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MEAN SEA LEVEL EXTRACTION AND ANALYSIS FROM TIDAL MEASUREMENTS

1. Study of mean sea level is an important aspect in any climate related research and this paper presents the work carried out at NIOT on the measurement of sea level, extraction of mean sea level and analysis of the correlation with atmospheric phenomena at Tuticorin along the east coast of India.

Mean sea level (MSL) studies form the basis for understanding ocean atmosphere processes, climatic changes and variations in local weather phenomena. It is derived by averaging the elevations of the sea surface as measured by tide gauges over a long period of time. Sea levels vary greatly from one location to another and locally the levels of the surface of the world's oceans are disturbed by wind-driven waves and tides. Sea level therefore fluctuates in periods ranging from seconds to a year as a result of these factors. The variation of mean sea level over a long period has far reaching effects, such as inundation etc. A careful study of mean sea level can throw light on seasonal variation of mean sea level and global warming. Hence, the analysis of mean sea levels is the first step in carrying out any climate related research.

Fig. 1. NIOT ATG at Tuticorin

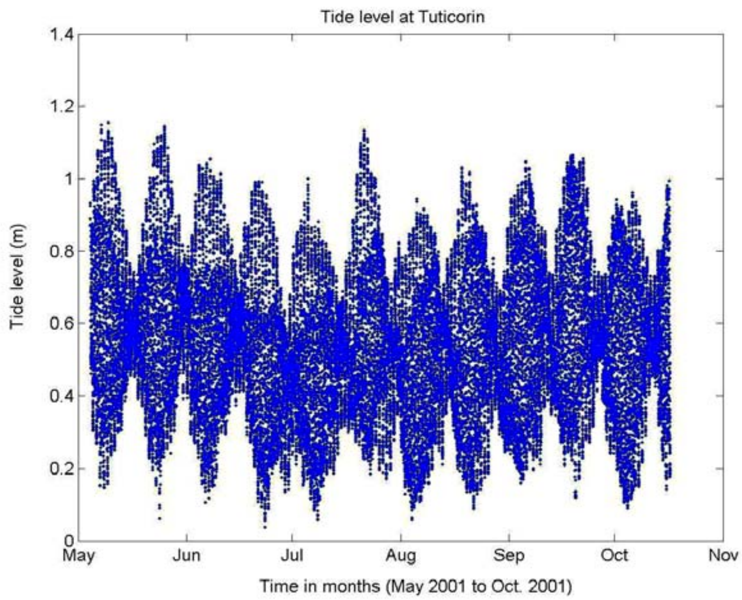

Fig. 2. Measured tide data at Tuticorin using NIOT ATG

The basis for analysis of sea level is the long series of careful measurements. Errors in measurement of sea level as well as the errors in time measurements can result in spurious mean sea level calculations. In view of the above, development of sea level observation systems and sea level monitoring have become globally significant over the last several years. In this context, Marine Instrumentation group of National Institute of Ocean Technology, has developed, tested and successfully demonstrated an Acoustic Tide Gauge (ATG), which records tide levels accurately.

The real time sea level data are obtained since the year 2000 using the ATG at few locations along the east coast of India. One of the objectives of this work is to initiate analysis of mean sea levels at these sites and correlate with weather phenomena. This would form the basis to carry out further research when a network of tide gauges are installed leading to more data along the coastal stations.

As a preliminary study, Ramadass *et al.* (2001) carried out daily mean sea level extractions from measured tides using NIOT ATG at Port Blair, India. Singh (2002) have studied ENSO (El-Nino Southern Oscillation) modes of inter-annual variability of sea level along the Indian coast. The correlation of SOI (Southern Oscillation Index – a parameter indicating El Nino and La Nina phenomena) with MSL has been presented in their work. They obtained a high correlation coefficient of SOI and MSL along the east coast of India during intense cyclone periods. In this paper daily mean sea levels are extracted from measured tides at Tuticorin, India. Then the trends of mean sea levels are analysed and correlation with the ENSO epoch is deduced.

2. ATG works based on the principle of acoustic ranging. An acoustic pulse generated by a transducer is guided towards the water surface by a sounding tube whose open end is immersed in water. The same transducer is used to receive the echo from the water. A unique calibration technique, based on which a patent is obtained, is used to calibrate each water level measurement, against the variation of temperature and humidity.

Centered around every 6^{th} minute of each hour, water level samples have been recorded continuously and the average and standard deviation are computed. Outliers have been removed and mean is recomputed. This process removes the effect of waves and other high frequency water level variations. Each tide measurement is time stamped by the on board computer of Acoustic Tide Gauge. Thus, accurate tide levels are recorded.

NIOT ATG 'SWARAJ' (Fig. 1) has been installed at Tuticorin in May 2001 and the sea level is being obtained from ATG.

3. Sea level at any instant of time is defined as

Mean sea level + tide + surge

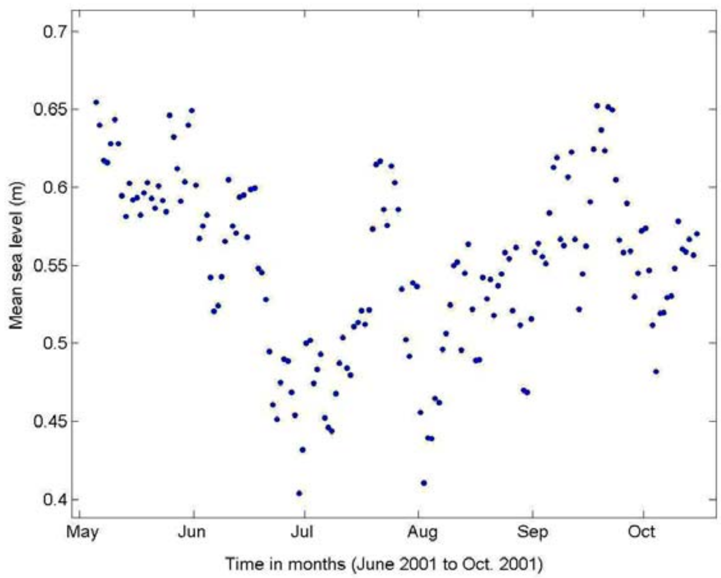

Fig. 3. Daily mean sea level at Tuticorin for the period May-October 2001

Mean sea level is not a constant quantity, but the variation is small when compared to the variation in the tide level due to diurnal, semi diurnal and other geophysical components.

The data collected in the year 2001 is shown in Fig. 2. The maximum tidal variation is around 1.2 meters above the chart datum.

There are no gaps in the data for the period shown. There are several techniques available to extract the mean sea level from the tide data. David (1987) and UNESCO Report (1985) presented some of these techniques. All these methods are based on the application of suitable filters to eliminate the unwanted components except the mean sea level. Doodson and Warburg (1941) filter is one of the earliest of these filters and is a robust technique for data with occasional gaps. Implementation of this X_0 filter for calculation of sea level for a day at 12 noon, needs 39 hourly tidal values centered around 12 noon. The purpose of this low pass filter is to remove the tidal energy at diurnal and higher frequencies from sea level elevation.

This filter is defined as follows :

$$F(t) = (2,1,1,2,0,1,1,0,2,0,1,1,0,1,0,0,1,0,1) \text{ for } 1 \geq t \geq 19$$

The filter is symmetric, so that

F(t) = F(-t) and can be applied for each day given the mean

$$X_T = 1/30 \sum_{-19}^{+19} F(d)\, H(H + d)$$

where $d \neq 0$;

where H(d) is the sea level elevation and T = 1200 hours.

The implementation of other filters using 72 or more hourly data improves the filtering over Doodson filter only marginally, but can cause oscillations due to sharp cut off.

The NIOT ATG data starting May 2001 have been used and hourly data have been obtained by suitable interpolation method. Doodson X_0 filter is applied on this data to obtain daily mean sea level. Also a polynomial fit for the monthly mean sea level is made and the trend is analyzed.

4. The daily mean sea level extracted from the ATG data is shown in Fig. 3. Along the east coast of India, the intense tropical cyclone period is May, October, November and the southwest monsoon season is between June and September. The results show that the

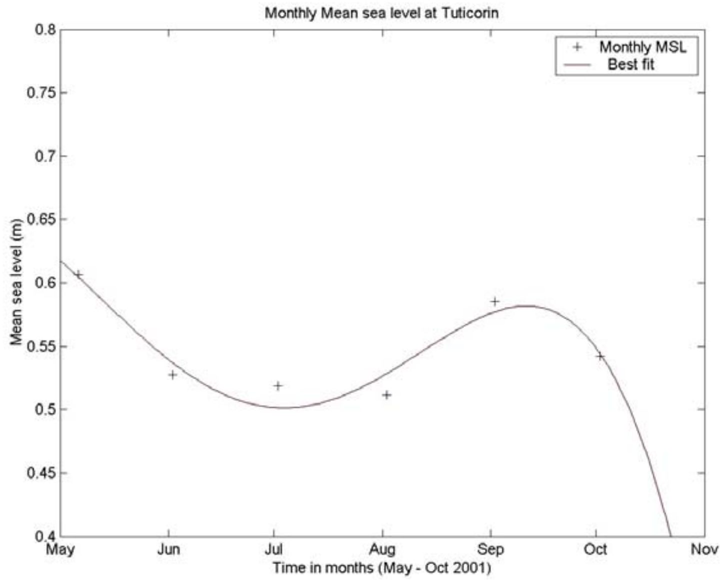

Fig. 4. Monthly mean sea level at Tuticorin for May to October 2001

MSL is high during May compared to other months and two significant peaks are also seen clearly indicating the influence of intense cyclone period. The Southern Oscillation Index in the year 2001 for the period May-September is 0.8, 0.7, 1.1, 0.6, 1.0 (obtained from the NCEP, National Weather Service, NOAA) which are positive indicating that to be a La-Nina epoch (reverse of El-Nino) during which the sea level along the east coast of India is generally high. The SOI values are higher for May, July and September and the MSL peak values also indicate this trend during these months. The SOI value of August is the lowest and MSL during August illustrates these phenomena which does not have any significant peak. From August to September the MSL keeps increasing as it is second half of the southwest monsoon.

The monthly MSL in Fig. 4 shows that from August to September mean sea level increases and this is due the southwest monsoon activity that is predominant during this period which is well correlated with SOI for that period.

Further analysis of the data spanning over longer periods is proposed in the future and repeatability of the above features in the subsequent monsoons also will be studied.

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