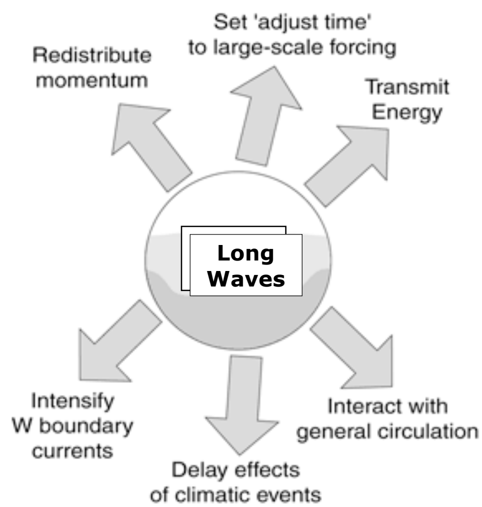
Kelvin and Rossby Waves

Krauss Chapter Nine

The Importance of Long Wavelength Waves



Barotropic Waves:

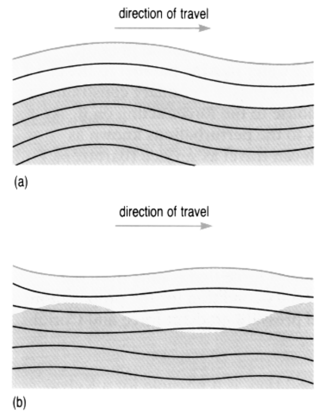
well mixed ocean

isopycnal and isobaric surfaces undulate in unison with the passage of the wave

Baroclinic Waves:

stratified ocean

isopycnal and isobaric surfaces undulates in near mirror image form with the passage of the wave - *except that the amplitude at the surface is small compared to the that of the thermocline*



Rossby Radius of Deformation (*L*) is the distance that a particle or wave travels before being significantly affected by the earth's rotation.

$$L = \frac{U}{f} = \frac{C}{f} = \frac{\sqrt{gh}}{f}$$

If *h* is the depth of the upper ocean layer, we L the
<u>BAROCLINIC DEFORMATION RADIUS</u>

If *h* is the depth of the ocean, we call L the
<u>BAROTROPIC DEFORMATION RADIUS</u>

Note that L decreases with latitude (increasing *f*) so that a wave (or current for that matter) at high latitude need only travel a short distance before being affected by Coriolis Force.

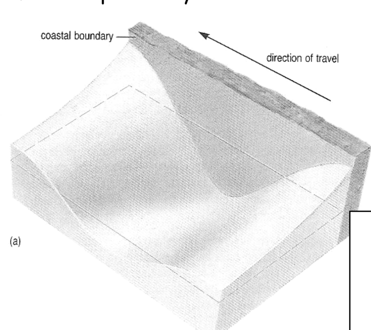
Kelvin Waves

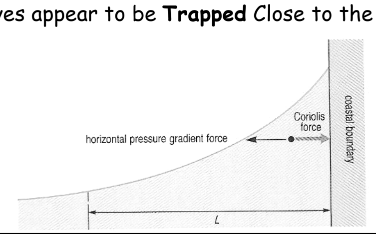
(Coastal and Equatorial)

Coastal Kelvin Waves balance the **Coriolis Force** against a **Topographic Boundary** (i.e., Coastline). They always propagate with the shoreline on the right in the northern and the left in the southern hemisphere.

A Coastal Kelvin Wave moving northward along the coast is deflected to the right, but the coast prevents the wave from turning right and instead causes water to pile up on the coast. The pile of water creates a pressure gradient directed offshore and a geostrophic current directed northward.

Kelvin Wave Amplitude is negligible at a distance offshore given by the Rossby Radius of Deformation. For mid-latitude Kelvin Waves traveling <u>on the ocean surface</u> this is about 200 km. For mid-latitude Kelvin Waves traveling <u>in the thermocline</u> this is about 25 km. Because of this rapid decay Coastal Kelvin waves appear to be **Trapped** Close to the Coast.

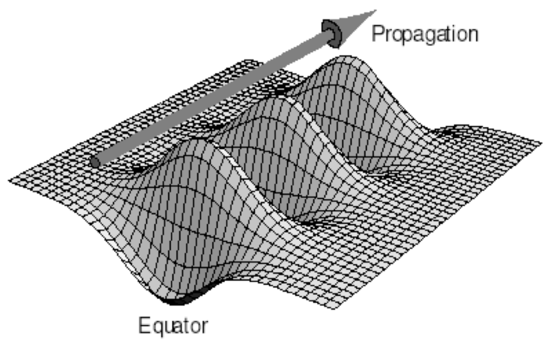




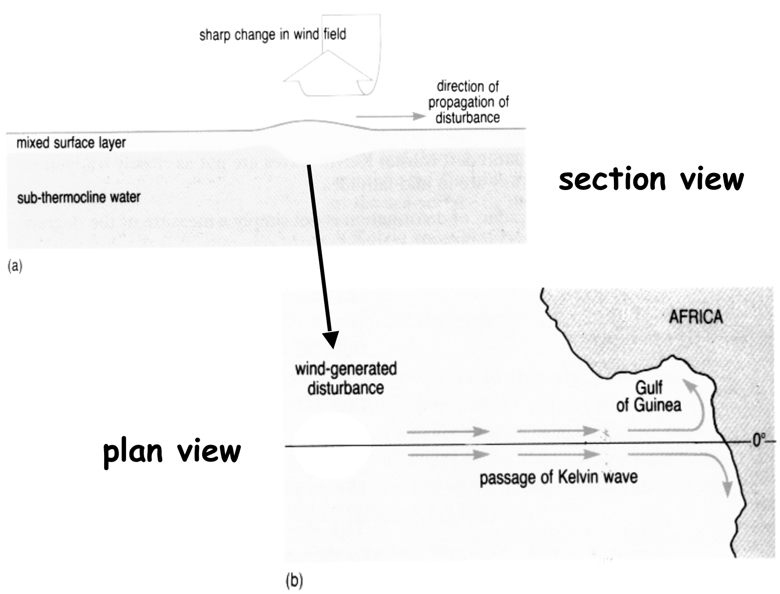
$$L = \frac{\sqrt{gh}}{f}$$

Equatorial Kelvin waves are a special type of Kelvin wave that balances the Coriolis Force in the northern hemisphere against its southern hemisphere counterpart. This wave always propagates eastward and only exists on the equator.

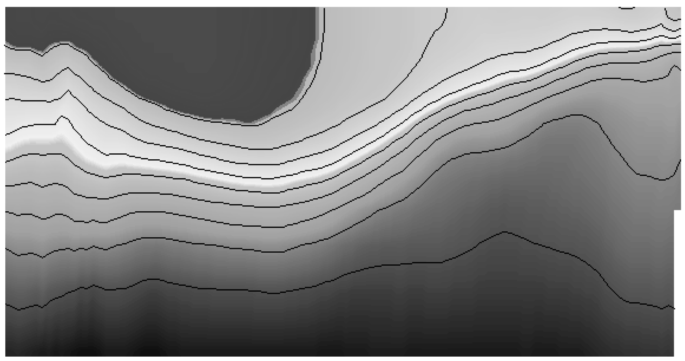
Equatorial Kelvin Waves propagating <u>in the thermocline</u> have wave speeds slow enough to give a Rossby Radius of Deformation that is on the order of 250 km and thus they appear to be **trapped** close to the equator.



An Example of an Equatorial Kelvin Wave



Equatorial Kelvin Wave Traveling Along the Thermocline



11–17 Jan 2004

Rossby Waves

144

The **"Restoring Force"** for a Rossby Wave is the Requirement to Conserve Potential Vorticity

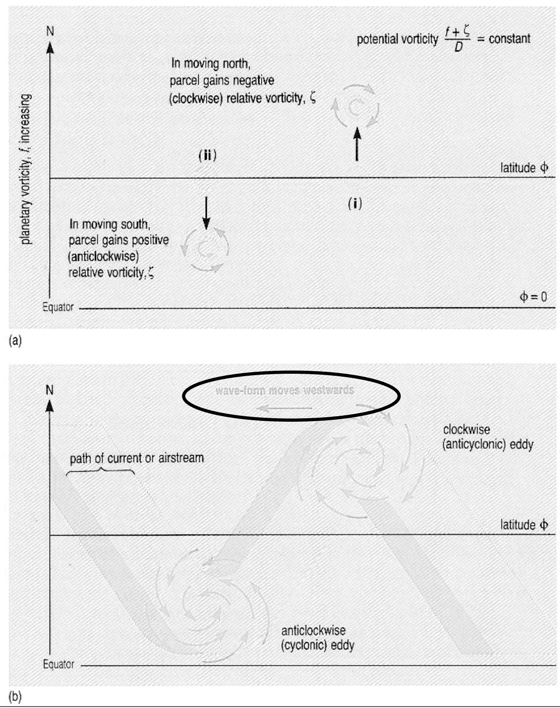
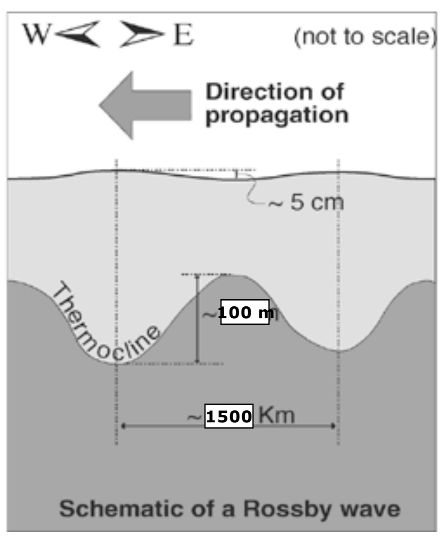


Figure 5.15 (a) Diagram to show how in a Rossby wave the need to conserve potential vorticity $(f+\zeta)/D$ leads to a parcel of water oscillating about a line of latitude ϕ while alternately gaining and losing relative vorticity ζ. For details, see text.

(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

Vertical Scale of Rossby Waves



Latitudinal Variation of Rossby Wave Phase Speed

Latitudinal variation of the phase speeds of nondispersive Rossby waves obtained from historical hydrographic data based on the classical theory (solid line) and from T/P observations in the Pacific (solid circles) and the Atlantic and Indian oceans (open circles).

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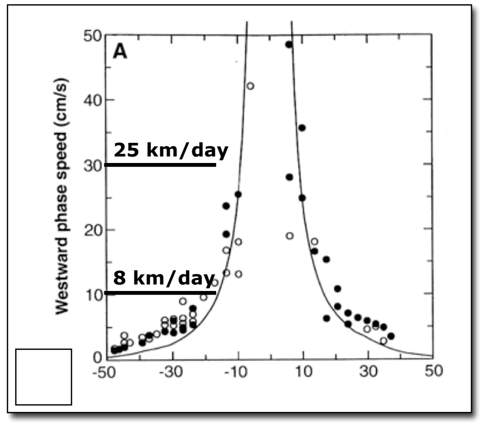
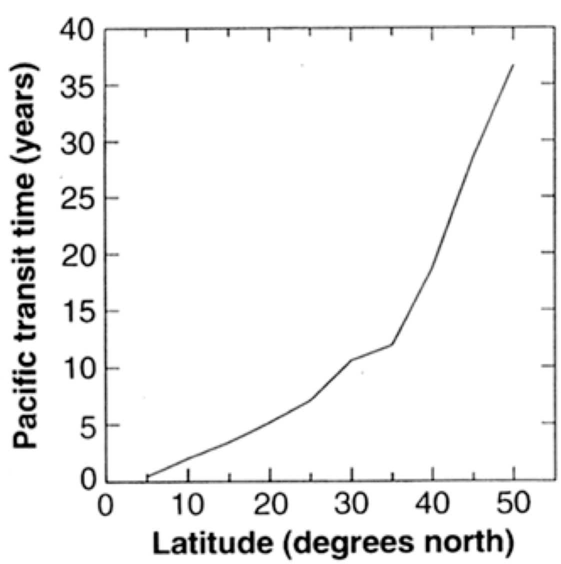
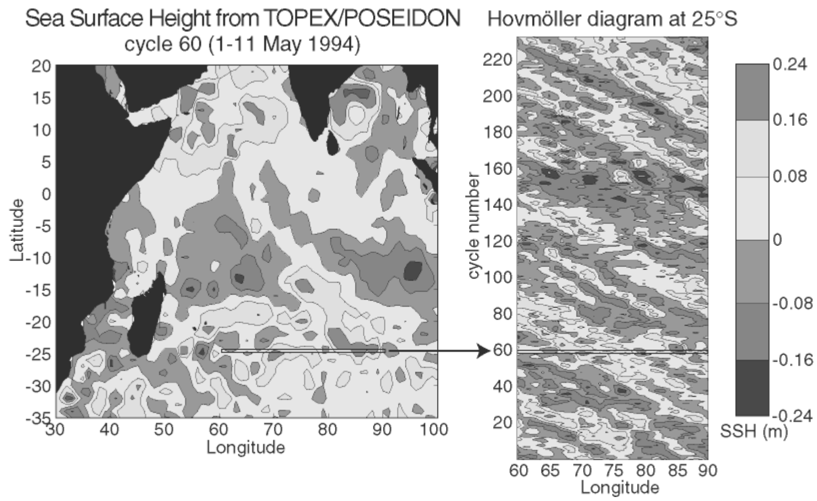


$$C_R = -\frac{\beta}{\kappa^2 + \frac{f^2}{gh}}$$

Krauss, page 228



Time-Distance or "Hovmoller" Diagrams are Commonly used to Depict Wave Propagation in the Ocean



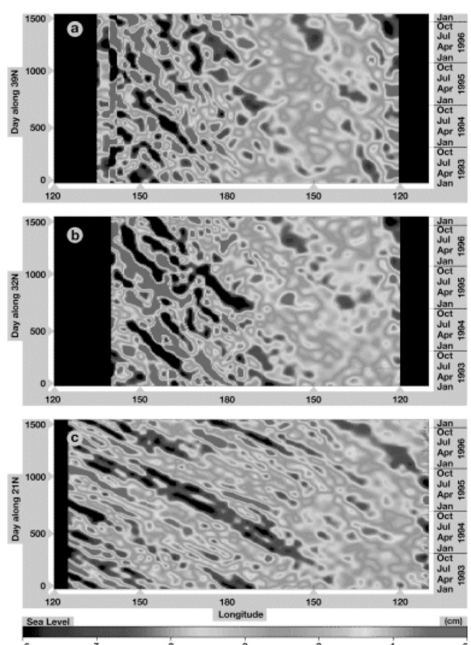


Figure 2: Time-longitude plots of seasonal sea level variability (periods longer than 100 days) from T/P data along 21°N (a), 32°N (b) and 39°N (c) in the North Pacific.

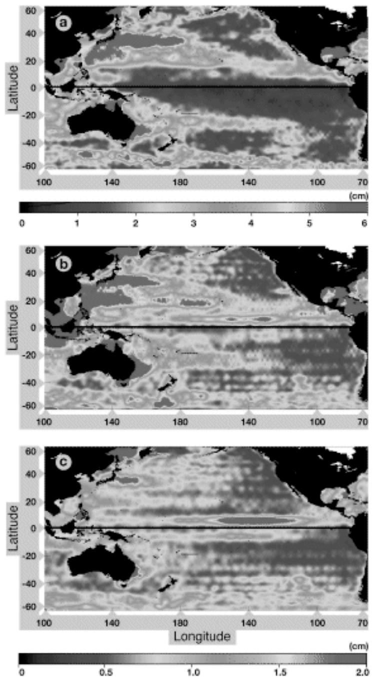
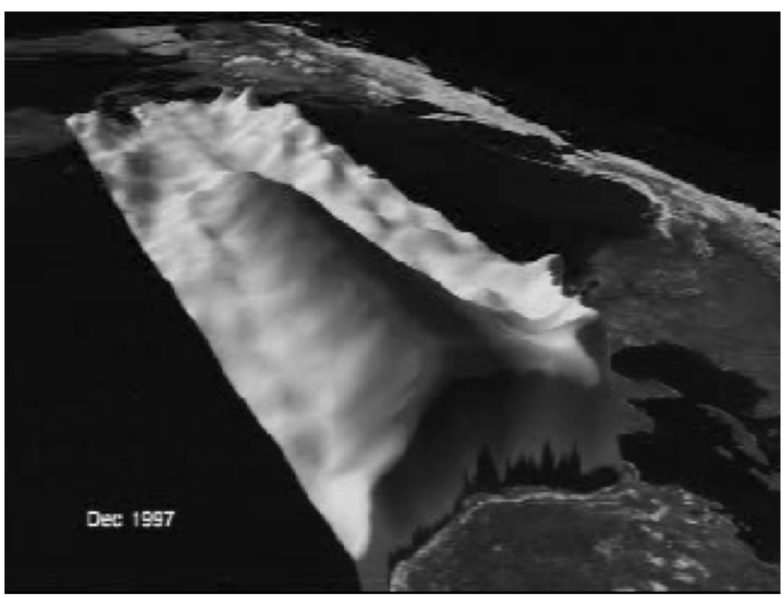
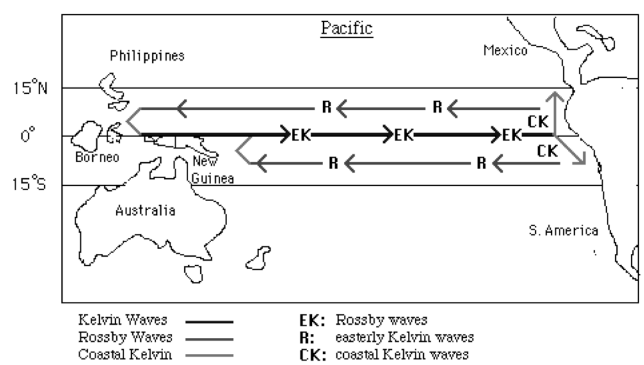


Figure 3:
Maps of the standard deviation of T/P sea level variability for periods longer than 100 days (a), periods between 50 and 100 days (b) and periods between 30 and 50 days (c) (in cm).



Kelvin-Rossby Wave Interactions



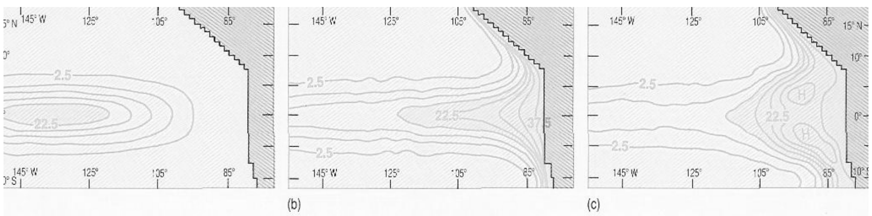
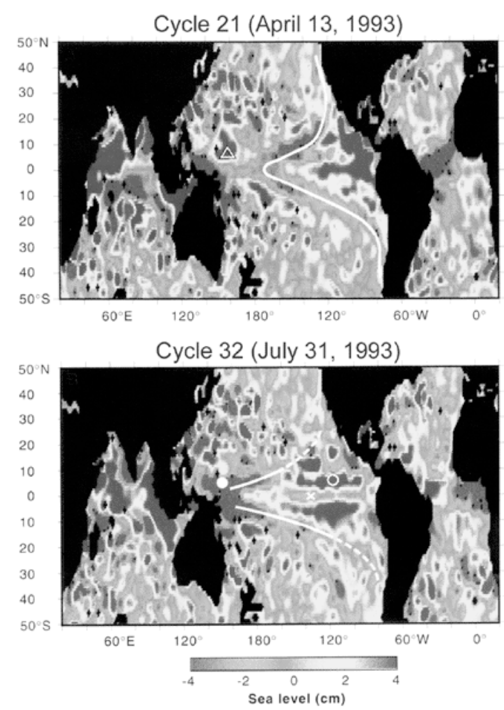
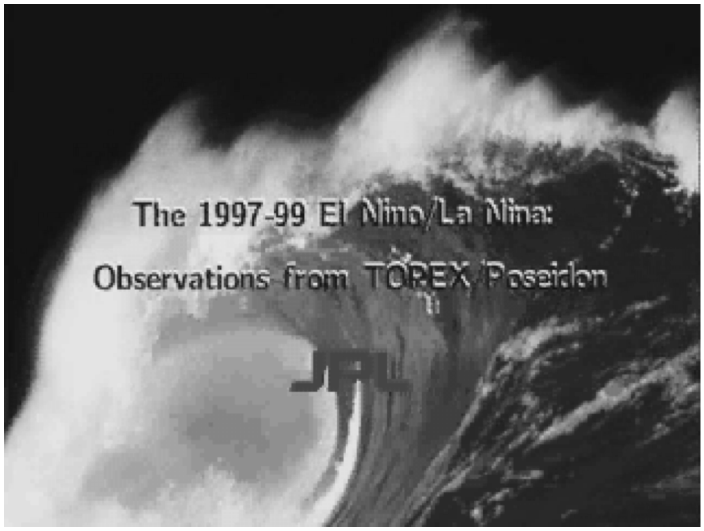


Figure 5.16 Computer-generated diagrams showing the progress, from mid-Pacific to the South American coast, of an internal equatorial Kelvin wave. The contour numbers may be regarded as either the depression of the thermocline in metres or the accompanying rise in sea-level in centimetres. The diagrams 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).)

A westward-propagating Rossby wave trough centered on the equator and extending to midlatitudes in both hemispheres can be seen in the Pacific Ocean in the April 13, 1993 frame. The refracted shape that is characteristic of Rossby waves is due to the latitudinal variation of phase speed.

In the July 31, 1993 frame, this Rossby wave trough has impinged on the western boundary of the Pacific and an equatorial Kelvin wave trough centered at about 140 W has propagated rapidly eastward more than half way across the Pacific, splitting a newly formed Rossby wave crest that has propagated westward from South America.




The 1997-99 El Nino/La Nina:
Observations from TOPEX/Poseidon
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