CHAPTER 1

INTRODUCTION

1. Notes

Thailand, officially the Kingdom of Thailand, is a kingdom in Southeast Asia bounded by Burma (Myanmar) on the north and west, by Laos on the northeast, by Cambodia and the Gulf of Thailand (Siam) on the southeast, by Malaysia on the south, and by the Andaman Sea and Burma on the southwest. The total area of Thailand is 513,115 sq km (198,115 sq mi) with Bangkok as the capital and the largest city.

The Gulf of Thailand is an inlet of the South China Sea, lying between the Malay Peninsula on the west and the Southeast Asian mainland on the north and east. It is bounded mainly by Thailand, but also by Cambodia and Vietnam. At its northern head the Gulf receives the Chao Phraya River. Bangkok, the Gulf's leading port, is upstream from the mouth of this river (Encarta 96 Encyclopedia).

2. Tides in general

Tides are periodic short-term changes in the height of the ocean surface at a particular place caused by a combination of the gravitational force of the Moon and Sun and the motion of the Earth (Garrison, 1994).

Sea-level oscillations of approximately daily (diurnal) and twice daily (semidiurnal) period are worldwide phenomena observed at continental coasts and islands. According to Newton's laws, this motion is caused by the difference of the gravitational attraction between celestial bodies and the centrifugal acceleration of their rotation. Tidal oscillations are periodic because they are related to the motion of the Earth, the Sun, and the Moon.

At most coastal or island locations the interval between successive high waters is about 12 hours and 25 minutes, which is half the time of the Moon's apparent revolution around the Earth called *semidiurnal tides*. In some areas, such as the China sea, the interval is 24 hours and 50 minutes called *diurnal tides*. If there is a prevailing semidiurnal tide, the difference between the high-water time and the time the Moon crosses the meridian at the location is approximately constant, and this difference is known as the *high-water interval* for the particular location.

The difference in sea level between successive high and low waters, called *the range of tide*, may vary from day to day in a certain place. Within a fortnight it reaches a maximum value, known as *spring tide*, and a minimum value, known as *neap tide*. In the open sea the distances of the high and low-water levels from undisturbed sea level are more or less equal to one another. The vertical tidal motion of the sea level is combined with components of horizontal motion. The water particles moved by harmonic tidal currents oscillate in an ellipse within one tidal period (Middlehurst, 1979).

2.1 The causes of tides

The gravitational attraction of two bodies such as the Earth and the Moon is proportional to the product of their masses and inversely proportional to the square of the distance between their centers. Their gravitational attraction tends to force them to approach one another, but this is inhibited by the centrifugal force of rotation around their joint center of gravity. If it is assumed that the mass of each body is concentrated in its center, then the two forces balance each other. There is an important difference between these two forces, gravitational attraction and the centrifugal force of rotation. The first depends on the distance and consequently varies for different water particles on the Earth, the second is constant for all points of the Earth. If a single water particle of the ocean is considered, there is no balance, the gravitational attraction of the Moon may be different from the centrifugal force of rotation.

These differences are the tide-generating forces. In the same way, tide-generating forces are caused by the gravitational attraction of the Sun. They are determined by the motion of the Sun, the Earth and the Moon, the distance, the mass, and the volume. Tide-generating forces are vectors. One component is directed to the center of the Earth and coincides in direction with the gravitational force of the Earth itself, altering this only in a very small amount (the ratio is 1:9,000,000). The other components are situated on a tangential plane at the sea surface and drive the water masses in the direction of the Moon and Sun, respectively (Middlehurst, 1979).

2.2 Lunar tides

The Moon, being much nearer to the Earth than the Sun, is the principal cause of tides. When the Moon is directly over a given point on the surface of the Earth, it exerts a powerful pull on the water, which therefore rises above its normal level. Water covering the portion of the Earth farthest from the Moon is also subject to this pull, so that another distinct dome of water is formed on the farther side of the Earth providing the basis for a second wave. The lunar wave crest directly beneath the Moon is called the direct tide, and the crest on the side of the earth diametrically opposite is called the opposite tide. At both crests, the condition known as high water prevails, while along the circumference of the Earth perpendicular to the direct-opposite tidal axis, phases of low water occur. Low and high waters alternate in a continuous cycle. The variations that naturally occur in the level between successive high and low waters are referred to as the range of tides. At most shores throughout the world, two high waters and two low waters occur every lunar day, the average length of a lunar day being 24 hr, 50 min, and 28 sec. One of these high waters is caused by the direct-tide crest and the other by the opposite-tide crest. Two successive high waters or low waters are generally about the same height. At various places outside the Atlantic Ocean, however, these heights vary considerably. This phenomenon is known as the *diurnal inequality* (Encarta 96 Encyclopedia).

2.3 The tidal day

While the Earth turns upon its axis, the Moon is moving in the same direction along its orbit about the Earth. After twenty-four hours the Earth point that began directly under the Moon is no longer directly under the Moon. The Earth must turn for an additional fifty minutes, about 12°, to bring the starting point on

Earth back in line with the Moon. Therefore a tidal day is not twenty-four hours long, but twenty-four hours and fifty minutes. This difference also explains why corresponding tides arrive at any location about one hour later each day (Duxbury and Duxbury, 1994).

2.4 Declination tides

The Moon does not revolve about the Earth in exactly the same plane as the Earth. It is said to have a declination (elevation) relative to the Earth's equatorial plain. This effect is sometimes called declination-type tides. Imagine a stack fixed in the Earth and extending well above the water's surface, no matter what the depths of water bulges are. As the stake moves with the rotating Earth, it experiences water of different depths because it moves through different parts of the two bulges. Tides for a given point on Earth are expected to have this diurnal inequality (Ingmanson and Wallace, 1994). The twice-daily high and low waters for the semidiurnal and mixed tides are rarely equal in height. Only when the Moon is above the equator when the Moon's declination is zero will the bulges be equal. During these periods, the tide-producing forces are more diurnal than semidiurnal (McCormick and Thiruvathkal, 1981).

2.5 Time lags

Regardless of type, tides more or less repeat themselves at each location on successive lunar days, although there may be a time lag of up to a few hours between the appearance of the Moon overhead and the occurrence of a high tide. This time lag is constant for each locality and is caused by friction between the ocean bottom and the water and by the fact that continents block the free transfer of water around the globe. It can also be seen that spring and neap tides do not exactly coincide with the alignment of the Earth, the Moon, and the Sun. That is, spring tides, for example, do not always coincide with full or new moons. There is usually a few days' delay, which is also constant for each locality (McCormick and Thiruvathkal, 1981).

2.6 Elliptical orbits

Tides also vary because the Earth-Moon and Earth-Sun distances vary with time. The orbits of the Moon and the Earth are not circular, but are elliptical. Once a month the Moon is closest to the Earth (perigee) and two weeks later is farthest from the Earth (apogee). The tide-producing forces are greatest at perigee and least at apogee, resulting in biweekly inequality of the tides. Similarly, the Earth's orbit brings it closest to the Sun on January 2 (perihelion) and farthest from the Sun on July 2 (aphelion), resulting in a semiannual inequality (McCormick and Thiruvathkal, 1981).

2.7 Solar tides

The Sun likewise gives rise to two oppositely situated wave crests, but because the Sun is much further from the Earth, its tide-raising force is only about 46 percent that of the Moon. The sum of the forces exerted by the Moon and Sun result in a wave consisting of two crests, the positions of which depend on the relative positions of the Sun and Moon at the time. During the periods of new and full moon, when the Sun, Moon, and Earth are directly in line, the solar and lunar waves coincide. This results in the condition known as spring tides, in which the high water is higher and the low water is lower than usual. When the Moon is in first or in third quarter, however, it is at right angles to the Sun relative to the Earth, and the height of the waves is subject to the opposing forces of the Sun and Moon. This condition produces neap tides, in which the high water is lower, and the low water is higher than normal. Spring and neap tides occur about 60 hours after the corresponding phases of the Moon, the intervening period of time being known as the age of the tide or age of the phase inequality. The interval of time between the crossing of a meridian by the Moon at one point and the next high water at that point is called the lunitidal interval, or the high-water interval for that point. The low-water interval is the period between the time the Moon crosses the meridian and the next low water. Average values for the high-water lunitidal intervals during periods of new and full moon are known as the establishment of the port. Values for the intervals during other periods of the month are often referred to as the corrected establishment (Encarta 96 Encyclopedia).

2.8 Tidal currents

Tides move large quantities of water. The water piled up along the coast during the high tide must return to the sea, thus creating a current (McCormick and Thiruvathkal, 1981). In the Gulf of Thailand the velocities are maximal between high and low tides. However, the actual tidal currents observed may vary considerably due to the monsoon, depending on the configuration of the basin.

Table 1.1 shows the periods of the major tidal components (d = day, h = hour, s = second).

Table 1.1 Major tidal components

phenomenon	period	related astronomical cycle	cause
Semidiurnal tide	12 h, 2 min, 23.5 s	Time between upper and lower transits of moon	Rotation of earth
Diurnal tide	24 h, 50 min, 47 s	Time between succeeding upper or lower transits of moon	Rotation of earth and declination of sun and moon
Interval between spring tides	14.76 d (average)	Time from conjunction to opposition of sun and moon or vice versa	Phase relation between sun and moon
Lunar fortnightly	13.66 d	Time for moon change declination from zero to maximum and back to zero	Varying declination of moon
Anomalistic month effect	27.55 d	Time for moon to go from perigee to perigee	Ellipticity moon's orbit
Solar semiannual effect	182.6 d	Time for sun to change declination from zero to maximum and back to zero	Varying declination of sun
Anomalistic year effect	365.26 d	Time for earth to go from perihelion to perihelion	Ellipticity of earth's orbit

Source: Ingmanson and Wallace, 1994 : 207.

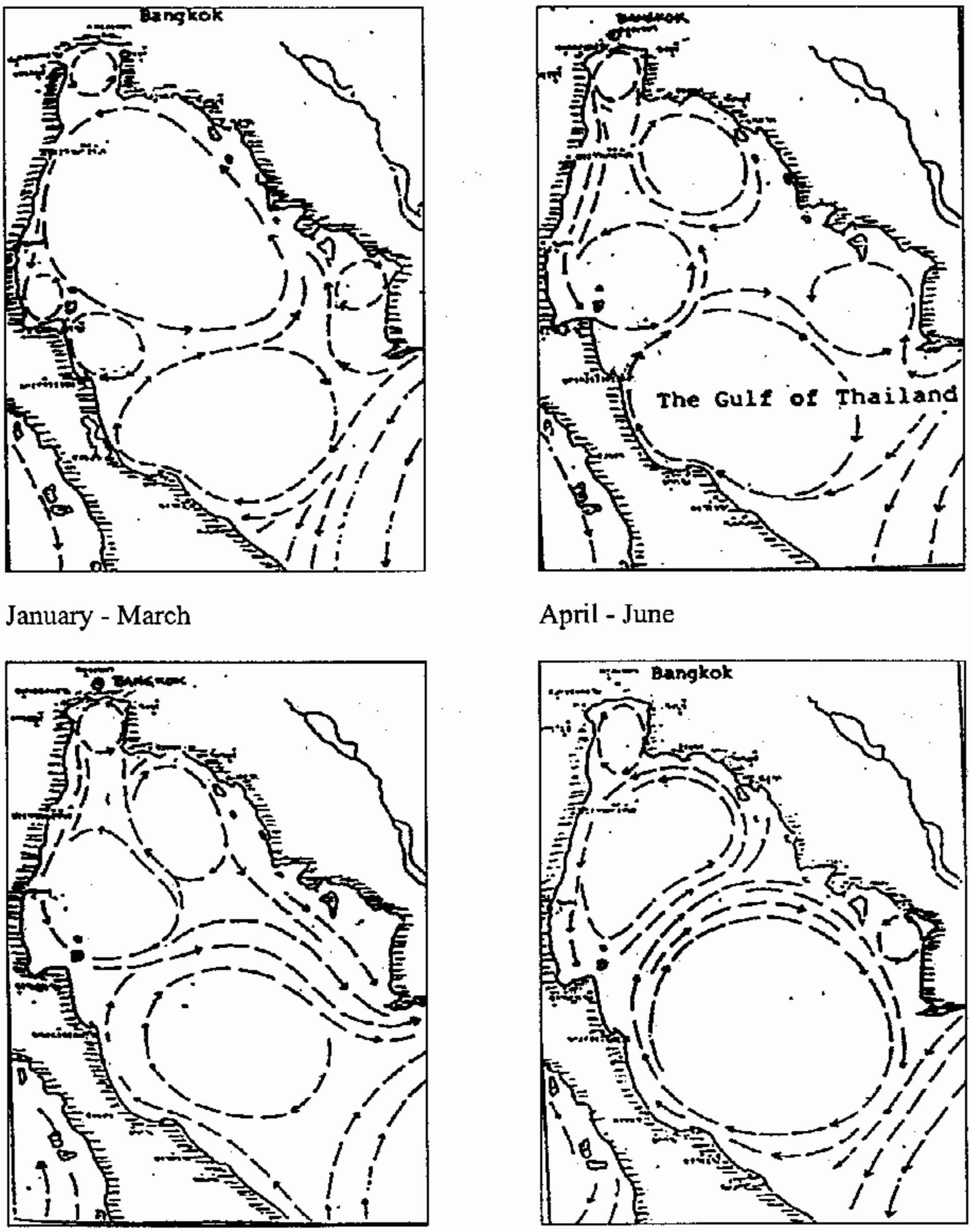
3. Tides in the Gulf of Thailand

3.1 Tidal characteristics

Measurements of tidal movements around the Gulf of Thailand show the three basic types of tides, the diurnal, the semidiurnal and mixed type. There is a marked difference in characteristics of tides at each locality in the Thai waters. The tide at Bangkok Bar is a mixed type, Laem Sing (Chanthaburi) is a regular diurnal, Songkhla and Pattani are semidiurnal with inequality and Phuket is a regular semidiurnal.

3.2 Longshore current and monsoon

The south-east current between the eastern coast of the Malay Peninsular and South Vietnam generates a system of currents in the Gulf of Thailand as shown in Figure 1.1 (Brans et al., 1995). It shows that throughout the year, a longshore current from the south is dominant at the southern coastline of Thailand. Because of this current, there is a longshore sediment transport along the coast of the southern part of Thailand to the north during most of the year. This longshore sediment transport has a great effect on the coastline. Also important are monsoons. There are two monsoons throughout the year. The first monsoon, during July, August and September is accompanied by strong winds from the northwest. These winds do not have a great impact on the southern coast, because they are blocked by the inland mountains. The second monsoon, during October, November and December, is accompanied by strong winds from the northeast. These winds generate waves with a maximum high of about 0.5 m. The number of days with these strong winds and waves is about 25 in the entire monsoon.



January - March

April - June

July - September

October - December

Figure 1.1 System of currents in the Gulf of Thailand

Source : Brans et al., 1995 : 48.

4. Scope of investigations

4.1 Objectives

The study described in this thesis has two objectives, as follows.

(1) To find a simple graphical method for characterizing the tides at a given location.

(2) Using this simple graphical representation as a basis for analysis, to reconstruct the tide height at successive high and low tides based on a fitted model.

4.2 Rationale

Plotting tide data is essential as a means of understanding their principal characteristics, of exploring relationships between variables, and of comparing the fit of a model with the tabulated data. In addition to the use of graphical procedures, another aim is to reduce large data sets to simple summary measures that are more easily understood.

The graphical method developed in this study is new, and has wide application. It involves the simultaneous display of three variables (a) the time of occurrence of high or low tide (b) the height of the corresponding tide and (c) the lunar day in which it occurs.

The statistical methods to be used involve the Fourier analysis of time series data. These methods have been used successfully by Khumpai (1997) in analysing tidal movements in Pattani and Songkhla in 1996.

In Chapter 2 of this thesis the methods for data selection, graphical presentation, and statistical modelling (both analysis and synthesis) are described. Chapter 3 contains the new graphical displays for the tides at the four selected locations. In Chapter 4 statistical model-fitting is carried out, and the fitted model is then used as a basis for reconstructing the tidal movements. Finally, conclusions in Chapter 5, as well as the limitations of the study, and suggestions for further studies needed to be undertaken are described.