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Monitoring of Climatological Variability Using EOS and OSMI Data

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Abstract : Dramatic changes in the patterns of satellite-derived pigment concentrations, sea-level height anomaly, sea surface temperature anomaly, and zonal wind anomaly are observed during the 1997-1998 El Niño. By some measures, the 1997-1998 El Niño was the strongest one of the 20th century. A very strong El Niño developed during 1997 and matured late in the year. A dramatic recovery occurred in mid-1998 and led to La Nina condition. The largest spatial extent of the phytoplankton bloom was followed recovery from El Niño over the equatorial Pacific. The evolution towards a warm episode (El Niño) started from spring of 2002 and continued during January 2003, while equatorial SSTA remained greater than +1°C in the central equatorial Pacific. The OSMI (Ocean Scanning Multispectral Imager) data are used for detection of dramatic changes in the patterns of pigment concentration during next El Niño.

Key Words : El Niño, Climatological Variability, OSMI, EOS.

1. Introduction

El Niño is characterized as one of the most dramatic examples of a large amplitude, interannual response of the ocean to atmospheric forcing. The 1997-1998 El Niño is the best documented and strongest event of this nature to date. Chavez *et al.* (1999) investigated dramatic biological and chemical response of the equatorial Pacific ocean to the 1997-1998 El Niño. It is possible to capture the dramatic event because of in situ sensors on moorings, regular ship visits to service the moorings, and remote sensing of ocean variables. Takayabu *et al.* (1999) examined the reason which resulted in abrupt the termination of the 1997-1998 El Niño. According to the research, in spite of no previous observations of the Madden-Julian oscillation (MJO) that triggered the termination of El Niño events, MJO may be the possible reason for the abrupt termination.

In this paper, 1997-1998 El Niño was investigated with EOS (Earth Observing System) and TAO (Tropical Atmosphere Ocean) data. Here we combine the biological and dynamical information from the moorings, Sea-viewing Wide Field-of view Sensor (SeaWiFS), and reanalysis data that can be helpful for the description of the biological-dynamical coupling in the equatorial Pacific. It is also examined whether the

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global distribution of chlorophyll by OSMI can be used for detection of El Niño.

2. Data

The datasets used for this study consist of TAO array data, National Center for Environmental Prediction (NCEP) optimum interpolation (OI) sea surface temperature (SST) and reanalysis data, SeaWiFS and Ocean Scanning Multispectral Imager (OSMI) chlorophyll concentration, TOPography EXperiment for Ocean Circulation (TOPEX)/POSEIDON sea level height.

The development of TAO array was initiated by the 1982-1983 El Niño, the strongest one of the century up to that time, which was neither predicted nor observed until nearly at its peak. The event emphasized the need for real-time data from the tropical Pacific for monitoring, prediction, and improved comprehension of El Niño event. In 1985 at the start of the 10-year (1985 - 94) international Tropical Ocean Global Atmosphere (TOGA) program, NOAA Pacific Marine Environment Laboratory (PMEL) began deployments of the TAO array with support from NOAA's Equatorial Pacific Ocean Climate Studies (EPOCS) program. The TAO array operationally supports measurements of winds, SST, relative humidity, air temperature, and subsurface temperature at 10 depths in the upper 500m.

The NCEP OI SST data is produced using in situ and satellite SST's plus SST's simulated by sea-ice cover. A description of the OI SST analysis is found in Reynolds and Smith (1994) and the bias correction improves the large scale accuracy of the OI SST. The SST anomaly (SSTA) is the departure from the adjusted OI climatology for the 1961 - 1990 base period (Smith and Reynolds, 1998). The NCEP reanalysis data has a horizontal resolution of 2.5° × 2.5° and 17 vertical levels (Kalnay *et al.*, 1996). Through internet site(http://www.scd.ucar.edu/dss/pub/reanalysis), the reanalysis data are available for the period starting from 1949 up to the present.

In August 1992, TOPEX/POSEIDON was launched from the European Space Agency's Space Center located in Kourou, French Guiana. From its orbit 1,336 kilometers above the Earth's surface, TOPEX/POSEIDON measures sea level height along the same path every 10 days using the dual-frequency radar altimeter developed by NASA and the CNES single-frequency solid-state radar altimeter. In the central equatorial Pacific, the large area associated with growing El Niño conditions which is higher than normal sea surface heights can be observed.

3. Analysis of the 1997 - 1998 El Niño Case

Since the observation of an El Niño during 1997 - 1998, it has been classified as the greatest large-scale El Niño. Through the analysis of meteorological and oceanic data (SST, sea level height, ocean color, wind field) investigation into the 1997 - 1998 El Niño was carried out. Satellite data as well as TAO data were acquired for analysis. The TAO data are very useful for El Niño, La Nina, Global Climate Observing System (GCOS) and Global Ocean Observing System (GOOS).

The average of ocean variables of the equator areas ranging between 2°S - 2°N was obtained from TAO data, which were observed from January 1997 to December 1999. Fig. 2 displays the 20°C isotherm depth and anomalies. During the period of 1997 - 1998 El Niño occurring and maturing, while the 20°C isotherm depth of the East Pacific Ocean deepened, the 20°C isotherm depth of La Nina (observed during 1998 to 1999) lowered, which can be understood in Fig. 2. The average of the identical area was obtained using the same method and as a result, the distribution of the SST

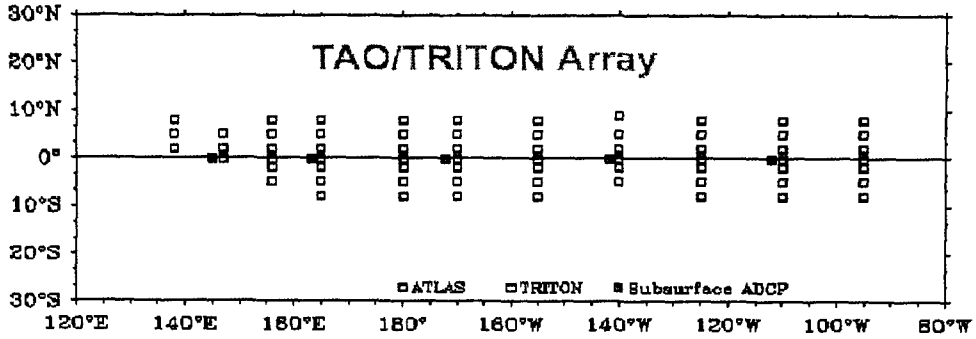

Fig. 1. TAO set up locations.

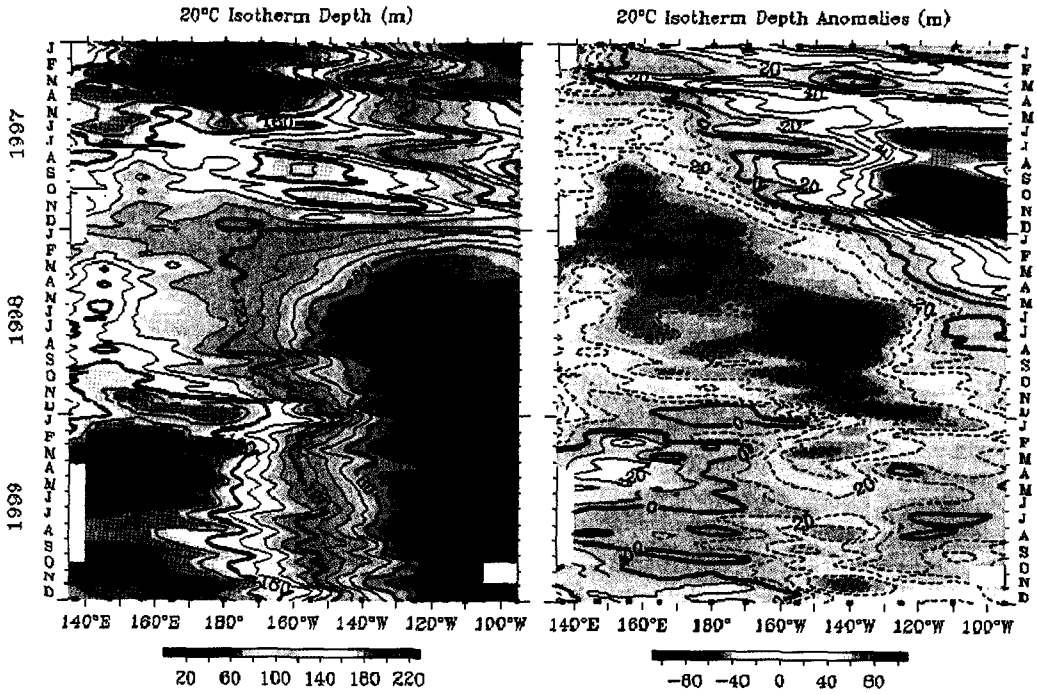

Fig. 2. 20°C isotherm depth and anomalies distribution of the observation/averages observed from TAO between 2°S - 2°N.

and SSTA presented in Fig. 3 was derived. During the occurrence and maturing period of an El Niño from 1997 - 1998 (East Pacific Ocean), the SST rose over 4°C. However, La Nina reacted oppositely. During the period of La Nina from 1998 to 1999, the SST declination was observed.

Other than the data observed from TAO, sea level height, sea surface temperature anomaly (SSTA), ocean color, and wind field of January, July and December (1998) were examined. Fig. 4 shows NCEP SSTA in January 1998, when an El Niño matured, in July when an El Niño was breaking down, and then in December when a La Nina began to appear. SSTA in January 1998 was close to the highest value observed during the

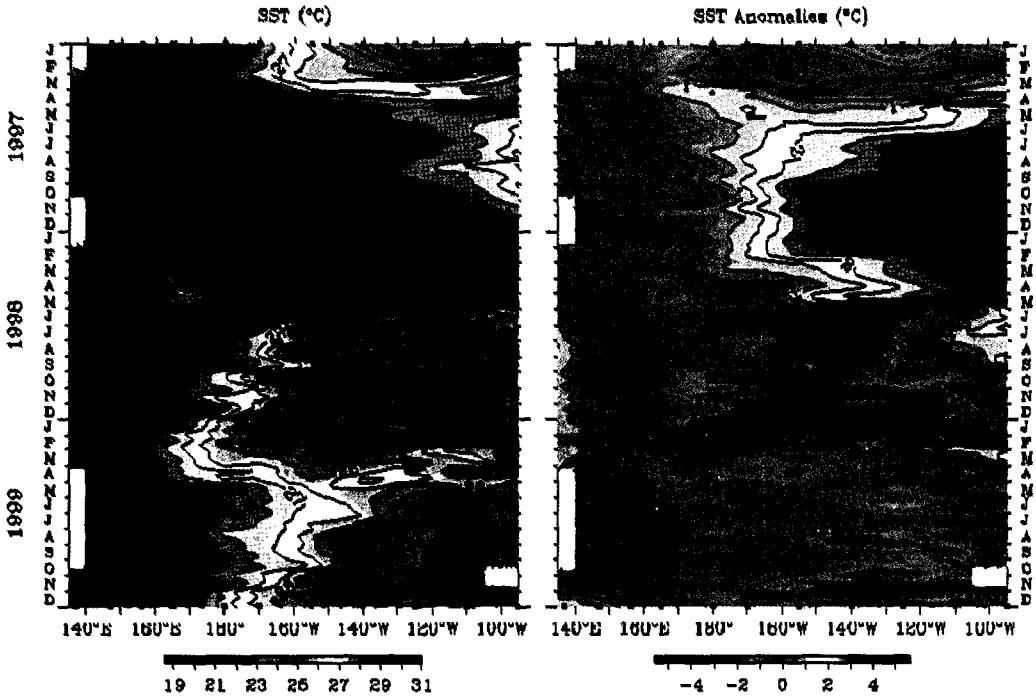

Fig. 3. Sea surface temperature and anomaly distribution of the observations/averages observed from TAO between 2°S - 2°N

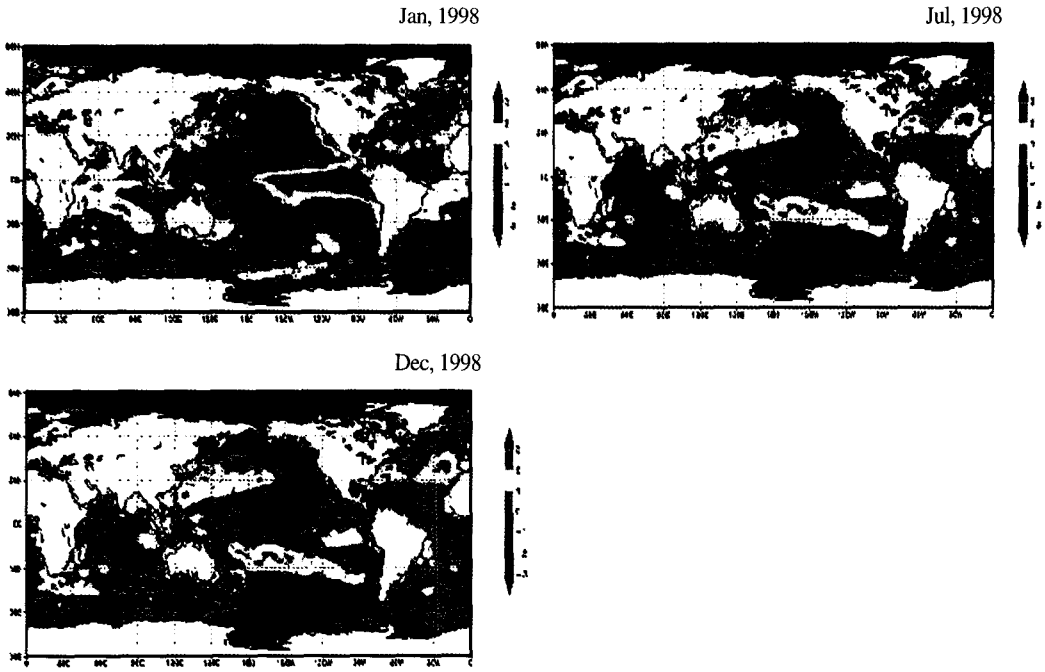

Fig. 4. SSTA observed in January, July, and December of 1998.

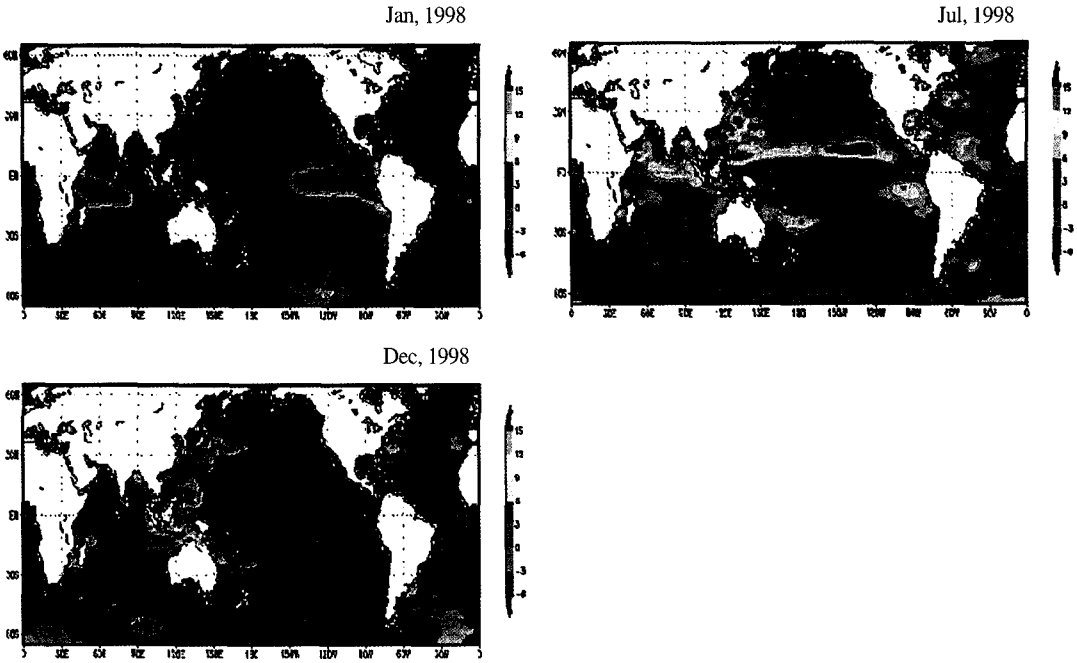

Fig. 5. Sea level height anomaly observed in January, July, and December of 1998.

1997 - 1998 El Niño. A weakening and reversal of the trade winds in the western and central equatorial Pacific was followed by the rapid development of extraordinarily warm SST in the eastern direction of the international date line in early 1997. It was not until the trade winds abruptly returned to near normal in the east Pacific in mid-May 1998. Takayabu *et al.* (1999) suggested that MJO may be the possible reason for the abrupt termination of the 1997 - 1998 El Niño. Therefore, there might be a cold tongue over the central Pacific in July 1998.

The sea level height anomaly observed by TOPEX/POSEIDON is used as an index of an El Niño occurrence together with SSTA. Fig. 5 displays the sea level height anomaly during the identical periods of Fig. 4, which was the occurrence and maturing period of an El Niño. The SSTA appears higher in the East Pacific Ocean and the sharp rise in the sea level height anomaly can be seen. In reality, the El Niño already terminated in July as the rise in the sea level height anomaly in the East Pacific Ocean ceased. It is noticed in Fig. 4 that a La Nina began to develop in December, and in Fig. 5 that the heavy declination of sea level anomalies was observed. The time series of the rise in SST and sea level height referring to before and after an occurrence, that is, what variables are leading, are not analyzed in this study. Such research on the change of ocean variables in relation to an El Niño can be thought that there is value in its analyzing. Before the application of the 1992 TOPEX/POSEIDON, SSTA was the principle data that informed of an El Niño occurrence, even though during the 1997 - 1998 El Niño occurrence, the sea level height anomaly was also an important index.

SeaWiFS, which was launched by NASA in August 1997 and is currently in operation, has the same sensor characteristics as those of OSMI - observing ocean color through chlorophyll distribution. Fig. 6 displays the ocean color of identical periods, showing the plankton distribution of the ocean, while the plankton distribution of January 1998 in the East Pacific Ocean and South

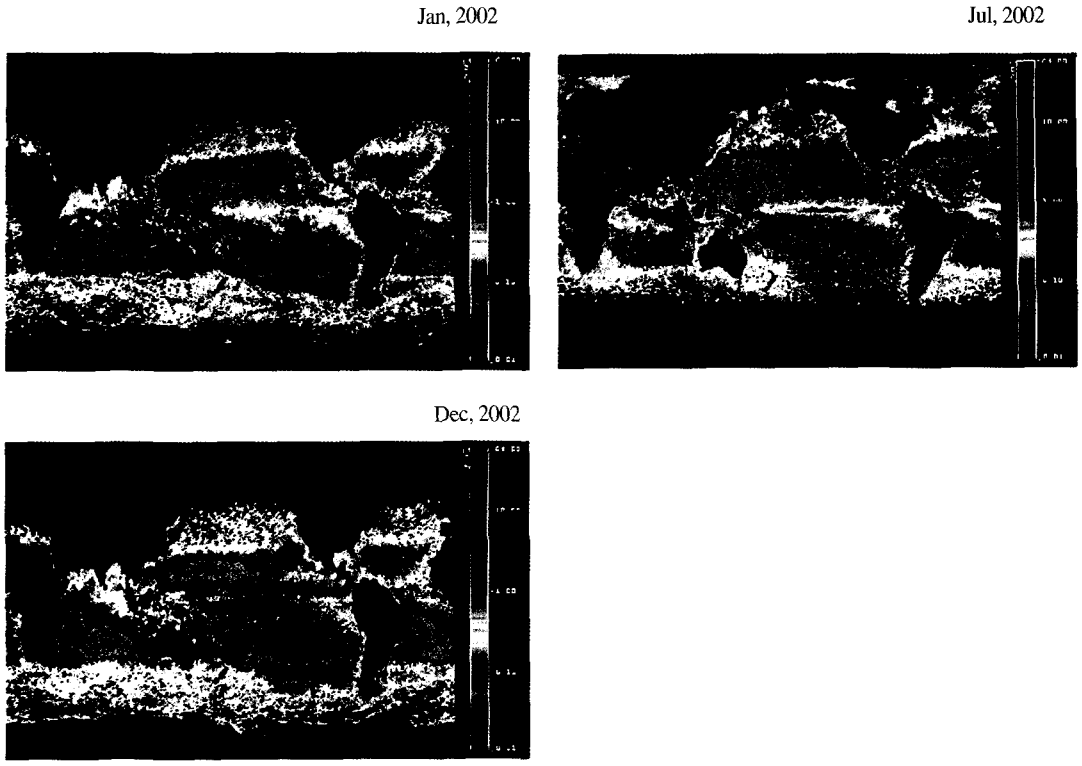

Fig. 6. Plankton distribution observed in January, July, and December of 1998.

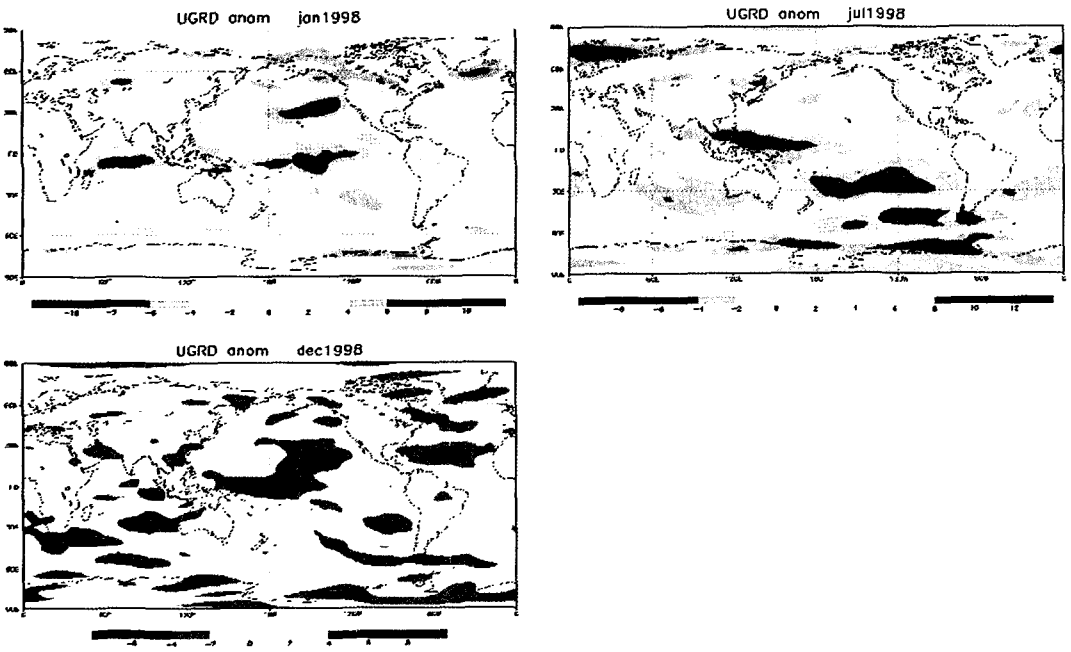

Fig. 7. East-westerly wind anomalies observed in January, July, and December of 1998.

American coast, where the SST has risen in Fig. 4, is distinctively low, in the months of July and December, it is very high. This is due to the weakening of upwelling, and thus the nutrient salts cannot appear up onto the surface during the maturing period of El Niño. Therefore, the fishing quantities (including anchovy) of the South American coast are rapidly reduced during the maturing period. That is, the fishing quantities naturally decrease due to the rapid reduction in plankton. Contrary to that, it is known that the upwelling strengthens again as El Niño weakens, the plankton distribution increases - similar to the case in July 1998.

The monthly means of global plankton distribution for April, May, and June 2002 were processed in KARI ground station (Figures not shown). Because of 20 % duty cycle, global map.is not like monthly mean map of SeaWiFS. Even though there are some missing data over the global area. It is possible to know the trend of the monthly mean of Plankton distribution. The evolution towards a warm episode (El Niño) started from spring of 2002 and continued during January 2003, as equatorial SSTA remained greater than +1°C in the central equatorial Pacific. Recent values of atmospheric and oceanic indices are considerably smaller in magnitude than those observed during the 1997 - 1998 El Niño. According to comparison with the previous El Niño for the whole equatorial Pacific, in the last 50 years, the current El Niño is moderate in intensity. Most forecast models indicate that El Niño conditions will continue to weaken through April 2003 and will be for near - normal conditions during May - October 2003.

When an El Niño occurs, Equatorial Pacific Ocean's SST, sea level height, chlorophyll distribution, and wind field are very different to normal periods. Among the NCEP reanalysis data, the anomalies of the east-westerly winds were examined (Fig. 7). During the maturing of an El Niño in January 1998, westerly winds were strengthening at the East Pacific Ocean equator, and in July, during the declining period, it was weakening. But it is known that the easterly winds strengthen once again in December.

4. Conclusions

Using EOS and TAO data, dramatic changes in the patterns of satellite-derived pigment concentrations, sea-level height anomaly, SSTA, and zonal wind anomaly are observed during the 1997-1998 El Niño, the strongest one of the 20th century. The evolution towards a warm episode (El Niño) started from spring of 2002 and continued during January 2003, while equatorial SSTA remained greater than +1°C in the central equatorial Pacific. Recent values of atmospheric and oceanic indices are considerably smaller in magnitude than those observed during the 1997 - 1998 El Niño. The OSMI data can be used for detection of changes in the patterns of pigment concentration during next El Niño.

Acknowledgements

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