CHAPTER 3 METHODOLOGY

This chapter describes the details of observations and the results from numerical ocean models: OCCAM and POM. The observations are obtained from the government organizations in Thailand, the Permanent Service for Mean Sea Level (PSMSL) and TOPEX/ERS satellite altimeter. The sea surface height from observation and results from OCCAM as well as from POM are investigated in the the Gulf of Thailand (GoT) and the South China Sea (SCS). Since the interested area containing the GoT and the SCS region is quite large, therefore the interested area is divided into two regions separately. The GoT region covers 98°E to 105°E and 5.5°N to 14°N and the SCS covers 105°E to 123°E and 0°N to 25°N. The sea surface height (SSH) from OCCAM with the resolutions of 1/4° and 1/12° are used to investigate in the GoT and the SCS. Moreover, SSH in the GoT from POM is investigated.

3.1 The Observations

There are two types of observations: data records from tide gauge stations and data grids from satellite altimeter. The data records are provided from 3 government organizations of Thailand and the PSMSL. The data grids are taken from TOPEX/ERS satellite altimeter.

3.1.1 Sea level observed from tide gauge stations

The observations and analysis are essential for many areas of study such as coastal engineering, fishery environment and marine environment. In this study, the 15 tide gauge stations from the Marine Department (MD), Hydrographic Department (HD) and Port Authority of Thailand (PAT) are disclosed. The locations of tide gauge stations are shown in Tables 3.1 - 3.3 and Figure 3.1. The observations for each station are available in various periods and there are some missing data in some periods.

Table 3.1 Tide gauge stations from Marine Department

Station Number	Station Name	Latitude	Longitude
1	Narathiwat	6°25′26″N	101°49′48″E
2	Pattani	6°54′08″N	101°14′57″E
3	Pakpanang	8°21′11″N	100°12′08″E
4	Sichon	9°00′45″N	99°55′07″E
5	Langsuan	9°56′38″N	99°09′38″E
6	Banlaem	13°15′47″N	99°56′44″E
7	Samutsongkram	13°22′36″N	99°59′44″E
8	Samutsakorn	13°30′36″N	100°16′40″E
9	Bangpakong	13°29′00″N	101°00′23″E
10	Rayong	12°39′30″N	101°16′28″E
11	Prasae	12°41′41″N	101°42′21″E
12	Thachalaep	12°31′54″N	102°03′41″E
13	Laemngop	12°10′07″N	102°23′45″E

Table 3.2 Tide gauge stations from Hydrographic Department

Station Number	Station Name	Latitude	Longitude
14	Ko Lak	11°47′42″N	99°48′58″E

Table 3.3 Tide gauge stations from Port Authority of Thailand

Station Number	Station Name	Latitude	Longitude
15	Phrachula Chomklao Fort	13°33′06″N	100°34′44″E

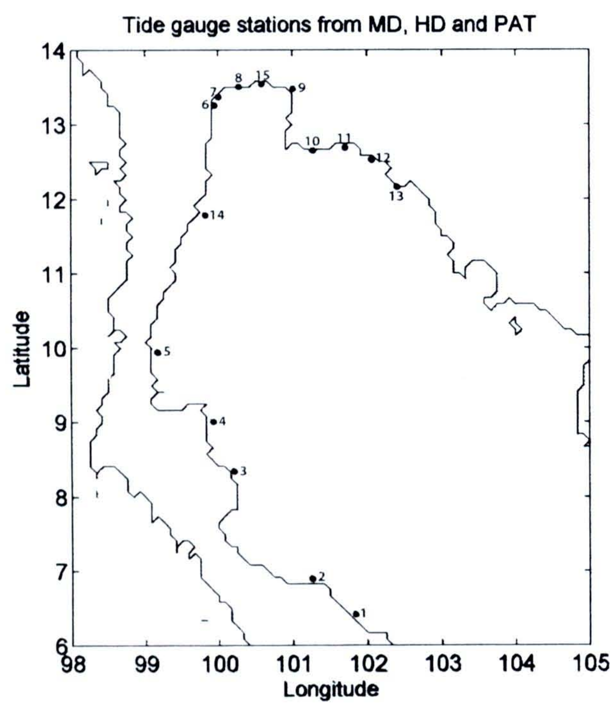

Figure 3.1 The 15 tide gauge stations in the Gulf of Thailand.

3.1.2 The Permanent Service for Mean Sea Level (PSMSL)

The global sea level are available through PSMSL at the Proudman Oceanographic Laboratory in UK. The PSMSL was established in 1933, and is a global data bank for long term sea level change information from tide gauges. The database of the PSMSL contains records of monthly and annual mean values of sea level from almost 27000 tide gauge stations around the world in the year 1987 and up to 61000 tide gauge stations in the year 2011 acquiring from national authorities. The monthly and annual mean values of sea level data from each station are entered directly as received from the authority into the PSMSL raw data files for all stations. The data sets of monthly mean sea level in the GoT and the SCS covering 90°E to 135°E and 15°S to 30°N are used in this study. There are 56 tide gauge stations of monthly mean sea level for the year 1988 - 2004. The tide gauge stations are given in Tables 3.4 - 3.11 and Figure 3.2.

Table 3.4 Tide gauge stations of PSMSL in Malaysia

Station Number	Station Name	Latitude	Longitude
1	Kukup	01°20′N	103°27′E
2	Johor Bahru	01°28′N	103°48′E
3	Tanjung Sedili	01°56′N	104°07′E
4	Pulau Tioman	02°48′N	104°08′E
5	Tanjung Gelang	03°59′N	103°26′E
6	Cendering	05°16′N	103°11′E
7	Geting	06°14′N	102°15′E
8	Labuan 2	05°16′N	115°15′E
9	Kota Kinabalu	05°59′N	116°04′E
10	Kudat	06°53′N	116°51′E
11	Sandakan	05°49′N	118°05′E
12	Lahat Datu	05°01′N	118°21′E
13	Tawau	04°14′N	117°53′E

Table 3.5 Tide gauge stations of PSMSL in Indonesia

Station Number	Station Name	Latitude	Longitude
14	Benoa	08°45′N	115°13′E
15	Surabaya II	07°13′N	112°44′E

Table 3.6 Tide gauge stations of PSMSL in the Gulf of Thailand

Station Number	Station Name	Latitude	Longitude
16	Ko Mattaphon	10°27′N	99°15′E
17	Ko Lak	11°48′N	99°49′E
18	Bangkok Bar	13°27′N	100°36′E
19	Phrachula Chomklao Fort	13°33′N	100°35′E
20	Ko Sichang	13°09′N	100°49′E

Table 3.7 Tide gauge stations of PSMSL in Viet Nam

Station Number	Station Name	Latitude	Longitude
21	Vungtau	10°20′N	107°04′E
22	Quinhon	13°46′N	109°15′E
23	Danang	16°06′N	108°13′E
24	Honngu	18°48′N	105°46′E
25	Hondau	20°40′N	106°48′E

Table 3.8 Tide gauge stations of PSMSL in China

Station Number	Station Name	Latitude	Longitude
26	Beihai	21°29′N	109°05′E
27	Zhapo	21°35′N	111°50′E
28	Nan Sha	09°32′N	113°53′E
29	Xi Sha	16°50′N	112°20′E
30	Xiamen	24°27′N	118°04′E
31	Shanwei	22°45′N	115°21′E
32	Haikou	20°01′N	110°17′E
33	Dongfang	19°06′N	108°37′E
34	Kanmen	28°05′N	121°17′E

Table 3.9 Tide gauge stations of PSMSL in Hong Kong

Station Number	Station Name	Latitude	Longitude
35	Waglan Island	22°11′N	114°18′E
36	Chi Ma Wan, Lantau Island	22°14′N	114°00′E
37	Tamar	22°17′N	114°10′E
38	North Point (Quarry Bay)	22°18′N	114°13′E
39	Tai Mui Wan	22°16′N	114°17′E
40	Ko Lau Wan	22°28′N	114°22′E
41	Tai Po Kau, Tolo Harbour	22°27′N	114°11′E
42	Tsim Bei Tsui	22°29′N	114°01′E
43	Lok On Pai	22°22′N	114°00′E
44	Tai O	22°15′N	113°51′E
45	Shek Pik	22°13′N	113°54′E

Table 3.10 Tide gauge stations of PSMSL in the Philippines

Station Number	Station Name	Latitude	Longitude
46	San Jose	12°20′N	121°05′E
47	Port Irene	18°23′N	122°06′E
48	Manila, S. Harbor	14°35′N	120°58′E
49	Legaspi, Albay	13°09′N	123°45′E
50	Cebu	10°18′N	123°55′E
51	Puerto Princesa, Palawan	09°45′N	118°44′E
52	Davao, Davao Gulf	07°05′N	125°38′E
53	Jolo, Sulu	06°04′N	121°00′E
54	Surigao	09°47′N	125°30′E

Table 3.11 Tide gauge stations of PSMSL in Taiwan

Station Number	Station Name	Latitude	Longitude
55	Keelung II	25°08′N	121°44′E
56	Kaohsiung II	22°32′N	120°19′E

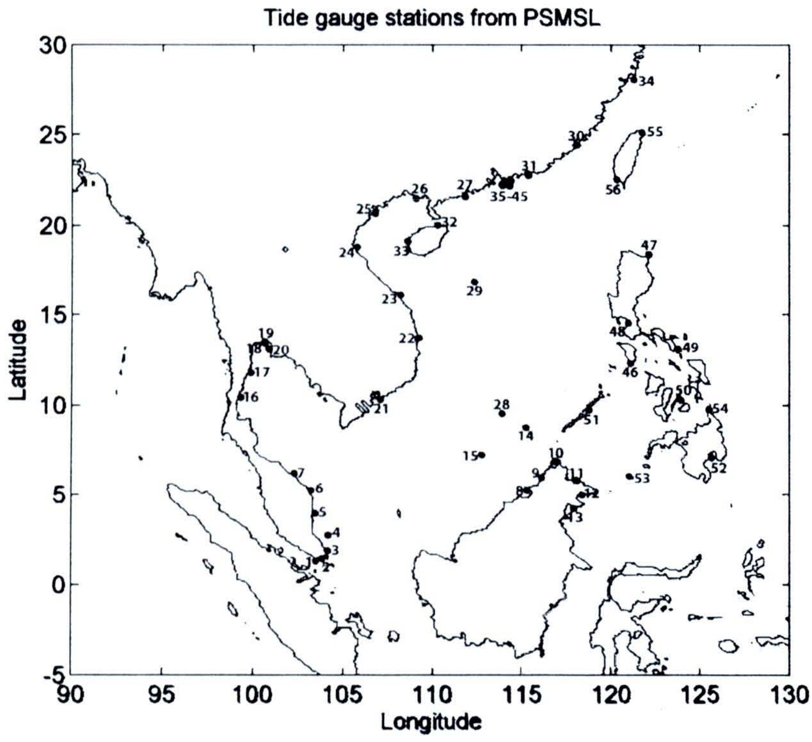

Figure 3.2 The tide gauge stations in the Gulf of Thailand and the South China Sea from PSMSL.

3.1.3 The TOPEX/ERS merged data

The grided data sets of monthly sea surface height anomaly (SSHA) used in this study are obtained by merging TOPEX/ERS altimeter measurements between 1993 to 2004. The SSHA which mapped on irregular grid about 1/3° spacing is calculated with respect to 7 year mean (January 1993 to December 1999). The data grids cover the two regions: the Gulf of Thailand (98°E to 105°E and 6°N to 14°N) and the South China Sea (105°E to 123°E and 0°N to 25°N). The grided data in space is 23×26 and 56×79 for each time in the GoT and the SCS, respectively.

3.2 Data from the OCCAM Global Ocean Model

The SSHs from OCCAM with resolutions of 1/4° and 1/12° are studied. There are 120 months during February 1993 to January 2003. The data grids from OCCAM with a resolution of 1/4° in space are 29×33 and 73×101 for each time in the GoT and the SCS, respectively. For OCCAM with a resolution of 1/12°, the data grids are investigated only in the GoT with 85×97 in space. In the SCS region, there are large in dimensions. So, the performance of computer currently used can not compute in that large domain.

3.3 Data from the POM

In this study, the model has been modified for spinup phase. This model is re-initialized every month using initial data such as temperature, salinity, wind velocity and bottom topography. The temperature and salinity data from Levitus94 (Levitus and Boyer, 1994; Levitus, et al., 1994) have resolutions of $1° \times 1°$. The wind velocity with a resolution of $1.125° \times 1.1213°$ is taken from European Centre for Medium-Range Weather Forecasts (ECMWF). The bottom topography is taken from the ETOPO5. The spinup process is run until the ocean model reaches state of equilibrium, that is the time series of total kinetic energy (EK) and surface potential energy (EAS) reach a steady state under the applied force (Aschariyaphotha, 2006). The total energies are following

$$EK = \frac{1}{2}\int\int \rho_0(u^2+v^2)dxdy, \tag{3.1}$$

$$EAS = \frac{1}{2}\int\int \rho_0 g\eta^2 dxdy. \tag{3.2}$$

The spinup process is required so that the ocean state has adjusted to the initial condition and can be used for prediction after this process. The POM has been applied to the GoT with resolution of 1/6° in longitude and 1/12° in latitude which covers 99°E to 105.5°E and 5.5°N to 13.5°N. The monthly SSH from POM during February 1993 - January 2003 total of 120 months has been used in the analysis. The data grids have 37×97 in space for each time in the GoT.

3.4 Filling Data

Since the observations contain some missing data, thus there are gaps in the observed data. In order to analyze these data via EOF method, the data must be filled. There are many methods to fill the gaps in the data such as interpolation methods, curve fitting method and approximation method. The missing data from tide gauge stations in the GoT is less than 1% of total data records (as shown in Appendix), so the missing values are filled by their monthly mean. The data records of PSMSL are 99.5% complete during the year 1977 to 2007. The missing values were filled using values averaged of nearby stations with conditions as following (see Figure 3.3),

condition 1: If there are tide gauge stations in area within radius of 1/2° then the missing value can be filled using values averaged of these tide gauge stations.

condition 2: Else if there are tide gauge stations in area within radius of 1° then the missing value can be filled using values averaged of these tide gauge stations.

condition 3: Else if there are tide gauge stations in area within radius of 2° then the missing value can be filled using values averaged of these tide gauge stations.

condition 4: Otherwise, the missing value can be filled using monthly mean averaged of its tide gauge station.

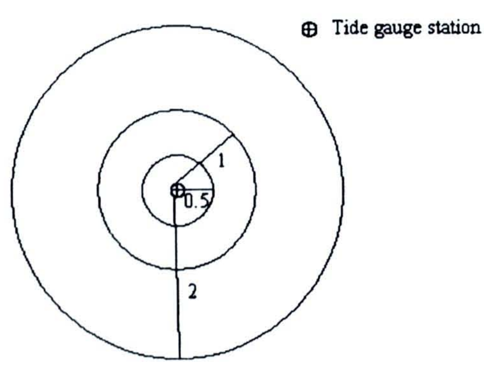

Figure 3.3 The range for filling the missing data using data from nearby stations.