SEA LEVEL VARIABILITY IN THE WEST COAST OF SRI LANKA

KW Indika[1#], EMS Wijerathne[2], GWAR Fernando[3], M Ranagalage[4], SSL Hettiarachchi[5]
[1]National Aquatics Resources Research and Development Agency, Sri Lanka
[2]School of Civil, Environmental and Mining Engineering, University of Western Australia
[3]Department of Physics, Open University of Sri Lanka
[4]Department of Environmental Management, Rajarata University of Sri Lanka, Sri Lanka
[5]Department of Civil Engineering, University of Moratuwa, Sri Lanka
iweligamage@yahoo.com

Abstract - Sea level variability in west cost of Sri Lankan waters was investigated by means of in-situ (Tide gauge) and satellite altimetry data over a period spanning two decades from 1993 to 2014. This paper describes the sea level variations during the mentioned time period retrieved from the two data sets. The gauge data were used from the global network of Inter-Gaovernmental Oceanographic Commision (IOC)and Achiving, Validation and Interpritation of Satellite Oceanographic (AVISO)sattelite data.

Mean sea level (MSL) estimates obtained from tide gauge data showed root mean square differences (RMSDs) were approximately 80% of the variance of the MSL signal estimated from satellite altimetry data. Considering the individual time series, the results showed that coastal tide gauge and satellite sea level signals are comparable, with RMSDs less than 4cm and correlation coefficients up to the order of 0.9. Positive sea level linear trend for the analysis period were estimated for both the mean sea level and the coastal stations.

From 1993 to 2014, the mean sea-level trend (1.9824 mm/year) was found to be affected by the positive anomalies of 2008 and 2014, which were observed in all the cases analysed and were mainly distributed in coast of the western and southern Sri Lanka. Analysis of climatology salinity and temperature field and model outputs, it was evident that change in steric sea level (or dynamic height) is the main factor leading to seasonal MSL change and trend. Ensemble empirical mode decomposition showed that inter-annual variability was related to the processes that have dominant periodicities of 4-6 years related to El Nino Southern Oscillation (ENSO) events. In terms of mean sea level trends, a significant positive sea level trend (>>95%) was found on the basis of at least 10 years of data.

Keywords - Steric Height, Sea Level Changes, Sri Lanka

I. INTRODUCTION

This paper discusses the variation of sea level with the different time intervals in the west coast of Sri Lanka. Sea level is the mean water level, at which the oceans exist when averaged between high and low tides which associated with many kinds of forcing agents in the sea caused by astronomical and hydrological forces. Estimated average annual global mean sea level rise was 2.8 to 3.6 mm yr-1. Volume of ocean was increased causing warming the ocean, loss of glaciers and ice sheets, and reduction of liquid water storage on land (Intergovernmental Panel on Climate Change (IPCC) 5th Assessment report 2013).

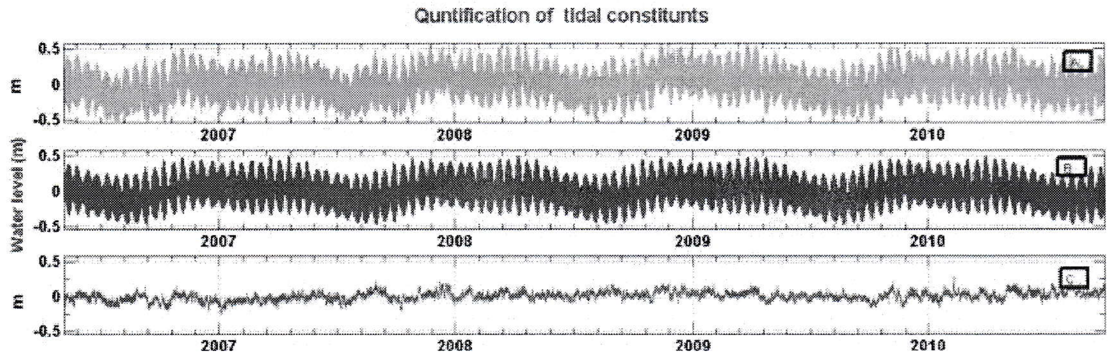
Sea level variation can be classified according to the time scale which that variability occurs from hours to hundreds of years such as seiches, tsunami, tides, storm surges, and sea level rise. Such variations under temporal consisted as hours, days, weeks, months, seasonal, annual and inter-annual while spatially can be classified as meso-scale, synoptic, global scale followed by local, regional

 ISBN number: 978-955-0301-41-6

and global scale respectively. The trend of mean sea level variation inferred from altimetry in Northern Indian Ocean (NIO) is 5±0.4mm/year from the period of 1993-2012 (Indika, 2016). Sea level changes related to density change of specific volume due to change of temperature and salinity is caused by seasonal changes in precipitation, evaporation and heat fluxes which referred to steric height variability (Tomczak and Godfrey, 1994).

The seasonal sea level range around Sri Lankan waters is about 0.2-0.3 m responding to the fresh water inflow, heat flux and other factors that are linked to climate change processes (Wijeratne, 2016). Meanwhile some of extreme variations are governed by sudden changes of atmospheric conditions in disturbed weather system such as Meteotsunami.

This study focused on the study of sea level variations deviate with different time scales using tide gauge and satellite data in the west coast of Sri Lanka.



(a). The green line shows the actual tide gauge one minute feequency reading
(b). Blue line shows the predicted tidal variation
(c). red line shows residual sea level variation

Figure 1: Obtaining of residual sea level variation by separating tidal component.

II. METHODOLOGY

Global Sea Level Observing System (GLOSS) is an international programme conducted under the auspices of the Joint Technical Commission for Oceanography and Marine Meteorology (JCOMM) of the World Meteorological Organisation (WMO) and the Intergovernmental Oceanographic Commission (IOC). This network consisted of 846 automated seal level monitoring stations where the data are transmitted via satellite communication systems across the world. For this study the gauge data collected from the sea level monitoring station at the fisheries harbour, 'Muttual', Colombo Sri Lanka by the National Aquatics Recourses Research and Development Agency (NARA) were used where achiving, validation and interpritation of satellite oceanographic (AVISO) data were done. The Quantified main tidal component was used for the calculation to obtain spring tidal range and neap tidal range separately according to the methodology of Hicks (2006).The tide pattern was analysed quantitatively using the ratio of (K1+O1) to (M2+S2), the Luni-solar Declinational diurnal constituent (K1), and the Principal Lunar Declinational diurnal constituent (O1). The astronomical effects produced by the moon and the Sun [semidiurnal lunar (M2) and the semidiurnal solar (S2) respectively] were calculated separately where the spring and neap tide variation in the western coast of Sri Lanka was determined. The seasonal and long term

variations were analysed by obtaining monthly mean values taken by high frequency gauge data and satellite separately. The final results of both gauge and satellite were super positioned each for the higher accuracy.

III. RESULTS AND DISCUSSION

The residual sea level variation was obtained by tidal constituents removed residual tidal variation. The predicted tidal variation was subtracted from actual tide gauge reading obtained from permanent sea level recording stations established in the west coast of Sri Lanka. The calculations were done using tide gauge data (frequency = one minute) obtained during five years from 2006 to 2011. The quantified tidal constituents assessed separately using 'MATHLAB' computer algebra system via the function of T_TIDE Harmonic analysis of the time series.

The results reveal that M2 is the main tidal constituent in Sri Lanka waters with amplitude of 0.1781 at the phase of 243. 3690 (Table1). These figures are in line with the findings of Wijerathne (2006) which stated that the value of M2 super positioned in between 0.10 – 0.18 m depending on the site. The second largest contributor for the tidal effect was S2 where the amplitude and the phase were 0.1233 and 285.9323 respectively. Furthermore, minute effects compared to M2 and S2 were made by K1 and O1.

Table 1: The resulted tidal constituents obtained quantitatively by harmonic analysis

Station	M2		S2		K1		O1		SA		Spring Tide	Neap Tide
ID-33	A (m)	go	A (m)	go	A (m)	go	A(m)	go	A (m)	go	2(m2+S2)	2(m2-S2)
Colombo	0.178	243.36	0.123	285.93	0.070	307.55	0.029	340.1	0.08	25.28	0.650	0.1102

The sea level change within synodic month, it was referenced to the sun (or phase of moon) and is 29.530588 days in length period. It was showed the pattern and the range of tide in the West coast in Sri Lanka. The pattern of tide was mixed semi diurnal with two high tide and two low tides per day with different strength. The variation shows within about 6 hours of time period in two cycles for a day (Hicks, 2006). The spring tidal range and neap tidal range were recorded as about 0.65m and 0.1102 m respectively with regard to the statistical quantification of Huckes (2006). However, according to the gauge reading analysis, these values were observed as about 0.70 m and 0.10 m respectively. Further in line with the findings of Wijerathne (2006), the tide around Sri Lanka was mixed semidiurnal with a spring tidal range of between 0.40 and 0.60 m.

The mean annual sea level variation was obtained by using monthly average sea level values separately. The value was computed as between 20 – 25 cm from both satellite (A) and gauge data (B). The maximum annual sea level variation occurred during December to January while the minimum variation occurred during July to August (Figure 04). Furthermore, the seasonal and long term sea level changed by the effect of steric which the change of temperature and salinity. Moreover, as Wijeratne (2016) explained, .the seasonal variation may include some effect from large amount of fresh water discharge to the ocean from main rivers. Accordingly, one of the main influences would be made by fresh water discharges from Kelani River.

Long term sea level variation was analysed using (1) satellite data for a period of 20 years and 10 months, from January 1993 to December 2012 and (2) almost seven years of tide gauge data obtained from May 2006 to March 2012. The mean value of both satellite and gauge data gathered considered period using the linear fitting curve of sea level changed. It shows positive sea level trend in 0.0413 m approximately two decade of time with 1.99 mm annual sea level trend. As explained by Tomczak and Godfrey , 1994, an analysis of climatologically salinity and temperature field and model outputs revealed that change in steric sea level (or dynamic height) is the main factor leading to seasonal mean sea level MSL change and trend.

(A) Long term variation plotted using satellite data in the West Coast of Sri Lanka.

(B) Long term variation using tide gauge data in the West Coast of Sri Lanka.

(C) The trend of the sea level variation during considered period.

IV. CONCLUSIONS

According to tide classification of Hicks (2006), the underlying form factor was 0.3317, and the tide in the west coast fits the category of 'Mixed Semidiurnal' with two highs tides and two lows tides per day with different strengths. The spring tidal range and the neap tidal range were 0.60 - 0.65 m and 0.5 - 0.15 m respectively under the category of 'Micro tide'. In line with the finding of Wejerathne (2006), the monthly mean sea level ranged among 20-30 cm. The maximum mean sea level change was recorded between December and January while

ISBN number: 978-955-0301-41-6

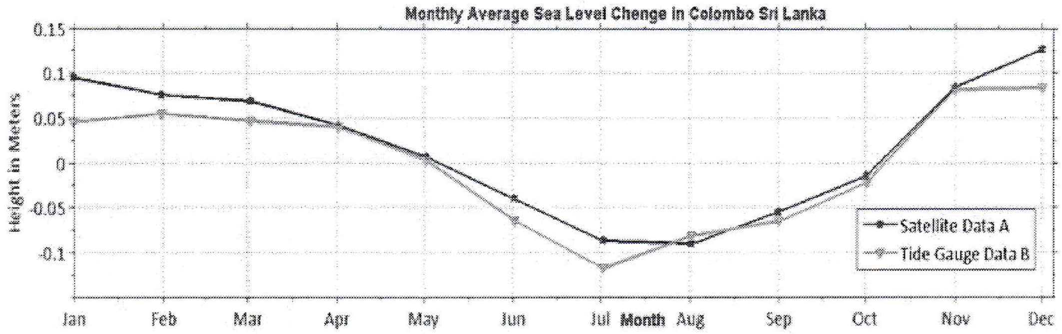


Figure 2. Tide variation within a month period in the west coast.

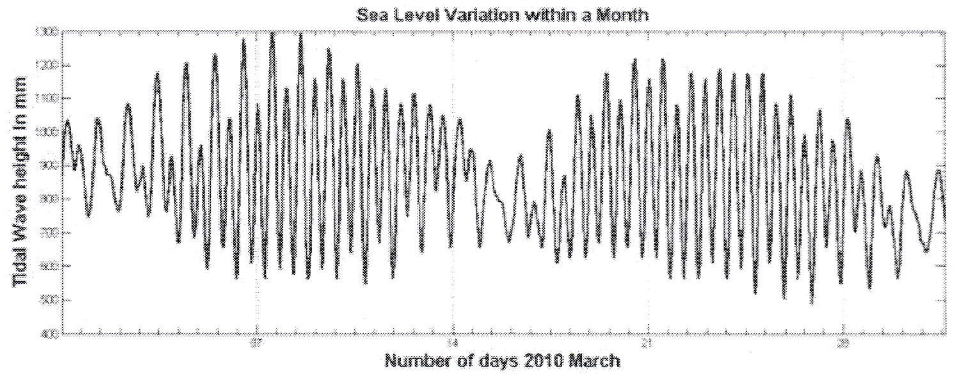


Figure 3. Monthly mean sea level variation in the west coast of Sri Lanka

the minimum level was recorded during July and August where those changes were significantly caused by the 'steric effect'. Long term sea level variation signifies a positive trend of about 1.9824 mm per annum which is influenced by the effects of global climate change. Inter-annual variability was related

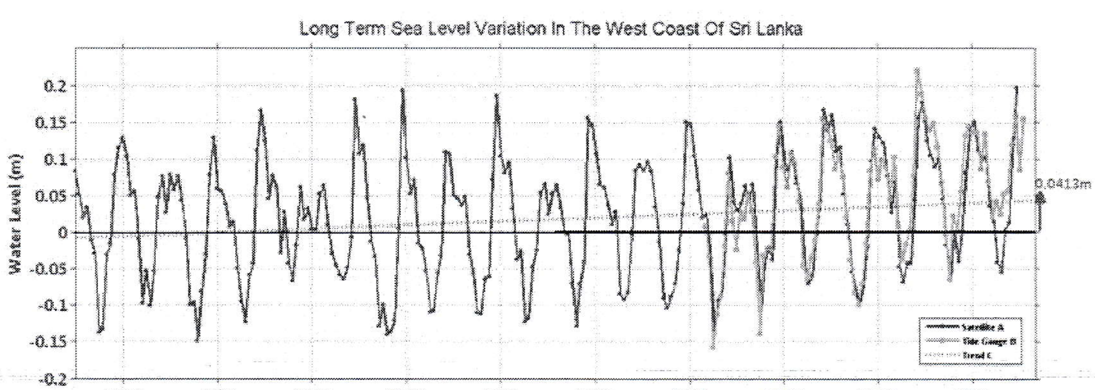


Figure 4: Long term Sea level changes in west coast of Sri Lanka. Blue line shows satellites data for 1993 - 2013 and Green line shows tide gauge record for 2006 - 2013.

to the processes that have dominant periodicities of 4-6 years related to El Nino Southern Oscillation (ENSO) events.

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