Mahasagar–Bulletin of the National Institute of Oceanography, 17(2), 1984, 113–118.

NOTE

SEASONAL CHANGES IN SEA LEVEL AT PORT BLAIR

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ABSTRACT

Monthly and annual mean sea levels at Port Blair have been studied from the tide data of eight years. Variations of monthly mean sea levels show two maxima and two minima with higher maximum in June and lower maximum in November, and lower minimum during March and the other minimum in October. The mean annual range is about 16 cm. An attempt has been made to explain the seasonal changes of sea levels in relation to the climatic factors which alter the density structure of the surface layers in the oceans and the atmospheric pressure that tilts the sea surface.

Key-words : Sea level, seasonal changes, Port Blair.

The oscillation of the sea surface due to tides was understood to be caused primarily by the gravitational attraction of the moon and the sun, whose magnitudes vary with time at any place. Some important investigations by Lafond (1939), Jacobs (1939), Pattullo, Munk, Revelle and Strong (1955), Montgomery (1937-38), Nomistu and Motojiro (1927) concluded that the sea levels undergo seasonal changes which are not related to the variations in gravitational forces alone but are also related to the changes in the density structure of sea water in the surface layers. Such variations in sea levels are called as meteorological tides (Nomistu and Motojiro, 1927) since the changes in salinity and temperature of sea water in the surface layers mostly depend upon heating, cooling, precipitation, evaporation and mixing caused by wind induced currents. Further, it has been established that the atmospheric pressure acting upon the sea surface tilts it at any place depending upon the relative pressure distribution over the oceans. The changes in sea levels related to the vertical density structures of the waters in the surface layer are called as steric oscillations and their magnitudes have been found to be nearly numerically equal to those of the dynamic heights (Pattullo, Munk, Revelle and Strong, 1955).

In the present investigation an attempt has been made to study the seasonal and annual variations in sea level at Port Blair adopting standard procedures and relating them to the fluctuations in climatic factors which govern the density structure and circulation in the surface layers of the ocean.

Tide data of Port Blair for a period of eight years from 1953-1960 have been obtained from Geodetic Research Branch, Survey of India, Dehra Dun. Monthly and annual mean sea levels (Table I), and the deviation of monthly values from the mean monthly sea level are shown in Fig. 1. The daily rainfall and atmospheric pressure for the corresponding years are taken

Table I. Monthly and annual mean sea levels at Port Blair (cm).

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Mean
1953	114.6	107.3	112.2	112.2	117.7	122.5	126.8	121.3	119.8	121.3	120.7	119.5	118.0
1954	118.3	112.2	112.2	121.3	120.7	123.4	127.4	128.3	125.3	128.0	127.4	126.8	122.60
1955	118.9	120.1	114.6	123.7	128.0	131.7	126.8	126.2	128.9	122.8	135.3	128.6	125.5
1956	119.5	113.4	115.8	116.7	123.7	130.1	128.3	125.6	123.1	123.1	128.6	121.3	122.4
1957	118.3	113.1	113.4	115.5	118.3	119.2	127.1	125.6	120.1	117.0	117.0	117.7	118.5
1958	114.5	110.5	110.1	114.9	116.7	146.3	126.6	123.6	126.8	122.6*	127.7	123.8	122.0
1959	116.4	114.1	109.4	114.6	124.8	130.2	129.2	126.7	121.8	119.0	127.4	126.1	121.60
1960	119.9	117.7	118.3	120.4	126.4	130.7	135.4	135.2	130.1	127.3	134.9	131.9	127.0
Mean Monthly	117.6	113.6	113.3	117.4	122.0	129.3	128.4	126.6	124.5	122.6	127.4	124.5	

* Interpolated value.

Table II.

Months	Bimonthly sea surface temperature °C	Bimonthly sea surface salinity ‰	Bimonthly sea surface density ρ_t	Bimonthly interpolated temperature at 100 m °C	Bimonthly temperature of the layer 0–100 °C	Bimonthly salinity of the layer 0–100 ‰	Bimonthly density of of the layer ρ_t
Jan.–Feb.	26.65	32.4	1.02093	22.20	24.40	33.45	1.022363
March–April	28.50	32.6	1.02045	20.75	24.62	33.55	1.022384
May–June	28.65	32.8	1.02055	21.46	25.05	33.65	1.022321
July–August	27.70	33.4	1.02131	21.78	24.74	33.95	1.022648
Sep.–Oct.	28.25	33.0	1.02029	21.38	24.81	33.75	1.022477
Nov.–Dec.	27.55	30.1	1.01888	19.13	23.34	32.30	1.021815

from the Indian Daily Weather Reports published by India Meteorological Department. The monthly mean atmospheric pressures over all oceans have been utilised as given by Pattullo, Munk, Revelle and Strong (1955). The sea level departures, related to the atmospheric pressure have been evaluated as pressure corrections. These are algebrically added to the recorded sea levels to correct for the effect of atmospheric pressure. Monthly sea surface temperatures, biomonthly average surface salinities, bimonthly interpolated temperatures and salinity at a depth of 100 m have been taken from Wyrtki (1971) and using these data, corresponding densities have been evaluated (Table II)

Port Blair is a small island situated in the Eastern Bay of Bengal (lat. 11° 41′ N; Long. 92°46′ E). The Port Blair and the sea in its neighbourhood possess tropical climate modified by the typical monsoonal type of climate similar to that over the Indian sub-continent. The annual sea surface temperature range is about 2.5°C. The monsoon winds during the year are either from southwest or northeast. Most of the intense tropical storms prevailing in the Bay of Bengal either originate or intensify in the neighbourhood of Port Blair during the period, October to December (India Meteorological Department, 1943). The salinities in the sea around Port Blair attained a minimum of 30.1 ppt during November–December and thereafter increases rapidly during January–February and attaining a peak value of 33.4 ppt (March to August) with a slight reduction to 33 ppt during September–October.

The monthly mean sea levels at Port Blair (Fig. 1) show two maxima, one in June–July and the other in November and two minima, one in February–March and the other in October. The annual range of variation of monthly mean sea levels is about 16 cm. The deviation of secondary maximum with the secondary minimum is only about 4.7 cm and both of them are higher than the annual mean sea level. The annual mean sea level experiences a relatively large change and the range was about 9.35 cm between the years 1953 and 1960.

The monthly corrections obtained adopting the procedure suggested by Pattullo, Munk, Revelle and Strong (1955) account for a maximum annual change of 8 cm of sea level between the months January and July while the actual sea level difference without correction for the corresponding months is about 11.7 cm. The sea levels corrected for the effect of atmospheric pressure indicate a maximum range of about 13.9 cm between November and March displacing a maximum sea level to November from the actual recorded minimum in June. However the concept of double maxima during an year remain unaltered, with an interchange of periods of primary maximum and secondary maximum as November and June instead of June and November (Fig. 1) and further, the annual sea level range has been reduced to about 14 cm. The influence of pressure accounted for a change of 1/3 of the change in sea level between March and June, the periods of actual sea level minimum and maximum respectively. Thus the influence of atmospheric pressure elevated the sea level from April to September while the same lowered the sea level during

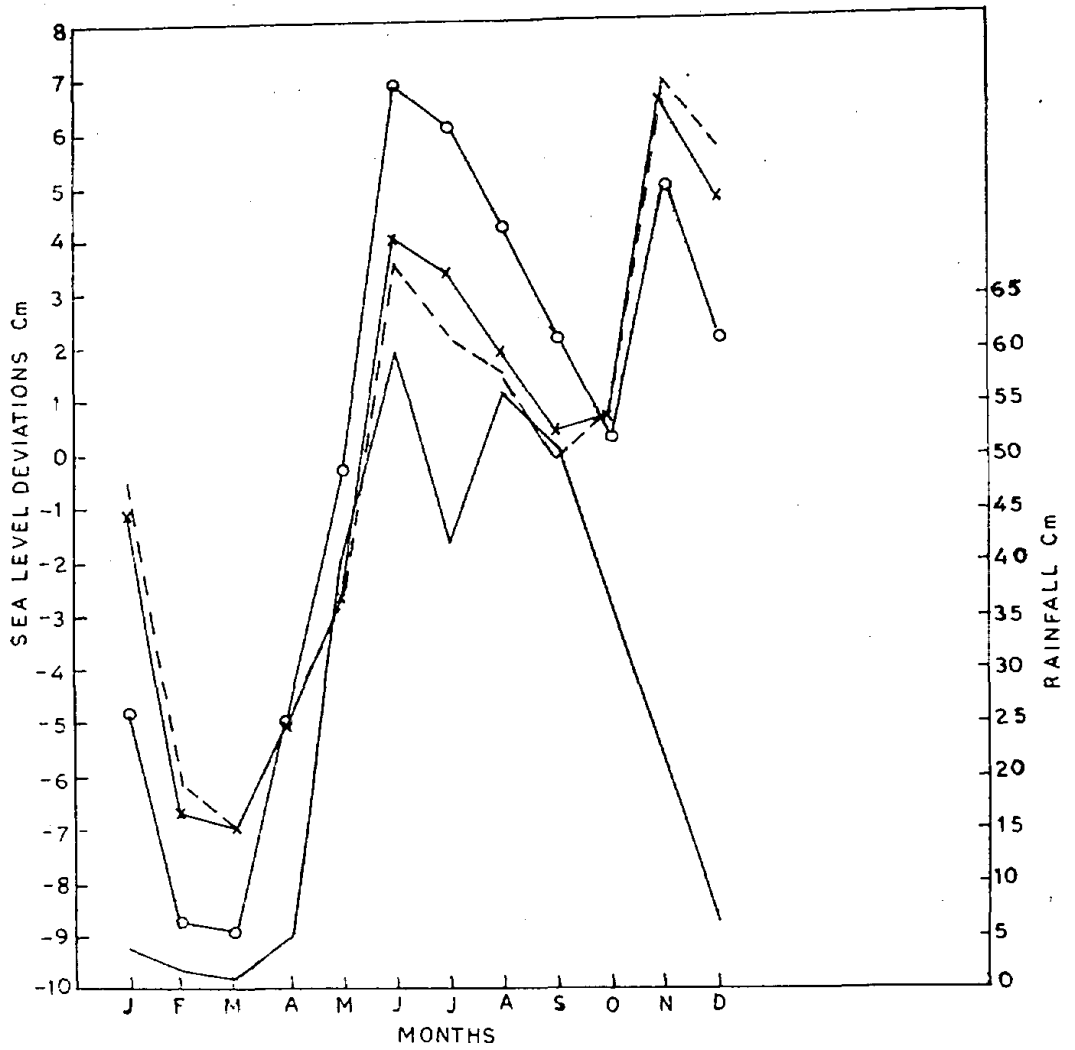

Fig. 1. Mean monthly deviations of actual sea levels and pressure corrected sea levels and rainfall at Port Blair. (o———o Mean monthly sea level deviations from M.S.L. in cm; — — — Mean monthly sea level deviations corrected for atmospheric pressures over all oceans; ——— Monthly average rainfall in cm; x———x Mean monthly sea level deviations corrected for local atmospheric pressure.)

the remaining months, thereby suppressing the November maximum caused by the steric departures. The influence of local monthly mean atmospheric pressure and the relative influence of local pressure with respect to the monthly mean atmospheric pressures over all the oceans have not shown appreciable differences.

Port Blair has high rainfall of about 330 cm per year with about 85% precipitating during half year from May to October and sea level change during this period is about 5.9 cm only. Earlier investigations by Lafond and Prasad Rao (1954), Ramanadham and Varadarajulu (1964) and Varadarajulu and Dhanalakshmi (1975) at Visakhapatnam and Madras, concluded that 90%

of the annual sea level changes relate to the local rainfall during the corresponding months. Further, the local rainfall showed good correlation with the reduction in the offshore salinities indicating a good agreement between the sea level changes at the coastal tide gauges and the offshore steric sea levels. During May to October the surface salinity off Port Blair is greater than the average salinity of March and April (Table II) indicating that the rainfall over the small island (Port Blair) is orographic and highly local, this may not represent the climate over the extensive ocean surface in the neighbourhood. The increase in salinity is found to have an effect of decreasing sea level during May to October. But the increased annual precipitation at Port Blair during the years 1954 and 1959 did not cause any increase in annual mean sea levels in those years.

The bimonthly average of the salinities of the surface layer and the corresponding densities (Table II) clearly indicate an increase in steric sea level which is in good agreement with the recorded sea levels corrected to the atmospheric effects. The dilution of the sea water during November and December appears to be related to the occurrence of large precipitation over the ocean surface associated with the tropical cyclones originating and intensifying in the Andaman Sea or may also be due to the advection of low salinity during early winter from the Pacific Ocean. The increased salinities and the changed temperatures from January to April which caused an increase in the densities of the surface layers can reduce the steric sea level during these months. Similarly the reduction in density of the sea water in surface layer during May and June can increase the sea level. However, the magnitude of the variations in sea level and the deviation in the densities of the surface layers from November to June are not showing any correlation except indicating agreement in trend. The reduction in density during May–June occurred due to significant increase in the temperature of the surface layer.

A fall in temperature and increased salinity of the surface layer from July to October caused increase in the mean density during this period, leading to a decrease in the steric sea level. Whereas the pressure corrected mean sea level during the corresponding period has shown slight increase. Except in January and February the thermal and haline departures counteracted each other and caused very slow changes in sea level. The anomalous changes in sea level during July to October with respect to the changes in the mean density of the surface layer appears to be caused by wind action or by the piling-up of water against the coast as wind drift. The increased temperature can cause an appreciable increase in sea level during March to June but the magnitude of its influence appears to be suppressed by the simultaneous increase in salinity. The seasonal changes in sea levels at Port Blair and the seasonal variations of the salinity of surface waters in the neighbourhood of Port Blair clearly indicate that there is an excessive evaporation over precipitation in the Andaman Sea and its neighbourhood during southwest monsoon season while large percentage of the annual precipitation occurs over the Indian

sub-continent during this period eventhough the entire region of the Indian sub-continent including Bay of Bengal is under the influence of the southwest monsoon.

ACKNOWLEDGEMENTS

The authors express their thanks to the Council of Scientific and Industrial Research, New Delhi, for the grant of a research fellowship. They also express their thanks to the authorities of Geodetic Research Branch, Survey of India, Dehra Dun for supplying the sea level data.

REFERENCES

Anon., 1943. *Climatological Atlas for Air-men in India*, published by India Meteorological Department, Pune.

Jacobs, W.C., 1939. Sea level departures on the California coast related to the dynamics of the atmosphere over the north Pacific Ocean. *Journal of Marine Research*, **2**: 181–194.

Lafond, E.C., 1939. Variations of sea level on the pacific coast of United States. *Journal of Marine Research*, **2**: 17–29.

Lafond, E.C., and R. Prasada Rao, 1954. Changes in sea level at Visakhapatnam on the east coast of India. *Andhra University memoirs in Oceanography*, **1**: 86–93.

Montgomery, R.B., 1937–38. Fluctuations in monthly mean sealevel on eastern US coast as related to the dynamics of the western north Atlantic Ocean. *Journal of Marine Research*, **1**: 165–185.

Nomistu, T., and O. Motojiro, 1927. The causes of the annual variation of the mean sealevel along the Japanese coast. *Memoirs of the College of Science, Kyoto Imperial University* **10**: 1–161.

Pattullo, J., W.H. Munk, R. Revelle and E. Strong, 1955. The seasonal oscillation in sealevel. *Journal of Marine Research*, **14**: 88–156.

Ramanadham, R. and R. Varadarajulu, 1964. Fluctuations in monthly mean sealevel at Visakhapatnam as related to the dynamics of atmospheric pressure over Western Bay of Bengal. *Indian Journal of Pure and Applied Physics*, **2**: 228–231.

Varadarajulu, R. and S. Dhanalakshmi, 1975. Sealevels and waves along the Madras Coast. *Indian Journal of Marine Sciences*, **4**: 115–123.

Wyrtki, K. 1971. Oceanographic Atlas of the International Indian Ocean Expedition. National Science Foundation, Washington D.C. 38.