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ASIAN I-LAC PROJECT AND ITS PROGRESS: OCEAN COLOR MONITORING OF THE ASIAN WATERS AND COASTAL ENVIRONMENTS

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ABSTRACT: Satellite remote sensing technology for ocean observations has been rapidly advanced in these twenty years. Ocean color is the most important product of satellite measurements on ocean; it has been shown to play important roles in ecological and photochemical processes. This paper reports an ongoing remote sensing project - "Asian I-Lac Project". The Asian I-Lac Project aims at generating a time series ocean color images, including Chlorophyll-a (Chl-a), Colored Dissolved Organic Matter (CDOM), and Suspended Material (SS). It started from Ocean Color and Temperature Scanner (OCTS) on board of ADEOS-I, and will produce a long-term time series images (planned for 10 years from 1996 to 2006) by combining several ocean color satellite data, i.e., ADEOS-I OCTS, SeaWiFS, ADEOS-II GLI, GCOM1B GLI and some other sensors. The Asian waters are related to about 30 Asian countries, representing about 60% of the world population. High spatial resolution (700m) OCTS images have been processed; processing of SeaWiFS images on the Asian waters is on going. OCTS image coverage and data quality were analyzed for the period of November 1996 to June 1997. The data system provides ocean color scientists with capability of testing or developing their algorithm, and transferring images for their research. By analyzing OCTS-derived Chl-a images, we observed sort-term variability of phytoplankton blooms associated with cold SST eddies in the Gulf of Oman in1996. Distribution pattern of OCTS-derived Chl-a, CDOM and SS have been also analyzed for the Arabian Sea, the Gulf of Thailand, and the Chinese coastal waters. Results demonstrate the potential of Asian I-Lac Project in research on marine biology, coastal environments, and ocean study.

1. INTRODUCTION

Satellite remote sensing technology for ocean observations has been rapidly advanced in these twenty years. At

the beginning of eighties, only AVHRR on board NOAA satellites for sea surface temperature was operationally flying and quite small number of oceanographers became aware of potentialities of the other satellite methods, i.e., the altimeter for geostrophic currents, the microwave scatterometer for surface wind vector, and the ocean color for marine biological parameters even though the first satellite measurements were presented by SEASAT and NIMBUS-7. In contrast, we have enough number of the satellite oceanographic sensors now orbiting and soon being launched. The oceanography-related communities have well understood performances of the satellite ocean observations and started to work for enhancements of their potentialities. The satellite observations are quite good tools for ocean monitoring because their repeated wide and frequent coverage with high spatial resolutions. It is considered that the huge satellite information on the ocean states will enable us to predict sort-term variations of the ocean, which leads us to the operational forecasting of ocean weather.

The Asian waters are related to about 30 Asian countries, representing about 60% of the world population. Recent rapid industrialization in Asia has placed very heavy burdens on the coastal environment. Although there are serious needs of appropriate observation systems for the Asian waters, it had been quite difficult to monitor these international waters by means of traditional *in situ* methods. Since wide coastal seas are bordered by coastal lines and open oceans, there appear both clear waters of open oceans and rather turbid coastal waters. For most regions of the world, the color of ocean is determined primarily by the abundance of phytoplankton and its associated photosynthetic pigments. As the concentration of phytoplankton pigments increases, ocean color shifts from blue to green. In contrast, color of the turbid coastal waters changes depending on its constituents of not only the phytoplankton pigments but also various types of suspended sediments and the others.

Among the several ocean remote sensing methods, the ocean color measurements provide us information on the organic and inorganic suspended materials in the surface layer. Impacts of human activities are transferred from the land to the ocean mainly through the rivers and the coastal lines, which changes the ocean color directly by advection and diffusion or indirectly by the biological and chemical processes. Therefore, to investigate the oceanic environment, the ocean color remote sensing is a key technology. The ocean color sensors have narrow bands of the visible and near-infrared and provide a discrete spectrum of target water color. It is well recognized that the chlorophyll-a (Chl-a) concentration can be retrieved well in the clear open oceans from the satellite ocean color measurements, but there are still some technical problems for its retrieval in the turbid coastal waters (IOCCG, 2000).

2. ASIAN I-LAC PROJECT

ADEOS-I carrying OCTS was launched on 17 August 1996. OCTS observed both ocean color and sea surface temperature from October 1996 to June1997, and provided a valuable 10 months record of high-spatial resolution (700 m) data set for oceanographic research (Kawamura and the OCTS team, 1998). SeaWiFS was launched on August 1, 1997 aboard the Orb View 2/Sea Star satellite, which is currently providing useful global observations of ocean color. Recently, several new ocean-color sensors have been launched by various countries, all providing excellent coverage of the Asian waters. The Indian OCM, the Korean OSMI, the Taiwanese OCI, NASA's

MODIS are now in space (IOCCG, 1998). Some other new ocean color sensors, such as MERIS on ENVISAT (ESA EU), GLI on ADEOS-II (NASDA Japan), and MODIS on AQUA (NASA US) will also be launched in near future.

The Asian I-Lac Project has been designed to: (i) reprocess ADEOS-I OCTS ocean color data with improved algorithms; (ii) establish a long-term series of ocean color images by combining several ocean color satellite data; and (iii) set up high-spatial resolution (<1 km) ocean color database for the Asian waters (Figure 1 and 2). The Asian I-Lac project, designed on the basis of the OCST I-Lac project (Kawamura and the OCTS team, 1998), was initiated in 1999. The new ocean color data processing system is now established at the Center for Atmospheric and Oceanic Studies of the Tohoku University in Japan. New algorithms with in-water correction and atmospheric correction are under development. Products of the OCTS reprocessing include, at least, nLws, Chl-a and K490. An OCTS image browsing system is developed to provide users with capability of browsing images, selecting data, and transferring images for their research.

3. RESULTS AND DISSCUSSION

3.1 Chlorophyll Distribution on the Asian Waters

Figure 3 is an example of composite image of OCTS-derived chlorophyll-a (by standard algorithm) in November 1996. The coastal lines are shown in white color and clouds are in black color. This image illustrates the distribution patterns of chlorophyll concentrations on that part of the Asian waters with good coverage. Chlorophyll concentrations were high in the north coastal area of the South China Sea, north coastal areas of the Bay of Bengal, and on the whole northern Arabian Sea, particularly on the mouth of the Gulf of Oman.

Distribution patterns of chlorophyll (by standard algorithm) on the Asian waters during December 1996 to March 1997 are shown in Fig. 4a-d. In November 1996 (Figure 3), chlorophyll concentrations were high on the coastal areas, and in the northern of Arabian Sea. A patch of intensive high chlorophyll concentrations appeared on the Gulf of Oman (white circle). In December 1996 (Fig. 4a, composed by 26 scenes), high chlorophyll concentrations appeared in the Yellow Sea (white circle) and northern of Arabian Sea, but that patch of high chlorophyll concentrations previously observed on the Gulf of Oman had disappeared. Fig. 4b (composed by 47 scenes) shows high chlorophyll value along the coastal area of China (white circle) in January 1997. Chlorophyll distribution pattern in the Bohai and the Arabian Sea in February 1997 are shown in Fig. 4c (composed by 34 scenes). The chlorophyll concentrations were also high in the northern of Arabian Sea (white circle). Fig. 4d (composed by 52 scenes) is a monthly composite image of March in 1997. High chlorophyll concentrations can be identified in the Bohai Sea and the coastal area of Australia (white circle).

3.2 Phytoplankton Blooms on the Northern Arabian Sea

When processing OCTS images for the Asian waters, we noticed intensive phytoplankton blooms with high chlorophyll values (>8mg m^3) in the northern Arabian Sea (small red box in Figure 3 and Fig. 5) in November

1996. The blooms had a round shape of 100 km in diameter in the Gulf of Oman (60.5 ^{o}E, 24. ^{o}N) (A in Fig.5). The bloom appeared as an anticyclone eddy feature and was accompanied by another cyclone eddy feature of lower chlorophyll values (B in Fig.5) in the southwest (61.5 ^{o}E, 22.5 ^{o}N). With high spatial resolution, Fig. 5 also shows some other eddy features on that area.

The northern Arabian Sea is a semi-enclosed sea. Despite the observations made during the international Indian Expedition (IIOE), lager regions of the northern Arabian Sea, including the Persian Gulf and the Gulf of Oman, have remained unknown or poorly know (Qasim, 1982; Shetye et al., 1994). Satellite ocean-color for chlorophyll concentrations is a new approach for understanding of the marine biology, such as phytoplankton blooms, and oceanic physical processes, such as eddies (Tang et al., 2001).

4. SUMMARY

The Asian I-lac Project is generating a long-term time series of the ocean color images with high spatial resolution on the Asian waters. The data system provides ocean color scientists with capability of testing or developing their algorithm, and transferring images for their research. The OCTS-derived chlorophyll concentrations varied from time to time on the Asian waters. In the winter season, chlorophyll concentrations were high on the north of Arabian Sea, and along the coasts of China and Australia. Intensive phytoplankton blooms and eddies were observed in the Gulf of Oman in the north of Arabian Sea. OCTS image coverage is good for the northern Arabian Sea during the winter season. The reprocessed Asian I-Lac OCTS images demonstrate the potential of the wide-ranging ocean color data with 700 m spatial resolution in research in marine biology, environment, and development of ocean color algorithms.

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Figure 1, Aerial coverage of Asian I-Lac region

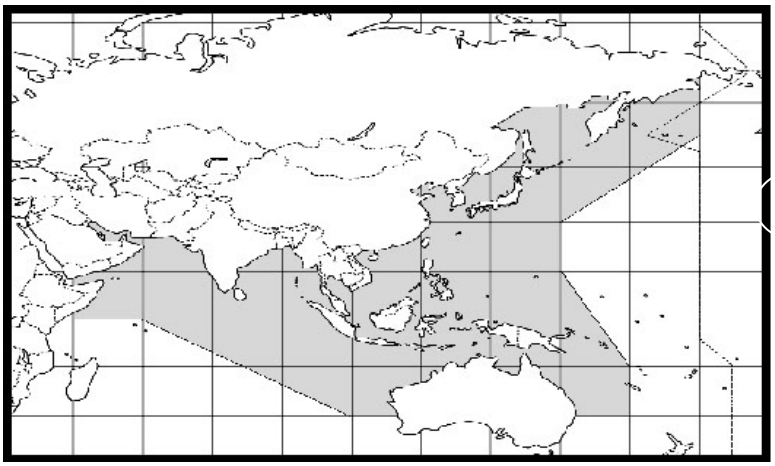


Figure 2, Time schedule of available satellites for AI project

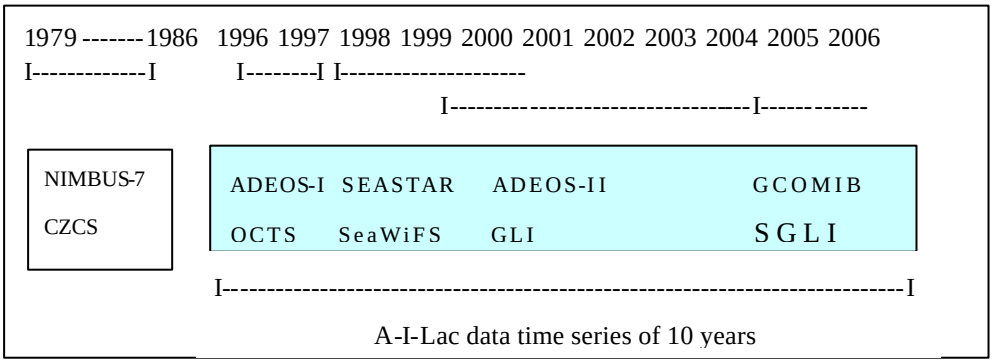


Figure 3, Monthly composite OCTS image (Chl-a) for November 1996

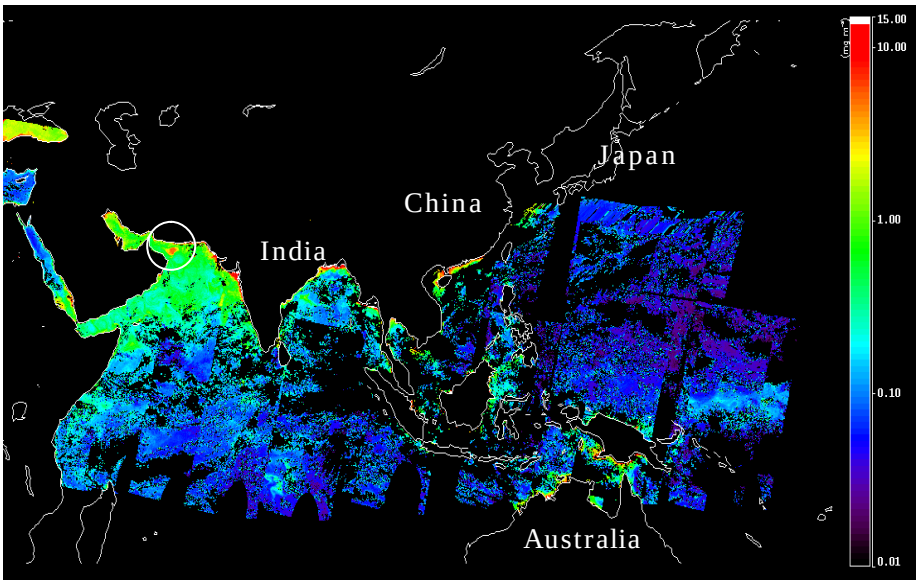
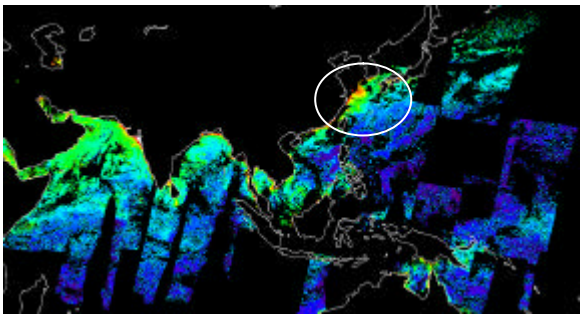
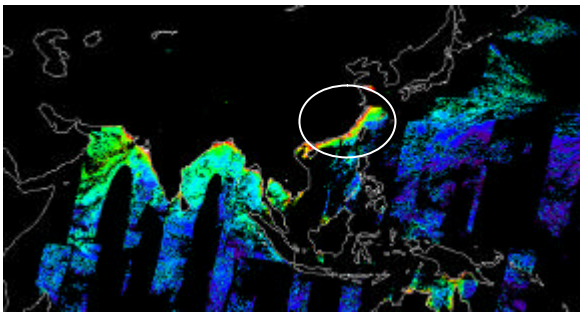


Figure 4, Monthly composites OCTS images (Chl-a) for December, January, February and March 1997

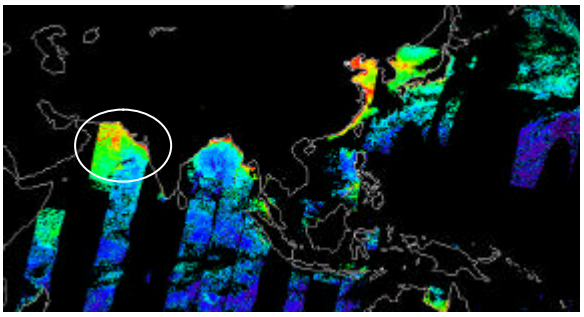
A, December 1996



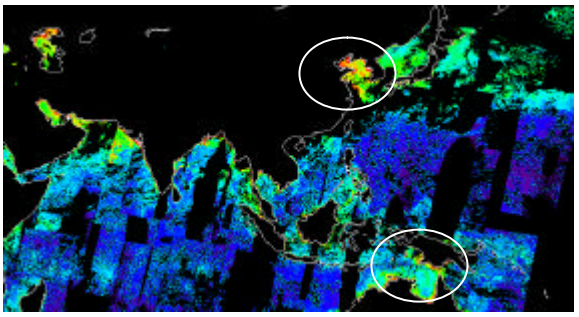
B, January 1997



C, February 1997



D, March 1997



(Color bar for Fig 4)

Fig. 5, OCTS-derived Chl-a images in the Arabian Sea in November 1996