

Reconstruction of late Pleistocene and Holocene Sea Level Curve for the East Coast of India

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Abstract

Holocene sea level curve has been generated for the East Coast of India. About seventy five ¹⁴C dates which are available from published works on coastal plains and offshore regions of the East Coast were considered and were subsequently calibrated into calendar years for analysis and plotting thereof. From the 100m depth, a moderate rate of sea level rising at the rate of about 0.88m/100 years is observed during 14,800 to 10,800 YBP. In between 10,800 to 9,200 YBP, a steep rise (Sea Level Rise - SR1) is noticed at the rate of 2.06m/100 years. Following a brief sluggish phase (for nearly about 1,100 years) of slow rising around 0.82m/100 years, another steep rate of rising of about 2.22m/100 years (SR2) is observed during 8,100 to 7,200 YBP. After that period to the Recent, there were 5 minor fluctuations with regression phases dominating over transgression phases in terms of duration and magnitude. It is also observed that the magnitude of all five high stands in between 7,200 to the recent has a decreasing trend from +4m to 0m. It obviously indicates that the most of the present day coastal plains were once under the sea as evidenced by the presence of many inland leftover paleo delta signatures in the East Coast of India.

1.0 Introduction

During the past few decades, research studies on global climate change has occupied a centre stage engaging scientists and others in data generation, predictive modelling and policy-making at global, regional and local levels. The many possible impacts of climate change have been perceived and felt through various environmental parameters among which the sea level fluctuations are of prime importance (Tooley, 1985; Morner,1996; Zazo et al., 1999; Lambeck et al., 2002). On the way to construct various predictive scenarios of future sea levels expected due to climate change, the baseline sea level history during the recent past is of prime importance. Many scientists from around the world have generated sea level curves especially of Holocene period for various coastal sectors (Fairbanks,1989; Pirazzoli,1991; Antonio, 1991; Panchang et al., 2008) of different countries.

In India, sea level studies were carried out in many parts of the country in the earlier decades (Chatterjee,1962; Gardner,1981; Bruckner,1989; Rajamanickam and Loveson, 1990; Merh,1987 and 1992; Rachna, et al.,1998; Banerjee, 2000; Somayajulu, 2002). Dots of sea level information are available for specific areas of East Coastal region (Mittre and Gupta 1972; Rajagopalan, et al., 1978; Gupta,1981; Barui, et al., 1986; Tissot 1987; Bruckner,1988; Rao, et al., 1990; Chakrabarti,1992; Vaidyanadhan and Ghosh, 1993; Mohana Rao and Rao 1994; Das, et al., 1996; Vaz,1996; Rao, et al.,1996; Vaz and Banerjee, 1997; Achyuthan,1997; Hameed, et al, 2006; Banerjee,2000; Vaz, 2000; Vaz et al., 2008). Though localised and patchy sea level information is available for East and West Coasts of India, a comprehensive regional Holocene sea level curve for the East Coast has not been attempted by anybody. However, Kale and Rajaguru (1985) and Hashimi et al., (1995) based on transgression and regression history of West Coast of India have prepared comprehensive sea levels curve for Holocene. Further, based on studies on Western Indian continental margin, Nigam and Hashimi (2002) have also compiled a comprehensive sea level curve. There were also attempts by Earth Scientists from countries adjacent to India on sea level studies and to work out sea level curves (Shahidul,1995; Katupotha, 1988) for Bangladesh and Sri Lanka respectively. The present study endeavours to construct a comprehensive Holocene sea level curve for the East Coast of India based on the available sources of information.

2.0 Geospatial importance and Back-up information of the study area

The East Coast of India is an emerging coast (Loveson and Rajamanickam 1988 a & 2000) with many major rivers draining into the Bay of Bengal through their deltas (Vaidyanadhan and Ghosh, 1993). Along this coast, there are several signature geomorphic features like marine terraces, beach ridges, paleo lagoons etc., spreading all over the coastal plains, indicating sea

level fluctuations in the Recent past. In most of the deltas, one can see many forms and features indicating progradation of deltas which were illustrated by many researchers with particular reference to the Holocene sea levels (Vaidyanadhan, 1971; Sambasiva Rao, et al., 1978; Vaidyanadhan and Ghosh, 1993). Foraminifers were sometimes used to decipher sea level changes (Nigam, 1996). Few archaeological evidences are also available reflecting sea level changes in the form of ancient and historic port cities (Rajguru and Guzder, 1973; Rajamanickam and Loveson, 1988; Sarma 1991).

3.0 Methodology

In the published literature on sea level studies along the East Coast of India, available dates and related details (such as elevation / depth at which samples are collected, nature of the samples, location information etc.) are collected and documented region wise. In the present study, only the carbon 14 dates (about seventy five ¹⁴C dates available on coastal plains and offshore regions of the East Coast of India) are considered for compiling and constructing a comprehensive sea level curve, particularly for the Holocene period. Available dates, from mostly carbonaceous and siliceous materials, are considered. In most of the sea level studies, shells, coral and wood materials were given importance for dating as they are the good indicators of sea level stands (Tooley, 1978; Van de Plassche, 1986). The information which was considered in the present study is presented in Table 1. Since the East Coast of India supports an intensive coral growth due to its shallow sea conditions, coral related dates predominate the list. Dated materials also included wood, peat, organic matter, shell, foram aggregate, carbonaceous tidal clay etc. Most of the samples were located at elevation range from +6m to -100m, above and below the present mean sea level respectively.

Table 1. Available data on Carbon dates along the East Coast of India

All available ¹⁴C BP dates were converted into calendar years using CalPal, an online program (<http://monrepos-rgzm.de>). This calibration algorithm uses the calibration curve. The calibrated ages are used to plot against the elevation to get the sea level curve. The availability of sufficient data points made the curve more comprehensive and inclusive to bring out various sea level stands (high and low), especially during the Holocene period. Though the curve generation is intended for the Holocene period, the plot was little extended up to 15,000 years to understand the rise of the sea level during the LGM (Last Glacial Maximum) period i.e., transitional period between the Holocene and the Late Pleistocene.

4.0 Results and Discussions

4.1 Sea Level Curve: Interpretation

The sea level curve generated for the East Coast of India has some similarities with the global prototype curve (Pirazzoli, 1991) in general but has its own specific characteristic pattern as well (**Fig.1**). There appears to be a good correlation with Sri Lankan sea level curve (Katupotha, 1988) and is also comparable with the sea level fluctuation events along the West Coast of India (Nair, 1974; Chauhan and Almeida, 1993; Wagle, et al., 1994; Wagle and Veerayya, 1996), as well as comparable with the sea level curve prepared by Hashimi, et al., (1995). One important commonality found in both the curves (of present study and of Hashimi, op cit) is that sea level rose at a very high rate ($\sim 2\text{m}/100$ years) from 10,000 to 7,000 years BP.

From the present study, two stages of steep rise are observed during late Pleistocene period between 10,800 and 9200 years (SR1) as well as between 8100 and 7200 years (SR2). During the earlier steep rise (SR1) stage, the sea level rose from -65m to -32m and recorded about 33m rise in nearly 1600 years i.e., at the rate of about $2.06\text{m}/100$ years. Similar trend of sea level rise has been documented by Rana, et al., (2007) off central East Coast of India based on dating of relict benthic foraminifera in seabed sediments at the depths 30-110m. The SR2 accounted for -23 to -3m rise during 900 years., i.e., 20m rise in 900 years which works out to about 2.22m rise in 100 years. The SR2 trend is a little steeper than SR1 indicating intense glacier melting periods of Late Pleistocene causing submergence of a extensive land area. The occurrences of oolitic sands between -100 to -145m indicate a lower stand (Subba Rao, 1964). Based on the bathymetric linear heights of East Coast continental shelf, Banerjee and Sengupta (1992) suggested three low stands between 30 to 90m depth. Prudhvi Raju and Vaidyanadhan (1981) and Srinivasa Rao et al., (1990) have reported submarine terraces at -23m (7000- 8000yrs) and -17m (8200 yrs) respectively which indicate paleo sea level low stands.

Around 14,500 years BP, the sea level was at 100m depth, exposing land connections between India and Sri Lanka as one land mass. Around 18,000 YBP, the major phase of transgression started worldwide. Vaidyanadhan and Prudhvi Raju (2000) have documented that the sea level was at 80m depth during 12,000 years before a transgression phase started. In the midst of rapid transgression, the present sea level curve suggests that during 9200 to 8100 years., i.e., about 1100 years long duration, there were very small sea level fluctuations and indicating a sluggish phase of transgression. This stage of slow changes is observed in the curve between the steep rises, i.e., SR1 and SR2. The continuous rise in sea level ever since late Pleistocene has reached the present sea

level during 6800 years 100 BP and the highest sea level of about ~4m above the present sea level is observed during 6050 BP. Since then, the sea level started fluctuating in lesser magnitudes (between +4.0m to -2.0m), responding to the cycles of global ice melting and climate thereof.

Based on the fluctuation of the sea levels on the East Coast of India in the last 15000 years, five significant major stages are observed (**Fig.2**). In the first stage up to 10800 years BP, the rising was considerable but not rapid. The second (SR1) and fourth stages (SR2) represent steep rises (@2.06m/100 years and 2.22m/100 years respectively) whereas 3rd stage is a sluggish phase (only @ 0.82m/100 years). This sluggish phase is well supported by many available 14C dates (**Fig.2 and Table 1**).

In the Holocene period, starting from 7200 YBP to the Recent, there were several minor fluctuations which can be classified into 5 sub-stages viz., 5a, 5b, 5c, 5d and 5e of high and low stands (**Fig.2**). The first sub-stage (5a) lasted nearly 2100 years and represented a high sea level stand of nearly ~+4 m. The sub-stage 5b existed for nearly 750 years and about ~+3m high stand is illustrated in the curve. Likewise, the 5c sub-stage from 4350 to 3100 years (lasted 1250 years duration) recorded ~+3.0m high stand but dropped to -2m low stand during this period. From 3100 years to the Recent years, there were two minor fluctuations (sub-stages 5d and 5e) which registered low high stands of +1.0 and +1.5m respectively (**Table 2**). Around 3800 to 3000 years, the curve exhibits a lower stand which could be attributed to the minor disturbances caused due to extreme events and land stabilization (Achyuthan and Baker, 2002). Another such event is seen during last 1000 years (Rajendren et al., 2006).

4.2 Holocene Cycles and Sea level Highs and Lows

From the sea level curve of the present study, the Holocene period exhibits 5 high stands and 4 low stands, in totality (**Table 2**). All these 5 sub-stages /cycles (Transgressions+ Regressions) have their characteristic elevation of high and lows. Though the cycle between 7200 to 5100 years BP displayed evidence of a high stand of about ~+4m with reference to present sea level, others are confined to small highs and lows respectively. More significantly, two cycles that happened between 5100 and 3100 years BP, were alike showing ~+3m highs (**Fig.2**). Agrawal and Kusumgar (1967) has estimated that the sea level rose to more than +3m above present day level during 6,000 years before and since then it had been fluctuating. Achyuthan (1997) has studied the oyster beds of Muthukadu tidal flat zone near Chennai (Tamil Nadu), South India) and explained a high sea level condition since 2500 BP (1920-1620 BC). From a study from Sularpet coast, Andhra Pradesh, Farooqui and Vaz (2000) have reported that the sea level reached its

maximum around 6650±110 BP. Prudhvi Raju et. al., (1993) inferred that the sea level has risen to about 1.0 to 1.5 m above present level during 6000 to 5000 BP along Vishakapatnam coast. From the observations from East and South Indian coast, Banerjee (1993) has traced a high stand at around 6000 YBP and categorised it as the natural pinnacle of the present day interglacial phase. Similar observations have been reported in the South-western and Southern Coast of Sri Lanka by Katupotha and Fujiwara, (1988) and they inferred that the mean sea level was around +1m higher than the present during 3210±70 to 233±60 BP. In the present study the sea level curve illustrates five high stands ~+4m at 6050 YBP, ~+3m at 4900 and 4100 YBP, ~+1m at 1900 and ~+1.5m at 500 YBP and subsequently shows a decreasing trend. Whereas the 4 low stands viz., ~+2.5m at 5100 YBP, ~+2m at 4350 YBP, ~-2 m at 3100 YBP and ~+0.5m at 1100 YBP indicate minor oscillations between +2.5 to -2 m vis-a-vis the present sea level. More or less, all low stands stood between +2.5 to -2.0m.

Table 2. Details of the high and low stands during various Holocene cycles

Further, the sea level curve indicates that around 6850, 3900, 2500, ~1500 and 900 YBP, the sea level was at a level as that of today. From **Figure 2** it can be observed that after the cycles 5a to 5c (i.e., 7200-3100 YBP), the sea level fluctuations were in a placid phase.

4.3 Transgressions and Regressions during the Holocene Period elsewhere

Kale and Rajguru (1985) have studied transgression and regression cycles of the west coast. Faroqui and Vaz (2000) have inferred a regressive phase from 4608±122 yrs BP around Sulurpet coast. Achyuthan and Baker (2002) advocated that the advance of the sea has been observed at the beginning of 1900±45 BP along northern part of Tamil Nadu. Based on the palyno-plankton stratigraphy and paleo-biology studies, transgression of the sea between 7000 and 6175 years BP and regression after 6175 years BP in Bengal basin has been recorded by Gupta, (1981), Banerjee and Sen, (1987), Sen and Banerjee (1988, 1990 & 2016). A transgression phase at 6,000 years in Saurashtra coast was assessed by Gupta (1977) and Somayajulu, et.al. (1985). Bruckner (1989) based on dating interpreted a marine transgression at 2,600 years along west coast (Amba, Dharamtar, Maharashtra coast) and Guzder (1980) inferred that sea level was 1m higher than the present level during 2500 BP along Konkan Maharashtra coast. Dating gastropod shells, Mathur, et al.,(2004) explained an overall regressing trend from 6000 to 200 years YBP along northwest coast. Along Kerala coast, a phase of transgression between 8000 and 6000 years BP and regression between 5000 to 3000 YBP has been reported (Rajendran, et al.,1989). During the Holocene period,

atleast 4 to 5 major transgressions were reported along Southern Tamil Nadu Coast based on beach ridges and marine terraces (Loveson and Rajamanickam, 1988a and 2000).

In the present study based on the highs and lows (of sea level) as observed in the Holocene sea level curve of the East Coast of India, various phases of transgressions and regressions are worked out. There were in total 5 transgression and regression phases during 7200 to the present (Table 3). Each cycle (transgression+regression) ranged from 2100 to 750 years. It is seen that the regression phases lasted for a little more duration than those of transgression phases to a ratio of about 52:48 in a total duration of last 7200 years.

Table 3. Details of the transgressions and regression phases

Recorded transgressions prove that most of the coastal plains were once under the sea. There are incontrovertible evidences in the form of paleo delta signatures along the East Coast of India (Vaidyanadhan 1971; Sambasiva Rao, et.al.,1978; Loveson, et.al., 1990; Ramasamy, et.al., 2006) supporting the transgressions. It is also significant to understand that the transgression events are more dynamic than those of the slower regression events. From the curve, it can also be observed that the magnitude of high stands is considerably coming down gradually from a high of ~4.0m during 6050 YBP to 1.5m at 500 YBP respectively (through 3.0m, 3.0m, and 1.0m during 4900, 4100 and 1900 YBP respectively).

5.0 Conclusions

The present attempt to construct the Holocene sea level curve for the East Coast of India is the first ever effort and is based on the several published ¹⁴C dates. From a depth of about 100m during 14800 YBP, the sea level rose to the present day level with significant stages of oscillations. Two steep rises are observed with the rate of 2.06m/100 years and 2.22m/100 years from 14800 to 7200 YBP. In between these steep rises, a stand still period is noticed from 9200 to 8100 YBP. After 7200 YBP, there were 5 minor fluctuations represented by various magnitudes of transgressions and complimentary regressions, up to the recent time. During the Holocene period many time (around 6850, 3900, 2500, 1500 and 900 YBP), the sea level recorded at the datum / azimuth level (i.e., 0 msl) along the East Coast of India.

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Table 1. Available data on Carbon dates along the East Coast of India

| Sl.no | Locality | Material | Elevation | 14C-age (B.P) | Calendric Age calAD | Lab No. | References |
|-------|-------------------------------------|-----------------------|-----------|---------------|---------------------|----------------|--------------------------|
| 1. | Illankalanvadi (Kanyakumari) | Shell | +6.0 | 4320±100 | 2980±171 BC | PRL 115 | IAR 75-76 p.83 |
| 2. | Korkai V.O.Chidambaranar | Wood | -3.17 | 2755 ±95 | 948 ± 103 BC | KRK 1 | IAR 69-70 P.68 |
| 3. | Paniya Tivu V.O.Chidabarana r | Shell | +3.0 | 1050±80 | 986 ± 94 AD | PRL 119 | IAR 75-76 P.38 |
| 4. | Pandiya Tivu V.O.Chidabarana r | Coral | +0.5 | 2130±100 | 187 ± 134 BC | PRL 120 | IAR 75-76 P.83 |
| 5. | Dubash Chetti V.O.Chidabarana r | Shell | +6.0 | 5470±110 | 4294 ± 133 BC | PRL 124 | IAR 75-76 P.84 |
| 6. | Dubash Chetti V.O.Chidabarana r | Shell | +3.0 | 5710±110 | 4569 ± 118 BC | PRL 125 | IAR 75-76 P.84 |
| 7. | Kamarajapuram Ramanathapuram | Shell | 6.0 | 2790±150 | 1013 ± 179 BC | PRL 126 | IAR 75-76 P.84 |
| 8. | Surangadu V.O.Chidabarana r | Shell | +3.0 | 430 ±150 | 1515 ± 134 AD | PRL 127 | IAR 75-76 P.84 |
| 9. | Korkai V.O.Chidabarana r | Shell | +6.5 | 3820±110 | 2269 ± 161 BC | PRL 128 | IAR 75-76 P.84 |
| 10 | Mandapam (4 km west) | Shell above HTL | +1.0 | 2740±60 | 906 ± 62 BC | KI-2338.001 | Bruckner, 1989 |
| 11 | Mandapam (east) | Coral above HTL | +0.50 | 3660±65 | 2047 ± 87 BC | KI-2339.001 | Bruckner, 1989 |
| 12 | Manappad point (north) | Shell above MSL | +0.20 | 6240±50 | 5197 ± 87 BC | HD 10981-10722 | Bruckner, 1989 |
| 13 | Kadiapatnam-30km WNW of Kanyakumari | Fossil wood below MSL | -8.0 | 7130±65 | 5997 ± 60 | HD 10979-10732 | Bruckner, 1989 |
| 14 | Pamban | Coral | +0.47 | 4020 ±160 | 2559 ± 236 BC | Gak 3187 | Stoddart and Pillai 1977 |

| | | | | | | | |
|----|---|----------|-------|-------------------|---------------|------------|---------------------------|
| 15 | Ramakrishnapuram | Coral | +0.20 | 140±45 | 1808 ± 103 AD | 26/196/c2 | Loveson 1994 |
| 16 | North of Mandapam | Coral | +0.62 | 2630±65 | 774 ± 94 BC | 27/238/c3 | Loveson 1994 |
| 17 | North of Mandapam | Coral | +0.42 | 3670±65 | 2059 ± 88 BC | 28/239/c4 | Loveson 1994 |
| 18 | Pamban | Coral | +0.48 | 3920±160 | 2418 ± 233 BC | 31/260/c6 | Loveson 1994 |
| 19 | Ariyan Kundu | Coral | +0.55 | 5440±60 | 4288 ± 53 BC | 30/248/c5 | Loveson 1994 |
| 20 | Rameswaram Island north shore | Acropora | +1.10 | 125.6 (±8.5/-7.9) | 1816 ± 96 AD | PKB 8a | P.K.Banrjee 2000 (Table2) |
| 21 | Rameswaram Island terrace | Pyrites | +2.90 | 104 (± 10/-10) | 1799 ± 89 AD | R5 | P.K.Banrjee 2000 (Table2) |
| 22 | Rameswaram Island terrace | Porites | +2.90 | 92.0 (±6.5/-6.5) | 1804 ± 96 AD | R6 | P.K.Banrjee 2000 (Table2) |
| 23 | Rameswaram Island terrace | Porites | +2.40 | 112 (±8/-5) | 1799 ± 83 AD | Vadakadu 4 | P.K.Banrjee 2000 (Table2) |
| 24 | Rameswaram Island terrace | Porites | +2.90 | 116 (±10/-10) | 1801 ± 85 AD | R3 | P.K.Banrjee 2000 (Table2) |
| 25 | Rameswaram Island terrace | Porites | +2.90 | 104 (±10/-10) | 1799 ± 89 AD | R7 | P.K.Banrjee 2000 (Table2) |
| 26 | Near Narikulam beach | Porites | +2.40 | 108 (±2/-5) | 1798 ± 85 AD | 01/97 | P.K.Banrjee 2000 (Table2) |
| 27 | Villundi Theertham, Rameswaram Island | Porites | +1.40 | 6210 ±120 | 5152 ± 143 BC | BS1119 | P.K.Banrjee 2000 (Table3) |
| 28 | Villundi Theertham, Rameswaram Island; 400 m west | Porites | +1.40 | 5700 ±120 | 4560 ± 129 BC | BS1223 | P.K.Banrjee 2000 (Table3) |
| 29 | North of Pamban | Porites | +1.40 | 5310±120 | 4146 ± 131 BC | BS 1121 | P.K.Banrjee 2000 (Table3) |
| 30 | Pisasu Munai, Rameswaram Island | Porites | +1.00 | 6450±160 | 5391 ± 151 BC | BS 1310 | P.K.Banrjee 2000 (Table3) |
| 31 | 1 km NE of CMFRI farm at Munaikkadu | Porites | +1.20 | 5410±110 | 4222 ± 125 BC | BS 997 | P.K.Banrjee 2000 (Table3) |

| | | | | | | | |
|----|---|---|-------|----------------|------------------|--------------------|--------------------------------------|
| 32 | Kaikallur, Kulleru lake (Godavari inter- deltaic plain) | Shell Anadara sp. | +3.90 | 5670±120 | 4534 ± 131 BC | BS 1274 | P.K.Banrj ee 2000 (Table3) |
| 33 | Kakinad lighthouse (Godavari inter- deltaic plain) | Shell Arca sp. | +3.90 | 5140±520 | 3897 ± 609 BC | BS 1347 | P.K.Banrj ee 2000 (Table3) |
| 34 | Narikulam, Rameswaram Island | Shell Arca ± Cardita | +2.90 | 4350±140 | 3031 ± 227 BC | BS 1440 | P.K.Banrj ee 2000 (Table3) |
| 35 | 600 m west of Villundi Theertham | Shell Erronea | +2.40 | 4860±100 | 3649 ± 114 BC | BS 1410 | P.K.Banrj ee 2000 (Table3) |
| 36 | 600 m west of Kovakulam | Shell Scapharca | +2.40 | 4400±100 | 3112 ± 161 BC | BS 1209 | P.K.Banrj ee 2000 (Table3) |
| 37 | 1 km NE of CMFRI farm at Munaikkadu | Insitu colony above 0.5m thick shell sandstone | +1.70 | 4162±115 | 2730 ± 141 BC | BS 1224 BS1249 | P.K.Banrj ee 2000 (Table3) |
| 38 | Pamban coast - Unconsolidated dune base, over shelly sst | Shells (centimeter sized) | +2.90 | 3800±130 | 2246 ± 184 BC | BS 1276 | P.K.Banrj ee 2000 (Table3) |
| 39 | 600 m west of Vilundi Theertham | Embedded shells with disarticulate d fragments of Cardium | +2.40 | 3840±130 | 2291 ± 179 BC | BS 1441 | P.K.Banrj ee 2000 (Table3) |
| 40 | 750 m SSE of Karikovil | Disarticulat ed shells | +0.90 | 750±120 | 1234 ± 113 AD | BS 1212 BS 1408 | P.K.Banrj ee 2000 (Table3) |
| 41 | 750 m SSE of Karikovil | Loose and disarticulate d shells | +2.90 | 100±1.6 | 1798 ± 90 AD | --- | P.K.Banrj ee 2000 (Table3) |
| 42 | Mamallapuram | Organic matter | +0.30 | 1085±60 BP | 939 ± 56 AD | AA-30022 | Achyutha n and Baker (2002) |
| 43 | Mamallapuram | Organic matter | +0.50 | 1620±110 BP | 410 ± 125 AD | AA-30024 | Achyutha n and Baker (2002) |
| 44 | Mamallapuram | Organic matter | +0.90 | 1900±45 BP | 111 ± 55 AD | AA-30027 | Achyutha n and Baker (2002) |
| 45 | Mamallapuram | Charcoal | -1.0 | 955±30 | 1082 ± | MB/AR/U | Rajendran |

| | | | | | | | |
|----|----------------------------|---|-------|----------------|---------------------------------------|--------------|------------------------------------|
| | | | | | 47 AD. 1019- 1161 AD | L | et al., 2006 |
| 46 | Mamallapuram | Charcoal | -1.0 | 1674±30 | 364 ± 35 AD. 321-427 AD | MB/AR/B L | Rajendran et al., 2006 |
| 47 | Mamallapuram | Charcoal | -1.0 | 1581±35 | 478 ± 44 AD. 405-564 AD | MB/T1/B L | Rajendran et al., 2006 |
| 48 | Sulurpet (Pit 1) | Peat sediment | +4.98 | 6650±110 BP | 5585 ± 81 BC | --- | Farooqui A and Vaz GG (2000) |
| 49 | Kasdreddinilem (Pit A) | Peat sediment | +1.0 | 4608±122 BP | 3326 ± 189 BC | --- | Farooqui A and Vaz GG (2000) |
| 50 | Cheruvukandrige (Pit B) | Sandy clay with reddish brown layers | +1.5 | 1972±277 BP | 6 ± 326 BC | --- | Farooqui A and Vaz GG (2000) |
| 51 | Attakanitippa (Pit C) | Pellicipods | -0.90 | 2260±80 BP | 304 ± 87 BC | --- | Farooqui A and Vaz GG (2000) |
| 52 | Sriharikotta | Shell | -2.0 | 3100 ±96 BP | 1344 ± 118 BC | --- | Farooqui A and Vaz GG (2000) |
| 53 | Marakkanam | Shell | -0.40 | 1115±132 | 900 ± 136 AD. 612- 1082 AD | BS-1605 | Hameed et al (2006) |
| 54 | Marakkanam | Shell | -0.86 | 1563±132 | 458 ± 133 AD. 136-680 BC | BS-1608 | Hameed et al (2006) |
| 55 | Marakkanam | Shell | -1.50 | 8200±230 | 7151 ± 297 BC. 9230- 8460 BC | BS-2270 | Hameed et al (2006) |
| 56 | Odinur (TN) | Sediment | -1.90 | 2750±140 | 963 ± 161 BC. 2920- 2710 BC | BS-2398 | Hameed et al (2006) |
| 57 | Odinur (TN) | Sediment | -2.10 | 5540±430 | 4404 ± 482 BC. 6640- 5660 BC | BS-2272 | Hameed et al (2006) |
| 58 | Muthukadu | Tidal Clay Organic matter | -0.50 | 3145±55 | 1415 ± 65 BC. 1520- | AA-18459 | Achyutha n, Hema (1997) |

| | | | | | | | |
|----|--|---------------------------------|---------|---------------|--------------------------------------|----------------------------|----------------------------|
| | | | | | 1260 BC | | |
| 59 | Muthukadu | Tidal clay Organic matter | -0.70 | 3475±55 | 1805 ± 70 BC. 1920- 1620 BC | AA-18458 | Achyuthan, Hema (1997) |
| 60 | Muthukadu | Oyster Shell | -1.85 | 5000±70 | 3814 ± 94 BC. 4358- 3991 BC | AA-8374 | Achyuthan, Hema (1997) |
| 61 | Calcutta | Peat | -1.26 | 7030+150 | 5909 ± 137 BC | --- | Barui et al 1986 |
| 62 | Kolaghat | Peat | -0.69 | 6900+70 | 5801 ± 69 | --- | Das et al., 1996 |
| 63 | Panighata | Peat | -0.57 | 5000 | 3815 ± 89 | --- | Shahidul 1995 |
| 64 | Sankril | Peat | -0.275 | 2615+100 | 726 ± 147 BC | --- | Mitre and Banerjee 1990 |
| 65 | Namkhana | Silty lay | -1.75 | 3170+70 | 1445 ± 72 BC | --- | Gupta 1981 |
| 66 | Gangasagar | Silty Clay | -1.7 | 2900 | 1111 ± 118 BC | --- | Chakrabarti 1992 |
| 67 | Btn Kulasekaraatnam to Tiruchendur | Shells in ridge | +7.0 | 6240+50 | 5197 ± 87 BC | Tuti-5A HD-1061 | Bruckner 1989 |
| 68 | Mandapam 4 km west | Cardium sp. lagoonal loam | +1.0 | 2740+60 | 906 ± 62 BC | Man- M(K1- 2338-001) | Bruckner 1989 |
| 69 | Kaveripatnam | Wood- Arche sample | -1.0 | 2316+103 | 427 ± 177 BC | --- | --- |
| 70 | Pichavaram | Mangroves root tip | 0.0 | 2000 | 16 ± 63 BC | --- | Tissot 1987 |
| 71 | Marakkanam | Sediment | -1.52 | 9170±290 | 10360- 8460 BC | BS-2275 | Hameed et al (2006) |
| 72 | Rameswaram north | Coral | +0.80 | 12010±12 0 | 12074 ± 264 BC | 20/164/b7 | Loveson, 1994 |
| 73 | Olaikuda marine terrace | Porites | +1.90 | 13170±20 0 | 14138 ± 475 BC | BS 1120 | P.K.Banerjee 2000 (Table4) |
| 74 | Vishagapatnam shelf | Carbonate rock sample | -100.00 | 12539+17 0 | 12889 ± 397 BC | --- | Mohana Rao and Rao 1994 |
| 75 | Vishagapatnam shelf | Carbonate rock sample | -85.00 | 10790+17 0 | 10787 ± 191 BC | --- | Mohana Rao and Rao 1994 |

Table 2. Details of the high and low stands during various Holocene cycles

| Sub-stage | Years BP | | Cycle (T+R)* Duration | High stand (a) | | Low stand (b) | | Cycle Fluctuation (m) (a-b) |
|-----------|----------|------|-----------------------|----------------|---------------|---------------|---------------|-----------------------------|
| | From | To | | Year BP | Elevation (m) | Year BP | Elevation (m) | |
| 5a | 7200 | 5100 | 2100 | 6050 | +4.0 | 5100 | +2.5 | 1.5 |
| 5b | 5100 | 4350 | 750 | 4900 | +3.0 | 4350 | +2.0 | 1.0 |
| 5c | 4350 | 3100 | 1250 | 4100 | +3.0 | 3100 | -2.0 | 5.0 |
| 5d | 3100 | 1100 | 2000 | 1900 | +1.0 | 1100 | +0.5 | 0.5 |
| 5e | 1100 | 0 | 1100 | 500 | +1.5 | 0 | 0 | 1.5 |

*(T = Transgression; R= Regression)

Table 3. Details of the transgressions and regression phases

| Phases | Sub-Stage | Cycle * | Years BP | | Duration (Years) | Stands (m) | Remarks |
|---------------|-----------|---------|----------|------|------------------|------------|---|
| | | | From | To | | | |
| Transgression | 5a | T1 | 7200 | 6050 | 1150 | +4.0 | Out of total Holocene years of 7200, Transgression phase occupied 3400 years, i.e., 48% of total years. |
| | 5b | T2 | 5100 | 4900 | 200 | +3.0 | |
| | 5c | T3 | 4350 | 4100 | 250 | +3.0 | |
| | 5d | T4 | 3100 | 1900 | 1200 | +1.0 | |
| | 5d | T5 | 1100 | 500 | 600 | +1.5 | |
| Regression | 5a | R1 | 6050 | 5100 | 950 | +2.5 | Regression phase spread over 3800 years of the total, i.e., 52% of Holocene |
| | 5b | R2 | 4900 | 4350 | 550 | +2.0 | |
| | 5c | R3 | 4100 | 3100 | 1000 | -2.0 | |
| | 5d | R4 | 1900 | 1100 | 800 | +0.5 | |
| | 5e | R5 | 500 | 0 | 500 | 0 | |

*(T = Transgression; R= Regression)

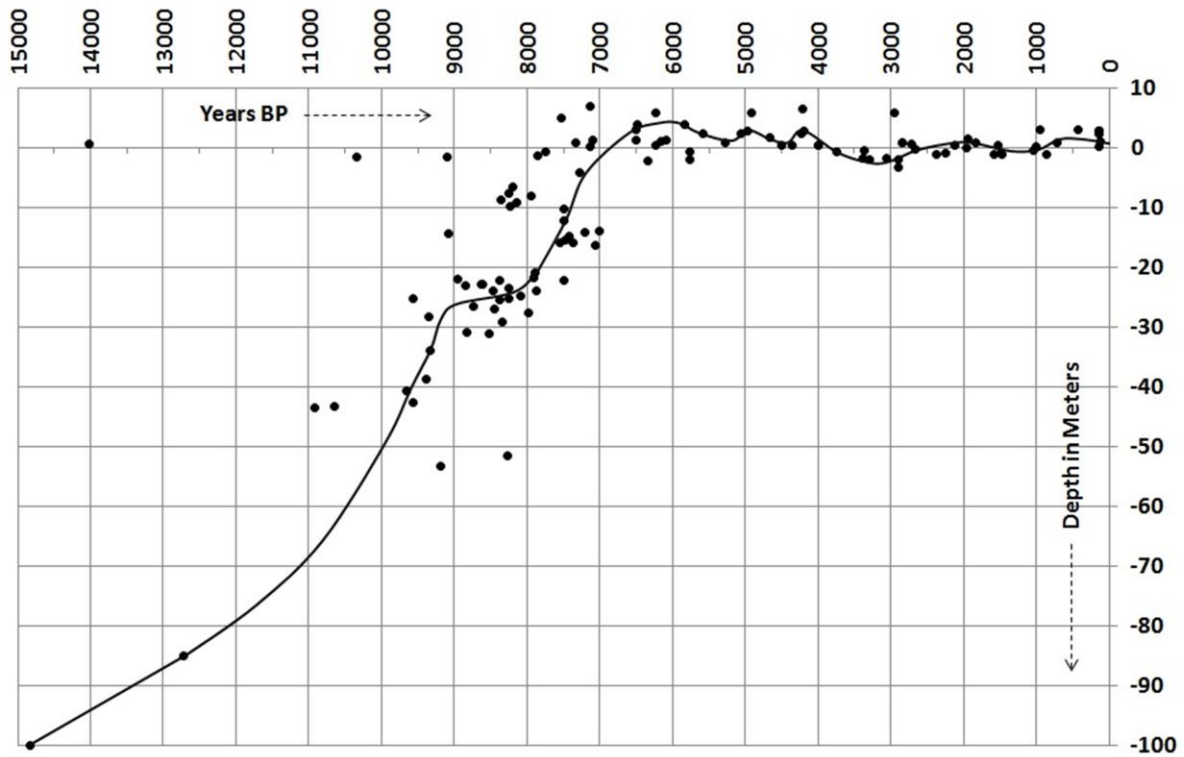


Figure 1. Late Pleistocene and Holocene Sea level curve of East Coast of India

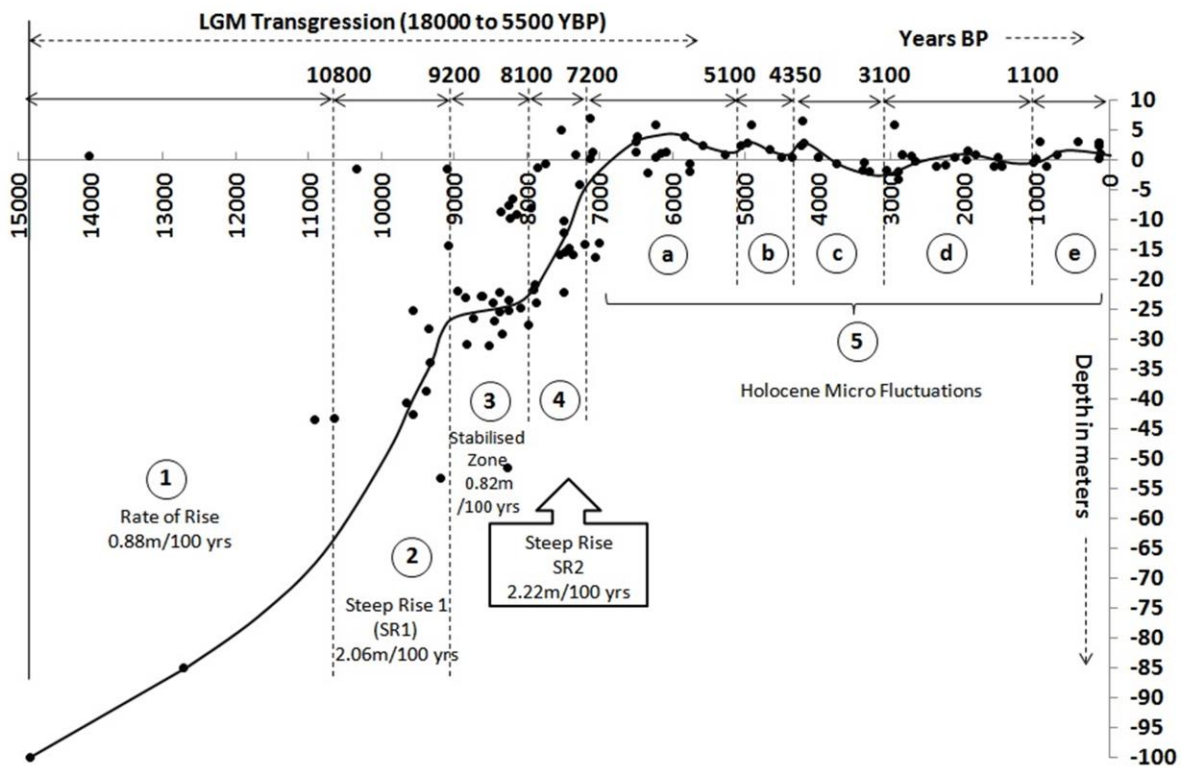


Figure 2. Major and minor stages in sea level fluctuations along East Coast of India