OPENING MINDS: RESEARCH FOR SUSTAINABLE DEVELOPMENT

Sea Level Variability in the East Coast of Male, Maldives

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1 INTRODUCTION

This paper discusses the variation of sea level with different time intervals in the East coast of Male, Maldives. Sea level is the mean water level, at which the oceans exist when averaged between high and low tides which is 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 of the ocean, loss of glaciers and ice sheets, and reduction of liquid water storage on land (Intergovernmental Panel on Climate Change 5th Assessment report 2013). Sea level variation can be classified according to the time scale in which variability occurs from hours to hundreds of years such as seiches, tsunami, tides, storm surges, continental shelf waves, annual, inter-annual and sea level rise. Such variations under temporal dimension consist as hours, days, weeks, and months, seasonal, annual and inter-annual while spatial dimension can be classified as meso-scale, synoptic, global scale followed by local, regional and global scale respectively. The trend of mean sea level variation inferred from altimetry in Northern Indian Ocean (NIO) is 5±0.4 mm/year for the period of 1993-2012 (Indika *et al.*, 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 the lower part of the northern Indian Ocean 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 and Pattiarachchi, 2006, 2011). Meanwhile some extreme variations are governed by sudden changes of atmospheric conditions in disturbed weather systems such as Meteotsunami. Exploration of Sea level dynamic is important for future challenges induced with global change to sustainable use of the ocean resources for navigation, harvesting of ocean recourses and coastal development planning for Maldives as an Island country.

2 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), where the station data are transmitted via satellite communication systems across the world. The gauge data used were collected from sea level monitoring station at Hulhule, Male which is maintained under the Maldives Meteorological Department while satellite data were used from Achieving, Validation and Interpretation of Satellite Oceanography (AVISO).The spring and neap tidal range were calculated using quantified tidal constituents according to the methodology of Hicks (2006).The tide pattern was analyzed quantitatively using the ratio of (K1+O1) to (M2+S2). Here the K1 is Luni-solar declinational diurnal constituent and O1 is Principal Lunar Declinational diurnal constituent. The astronomical effects produced by the moon and the Sun (semidiurnal lunar - M2 and the semidiurnal solar - S2) were calculated separately. Then the spring and neap tide variation in the western coast of Male' Maldives was calculated. The seasonal and long term variations were analyzed separately, using monthly mean values of high frequency tide gauge data and satellite data. The final results of both tide gauge and satellite were superposition for the accuracy of different data sources.

3 RESULTS AND DISCUSSION

3.1 Quantification of tidal constituent

The astronomical effect removed residual sea level variation was obtained reducing tide gauge time series by the tidal component time series. The tidal constituents were quantified using one minute frequency tide gauge data obtained during eight years from 1990 to 1998. The T_TIDE harmonic analysis function of time series analysis in MATLAB' software was used to quantify the tidal constituents.

3.2 Determination of tidal pattern

The resulted main tidal constitute and their amplitudes of M2, S2, K1, O1 is shown in Table 1. The results reveal that M2 is the main tidal constituent with amplitude of 0.207 (m). These figures are in line with the findings of Wijerathne (2006, 2008) which stated that the value of M2 super is positioned in-between 0.200 - 0.235 m depending on the site. The second largest contributor for the tidal effect was S2 where the amplitude and the phase were 0.119 and 270.431 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	ID 28	Maldives
M2	A (m)	0.207
	g^0	37.923
S2	A (m)	0.119
	g^0	270.431
K1	A (m)	0.096
	g^0	348.527
O1	A (m)	0.049
	g^0	166.371
Spring Tide	$2(M_1+S_2)$	0.652
Neap Tide	$2(M_2-S_2)$	0.176

Figure 2 shows sea level change within synodic month, which was referenced to the sun or phase of moon with a length of 29.53 days. The graph visualized the pattern and the range of tides in the east cost of Male, Maldives. The form factor was derived using the ratio of major tidal constituents (K1+O1) and (M2+ S2). The pattern of tide was mixed semi diurnal with two high tide and two low tides per day with different strength according to the form factor (0.44) classification. The variation of tide was shown within about 6 hours of time period in unequal two cycles for a day (Hicks, 2006).

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Tide guage time series in one minutes

Tidal component time series from the harmonic analysis

Residual time series [observed record (A) - predicted tide (B)]

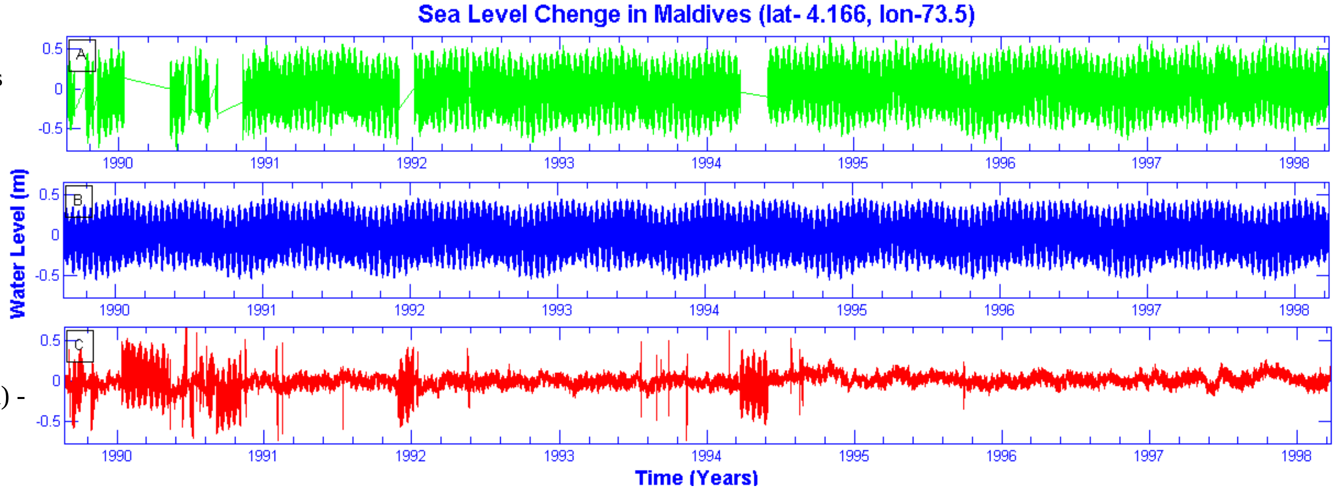


Figure 1: Obtaining of residual sea level vation by separating tidal component

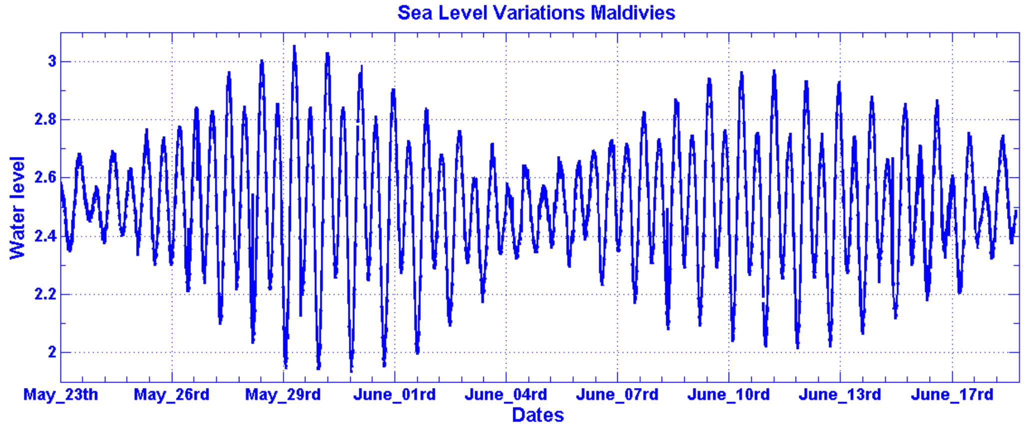


Figure 2: Tide variation within a month period in the east coast of Male, Maldives

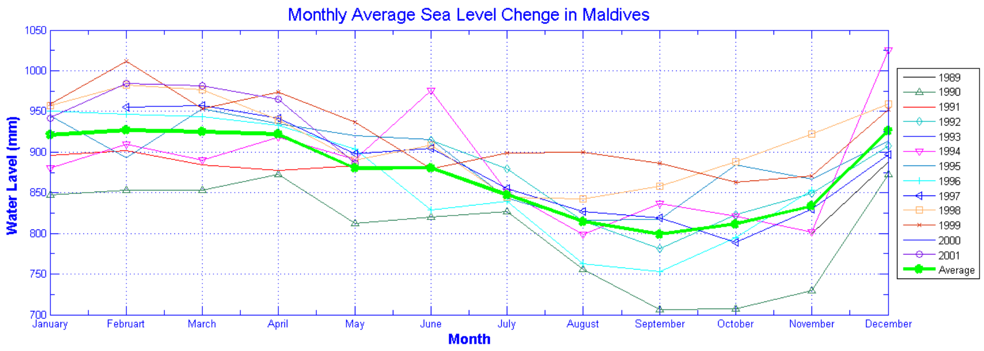
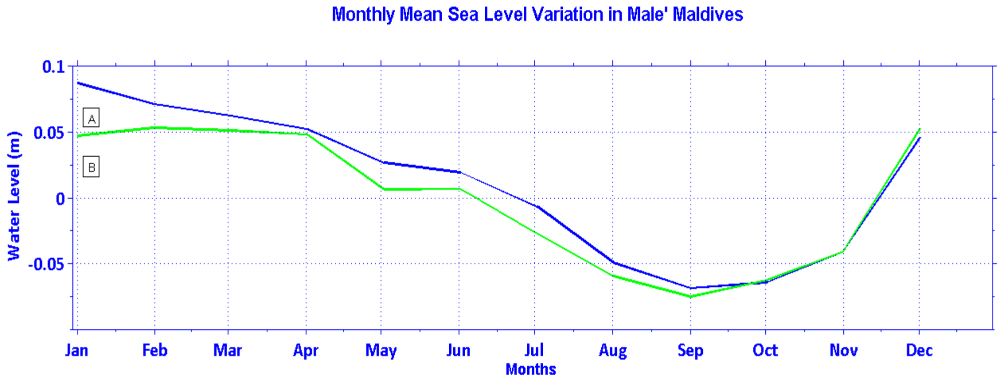
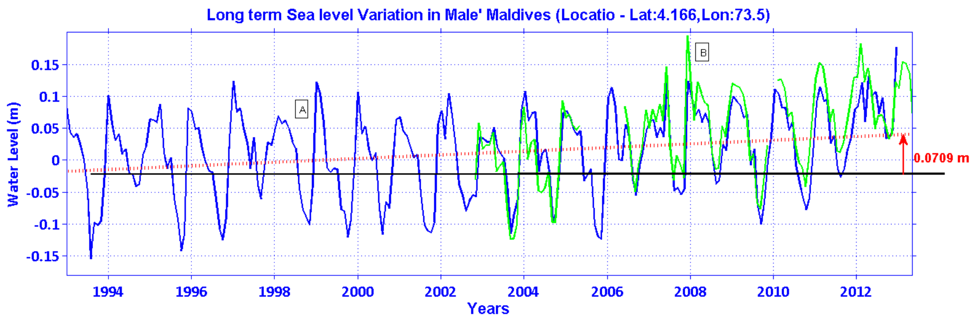


Figure 3: Seasonal sea level variation in the east coast of Male, Maldives



(A) . The Blue - Monthly average AVISO Satellite data
(B) . The Green – Monthly average gauge data

Figure 4: Comparison of seasonal sea level Variation in the east coast of Male' Maldives



(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

Figure 5: Long term Sea level changes in east coast of Male, Maldives. Blue line shows satellites data from 1993 to 2013 and Green line shows tide gauge record from 2006 to 2013.

4 CONCLUSIONS AND RECOMMENDATIONS

According to tide classification of Hicks (2006), tides on the east coast of Male, Maldives is in the category, 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 0.652m and 0.176 respectively under the category of 'Micro tide'. In line with the results of Wijerathne (2006), the monthly mean sea level ranged between 8-15 cm. The maximum mean sea level change was recorded between December and January while the minimum level was recorded during September to October where those changes were significantly caused by the 'steric effect'. Long term sea level variation signifies a positive trend of about 3.40 mm per annum which is influenced by the effects of global climate change.

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