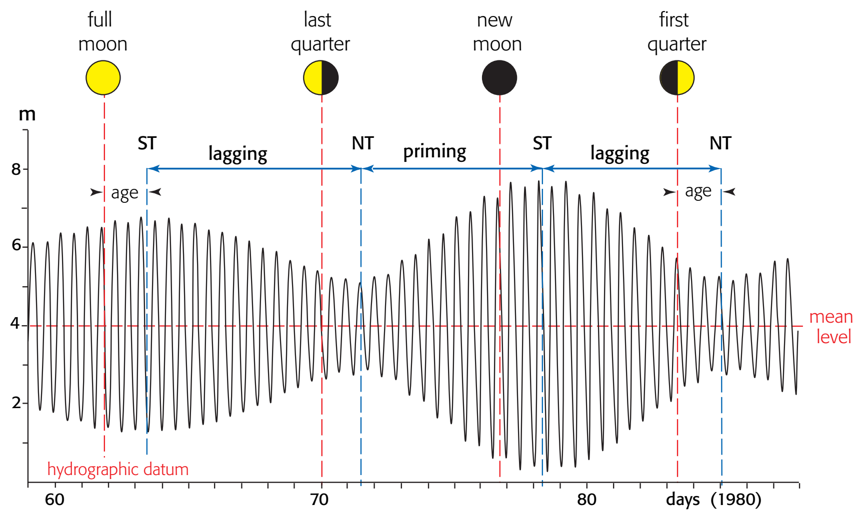

FIGURE 1.5: Semidiurnal tide prediction curve over one lunation cycle (29 days) showing tidal range variations according to phases of the Moon (Brest, France).

a. Semidiurnal tide. — Brest, France, figures 1.4 and 1.5; Casablanca, Morocco, figure 1.6A. The curves for this type of tide, as already discussed for Brest, clearly show two daily high and low waters with almost identical respective heights, corresponding to almost identical tidal ranges. Semidiurnal tides prevail in the Atlantic, especially along the African and European coasts.

b. Mixed semidiurnal tide. — Mui-Vung-Tau, Vietnam (southern coast), figure 1.6B. The tidal range varies markedly over one lunar day. The diurnal inequality, i.e. the difference between the high and low tidal ranges, is greatest when the declinations of the stellar bodies are reaching their maxima.

Diurnal inequality may also be noted along the European coasts, but the tide is classified as semidiurnal since this inequality is slight. However, the inequality is very high in many ports in the Pacific and Indian Ocean regions.

c. Mixed tide. — Qui-Nhon, Vietnam (eastern coast), figure 1.6C. In ports with a mixed tide, a semidiurnal tidal period is succeeded by a diurnal tidal period over one lunation cycle. This type of tide is also noted along the coasts of Indonesia, Siberia and Alaska, as well as in some ports in the Atlantic and Caribbean (Fort-de-France).

d. Diurnal tide. — Do Son, Vietnam (northern coast), figure 1.6D. There is only one high and low tide per lunar day along coasts where diurnal tides prevail. The associated tidal range varies with the declination of stellar bodies. This uncommon tidal type occurs especially in the Pacific Ocean,

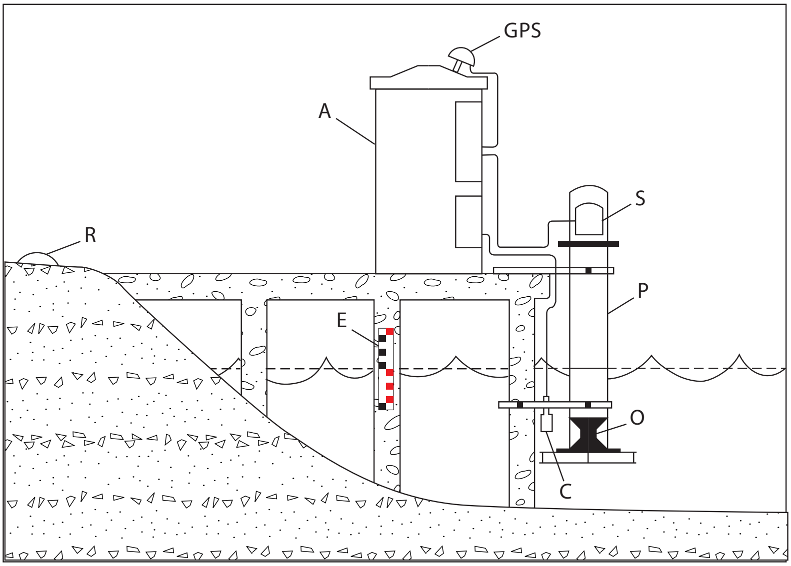

Figure 2.2: Diagram of a Seaframe-type tide station (Australia). A: protective housing for the recorder and transmitter; C: pressure sensor; E: tide staff; GPS: antenna for GPS positioning of the station; O: stilling well intake opening (note the Venturi tube and wave protection plate); P: protective housing for the stilling well; R: control mark (geodetic point); S: ultrasonic depth finder (Source: IOC Manuals and Guides).

this fault by renovating a tide station that has been operating for decades as such modifications could upset long-term monitoring of tidal phenomena. This fault actually induces differences in water level caused by factors similar to those that induce systematic water level differences that may be observed between the internal and external sections of a port, roadstead or bay.

3 • Conventional tide recording systems

A stilling well is essential when setting up a permanent tide station along a coast. Many permanent tide gauges managed by hydrographic services are located in harbour areas or along navigable estuaries. Data from temporary stations are generally processed for short-term hydrographic purposes.

Several techniques are used for sea level measurement. The most long-standing techniques remain important and widely used, such as tide staffs (or poles). Float gauges are still used, whereas so-called analogic graphic recording systems are gradually being replaced by automatic digital data logging systems.

The acceleration $\vec{\gamma_T}(M)$ of object M in the terrestrial reference frame could thus be expressed as:

$$\vec{\gamma_T}(M) = \vec{\gamma_S}(M) - \vec{\gamma_S}(T) - 2\vec{\omega_T} \wedge \vec{v_T}(M) - |\vec{\omega_T}|^2 \overrightarrow{RM} \qquad (3.4)$$

where point R represents the projection of point M on the polar axis (figure 3.1).

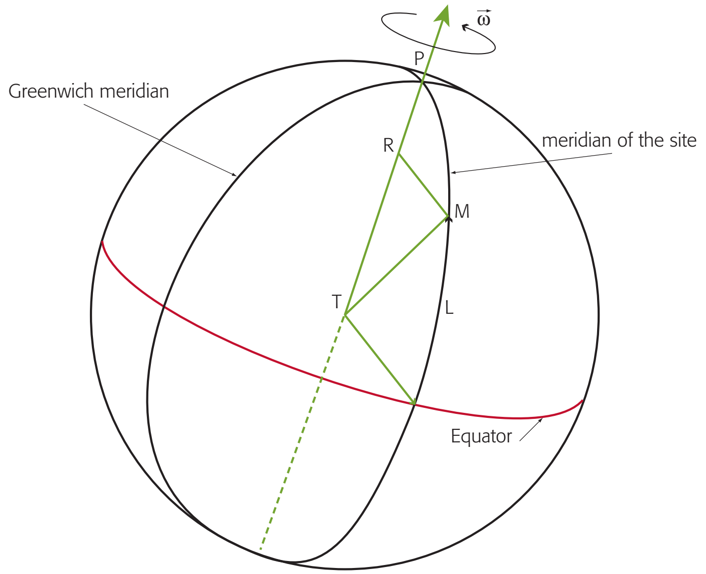

FIGURE 3.1: The terrestrial reference frame (relative reference frame), where T is the Earth's centre, M is the object of unit mass at latitude L, and R is the projection of M on the polar axis.

In relation (3.4):

• the term $\vec{\omega_T} \wedge (\vec{\omega_T} \wedge \overrightarrow{TM}) = |\vec{\omega_T}|^2 \overrightarrow{RM}$ is the centrifugal force due to the Earth's rotation applied at point M;

• component $2\vec{\omega_T} \wedge \vec{v_T}(M)$ represents the so-called acceleration of Coriolis which deviates (to the right in the Northern Hemisphere and to the left in the South) particle M at velocity $\vec{v_T}(M)$;

• acceleration $\vec{\gamma_S}(T)$ is the result of the sum of external forces applied on T–with the only significant ones being the gravitational forces exerted by each tide-generating celestial body. We will first investigate the action of a single celestial body, so acceleration $\vec{\gamma_S}(T)$ will here be assimilated to the force $\vec{F}_{A/T}$ exerted by celestial body A on the unit mass object in T.

5.1 • Observations

Long-term tidal observations are essential for climate studies, especially those that have been recorded at Brest since 1806.

Tide levels have been measured for almost 200 years at the Brest tide monitoring station, which is a long enough period to document long-term sea level variations (figure 8.4).

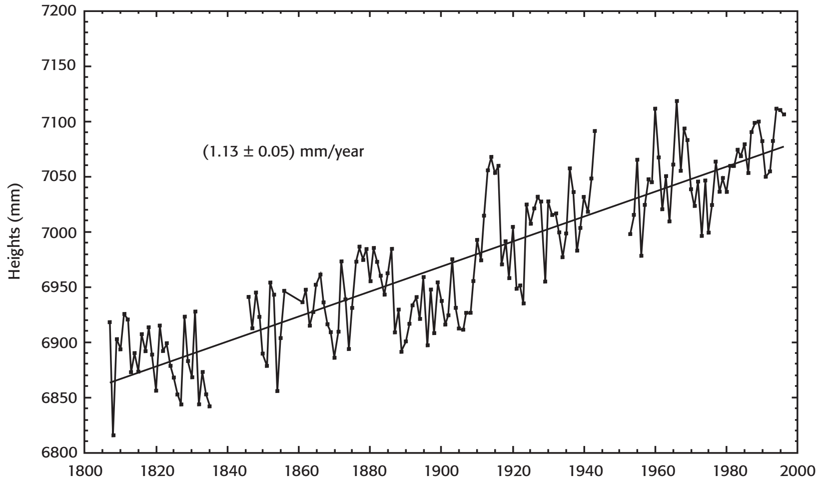

Figure 8.4: Evolution of the mean annual sea level at Brest between 1806 and 1997. Each point represents a mean annual level. Over this period of almost two centuries, a regular trend of 1.13 ± 0.05 mm/year is noted, but without any obvious acceleration.

This example shows that there are relatively marked local variations in the mean annual level, i.e. as high as or over ±5 cm between years. This is why at least a century of observations are necessary to be able to evaluate trends with a good degree of accuracy.

At Brest, the mean level increased by 25 cm in 200 years. This example is, however, not representative of all long-term observations available worldwide. In most cases, these observations actually reveal a mean increase of around 1-2 mm/year, with about the same extent of scatter around these values as that documented at Brest. There are sites, especially in Scandinavia, where the reverse trend has been noted.

Otherwise, available observations do not provide an accurate indication of the overall trends because of the very irregular distribution of tide monitoring stations, which are mostly located in temperate regions in the Northern Hemisphere. The variability in the trend between sites is mainly due to vertical crustal movements that tide gauges obviously cannot detect