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Tidal regime along Vietnam coast under impacts of sea level rise

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Abstract. The characteristics of the tides in coastal areas are formed by the resonance between the astronomical waves transmitted from the ocean into shallow water and topography in both horizontal (scale of water bodies) and vertical (depth) directions. Thus, sea level rise due to climate change that would alter the depth and scale of the ocean will lead to changes in tidal characteristics. The ROMS model (Regional Oceanography Modeling System) was used to study the impact of sea level rise on tidal regime along the coast of Vietnam. The model was validated by using tidal current regime, and, consequently, used to simulate for the cases of global sea level rise scenarios of 0.5m, 0.75m and 1.0 m.

Keywords: Tidal regime, mean sea level, coast of Vietnam.

1. Introduction

The tidal oscillation in coastal areas is caused by the resonance of the astronomical long waves under the influence of local topography (in both horizontal and vertical directions).

If the globally averaged sea level raises by 1.0 m the future, the SLR will be different across the world because of the changes in ocean circulation, temperature and salinity. Also, the long wave resonance will be different compared to the present since the depth increase by about 1 meter and width of the oceans also tends to increase. Figure 1 illustrated the highest tide in the region A increased only by 0.8m, while it was 1.2 m in area B compared with the present. In this study, the Regional Oceanographic Modeling System (ROMS) [1] was used to assess the impacts of sea level rise scenarios on tidal regime along Vietnam coastlines.

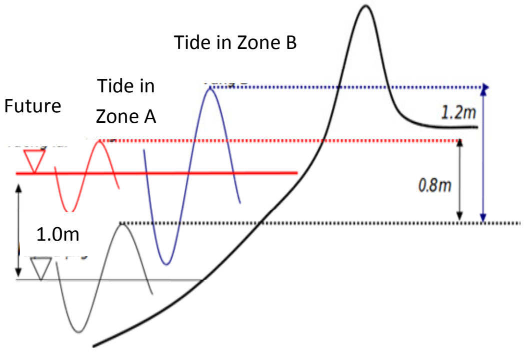

Figure 1. Mechanism of tides regime change due to impact of SLR.

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2. Data

Topographic data used to study the influence of SLR to tidal regime along Vietnam coast is ETOPO2v2 with 2x2 deg. resolutions, version 2006. The computation domain covers from 98.5°E - 128°E and 10°S - 28°N and is made of 355 rows, 472 columns and 12 vertical layers. The maximum depth is more than 8000 meters and the minimum is 10 meters (Figure 2).

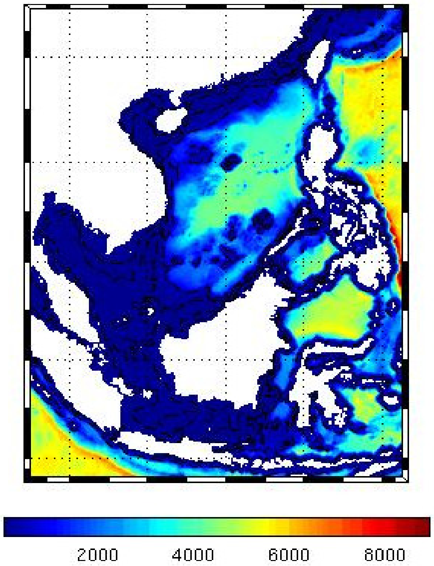

Figure 2. The model domain and the depths in meter (300 x 500 x 12).

Initial conditions were built from the World Ocean Atlas (WOA). At a layer where no observation data is available, the value obtained by the Objective Analysis method will be used. The final horizontal and vertical matrices are interpolated to match the sigma grid. For tidal runs, tidal components (high frequency currents and elevations) are calculated from the tidal model TPXO7.1.

In order to simulate sea weather conditions at certain time in the past or in the future, the outputs from Ocean Global Circulation Model (OGCM) model were used as boundary and initial conditions. In this study, meteorological data including surface wind speed at 10 m elevation, wind stress, surface heat flux, temperature, sea surface salinity, and shortwave radiation were extracted from the Comprehensive Ocean – Atmospheric Data Set (COADS).

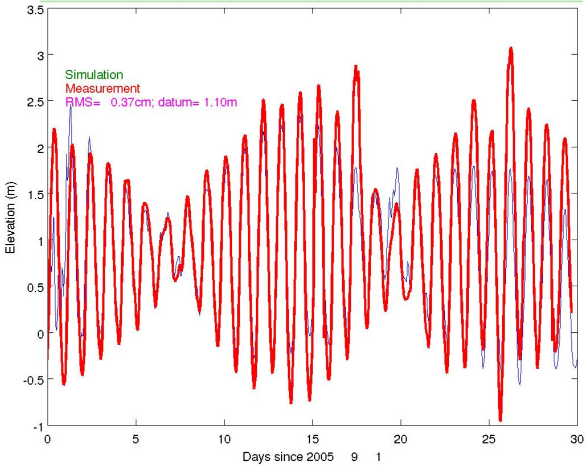

Figure 3. Water level comparison at Hon Dau station.

3. Output analysis

Before incorporating SLR scenarios into the initial and boundary conditions in order to simulate the impacts of SLR on a tidal regime, ROMS had been calibrated to ensure that the parameters were appropriately selected. Two episodes were: September 2005 and November 2006. This was also the time when the sea was forced by storm events.

The parameters (such as track and pressure) of the storms at irregular time step downloaded from UNISYS WEATHER website depend on observation data (possibly 3, 6 or 12 hours) and, consequently, missing values were recovered by linear interpolation so that the nudging fields were always available at certain regular time step (3 hours). Figure 3 and 4 showed the comparisons between the simulated and measured water levels for Hon Dau and Vung Tau stations.

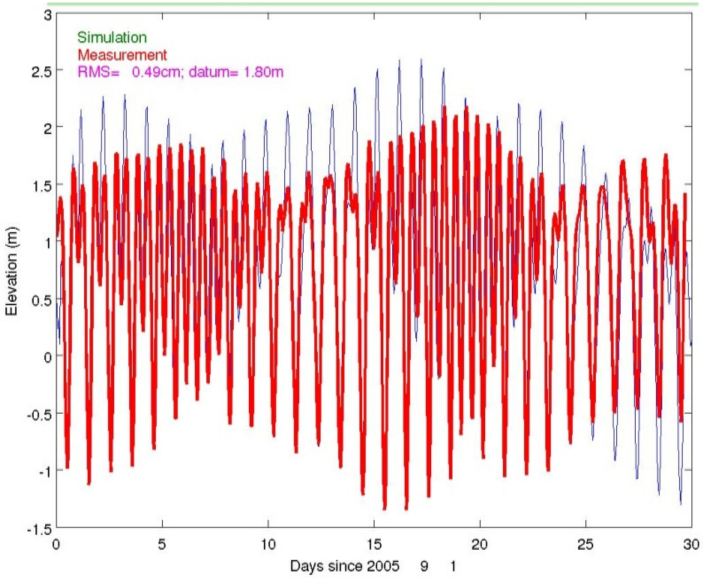

Figure 4. Water level comparison at Vung Tau station.

In term of the water level phase, the computations and observations were quite matched to each other; however, for the tidal amplitude, the root mean square error (RMS) at Hon Dau station (37 cm) was significant though it is lower than Vung Tau station (49 cm).

Harmonic analysis of sea level may provide useful information on the hydrodynamic mechanism as well as the response of the sea to tide creating forces. The numbers of tidal wave components that can be determined depend on the size of data. Because of negligible impacts of long wave components to short-term simulation results, a one-month simulation output is often enough for the analysis of short wave components. This study used T_tide developed from the Foreman's FORTRAN harmonic analysis [2].

Table 1. Comparison of harmonic constants for 32 waves at Hon Dau and Vung Tau stations

Tidal comp.	HD-Amplitude (m)		HD-Phase Angle (°)		VT- Amplitude (m)		VT-Phase Angle (°)	
	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.	Sim.	Obs.
MSF	0.1208	0.0381	49.58	53.17	0.1076	0.0193	61.35	94.37
*2Q1	0.0635	0.068	135.60	245.63	0.0129	0.0402	212.55	200.82
*Q1	0.1176	0.2425	290.62	125.95	0.103	0.136	180.12	9.08
*O1	0.6303	1.2648	300.95	324.67	0.5708	0.6935	190.40	199.01
*NO1	0.043	0.0465	192.84	119.47	0.0376	0.0166	61.25	13.38
*P1	0.1951	0.1766	8.57	96.99	0.234	0.1508	251.72	321.88
*K1	0.5896	0.5336	1.50	89.92	0.7071	0.4557	244.65	314.81
*J1	0.0197	0.0653	317.76	301.54	0.0219	0.0539	237.60	151.03
*OO1	0.0168	0.1029	83.07	278.74	0.0226	0.0656	349.10	104.94
UPS1	0.0011	0.0245	216.07	259.16	0.0071	0.0122	208.22	197.72
*N2	0.0171	0.0053	174.64	169.55	0.1291	0.1626	154.23	149.41
*M2	0.0961	0.0491	200.09	347.42	0.7367	0.7538	185.41	347.00
*S2	0.0656	0.0999	236.42	234.77	0.3326	0.4976	210.49	226.35
*K2	0.0178	0.0272	258.82	257.17	0.0905	0.1354	232.89	248.75
ETA2	0.0032	0.0141	276.18	12.81	0.0122	0.0493	257.07	327.69
MO3	0.0141	0.0434	272.23	169.70	0.0496	0.0526	291.10	36.00
M3	0.0073	0.005	43.44	358.48	0.0092	0.0033	320.95	260.46
MK3	0.0149	0.0136	274.48	311.02	0.0257	0.0243	49.93	177.72
*SK3	0.0276	0.017	135.00	259.89	0.0362	0.0239	40.97	102.65
MN4	0.0048	0.0078	355.69	271.24	0.0092	0.005	288.12	12.08
M4	0.0196	0.0034	271.20	13.02	0.0398	0.011	299.97	212.06
MS4	0.0108	0.0051	293.92	335.64	0.0175	0.0112	348.52	94.38
S4	0.009	0.0035	179.44	201.62	0.0048	0.0037	58.42	329.82
2MK5	0.0041	0.0098	113.97	233.21	0.003	0.0026	132.40	211.97
2SK5	0.0026	0.0128	87.61	184.59	0.0007	0.0054	56.76	344.89
2MN6	0.0038	0.0039	314.93	274.97	0.0028	0.0013	200.43	130.90
*M6	0.0131	0.005	6.98	40.58	0.0068	0.0044	292.08	37.86
*2MS6	0.018	0.0061	70.04	8.90	0.0099	0.0067	317.24	287.15
*2SM6	0.0077	0.0031	143.54	275.35	0.0034	0.0031	334.24	134.88
3MK7	0.0009	0.0053	314.93	184.33	0.0023	0.0009	182.24	316.73
M8	0.0005	0.0022	51.96	306.12	0.0017	0.0011	19.08	136.46
*M10	0.0011	0.001	56.79	296.63	0.0016	0.001	90.44	254.19

The calculation results for September 2005 were shown in Table 1. At Vung Tau station, semi-diurnal tides are dominant over diurnal components while the earlier are negligible at Hon Dau. The calculations were generally consistent with the measurements, in term of the amplitude, except the O1 wave at Hon Dau, the calculated amplitude was about 1.26 m when the measured was only 0.63 m. The table also showed considerable phase discrepancy between computation and measurement of Q1 and Q1, M2 at Hon Dau and Vung Tau respectively. In the computation, water depths were 10.57 m and 10.00 m at Hon Dau and Vung Tau respectively. The horizontally spatial (computational grid size of about 17 km) and vertical (depth in ETOPO2 counted in metres) accuracy could be the main reasons for the inconsistency between computation and measurement.

To assess the role of climate change related SLR on the tides along Vietnam coast and the East Sea as a whole, the above calculations were repeated with the following conditions:

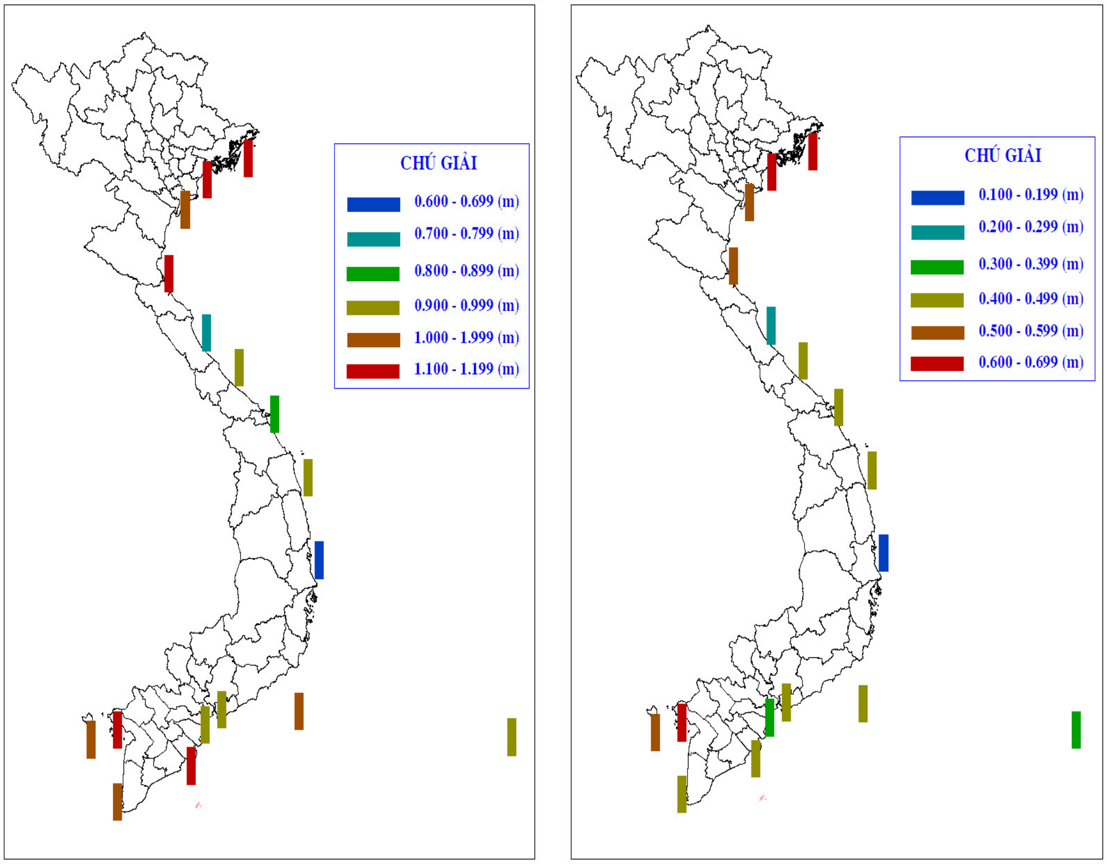

Figure 5. Changes in yearly mean water level in SLR scenarios.

(1) One-year simulation; (2) Applied SLR effects into the calculation (replacing the water elevation scenarios of 0.5m, 0.75m and 1.0m into the initial and boundary conditions); and (3) Assumption that the impact of climate change to tide regime is only through the mean sea level.

Figure 5 and Table 2 indicated changes in annual mean sea level under the scenarios compared to the present. Of the 52 nodes calculated in this study, 10 were tide gauges with more than 20 years' data in the series, 15 nodes were located at seven major estuaries, 20 nodes were located at approximately every 100 km along the coast of Vietnam, and some nodes were near main islands and straits of the East Sea. Overall, the trends in change in mean sea level were relatively heterogeneous: either increase (in the North) or decrease (in the South) in all 3 scenarios.

Table 2. Changes in annual mean water level in SLR scenarios

No	Station	Lat	Long	KB3	KB2	KB1
1	Co To station	21	107.7	1.16	0.90	0.63
2	Bai Chay station	20.9	107.6	1.16	0.89	0.62
3	Hon Dau station	20.6	106.7	1.14	0.87	0.59
4	Hon Ngu station	18.8	105.8	1.12	0.83	0.55
5	Con Co station	17.2	107.4	0.99	0.74	0.49
6	Son Tra station	16.1	108.3	0.89	0.67	0.43
7	Quy Nhon station	13.3	109.4	0.65	0.41	0.15
8	Phu Quy station	10.5	108.9	1.09	0.77	0.47
9	Vung Tau station	10.3	107	0.98	0.68	0.42
10	Bach Dang river	20.9	107	1.13	0.88	0.65
11	Thai Binh river	20.6	106.7	1.16	0.89	0.61
12	Ba Lat gate	20.3	106.6	1.12	0.86	0.60
13	Ninh Co river	20	106.2	1.10	0.82	0.54
14	Ca river	18.8	105.8	1.11	0.83	0.55
15	Thu Bon river	15.9	108.4	0.85	0.61	0.37
16	Thi Vai river	10.3	107	0.98	0.69	0.42
17	Nha Be river	10.4	107	0.97	0.69	0.43
18	Cua Tieu river	10.3	106.8	0.90	0.59	0.35
19	Cua Dai river	10.2	106.8	0.92	0.62	0.36
20	Ba Lai river	10	106.7	0.95	0.65	0.39
21	Ham Luong river	10	106.7	0.96	0.65	0.39
22	Cung Hoa river	9.8	106.6	0.90	0.62	0.42
23	Hau river	9.5	106.3	1.12	0.78	0.46
24	Truong Sa	10	114	0.99	0.73	0.38
25	Phu Quoc	9.9	103.9	1.07	0.80	0.55
26	Gulf of Thailand	10	102	1.08	0.79	0.54
27	Taiwan - Philippines	21	120.5	1.04	0.85	0.59
28	Singapore-Indonesia	2	106.5	1.10	0.79	0.46

4. Conclusion

If only the factors of topography and tidal regime are considered, the global sea level rise will have different effects on various coastal areas in Vietnam. This study showed that only changes in depth of the continental shelf due to sea level rise could alter the tidal regime along Vietnam coast to 20%. The impact of horizontal size changes of the continental shelf on tidal regime and distribution shifts of tidal characteristics should be conducted in subsequent studies.

References

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