⑩❸ Ondas Longas; ondas barotrópicas e baroclínicas; ondas de Kelvin e de Rossby.

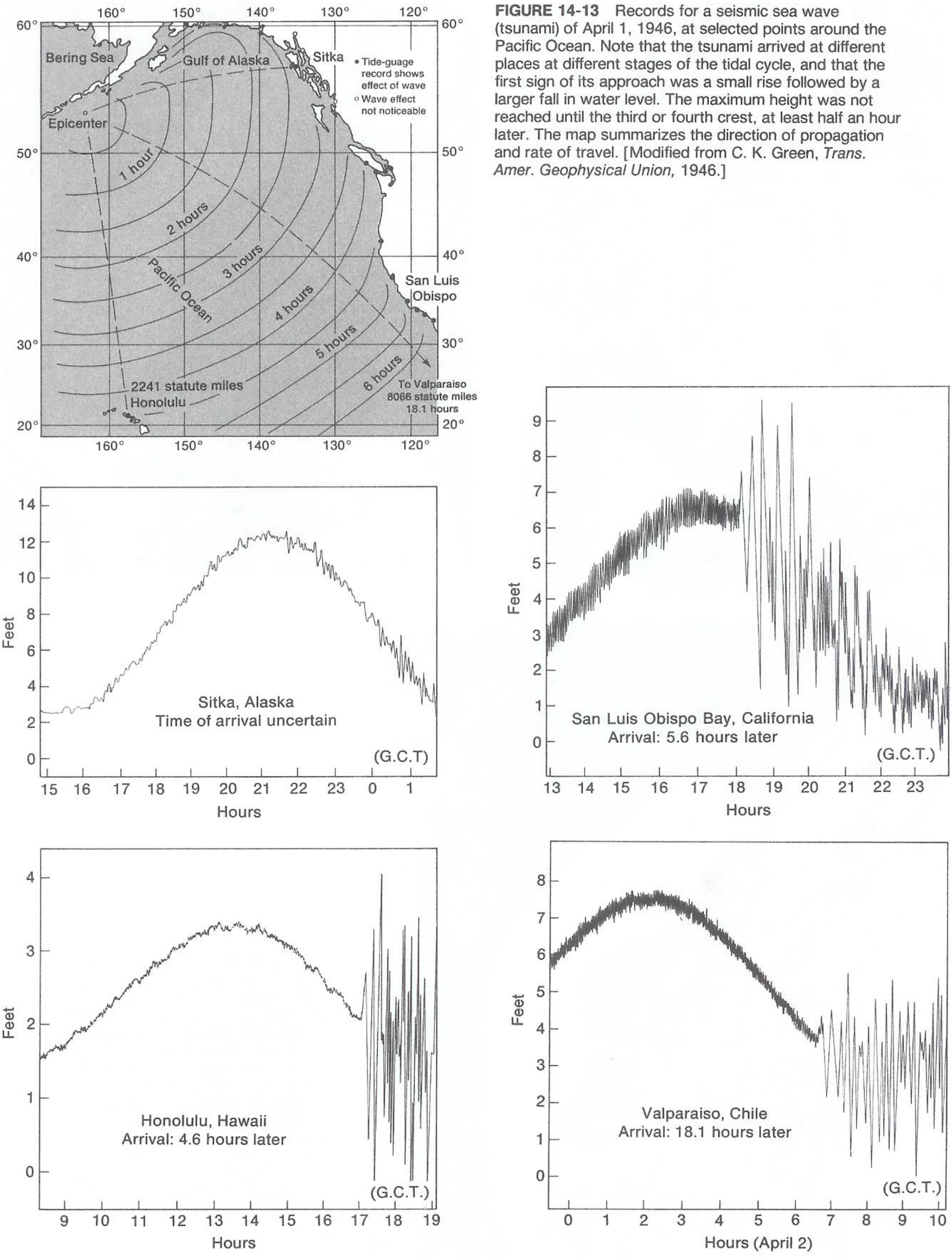


FIGURE 14-13 Records for a seismic sea wave (tsunami) of April 1, 1946, at selected points around the Pacific Ocean. Note that the tsunami arrived at different places at different stages of the tidal cycle, and that the first sign of its approach was a small rise followed by a larger fall in water level. The maximum height was not reached until the third or fourth crest, at least half an hour later. The map summarizes the direction of propagation and rate of travel. [Modified from C. K. Green, *Trans. Amer. Geophysical Union,* 1946.]

Sitka, Alaska
Time of arrival uncertain

San Luis Obispo Bay, California
Arrival: 5.6 hours later

Honolulu, Hawaii
Arrival: 4.6 hours later

Valparaiso, Chile
Arrival: 18.1 hours later

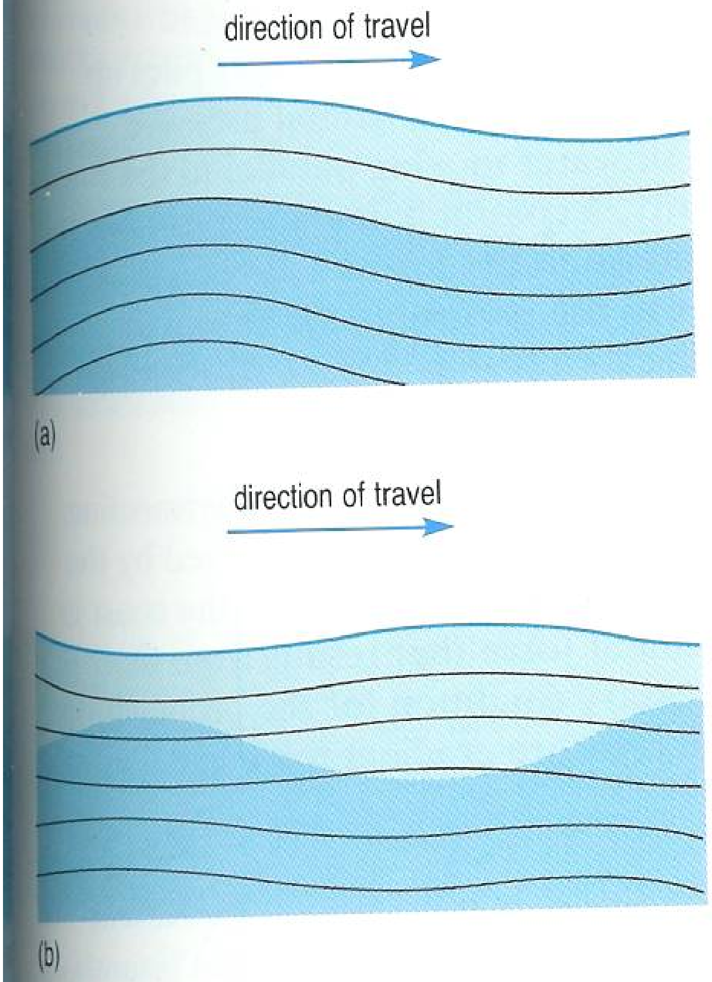
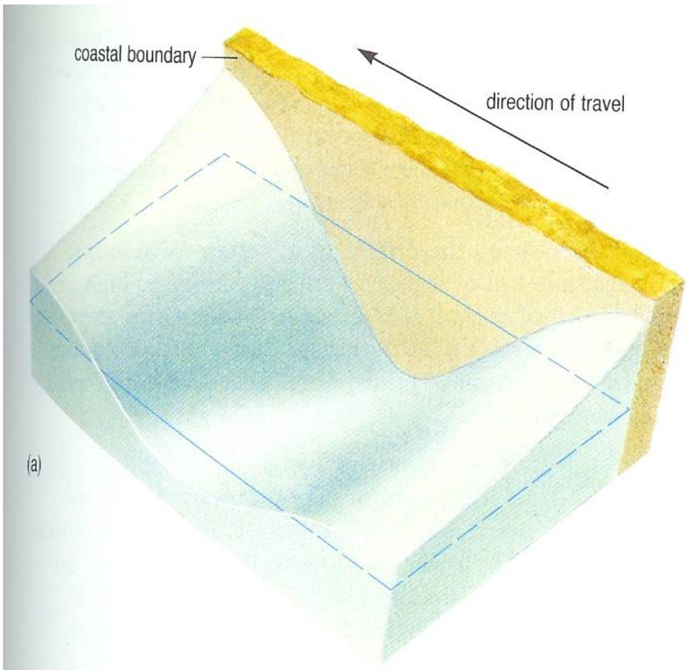
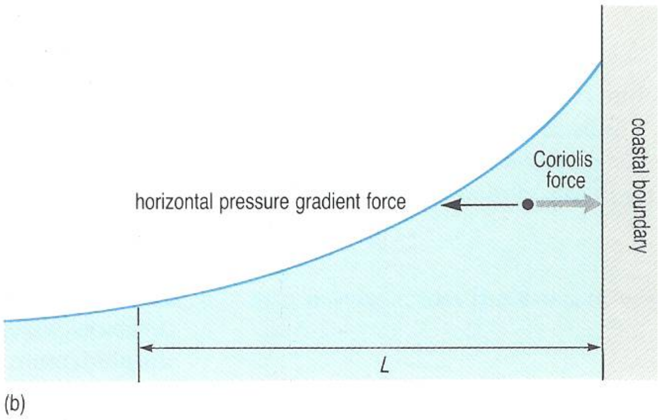


Figure 5.12 Examples of (a) a 'surface' long wave and (b) a long wave in the thermocline. In (a), the surface ocean as a whole moves up and down, and isobaric and isopycnic surfaces remain parallel. Such waves are therefore described as 'barotropic'. In (b), the passage of the wave changes the vertical density distribution, so that isopycnic surfaces are alternately compressed and separated. In addition, there are pressure variations over the surface of the density interface so that isobaric and isopycnic surfaces intersect; such waves are therefore described as 'baroclinic'.





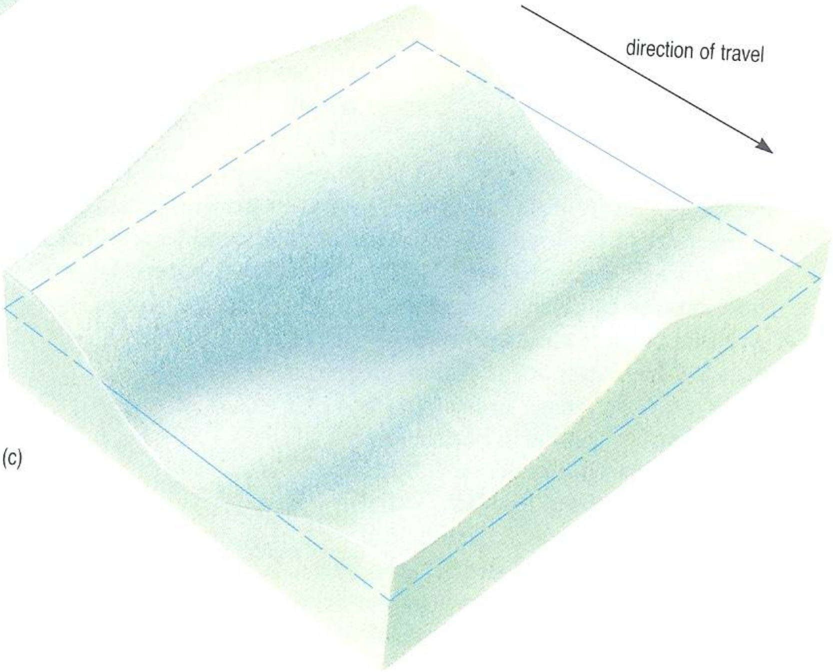


Figure 5.13 (a) Schematic diagram of a surface Kelvin wave in the Northern Hemisphere. In the case of a Kelvin wave in the thermocline, the thermocline would adopt the shape shown, while the sea-surface would take on a similar shape in 'mirror image', although to a much lesser extent.

(b) Diagram to show the horizontal balance of forces in a Kelvin wave, and the Rossby radius, *L* (which is discussed in the text).

(c) An equatorial 'double' Kelvin wave (here shown for a surface wave); the wave travels from west to east.

decayed away so as to be hardly discernible. This distance is known as th **Rossby radius of deformation** (L) and can be calculated from $L = c/f$ where f is the Coriolis parameter and c is the wave speed. For a surface Kelvin wave, c is of the order of $200\,\mathrm{m\,s^{-1}}$; for a Kelvin wave with its maximum displacement in the thermocline, c is typically between 0.5 and $3\,\mathrm{m\,s^{-1}}$. In mid-latitudes, the Rossby radius for a Kelvin wave in the thermocline is generally about 25 km.

can have dramatic effects, particularly in low latitudes where the mixed surface layer is thin. They may be generated by an abrupt change in the overlying wind field, as occurs for instance in the western Atlantic when the ITCZ moves northwards over the region and it comes under the influence of the South-East Trades. This causes a disturbance in the upper ocean (*cf*. Figure 5.14(a)), which travels eastwards along the equatorial wave guide as a double Kelvin wave (this takes about 4–6 weeks) and, on reaching the coast, splits into two coastal Kelvin waves, each travelling away from the Equator (Figure 5.14(b)). In

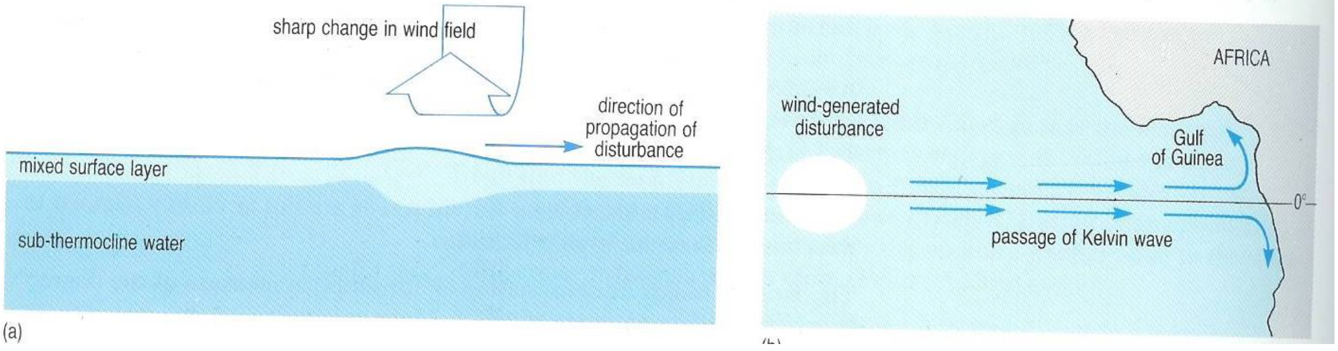


Figure 5.14 (a) Schematic diagram showing a disturbance of the upper ocean caused by an abrupt change in the overlying wind field.

(b) Such a disturbance may be generated in the western Atlantic and travel eastwards as an equatorial Kelvin wave; at the eastern boundary, this splits into two coastal Kelvin waves, which cause seasonal upwelling in the Gulf of Guinea (*cf.* Figure 5.7).

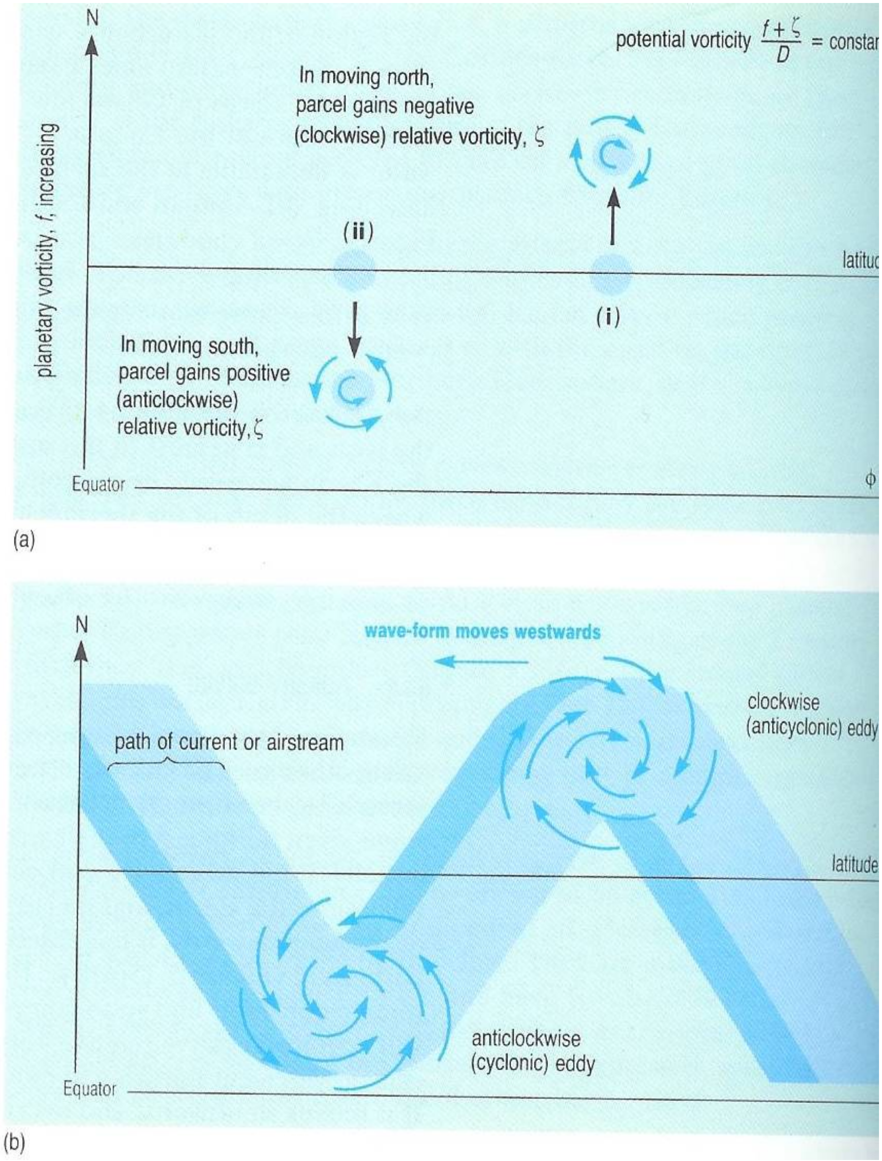


Figure 5.15 (a) Diagram to show how in a Rossby wave the need to conserve potential vorticity $(f + \zeta)/D$ leads to a parcel of water oscillating about a line of latitude φ while alternately gaining and losing relative vorticity ζ. For details, see text.

(b) The path taken by a current or airstream affected by a Rossby wave. Note that the flow pattern is characterized by anticyclonic and cyclonic eddies, and that the wave-form moves *westwards* relative to the current or airstream computer-generated diagrams shown in Figure 5.16.

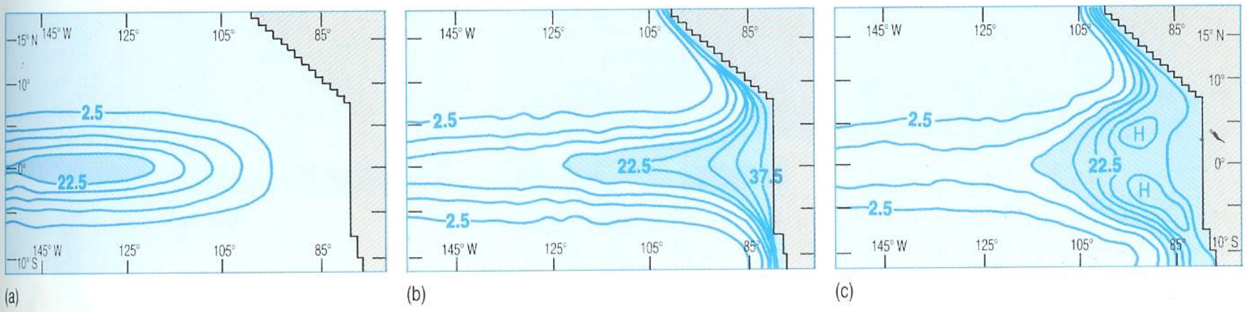


Figure 5.16 Computer-generated diagrams showing the progress, from mid-Pacific to the South American coast, of an internal equatorial Kelvin wave. The contour numbers may be regarded as either the depression of the thermocline in metres or the accompanying rise in sea-level in centimetres. The diagrams show the situation at successive monthly intervals. In (c), the equatorial Kelvin wave has split into two poleward-travelling coastal Kelvin waves. Note that the coastal boundary has the effect of considerably amplifying the disturbance. The equatorial Kelvin wave has also just been partially reflected as an equatorial Rossby wave, as can be seen by the circular contours which result from the rotatory motion associated with the wave. (Note that because the two eddies are on *either side of the Equator*, both are anticyclonic and lead to topographic highs (H), although the northerly one is clockwise and the southerly one anticlockwise (*cf.* Figure 5.15 (b).)