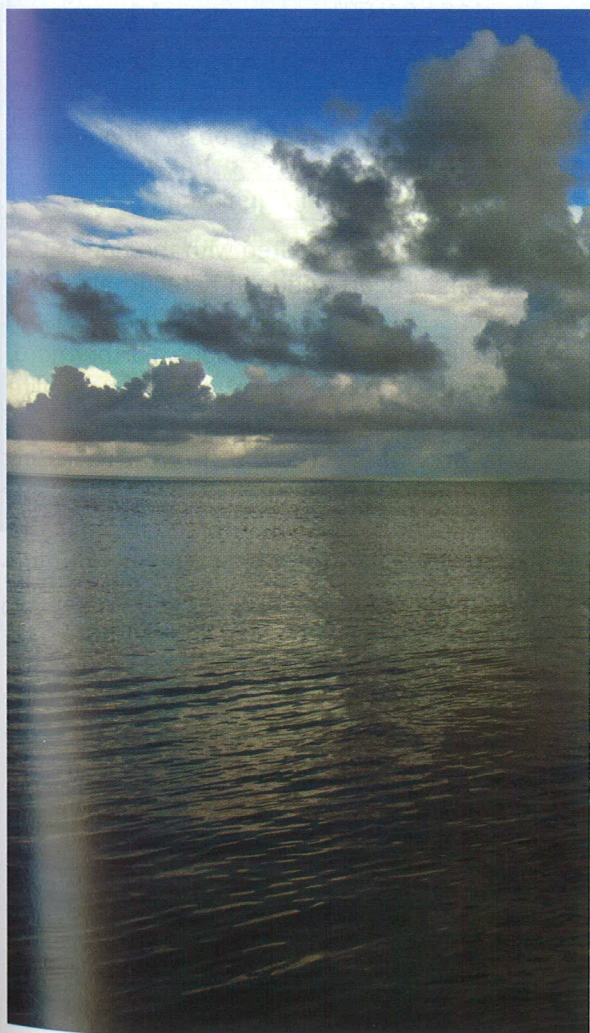


SEA LEVEL RISE IN MALAYSIA

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Sea level rise (SLR) is attributed to ocean thermal expansion, melting Greenland and Antarctic glaciers and decrease in terrestrial storage (*Dasgupta et al, 2007*). SLR can have a high economic impact especially on low lying areas, such as the destruction of assets and disruption to economic sectors, loss of human lives, mental health effects, or loss of plants, animals, and ecosystems. The severity depends on their extremes, exposure and vulnerability (*IPCC, 2012; McLean, 2009*). SLR may reduce the size of an island or a state and its' infrastructure such as, airports, roads, and capital cities, which tend to be situated in coastal areas. Inundation, erosion, and other coastal hazards; threaten vital infrastructure, settlements, and facilities; and thus compromise the socio-economic well-being of island communities and states (*Handmer et al., 2012*). SLR varies spatially hence coastal nations need to ascertain the likely extent of local impact.

The Malaysian Study on the Impact of Climate Change on Sea Level Rise (*NAHRIM, 2010*) was conducted with the purpose of first assessing the rates of SLR by analyzing the observed tide gauge and satellite altimeter data around the Malaysian coast, then determining the projection of the sea level rise along the coast.

Due to financial constraints, the SLR Study was conducted in several phases:-

Station No.	Location	Latitude	Longitude	SLR Rate (mm/year)
1	Pulau Langkawi	06° 25' 51"	99° 45' 51"	1.9
2	Pulau Pinang	05° 25' 18"	100° 20' 48"	2.3
3	Lumut	04° 14' 24"	100° 36' 48"	2.1
4	Pelabuhan Klang	03° 03' 00"	101° 21' 30"	1.3
5	Tanjung Keling	02° 12' 54"	102° 09' 12"	1.3
6	Kukup	01° 19' 31"	103° 26' 34"	3.0
7	Johor Bahru	01° 27' 42"	103° 47' 30"	2.3
8	Tanjung Sedili	01° 55' 54"	104° 06' 54"	1.2
9	Pulau Tioman	02° 48' 26"	104° 08' 24"	1.8
10	Tanjung Gelang	03° 58' 30"	103° 25' 48"	2.6
11	Chendering	05° 15' 54"	103° 11' 12"	2.2
12	Geting	06° 13' 35"	102° 06' 24"	1.3
13	Sejingkat	01° 34' 58"	110° 25' 20"	-5.8
14	Bintulu	03° 15' 44"	113° 03' 50"	0.2
15	Labuan	05° 16' 22"	115° 15' 00"	0.7
16	Kota Kinabalu	05° 59' 00"	116° 04' 00"	4.4
17	Kudat	06° 52' 46"	116° 50' 37"	3.0
18	Sandakan	05° 48' 36"	118° 04' 02"	4.1
19	Lahad Datu	05° 01' 08"	118° 20' 46"	3.6
20	Tawau	04° 14' 00"	117° 53' 00"	3.5

Table 1: The rates of sea level rise along the coast of Malaysia based on tide gauge observation data from 1984 -2010 (Source: NAHRIM, 2010)

1. To assess the trend/pattern of sea level rise along the Malaysian coast using observed data and determine the rate of SLR
2. To project SLR along the coast for the years 2020, 2040, 2060, 2080 and 2100;
3. To determine critical areas that will be impacted by the change in hydrodynamic processes caused by SLR, such as inundation, erosion, salt water intrusion etc., and to determine the impact on the coastal environment and resources. Measures can then be proposed to minimize economic loss.

Methodology

For the above study, recorded tidal gauge data (1984-2010) from 20 JUPEM stations and satellite altimetry data (1993-2010) from 30 stations around Malaysia were independently analysed using linear regression analysis to obtain the rates of SLR for Malaysia coast.

The linear trends in SLR along the coast were significantly higher for the satellite altimeter

observations when compared with the tide gauge observations. Uncertainties in satellite altimeter observations are well described and there was no missing data for these observations. Furthermore, it was possible to correct the errors in the satellite observations (NAHRIM, 2010).

Therefore, this study utilizes the rates obtained from satellite altimeter data derived from the global mean SLR projection from the results of 49 simulations of seven coupled Atmospheric-Oceanic General Circulation Models (AOGCM) as the basis for assimilating future SLR projections along the coast of Malaysia (NAHRIM, 2010).

NAHRIM (2010) noted that the spatial variation of SLR derived from tidal gauge and satellite altimeter data differed from that projected by the AOGCM. Eventually, the global mean sea level projections simulated from the AOGCM were assimilated into the satellite altimeter observations along the coastline (NAHRIM, 2010) to obtain the projected sea level rise along the Malaysian coastline.

Station No.	Location	Latitude	Longitude	SLR Rate (mm/year)
1	Sempadan Malaysia (Perlis) - Thailand	6	100	6.08
2	Sempadan P.Pinang – Perak Border	5	99	6.45
3	Perairan Laut Andaman	1	104	3.87
4	Perairan Selat Melaka	2	105	3.68
5	Selat Johor	3	104	2.88
6	Perairan Mersing	4	104	2.73
7	Pulau Tioman	5	104	2.78
8	Persisiran Pantai Pekan	6	103	3.46
9	Cherating	7	103	3.49
10	Pulau Perhentian, Terengganu	7	102	4.29
11	Sempadan Malaysia (Kelantan) – Thailand	7	101	5.20
12	Perairan Tumpat	6	99	5.70
13	Perairan Kelantan	7	99	5.02
14	Perairan Kuching dan Bau	4	113	4.74
15	Perairan Sejingkat (Sibu)	2	110	4.00
16	Perairan Sibu	5	115	5.37
17	Perairan Miri	6	116	5.23
18	Perairan Bintulu	7	117	5.06
19	Perairan Brunei	6	118	5.57
20	Luar Persisir Sabah - Sarawak – Brunei	5	119	6.28
21	Luar Persisir Sabah - Sarawak – Brunei	4	119	7.00
22	Persisiran Pantai Kota Kinabalu	7	118	5.25
23	Pulau Labuan	6	119	5.64
24	Persisiran Pantai Tuaran - Kota Belud	7	116	5.17
25	Teluk Marudu, Kota Marudu – Kudat	6	115	5.27
26	Perairan Pitas	5	114	5.11
27	Perairan Sandakan	5	113	4.84
28	Laut Sulu	4	112	4.51
29	Perairan Lahad Datu	3	111	4.13
30	Perairan Tawau	3	110	3.82

Table 2: The rates of sea level rise along the coast of Malaysia based on satellite altimetry observation data from 1993-2010 (Source: NAHRIM, 2010)

SLR Rates (mm/year)		
	Malaysia	Global
Tide gauge	0.2 – 4.4 (1984-2010)	1.2 – 2.2 *
Satellite Altimetry	2.73 – 7.0 (1993-2010)	2.4 – 3.8 *

* IPCC (AR4 2007)

Table 3: Comparison between the rates of Mean SLR for Malaysian coastline and Global Mean SLR using tide gauge and satellite altimeter (Source: NAHRIM, 2010)

Projection on Sea Level Rise at 2100 for Malaysia

	Sea Level Rise	Note
Projection 2100 (Peninsular Malaysia)	0.25m – 0.52m (2.5 – 5.2 mm/yr)	Maximum SLR – Northeast and West coast of Peninsular Malaysia (Kelantan & Kedah)
Projection 2100 (Sabah & Sarawak)	0.43m – 1.06m (4.3 – 10.6 mm/yr)	1. Maximum SLR– North & East coast of Sabah. 2. Inundation at low lying area and rivermouth/estuaries in Southwest coast of Sarawak (Meradong, located between Batang Igan & Batang Rajang). 3. Inundation at low lying area and rivermouth/estuaries in East coast of Sabah (Tawau, Semporna, Lahad Datu, Sandakan & Kudat).

Table 4: Projections of SLR for 2100 along the coast of Malaysia (Source: NAHRIM, 2010)

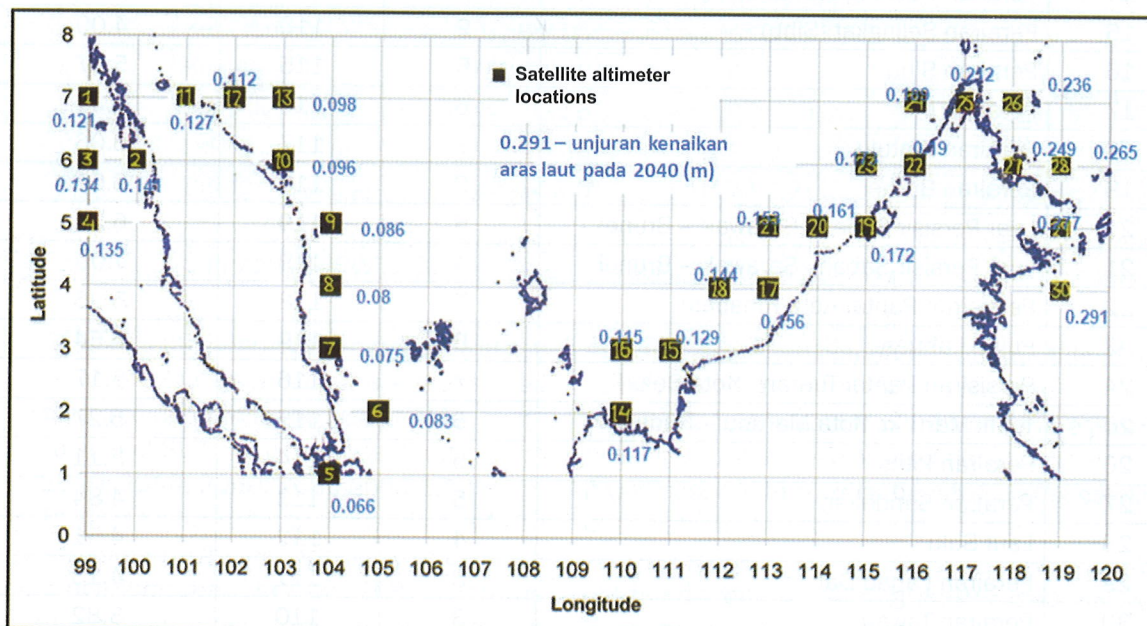


Figure 1: Projected mean sea level rise at the 30 satellite altimeter locations along the coast of Malaysia for year 2040 (Source: NAHRIM, 2010)

Sea Level Rise Findings/Predictions

Sea level rise can be projected from the linear trend analysis of tidal gauge and satellite altimeter data. Analysis of tidal gauge data from 1955 to 2003 around the Malaysian coast revealed a SLR of 1.6 to 3.6 mm/year depending on location. Satellite altimeter data became available only from 1993 onwards and the SLR found was from 3 to 9 mm/year.

Assimilating AOGCM output into the satellite altimetry data, the sea level rise predicted around Peninsular Malaysia ranged from 0.066 to 0.141 metres in 2040. For the 2100 scenario, the average sea level rise is predicted to be 0.253 to 0.517 metres. The highest SLR is expected to occur at the northwest coast and northeast coast.

Tables 1 and 2 show the rate of SLR along the coast of Malaysia based on JUPEM tide gauge data (from 1984-2010) and the rate of sea level

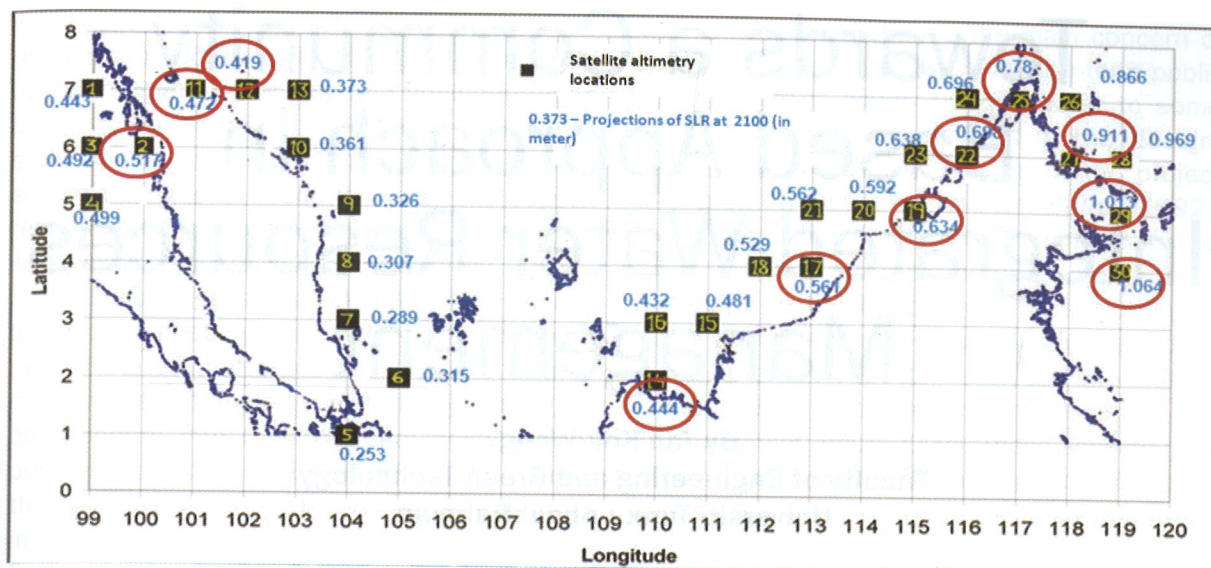


Figure 2: Projected mean sea level rise at the 30 satellite altimetry locations along the coast of Malaysia for year 2100. Red circles indicate values higher than 0.4 m rise (Source: NAHRIM, 2010)

rise based on satellite altimetry data (from 1993-2010), respectively.

Table 3 compares the Mean SLR for Malaysian coastline and Global Mean SLR using tide gauge and satellite altimetry data while Table 4 shows the projections of SLR for 2100 along the coast of Malaysia. Figures 1 and 2 indicate the projected mean sea level rise for the Malaysian coast in the year 2040 and 2100 respectively. ■

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