnishi *et al.* (2007) detected high satellite chlorophyll-*a* concentrations in summer in the inner part of Toyama Bay by SeaWiFS from 1998 to 1999, and found that it was associated with a spatial distribution of low-salinity water (Figure 12). They also noted that there were spring and fall blooms in the center and offshore areas of Toyama Bay, corresponding to spring and fall blooms of phytoplankton in the eastern part of the NOWPAP region observed by Yamada *et al.* (2004). Terauchi and Ishizaka (2007) reported that there was significant short-term variability in satellite chlorophyll-*a* concentrations in the Toyama Bay coastal area in summer, which was not detectable with temporally limited monthly in-situ based observations.

Hirata *et al.* (2011) presented the synoptic relationships between chlorophyll-*a* and its fractional contribution from three phytoplankton size classes (micro-, nano- and pico-plankton) and seven phytoplankton functional types (PFTs, i.e. diatoms, dinoflagellates, green algae, prymnesiophytes (haptophytes), pico-eukaryotes, prokaryotes and *Prochlorococcus* sp.) using a global in-situ dataset of pigment measurements. The authors found that variation in phytoplankton community structure at large scales was not independent of the variation in chlorophyll-*a* of the total community. The relationships quantified from the global in-situ datasets were applied to SeaWiFS chlorophyll-*a* from 1998 to 2009, to show the global climatological fields of the surface distribution of PFTs.

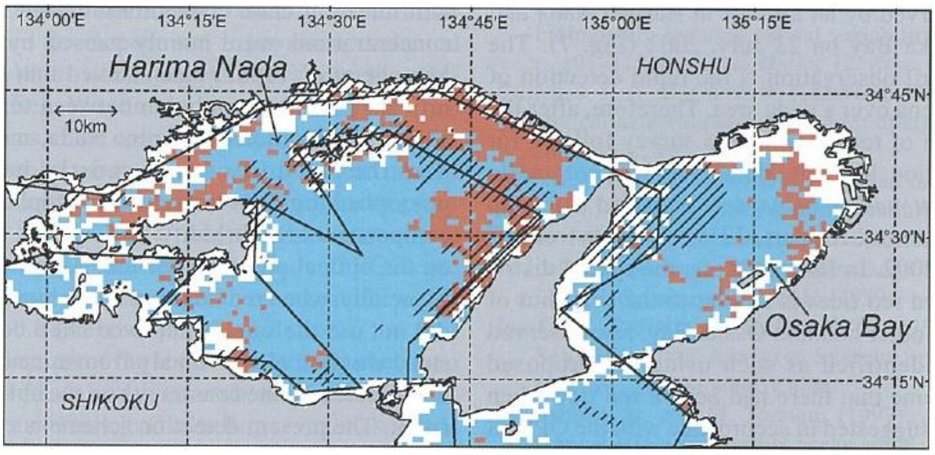


Figure 10. Comparison of the spatial distributions in the detected and observed red tides on 23 July 2002 in Harima Nada and the western Osaka Bay. Black lines indicate the flight routes of aircraft observations, and slashed areas show the observed red-tide areas. Red areas indicate water with a red tide, blue areas refer to water without a red tide, and white areas represent clouds.

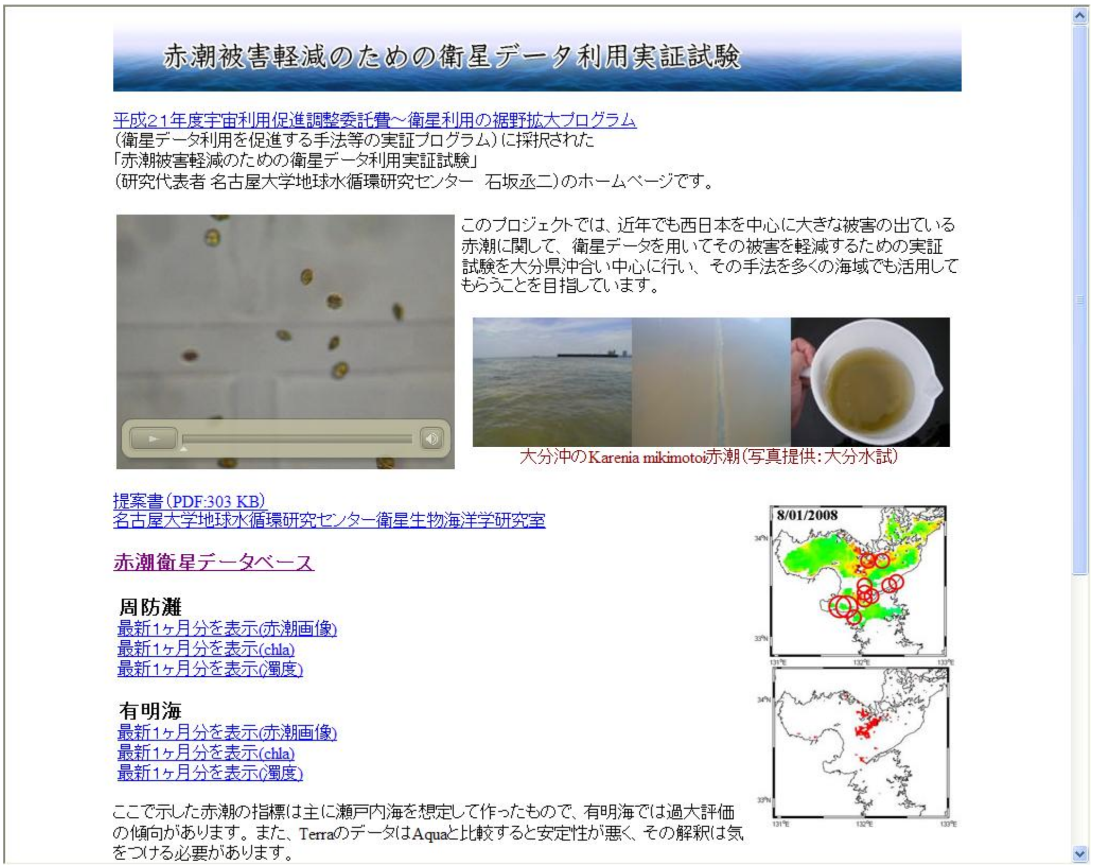


Figure 11. Website of red-tide distribution in the Oita Prefecture (in Japanese) <http://redtide.hyarc.nagoya-u.ac.jp/>

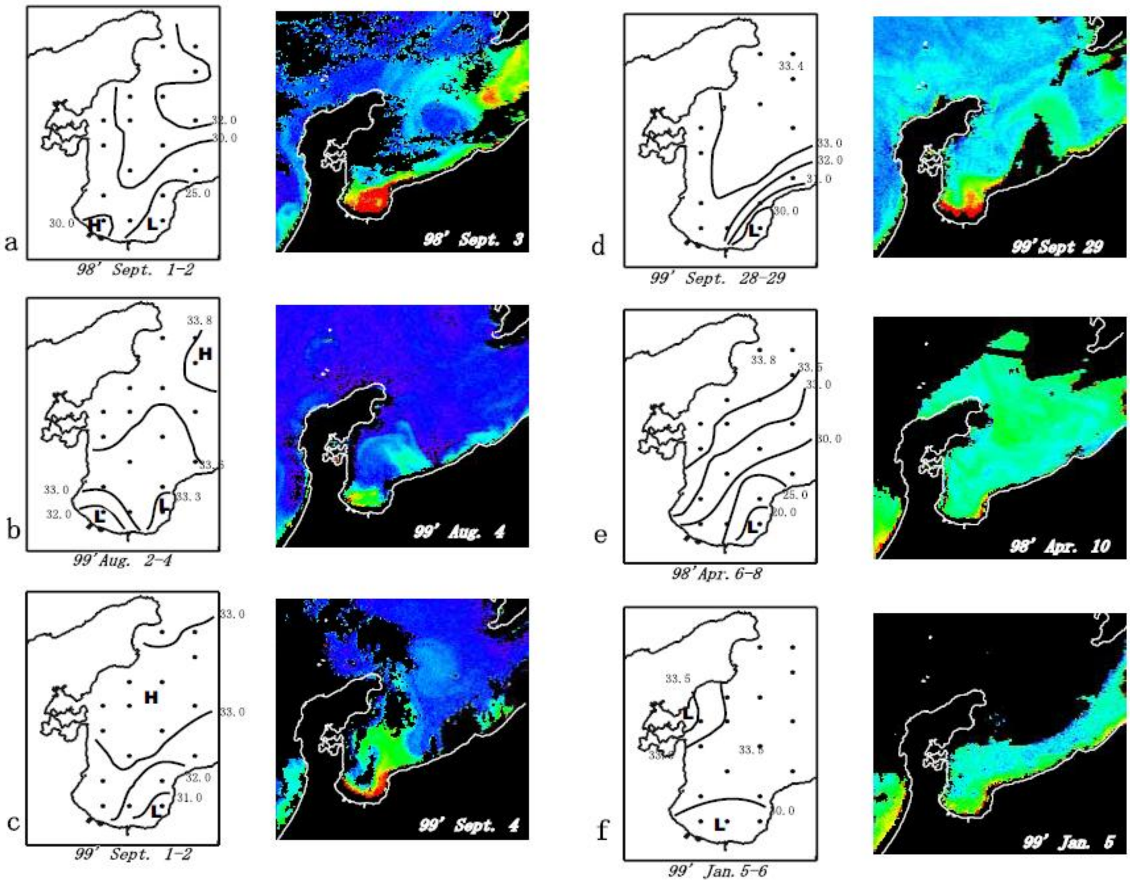


Figure 12. Horizontal distribution of in-situ measured salinity (left) and SeaWiFS derived chlorophyll-*a* (right)

4.3. Korea

Son *et al.* (2010) compared 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 (inherent optical properties, apparent optical properties, temperature, salinity, ocean optics, fluorescence, and turbidity datasets). Several ocean-color algorithms had been developed for GOCI using in-situ measurements. These datasets 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.

Ahn and Shanmugam (2006) and 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, SST from the National Oceanic and Atmospheric Administration (NOAA) AVHRR and wind speed/direction from the Quick Scatterometer (QuikSCAT) (Figure 13). RCA-chlorophyll was used in conjugation with field observation data to first describe comprehensively the occurrences of various HABs and their underlying mechanisms, and link them 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 YS by building a system of two dikes extending 33 km across the mouths of the Dongjin and Mangyeong rivers, offshore of the Saemangeum wetland. The construction of the Saemangeum Reclamation Project's northern dike was completed in June 2003 and the southern dike was finished in April 2006. 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 Wang (2009) showed that after closure of the dikes, water transparencies drastically increased and the amount of suspended sediments in the region decreased (Figure 14). The changes may reflect the significantly diminished tidal currents in the Saemangeum region.

Lee *et al.* (2010a) developed a technique for removing surface reflected light for the measurement of remote sensing reflectance. The derived water-leaving radiance (or remote sensing reflectance) can be highly inaccurate if a spectrally constant effective sea-surface reflectance is applied. However, these errors can be reduced by carefully filtering the measured raw data. To remove surface-reflected light in field measurements of remote sensing reflectance, a spectral optimization approach was applied, with results compared with those from remote sensing models and direct measurements. The agreement in results between the different determination methods suggests that reasonable results for remote sensing reflectance of clear blue water to turbid brown water can be obtained from above-surface measurements, even under high-wave conditions.

Lee *et al.* (2010b) studied the extraction of aerosol optical properties using GOCI data. An aerosol retrieval algorithm for GOCI retrieves aerosol optical depth (AOD), fine-mode fraction and aerosol type data at 500 x 500 m resolution. All products are retrieved over clear water, defined as a surface reflectance ratio of between 640 nm and 860 nm (SRR) that is less than or equal to 2.5, whereas only AOD is retrieved over turbid water due to high surface reflectance. To develop an optimized algorithm for the target area of the GOCI, the optical properties of aerosols are analyzed through extensive observation by

Aerosol Robotic Network (AERONET) sunphotometers to generate a lookup table. The surface reflectance of turbid water is determined from a 30-day composite of Rayleigh and gas corrected reflectance. To evaluate the performance of the developed algorithm, three different aerosol cases, dominated by anthropogenic aerosol containing black carbon, dust and non-absorbing aerosol, are analyzed by applying the algorithm for the top-of-atmosphere reflectance of MODIS. The algorithm retrieves AOD, size information and aerosol type, which are seen to be qualitatively consistent with the results inferred by RGB images. A comparison of the retrieved AOD with those of MODIS collection 5 and AERONET sunphotometer observations shows reliable results. The application of the turbid water algorithm has significantly increased the accuracy in retrieving AOD at Anmyon station. The sensitivity study between MODIS and GOCI instruments, in terms of relative sensitivity and scattering angle, shows promising applicability of the present algorithm to future GOCI measurements.

Ryu *et al.* (2011) studied the temporal variation of water characteristics in the Han River estuary using GOCI data. The temporal variations of suspended solid (SS) concentrations in coastal waters are key to understanding the patterns of sediment movement in semidiurnal tides, such as those on the west coast of the Korean Peninsula. An advantage of GOCI, the world's first geostationary ocean color observation satellite, over other ocean color satellite images is that it can obtain data every hour during the day, making it possible to monitor the ocean in real time. GOCI is used to qualitatively investigate the daily variation in turbidity on the sea surface in a coastal region. Nineteen water samples were collected from the coast to the open sea in southern Gyeonggi Bay on the west coast of Korea. These samples were collected in order to estimate SS concentration in the Bay. GOCI images acquired on the same day as these samples were used to generate water-leaving radiance images and to estimate the difference in turbidity displayed in each image. Temporal variations in turbidity were successfully identified from GOCI images acquired at hourly intervals, and the water-leaving radiance derived from these images showed a close similarity to in-situ measurements. GOCI can be effectively applied to monitor the temporal dynamics of turbidity on coastal water surfaces, such that the sediment movement according to the tidal cycle can be estimated.

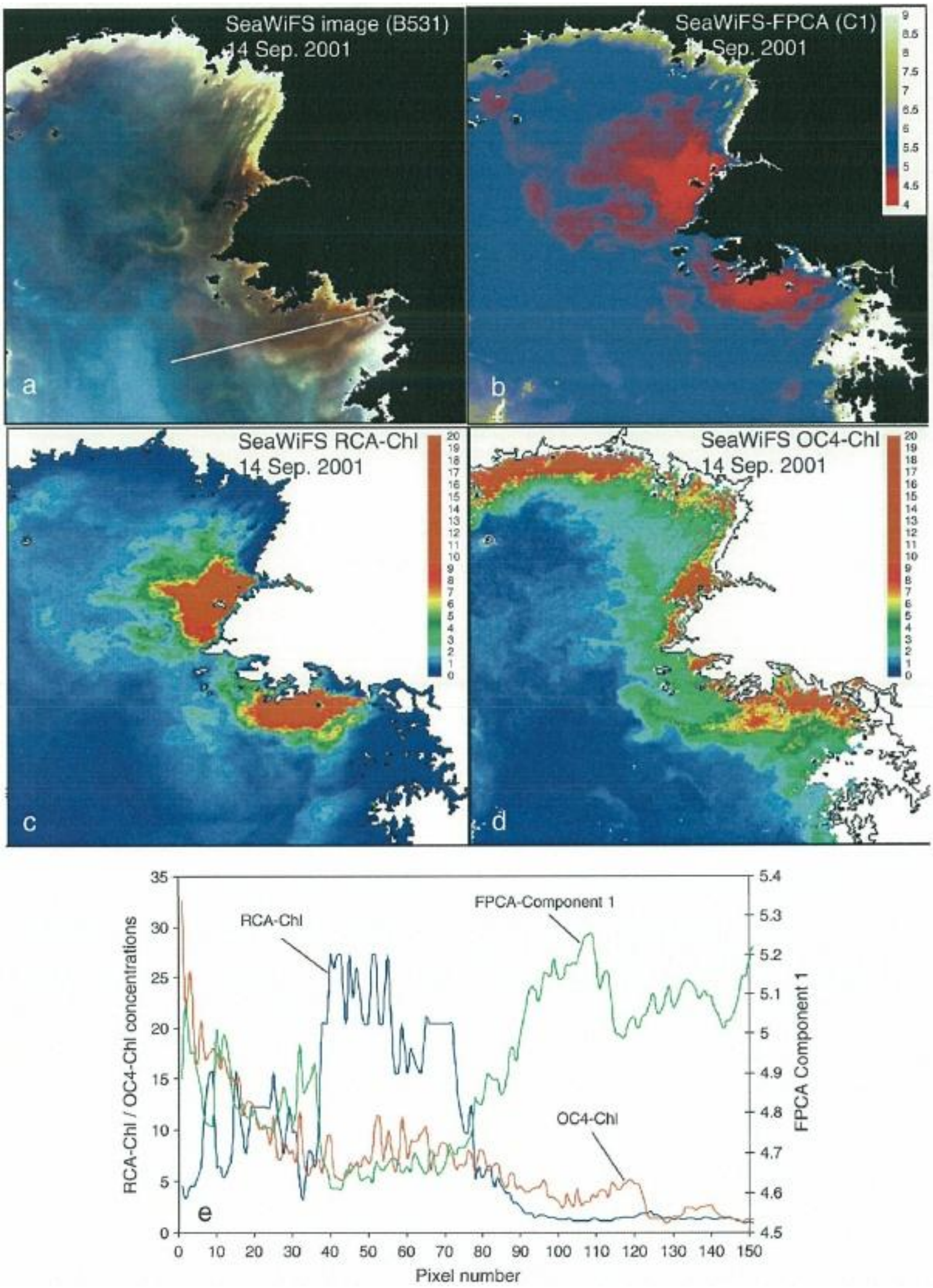


Figure 13. (a) SeaWiFS color composite image of 14 September 2001. (b) SeaWiFS-FPCA (Forward Principal Component Analysis) image from the component 1 (C1) which comprises nearly 98% of the critical data contained in the 8 bands. (c) SeaWiFS RCA-Chl image from the SSMM scheme, (d) SeaWiFS OC4-Chl image(mg/m^3) 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).

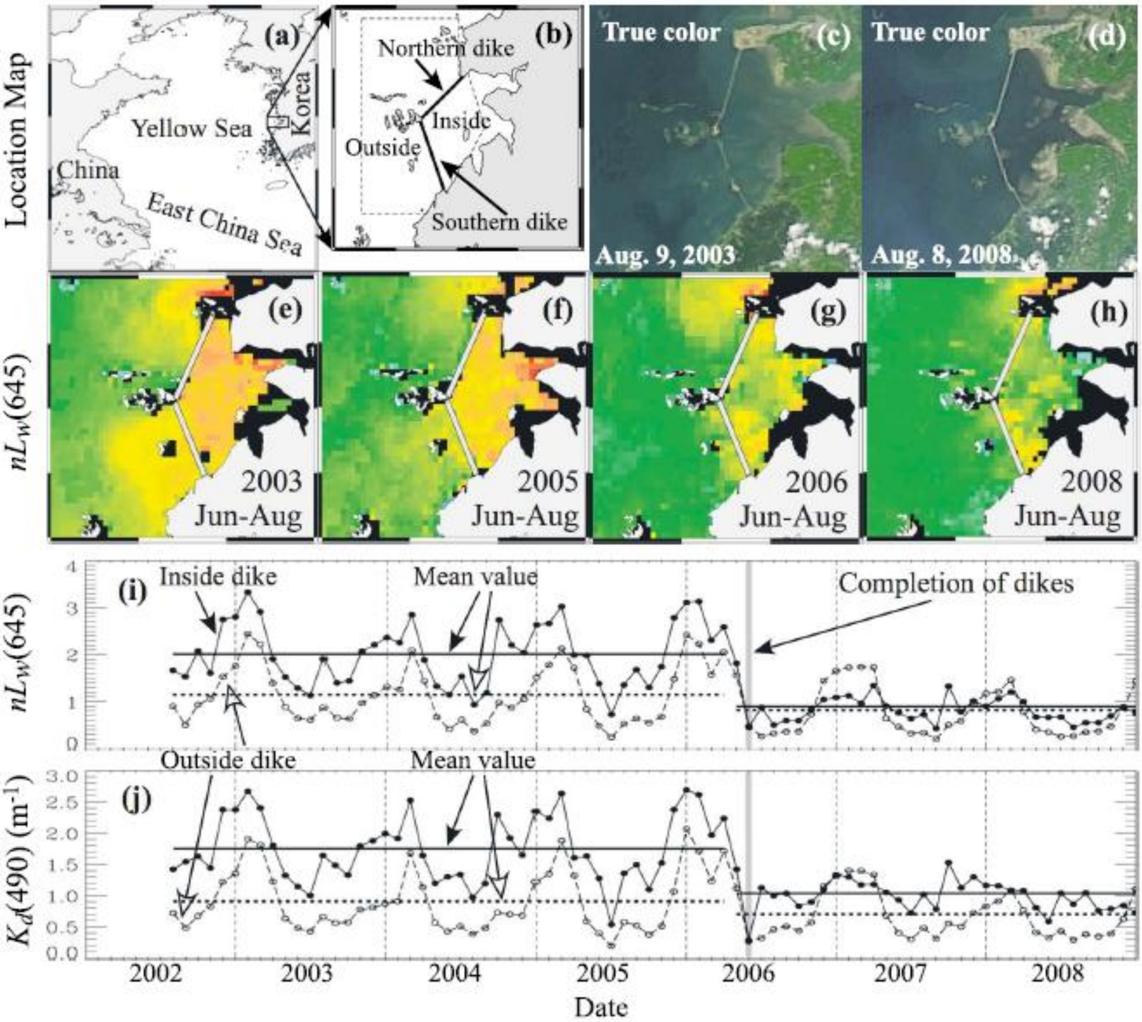


Figure 14. (a and b) Maps of the Saemangeum reclamation area on the middle-west coast of Korea. (c and d) MODIS true color images. (e-h) MODIS derived normalized water-leaving radiance (nLw) at a wavelength of 645 nm, nLw (645) for the summers (June-August) of 2003, 2005, 2006, and 2008. (i and j) MODIS 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 collect data for studying various biological and ecological issues. For the quantitative use of the data, algorithms and products need to be evaluated under various atmospheric and oceanic regimes. Current evaluation programs are limited (a couple of fixed buoys, a few dedicated cruises) and 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 interpretation of satellite imagery employ VSF to solve the radiative transfer equation. On the other hand, the measurements reveal the high variability in VSF for different types of seawater, especially in coastal areas. Thus, case specific VSF modeling is needed.

Mitnik *et al.* (2008), Mitnik and Dubina (2010) and Mitnik and Lobanov (2011) monitored the mesoscale (50 m-20 km) oceanic phenomena and sea ice in Peter the Great Bay, the eastern part of the NOWPAP region, Okhotsk sea, and Oyashio-Kuroshio frontal zone by analysis of multisensory satellite datasets. The datasets consisted of ERS-1/2 SAR, Envisat Advanced Synthetic Aperture Radar (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 weather maps, ship surveys and ground-truth data acquired from 1991 to 2010. Spatial resolution of SAR images was in the range of 10 to 150 m, and a swath width changed from about 70 to 400 km. This combination was unique and revealed the synoptic-scale, mesoscale and fine-scale features of the surface circulation, oceanic dynamic phenomena, wind field, biogenic slicks and oil spills independently of sun illumination and cloud cover. Measurements of SST and wind speed and direction were carried out at the Pacific Oceanological Institute of the Far Eastern Branch of the Russian Academy of Sciences (POI FEB RAS) Marine Stations and at several coastal points during the ASAR- and SAR- data acquisitions. Characteristics of the sea-surface roughness were determined by processing 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 the marine and coastal environment by remote sensing

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

The POI FEB RAS and NOWPAP CEARAC update their website on oil-spill monitoring by remote sensing on a regular basis (Figure 15). The provided satellite images are used as reference information to help assess damage to the marine environment due to oil spills, especially for severe cases such as the Hebei Sprit incident in Korea in 2007 and the Peng Lail 19-3 incident in 2011. The possibility of an extensive oil spill at the Sakhalin II Project has been a concern since crude-oil production became fully functional. This project off the Sakhalin Island in Russia started in 1999. Thus, NOWPAP expanded the geographical target areas of the NOWPAP Regional Oil and Hazardous and Noxious Substances Spill Contingency Plan to the east coast of Sakhalin Island in July 2006. To prevent enormous damage to the marine environment by an oil spill, such as the incident in the Gulf of Mexico in April 2010, it is necessary to conduct regular monitoring using remote sensing and other available best techniques while at the same time constructing a new framework to financially support the activity.

The United Nations Development Programme/Global Environment Facility (UNDP/GEF, 2007) project 'Reducing environmental stress in the Yellow Sea Large Marine Ecosystem' (YSLME) organized the workshop 'YSLME Ocean Color Workshop I' for consulting to develop a regional ocean color algorithm for the YS. The task of the team of scientists was to develop (or refine) an operational regional algorithm for ocean color that works for turbid Case-2 waters. Siswanto *et al.* (2011) published the outcome of this project and the developed algorithm in GOCI data processing for better assessment and future monitoring of primary productivity in the YS.

The IOC/Sub-Commission for the Western Pacific (WESTPAC) and CEARAC conducted the first NEAR-GOOS-NOWPAP joint training course on remote sensing data analysis at Nagasaki, Japan in September 2007. The second NOWPAP training course on remote sensing data analysis was organized by KORDI and CEARAC at Jeju, Korea in November 2008. The course consisted of lectures by specialists and hands-on practical sessions on the 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-area management. In collaboration with the North Pacific Marine Science Organization (PICES) and IOC/WESTPAC, CEARAC conducted the NOWPAP/PICES/WESTPAC Joint Training Course on Remote Sensing Data Analysis at the Far Eastern Federal University in Vladivostok, Russia in October 2011.

The third PICES international summer school entitled 'Satellite Oceanography for the Earth Environment' was held at Seoul, Korea in August 2009. The summer school was sponsored by PICES, the Scientific Committee on Oceanic Research (SCOR), the Research Institute of Oceanography at Seoul National University, the East Asian Sea Time-series project of the Ministry of Land, Transport and Maritime Affairs of the Republic of Korea, the 'Brain Korea 21' Program, 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 in December 2010 in Hakodate, Japan. The aim of this workshop 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 first Asian Workshop for Ocean Color research, 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).

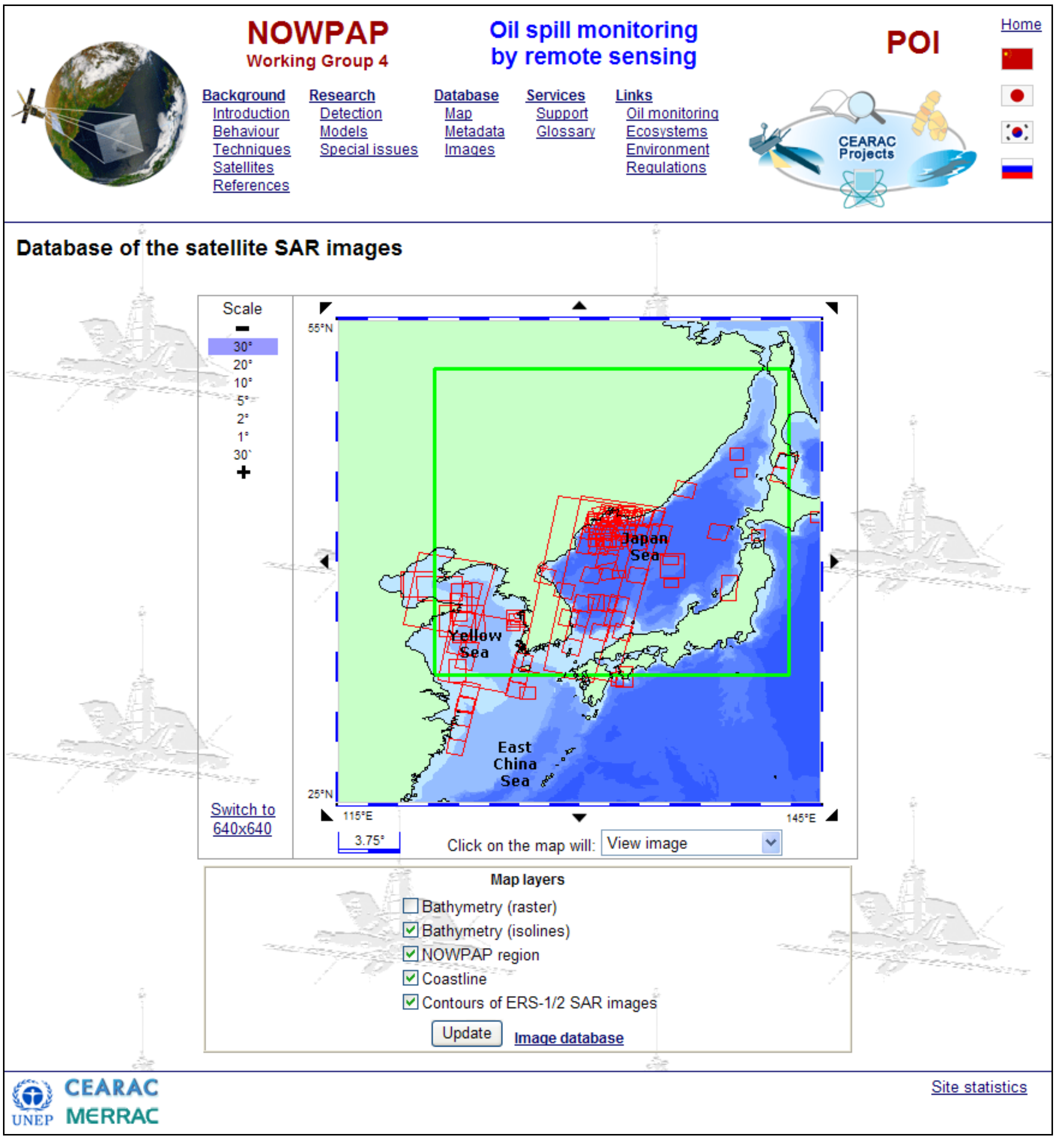


Figure 15. Website on oil spill monitoring by remote sensing <http://cearac.poi.dvo.ru/>

6. Challenges and prospects

6.1. Continuous observations

Satellite remote sensing is capable of providing information on the marine environment over a wider area, without interference of national boundaries, and is helping us to understand various oceanic phenomena that can only be observed 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 change. Therefore, it is ideal that the same sensor series of quality-controlled observation data be maintained for a longer and continuous period on a regular basis. Periodical and continuous ship observations are also necessary for calibration and validation of satellite data. In the areas where long-term observation with the same sensor is difficult, it is necessary to ensure calibration of satellite data among different sensors and to develop new data products.

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

Phenomena such as eutrophication, red tides, HABs and oil spills that can deteriorate the marine environment occur at various spatio-temporal scales. Large-scale phenomena often start from small scales or are an aggregation of small phenomena. The marine environment in coastal areas is dynamically changing because of complex physical processes due to intensive use in fishing and tourism. Thus, it is necessary to develop new sensors and satellites that have higher spatial (20-250 m) and temporal (1-2 per hour) resolution to observe these small phenomena.

The increased number of spectral bands of satellite spectroradiometers in the near future will solve the task of algal-species identification. The approach should be based on hyper-spectral data analysis. This approach is needed in a database of absorption and reflectance coefficients for identification of the most abundant harmful algal species. The database should be created using in-situ or/and laboratory measurements. The latter should be made using live cultures of the algal bloom species.

6.3. Ocean-color remote sensing in coastal areas

The main task for ocean-color remote sensing is the development of bio-optical algorithms for Case-2 waters. Coastal areas are usually areas of turbid waters. The atmosphere correction of radiance measured by satellites over turbid waters is not currently satisfactory (Moses *et al.*, 2009), and so regional algorithms are widely used. For example, the near infrared bands procedure is currently used for atmosphere correction of MODIS data, that often leads to overestimation of chlorophyll-*a* concentration. Bottom reflectance can also be a reason for inaccuracies in bio-parameter estimations that are based on satellite data from the shallow waters of coastal areas.

6.4. Education and capacity building

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

6.5. Evolution to new targets

In the 10th meeting of the Conference of the parties to the Convention of Biological Diversity, held in Nagoya, Japan, in October 2010, delegates adopted Aichi Targets. One of these was Target 11, which states that, by 2020, at least 10 percent of coastal and marine areas, especially areas of particular importance for biodiversity and ecosystem services, need to be conserved through effective and equitable management, ecologically representative and well-connected systems of protected areas, and other effective area-based conservation measures. Coastal areas include habitats such as sea-grass beds, tidal flats, mangroves and coral reefs, all of which construct biological diversity. The effective conservation of these habitats should be addressed.

IOC/WESTPAC organized the 8th IOC/WESTPAC International Scientific Symposium entitled 'Ocean Climate and Marine Ecosystems in the Western Pacific', at Busan, Korea in March 2011. The symposium 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. Parallel to the symposium, the IOC/WESTPAC Workshop on Remote Sensing for Coastal Habitat Mapping was one of the many workshops that took place (IOC/WESTPAC, 2011).

Conserving of marine habitats will lead to the conservation of the greater marine environment. Thus, understanding the status of the habitats and conducting regular monitoring are essential, and ocean-remote sensing can be an effective tool for achieving the ultimate goal.

7. Suggested activities for NOWPAP Region

7.1. Organization of technical training courses

Training courses organized by NOWPAP, PICES and IOC/WESTPAC have been playing an important role in promoting the use of remote sensing data for the conservation of the marine environment in the NOWPAP region. It is expected that these courses will be conducted continuously, will be highly sophisticated and will support past trainees in more effectively monitoring marine-environment problems in the NOWPAP region using remote sensing techniques.

7.2. Cooperation with other international organizations

There are many activities and programs being implemented globally by international organizations using remote sensing of the marine environment. Building a cooperative partnership for these activities and programs is key to effective and efficient implementation of the CEARAC's objectives.

The CoastColour project aims to increase global user uptake of advanced products from the ESA's MERIS mission by developing, demonstrating and validating the latest techniques for monitoring water constituents in coastal areas 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). The YS, ECS and eastern part of the NOWPAP region are registered as test sites and subsets for studying and making available data on surface reflectance, inherent optical properties, water constituent concentrations, water transparency/turbidity information and chlorophyll indices.

The ChloroGIN project aims to deliver products, namely ocean maps of chlorophyll and SSTs, as indicators of the state of the ecosystem needed for ecosystem and fisheries management. At some sites, a measure of light penetration into the ocean is also needed to calculate plankton primary production. The project builds up with the six ChloroGIN nodes, i.e. ChloroGIN-Europe, ChloroGIN-Indian Ocean, ChloroGIN-Antares, ChloroGIN-Africa, ChloroGIN-Canada, ChloroGIN-Asia, as well as Global ChloroGIN (Figure 16). ChloroGIN-Asia is divided into two regions, Northeast Asia and Southeast Asia. JAXA and NPEC, which distributes near real-time MODIS data for the Northeast Asian area, function as the Northeast Asia node of ChloroGIN.

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 area; observation systems being not fully cognizant of the ecological role of the wide variety of potentially HABs 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 HAB scientific communities would gain a great deal by identifying and addressing these issues. The combined IOCCG and IOC-SCOR Research Programme on the Global Ecology and Oceanography of Harmful Algal Blooms (GEOHAB) Working Group, aim to produce a highly approachable 'consumer's guide' to ocean color-based HAB methods. The ecosystem-specific nature of optimal ocean color based HAB observations, the technical difficulties of using ocean color in the optically-complex coastal area, and the need to understand the limitations of ocean color for deriving phytoplankton community composition will be primary focus areas.

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, 2010a). The IOCCG has also been contributing to NOWPAP through advertising and sponsoring of the past NOWPAP training course on remote sensing data analysis.

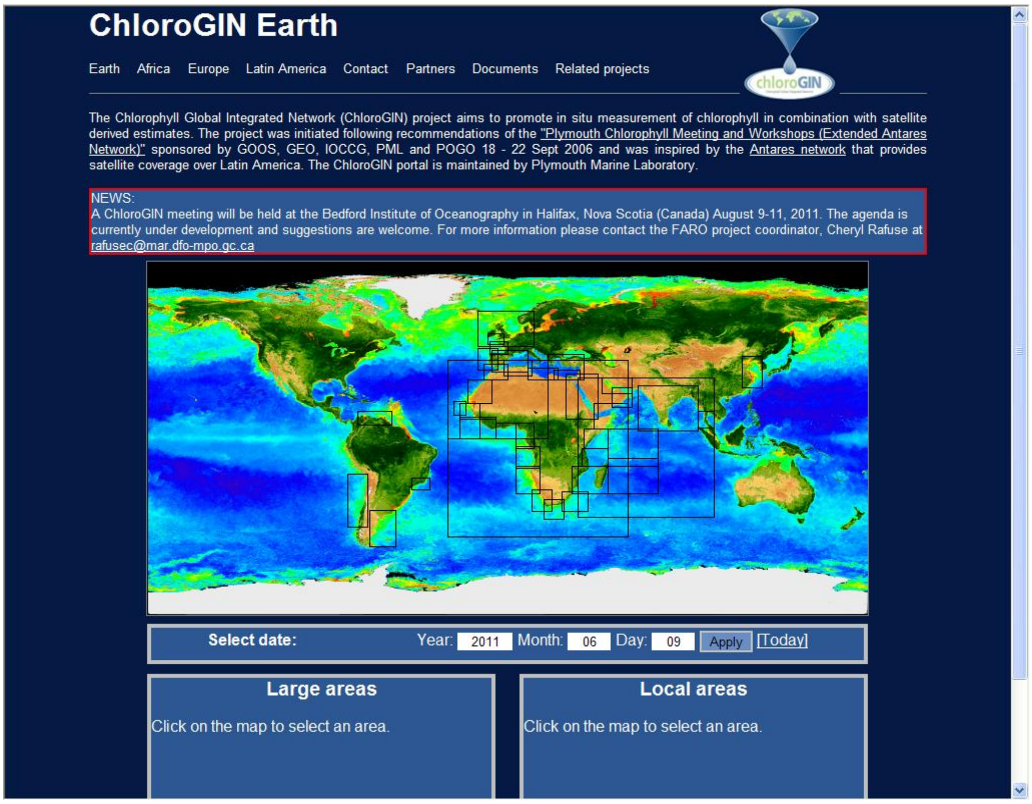


Figure 16. ChloroGIN Portal
<http://www.chlorogin.org/world/>

7.3. Maintaining and enrichment of the remote sensing information network

CEARAC has set up an information network on remote sensing of the marine environment. Information at the following websites of CEARAC should be updated on a regular basis to provide up-to-date information for users 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 relating 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 datasets such as chlorophyll-*a* concentration in turbid water and spectral parameters of HABs
- Time-series plots 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 the marine environment in various institutions and organizations globally. In particular, coordinated research arrangements are needed to address atmospheric correction problems with in-situ measurements in Case-2 waters to develop better algorithms for turbid waters. While outcomes from these research and development activities should be open to users in the NOWPAP region, researchers and scientists need feedback from end users to develop successful outcomes. Therefore, it is necessary to organize workshops or symposia that enhance information on a wide variety of topics from the state-of-the-art techniques to the operational use of remote sensing data.

8. Summary and recommendations

8.1. Summary

1) Remote sensing technology is feasible for the monitoring of eutrophication with longer time series of ocean-color data and oil spills detected by SAR in the NOWPAP region through the interplay of ship, buoy, airborne and satellite observations.
2) Previous, present and planned satellite-sensors from both NOWPAP and non-NOWPAP Members are useful, and the continuation of carefully planned satellite programs along with ground-truth data collection are necessary.
3) Chlorophyll-*a* concentration measured by ocean-color remote sensing for eutrophication monitoring in open ocean is ready for operational use.
4) Chlorophyll-*a* concentration measured by ocean-color remote sensing for eutrophication monitoring in coastal water is also becoming realistic, but careful evaluation of data quality is required for use at a regional level, and further refinement of the algorithms is necessary for some regions.
5) Red tides, suspended matter, organic matter, salinity and near-surface wind are promising indicators for monitoring coastal eutrophication, but refinement of the algorithms is necessary.
6) Detection of phytoplankton pigment groups by ocean-color remote sensing is becoming possible.
7) Monitoring of eutrophication and oil spills by satellite-remote sensing is feasible, but detailed and vast spatial and temporal coverage and financial mechanisms are necessary for its operational use.
8) Continuous support for research activities on algorithm development, the expansion of satellite data applications, and the enhancement of collaborations between researchers in NOWPAP members are needed.
9) Use of satellite data by local governments in each NOWPAP region should be encouraged, particularly in the field of eutrophication assessment and monitoring of oil spills.
10) Public education about the usefulness of remote sensing technology should be encouraged. Information on CEARAC activity associated with environmental monitoring and education should be sent to local governments and published in local newspapers to raise public awareness.

8.2. Recommendations

1) Utilization of ocean-color remote sensing data in the procedures for eutrophication assessment prepared by CEARAC for NOWPAP member states.
2) Training of young researchers, students, and officers of local governments, including a possible dedicated cruise.
3) Maintenance of the NOWPAP Ocean Remote Sensing Portal, a website on oil-spill monitoring by remote sensing and an environmental watch system, including a reference database and educational materials.
4) Joint activities with the IOC/WESTPAC project 'Remote Sensing for Integrated Coastal Area Management'.

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ESA, ESA Portal, http://www.esa.int/

IOCCG, Harmful Algal Blooms and Ocean Colour, http://www.ioccg.org/groups/habs.html

Ministry of the Environment, NPEC/CEARAC, Marine Environmental Protection of Northwest Pacific Region, http://www.nowpap3.go.jp/jsw/eng/

NOWPAP CEARAC, http://cearac.nowpap.org/

NOWPAP CEARAC, Portal Site on Remote Sensing, http://www.cearac-project.org/wg4/portalsite/

NOWPAP CEARAC, Educational materials for utilization of RS data for marine environmental conservation, http://www.cearac-project.org/wg4/em/

NASA, MODIS Website, http://modis.gsfc.nasa.gov/

NOAA, What is NPOESS?, http://www.ipo.noaa.gov/

NSOAS, http://www.nsoas.gov.cn/

PML, ChloroGIN Earth, http://www.chlorogin.org/world/

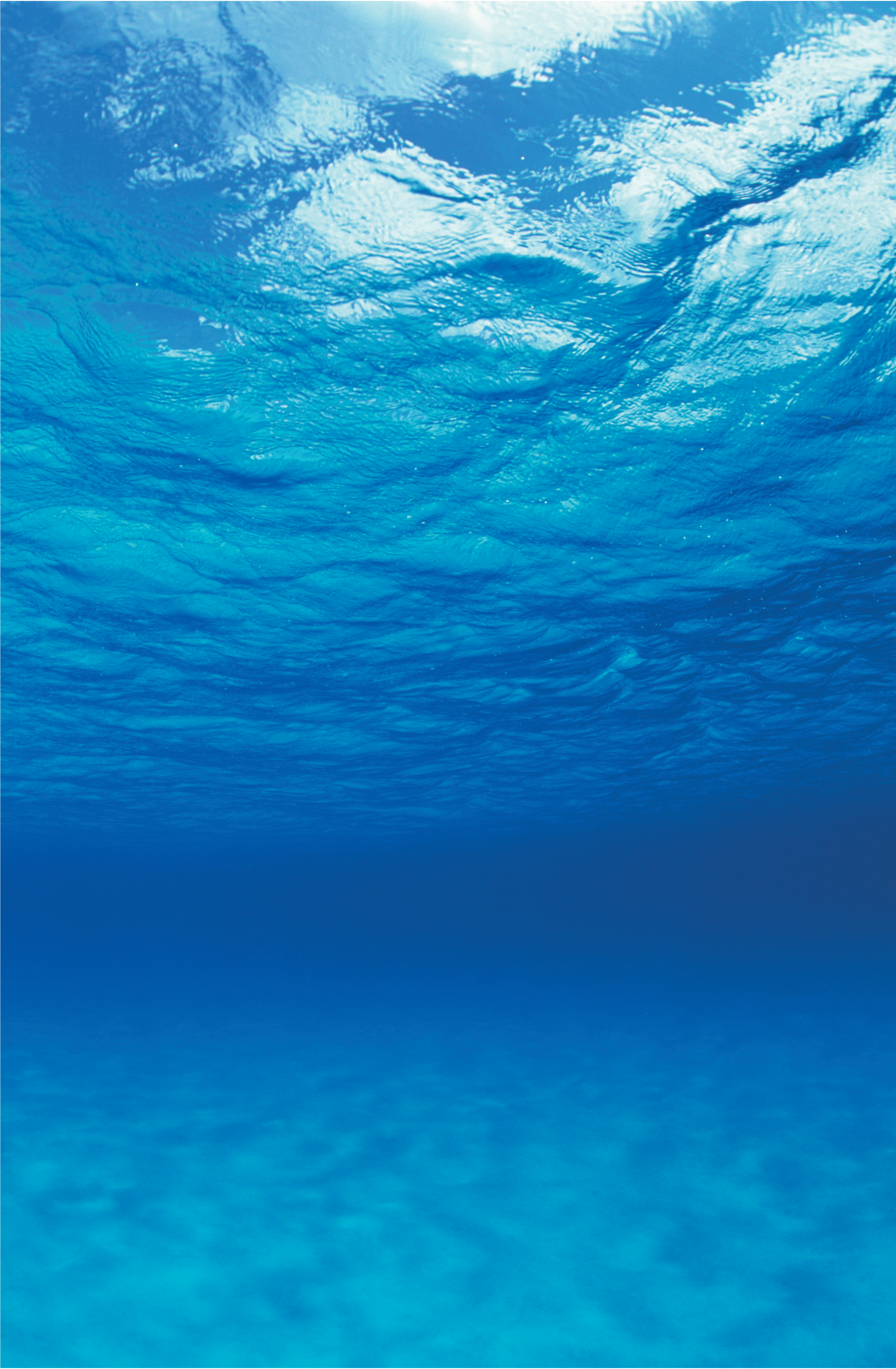
POI/NOWPAP CEARAC, Website on oil spill monitoring by RS, http://www.cearac.poi.dvo.ru/en/about/

Acronyms

AERONET	Aerosol Robotic Network
ADEOS	Advanced Earth Observing Satellite
ALOS	Advanced Land Observing Satellite
AMSR	Advanced Microwave Scanning Radiometer
AMSR-E	AMSR for Earth Observing System
AO	Announcement of Opportunity
AOD	aerosol optical depth
ASTER	Advanced Spaceborne Thermal Emission and Reflection radiometer
ASAR	Advanced Synthetic Aperture Radar
AVHRR	Advanced Very High Resolution Radiometer
AVISO	Archiving Validating and Interpretation of Satellite Oceanographic data
AVNIR	Advanced Visible and Near Infrared Radiometer
BEAM	Basic Toolbox for ENVISAT (A)ATSR and MERIS
BOC	Background Ocean Color
CAS	Chinese Academy of Sciences
CAST	China Association for Science and Technology
CCD	Charge Coupled Device
CDOM	Colored Dissolved Organic Matter
CDW	Changjiang Diluted Water
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
CPI	Composite Pollution Index
CRCS	China Radiometric Calibration Site
CRD	Changjiang River Discharge
CZI	Coastal Zone Imager
CZS	Coastal Zone Scanner
CZCS	Coastal Zone Color Scanner
DMSP	Defense Meteorological Satellite Program
ECS	East China Sea
Envisat	Environmental Satellite
EOL	End of Life
ERS	European Remote Sensing Satellite
ESA	European Space Agency
ETM	Enhanced Thematic Mapper
ETM+	Enhanced Thematic Mapper Plus
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FEB	Far Eastern Branch (Russia)
GAC	Global Area Coverage products
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
GMES	Global Monitoring for Environment and Security
GOCI	Geostationary Ocean Color Imager
GOOS	Global Ocean Observing System

H6	Himawari-6
HAB	Harmful Algal Bloom
IGM	Intergovernmental Meeting
IOC	Intergovernmental Oceanographic Commission of UNESCO
IOCCG	International Ocean Colour Coordinating Group
IPO	Integrated Program Office
IR	Infra Red
ISRO	Indian Space Research Organization
JAXA	Japan Aerospace Exploration Agency
JERS-1	Japanese Earth Resources Satellite-1
KARI	Korea Aerospace Research Institute
KJWOC	Korean-Japan Workshop for Ocean Color
KORDI	Korea Ocean Research and Development Institute
KOSC	Korea Ocean Satellite Center
Landsat	Land Remote Sensing Satellite
LDCM	Landsat Data Continuity Mission
MAPP	Marine Remote Sensing Data Application and Mapping Toolbox
MERIS	Medium Resolution Imaging Spectrometer
MERSI	Medium Resolution Spectral Imager
MODIS	Moderate Resolution Imaging Spectroradiometer
MSI	Multi Spectral Instrument
MSS	Multispectral Scanner
MTSAT	Multi-functional Transport Satellite
NASA	National Aeronautics and Space Administration (USA)
NEAR-GOOS	North-East Asian Regional - GOOS
Net PP	Net Primary Productivity
NFRDI	National Fisheries Research and Development Institute (Korea)
nLw	normalized water-leaving radiance
NOAA	National Oceanic and Atmospheric Administration (USA)
NOWPAP	Northwest Pacific Action Plan
NPEC	Northwest Pacific Region Environmental Cooperation Center (Japan)
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NPP	NPOESS Preparatory Project
NSOAS	National Satellite Ocean Application Service (China)
OCM	Ocean Colour Monitor
OCS	Ocean Color Scanner
OLCI	Ocean and Land Colour Instrument
OLI	Operational Land Imager
OLS	Optical Linescan System
PALSAR	Phased Array type L-band Synthetic Aperture Radar
PAR	Photosynthetically Available Radiation
PFTs	Phytoplankton Functional Types
PML	Plymouth Marine Laboratory (UK)
PI	Principal Investigators
PICES	North Pacific Marine Science Organization
POC	Particulate Organic Carbon
POI	Pacific Oceanological Institute (Russia)
PRESPO	Sustainable Development of the Artisanal fisheries in the Atlantic Area (Pesca RESPOnsável; in Portuguese PRESPO
PRISM	Panchromatic Remote-sensing Instrument for Stereo Mapping
QuikSCAT	Quick Scatterometer
RAS	Russian Academy of Sciences

RCA Red-tide Index Chlorophyll-Algorithm
RGB Red Green Blue
RMS Root Mean Square
ROSHYDROMET Federal Service for Hydrometeorology and Environmental Monitoring (Russia, ROSHYDROMET; in Russian)
ROSKOSMOS Russian Federal Space Agency (ROSKOSMOS; in Russian)
SAR Synthetic Aperture Radar
SCHL Satellite Chlorophyll-*a*
SCOR Scientific Committee on Oceanic Research
SeaWiFS Sea-viewing Wide Field-of-view Sensor
SGLI Second-Generation Global Imager
SIO Second Institute of Oceanography (China)
SLSTR Sea and Land Surface Temperature Radiometer
SOA State Oceanic Administration (China)
SOED State Key Laboratory of Satellite Ocean Environment Dynamics (China)
SPM Suspended Particulate Matter
SRAL Synthetic Aperture Radar Altimeter
SS Suspended Solid
SST Sea Surface Temperature
SWIR Short Wavelength Infrared
TBD To Be Determined
TIR Thermal Infrared
TIRS Thermal Infrared Sensor
TM Thematic Mapper
TSM Total Suspended Matter
UNDP/GEF United Nations Development Programme/Global Environment Facility
UNEP United Nations Environment Programme
UNESCO United Nations Educational, Scientific and Cultural Organization
USGS U.S. Geological Survey
VNIR Visible to Near Infrared
VSF Volume Scattering Function
WESTPAC Sub-Commission for the Western Pacific
WG4 Working Group 4
YS Yellow Sea
YSLME Yellow Sea Large Marine Ecosystem



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