Introdução à Oceanografia Física

Este material é um material didático de apoio, visando facilitar o estudo do aluno, sem entretanto estar diretamente associado ao plano de curso da disciplina.

Circulação e Movimentos de Massas de Água

- Energia Radiante de Origem Solar:
  - Principalmente ondas curtas (média 0,5µm);
  - Desvio para espaço;
  - Absorção pela atmosfera;
  - 40% alcança superfície do mar;
  - Dissipação de energia do mar:
    - Irradiação para espaço;
    - Evaporação superficial;
    - Transferência para atmosfera (difusão)

Oceanos e Sazonalidade

- Sazonalidade (Season= estação)

Circulação e Movimentos de Massas de Água

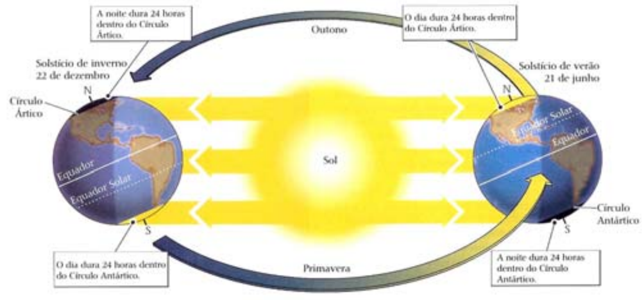


Fig. 4.2 **A orientação do eixo da Terra em relação ao Sol muda entre o inverno e o verão, causando variação sazonal do clima.** A posição do equador solar nos solstícios de verão e de inverno está indicada.

Circulação e Movimentos de Massas de Água

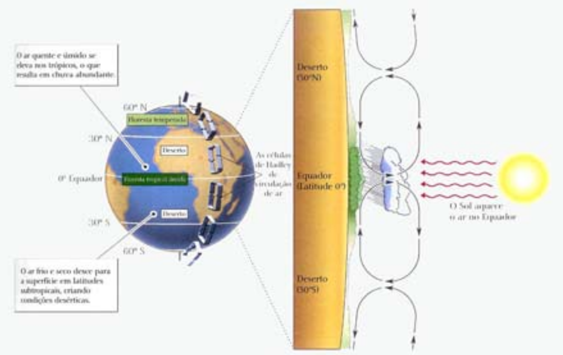
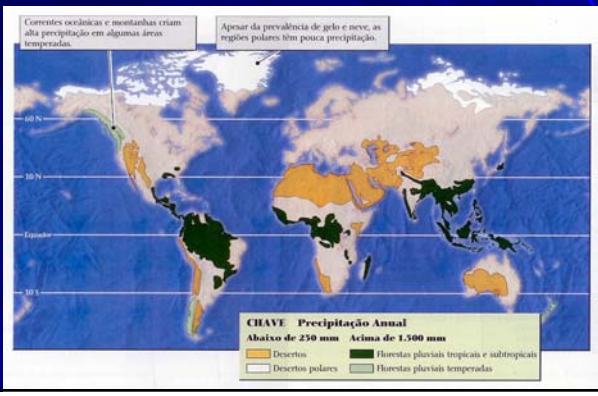


Fig. 4.4 **O aquecimento diferenciado da superfície terrestre cria as células de Hadley.** Ar quente e úmido se eleva nos trópicos, e o ar seco e frio das latitudes subtropicais se move em direção aos trópicos para substituí-lo. A convergência intertropical é o cinturão latitudinal no equador solar dentro do qual os ventos de superfície convergem do norte e do sul.

Circulação e Movimentos de Massas de Água



Circulação e Movimentos de Massas de Água

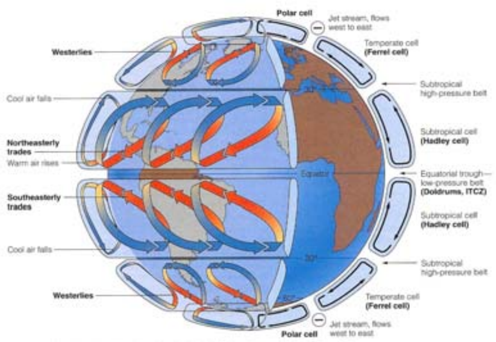


Figure 7.9 Global air circulation as described in the six-cell circulation model. As in Figure 7.5, air rises at the equator and falls at the poles. But instead of one great circuit in each hemisphere from equator to pole, there are three circuits in each hemisphere. Note the influence of the Coriolis effect on wind direction. The circulation shown here is ideal—that is, a *long-term average* of wind flow. Contrast this view with Figure 7.10, a snapshot of a moment in 1996.

Circulação e Movimentos de Massas de Água

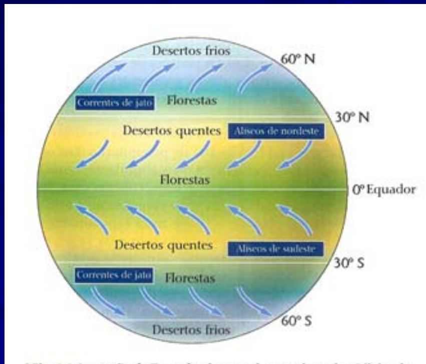


Fig. 4.6 A rotação da Terra desvia o movimento do ar das Células de Hadley para criar padrões globais de vento.

Circulação Oceânica

- Influência da circulação atmosférica

Figure 8.1 Winds, driven by uneven solar heating and Earth's spin, drive the movement of the ocean's surface currents. The prime movers are the powerful westerlies and the persistent trade winds (easterlies).

Circulação Oceânica

- Influência da circulação atmosférica

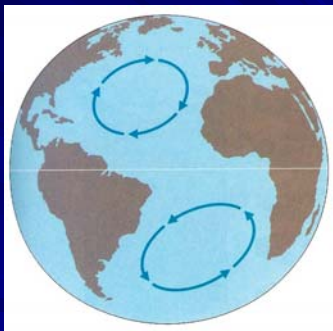


Figure 8.2 A combination of four forces—surface winds, the sun's heat, the Coriolis effect, and gravity—circulates the ocean surface clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere, forming gyres.

Circulação Oceânica

- Influência da circulação atmosférica

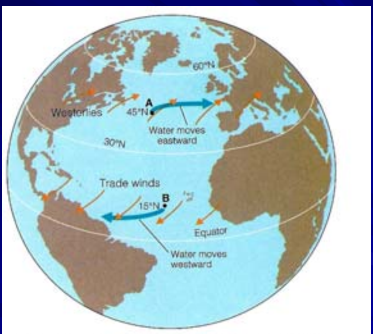
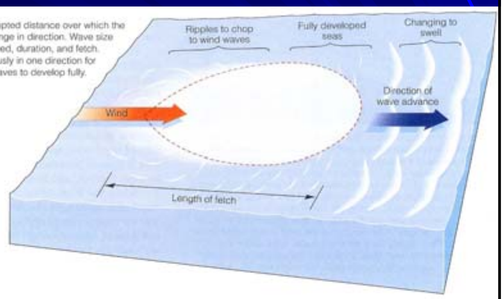


Figure 8.4 Surface water blown by the winds at point **A** will veer to the right of its initial path and continue eastward. Water at point **B** veers to the right and continues westward.

Ondas Oceânicas

Figure 9.9 The fetch, the uninterrupted distance over which the wind blows without significant change in direction. Wave size increases with increased wind speed, duration, and fetch. A strong wind must blow continuously in one direction for nearly three days for the largest waves to develop fully.



Circulação Oceânica

- Efeito Coriolis

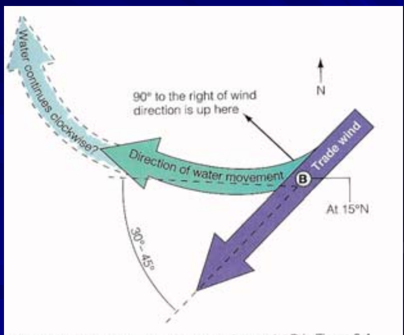


Figure 8.6 The movement of water away from point **B** in Figure 8.4 is influenced by the rightward tendency of the Coriolis effect and the gravity-powered movement of water down the pressure gradient.

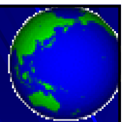
Circulação Oceânica

- Efeito Coriolis

Circulação Oceânica

- Efeito Coriolis

Circulação Oceânica



- Efeito Coriolis

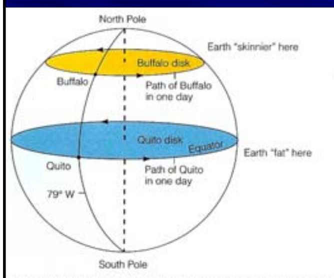


Figure 7.6 Sketch of the thought experiment in the text, showing that Buffalo travels a shorter path on the rotating Earth each day than Quito does.

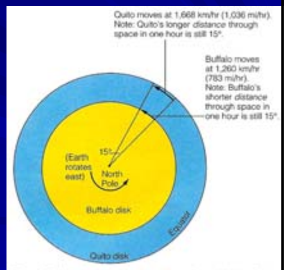
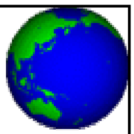


Figure 7.7 A continuation of the thought experiment. A look at Earth from above the North Pole shows that Buffalo and Quito move at different velocities.

Circulação Oceânica



- Efeito Coriolis

Número de Rossby

$$Ro = \frac{U}{f_0 L}$$

Onde: **U= Velocidade;**
f = parâmetro de Coriolis = 2 Ω sin θ
Ω = 7,292 x 10-5 s-1 (velocidade angular da Terra)
θ = latitude

$f > 0$ no Hemisfério Norte
$f < 0$ no Hemisfério Sul
$|f| \sim 10^{-4}\ s^{-1}$ em latitudes médias

Ro pequeno (atmosfera: *Ro* ~ 10^{-1})

Ro grande (piscina: *Ro* ~ 10^{3})

Circulação Oceânica

- Espiral de Ekman

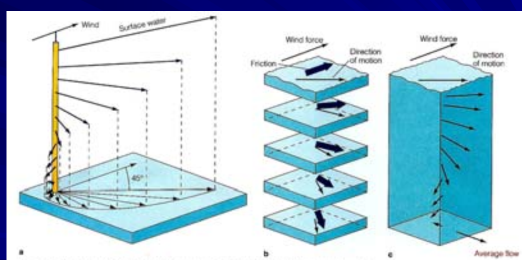
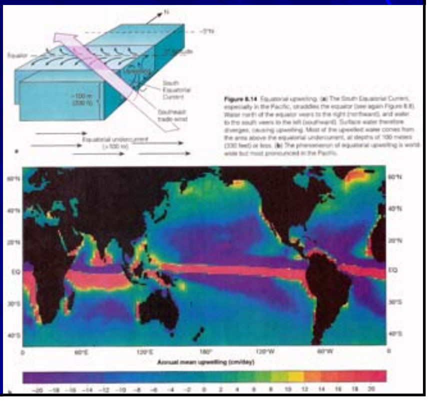


Figure 8.5 The Ekman spiral and the mechanism by which it operates. **(a)** The Ekman spiral model. **(b)** A body of water can be thought of as a set of layers. The top layer is driven forward by the wind, and each layer below is moved by friction. Each succeeding layer moves with a slower speed and at an angle to the layer immediately above it—to the right in the Northern Hemisphere, to the left in the Southern Hemisphere—until water motion becomes negligible. **(c)** Though the direction of movement varies for each layer in the stack, the theoretical net flow of water in the Northern Hemisphere is 90° to the right of the prevailing wind force. The length of the arrows is proportional to the speed of the current in each layer. (From *Laboratory Exercises in Oceanography*, 4/e by Pipkin, Gorslin, Casey, and Hammond. © 1987 by W. H. Freeman and Company. Reprinted by permission.)

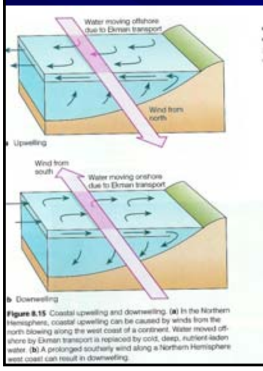
Circulação Oceânica

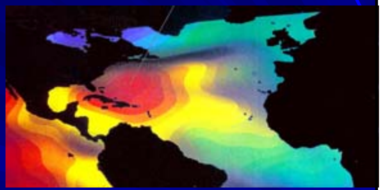
- Influência da circulação atmosférica

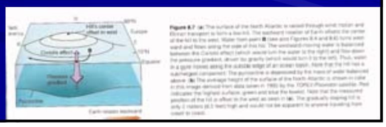


Circulação Oceânica

- Influência da circulação atmosférica

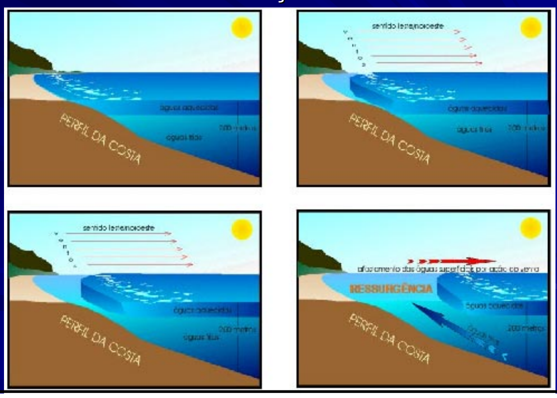




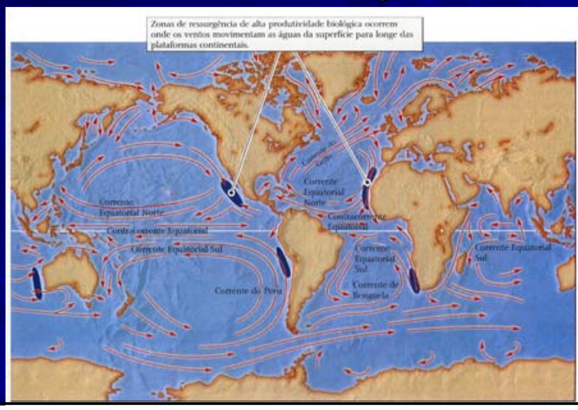


Circulação Oceânica

- Influência da circulação atmosférica



Circulação e Movimentos de Massas de Água



Circulação Oceânica

- Influência da circulação atmosférica

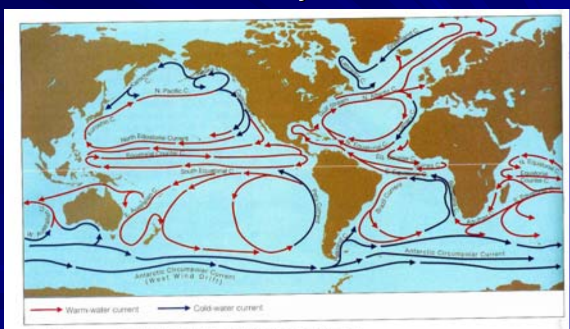
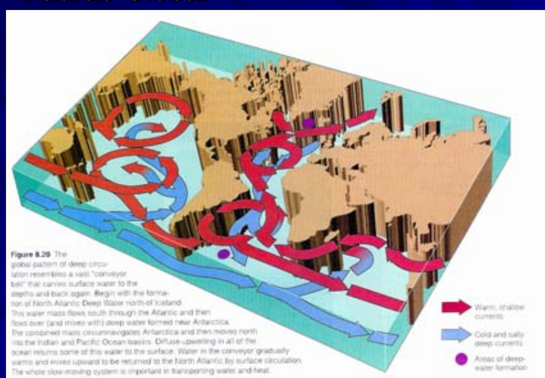


Figure 8.8 The names and usual directions of the world ocean's major surface currents. The powerful western boundary currents flow along the western boundaries of ocean basins in both hemispheres.

Circulação Oceânica

- Padrão Global



Circulação Oceânica

- Ressurgência

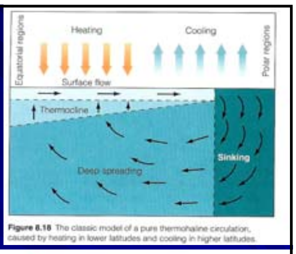
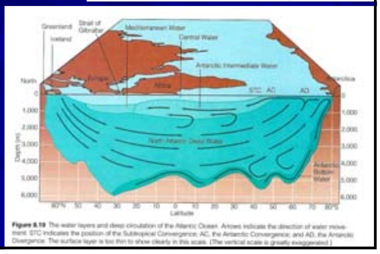
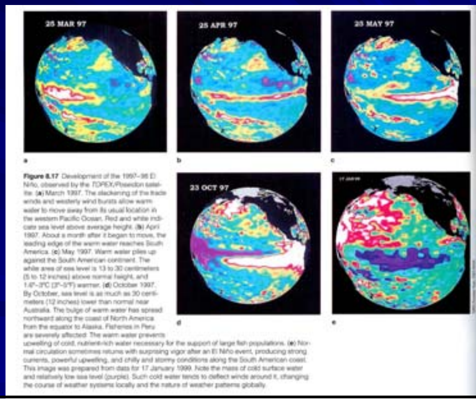


Figure 8.18 The classic model of a pure thermohaline circulation, caused by heating in lower latitudes and cooling in higher latitudes.



Circulação Oceânica

- Influência da circulação atmosférica: El Niño



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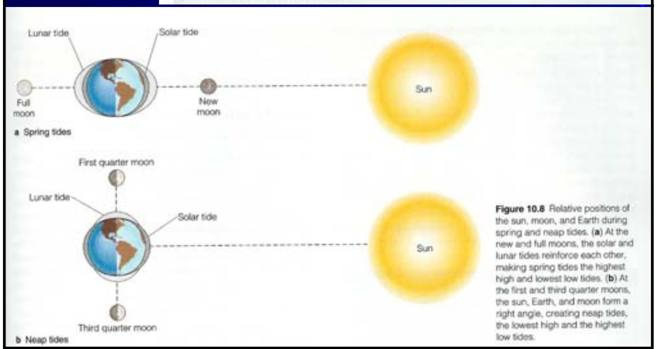

Figure 10.8 Relative positions of the sun, moon, and Earth during spring and neap tides. (a) At the new and full moons, the solar and lunar tides reinforce each other, making spring tides the highest high and lowest low tides. (b) At the first and third quarter moons, the sun, Earth, and moon form a right angle, creating neap tides, the lowest high and the highest low tides.

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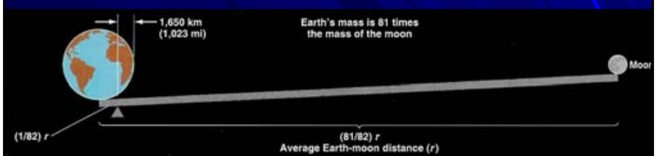
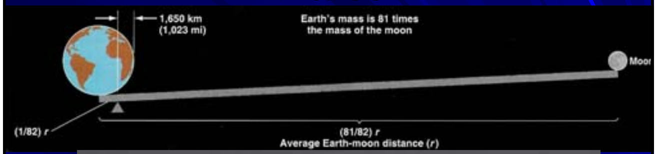
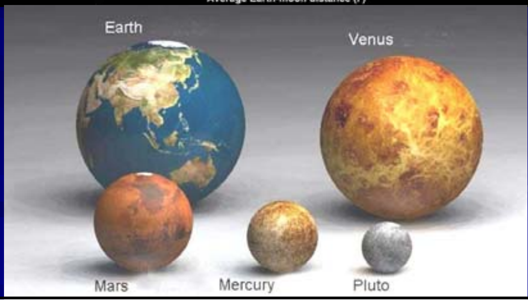


$$F = \frac{GMm}{r^2}$$

Sabe-se que:
- G representa uma constante de proporcionalidade, M a massa de um planeta, m a massa da Terra e r a distância entre ambos;
- A massa do Sol é cerca de 27000000 maior do que a da Lua;
- A distância entre a Lua e a Terra é cerca de 1/400 da distância entre a Terra e o Sol;
- A influência da Lua nas marés da Terra é duas vezes maior do que a do Sol.

Marés





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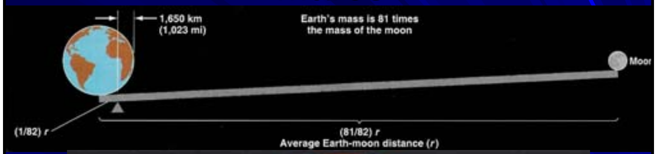

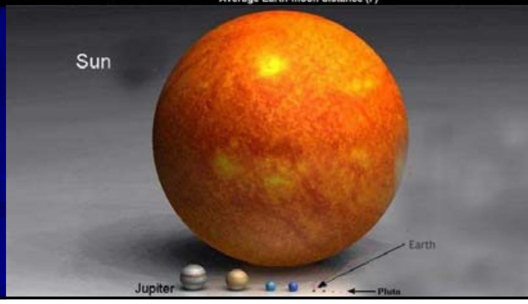

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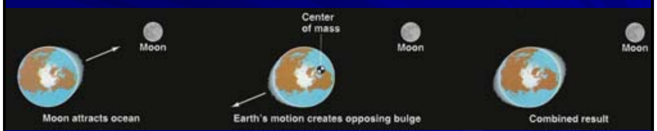

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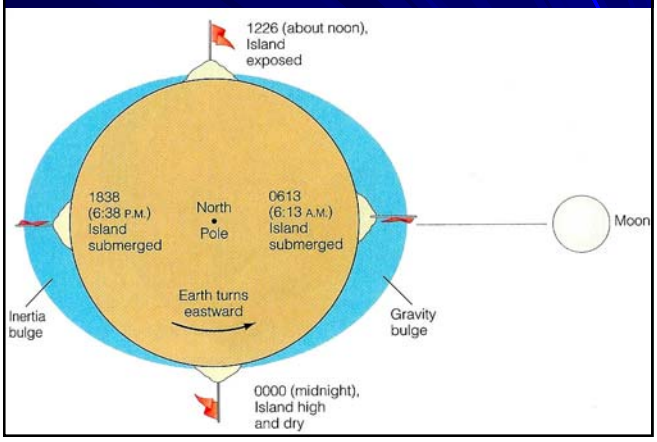

Marés

Figure 10.5 (**a**) A high tide at midnight. (**b**) The high tide one day later. Earth rotates once a day, and the Earth–moon system revolves around its center of mass once a month. Both turn in the same direction (eastward). During one complete Earth rotation (one day), the moon moves eastward 12.2°. So Earth must rotate for an additional 50 minutes to place the moon in the same place in the sky on consecutive days. Because Earth must turn an additional 50 minutes for the same tidal alignment, lunar tides usually arrive 50 minutes later each day.

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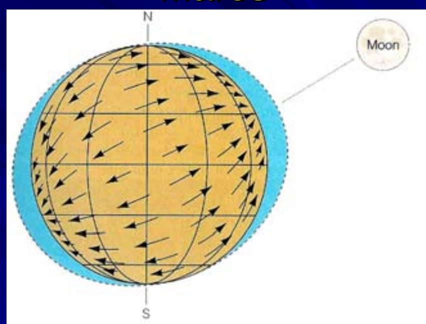


Figure 10.6 The bulges follow the moon. When the moon's position is north of the equator, the bulge toward the moon is also located north of the equator. The opposite inertia bulge is correspondingly below the equator. (Compare with Figure 10.3.) At intervals of about 18½ years, the plane of the moon's orbit is inclined 28½° relative to the plane of Earth's equator, so the moon can sometimes appear directly overhead as far north as Florida or southern Texas. Lunar tides are extreme at such times

Marés

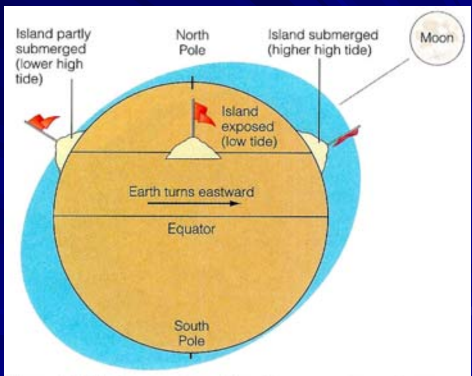
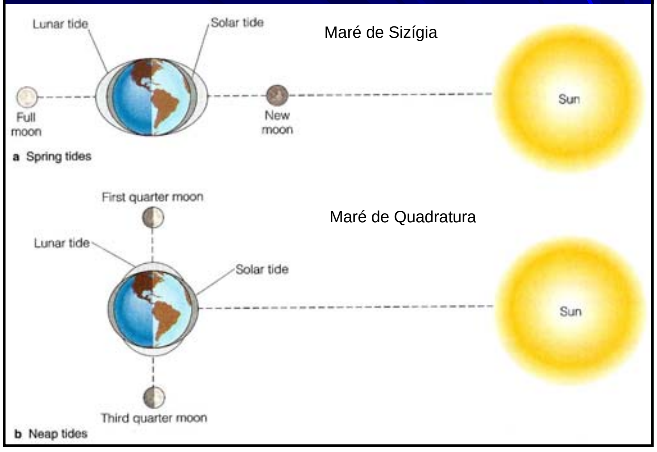


Figure 10.7 How the changing position of the moon relative to Earth's equator produces higher and lower high tides. Sometimes the moon is below the equator; sometimes it is above.

Marés



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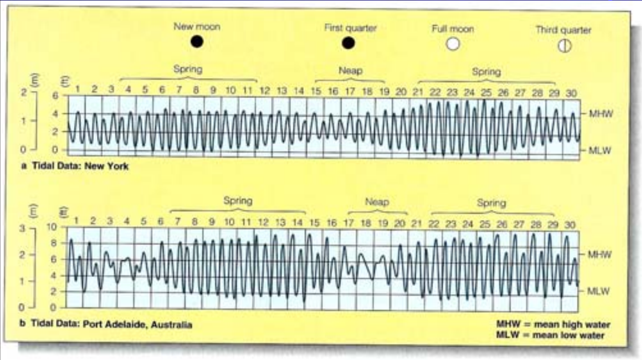

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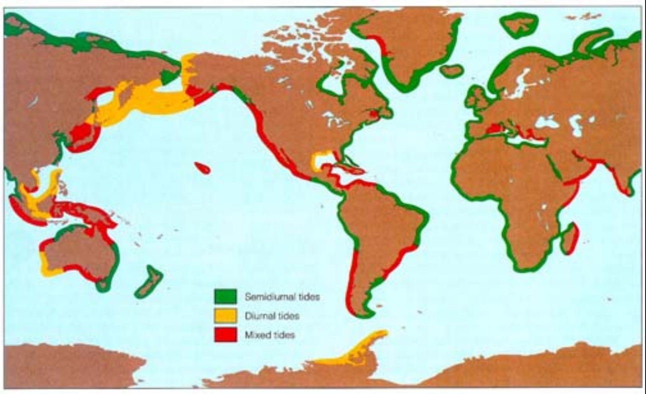

Figure 10.11 The worldwide geographic distribution of the three tidal patterns. Most of the world's ocean coasts have semidiurnal tides.

Marés

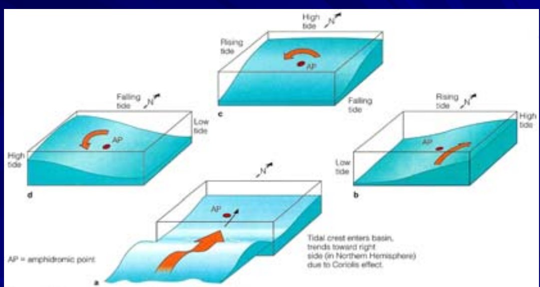

Figure 10.12 The development of amphidromic circulation. (**a**) A tide wave crest enters an ocean basin in the Northern Hemisphere. (**b**) The wave trends to the right because of the Coriolis effect, causing a high tide on the basin's eastern shore. (**c**) Unable to continue turning to the right because of the interference of the shore, the crest moves northward, following the shoreline and causing a high tide on the basin's northern shore. (**d**) The wave continues its progress around the basin in a counterclockwise direction, forming a high tide on the western shore and completing the circuit. The point around which the crest moves is an amphidromic point (AP).

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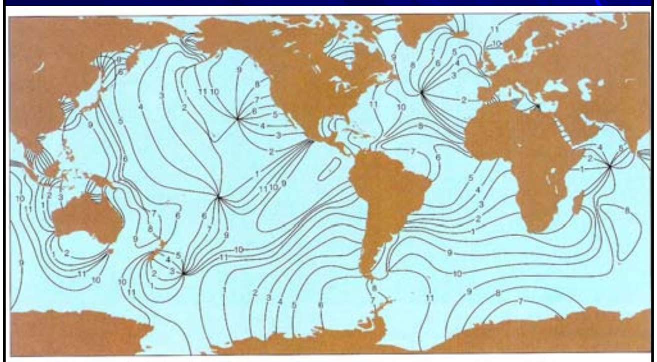

Figure 10.13 Amphidromic points in the world ocean. Tidal ranges generally increase with increasing distance from amphidromic points. Lines radiating from the points indicate tide waves moving around these points, counterclockwise in the Northern Hemisphere and clockwise in the Southern Hemisphere. The numbers represent the positions of a hypothetical tidal crest in passing hours.

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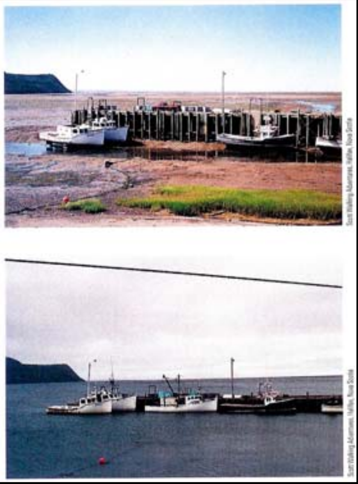

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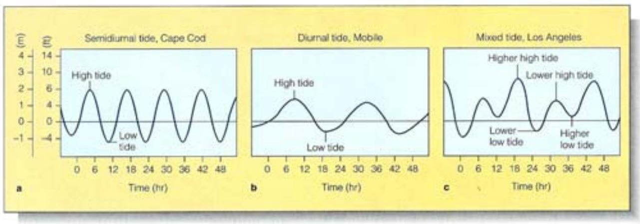


Figure 10.10 Tide curves for the three common types of tides. (**a**) A semidiurnal tide pattern at Cape Cod, Massachusetts. (**b**) A diurnal tide pattern at Mobile, Alabama. (**c**) A mixed tide pattern at Los Angeles, California.

Ondas Costeiras

- As massas de água superficial estão em constante movimento, gerado a princípio pela ação do vento. Esses ventos podem originar dois tipos de movimento:
  - Correntes oceânicas;
  - Ondas.

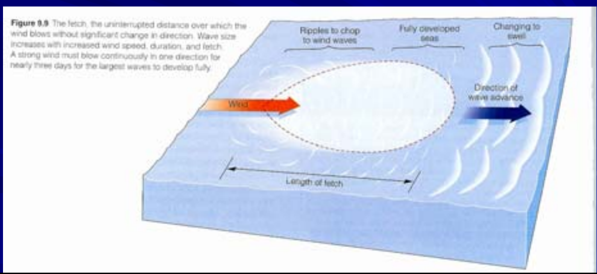
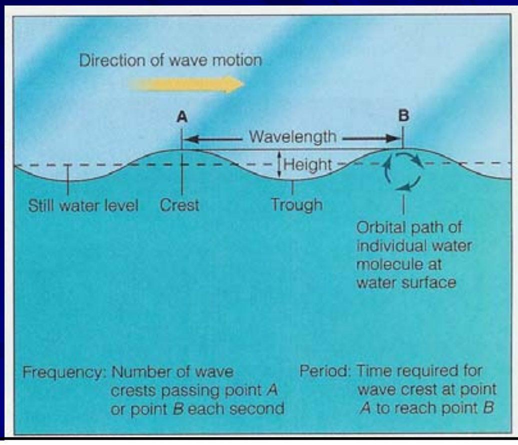


Figure 9.9 The fetch, the uninterrupted distance over which the wind blows without significant change in direction. Wave size increases with increased wind speed, duration, and fetch. A strong wind must blow continuously in one direction for nearly three days for the largest waves to develop fully.

Ondas Oceânicas



Ondas Costeiras

- As ondas variam de tamanho (poucos cm a 30m);
- Além da altura, são caracterizadas por:
  - comprimento de onda (distância horizontal entre duas cristas ou dois cavados de ondas sucessivas);
  - período (tempo da passagem de duas cristas de ondas sucessivas por um ponto fixo).

Ondas Costeiras

- Pode se somar à ação do vento (ciclones/tornados), atividades vulcânicas, maremotos e terremotos, gerando tsunamis;
- A altura da onda depende de: força do vento, distância do local de origem e de observação e período de duração do vento.

Ondas Oceânicas

- Primeira impressão: uma crista de água atravessando a superfície do mar.
- Definição de onda: "distúrbios causados por movimento de energia a partir de uma fonte através de algum meio (sólido, líquido ou gasoso)".

Ondas Oceânicas

- À medida que a energia do distúrbio desloca-se, o meio pelo qual ela passa se move de modo específico.
- Às vezes este movimento é visível para nós como cristas num meio.
- As cristas em deslocamento produzem a aparência de movimento que nós vemos em uma onda.

Ondas Oceânicas

- Em uma onda oceânica, uma faixa de energia está se movendo na velocidade da onda, mas <u>a água não está</u>!
- A água presente na crista da onda não se move continuamente atravessando a superfície do mar como a ilusão da onda sugere!

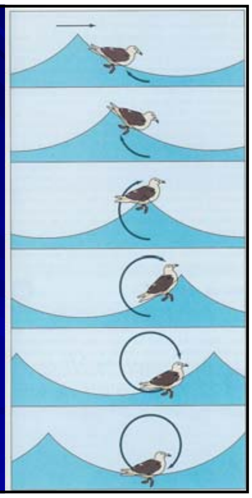
Ondas Oceânicas

- "Olla" e o conceito de onda

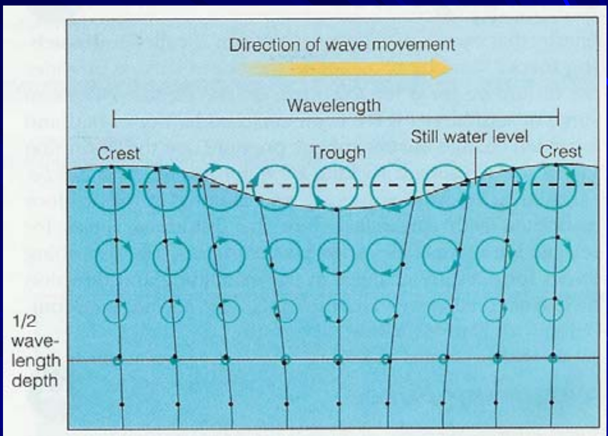
Ondas Oceânicas

- A passagem da onda gera movimento nas moléculas situadas até a profundidade igual à metade do comprimento da onda;

Ondas Oceânicas

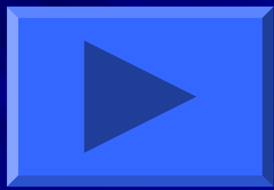


Ondas Oceânicas



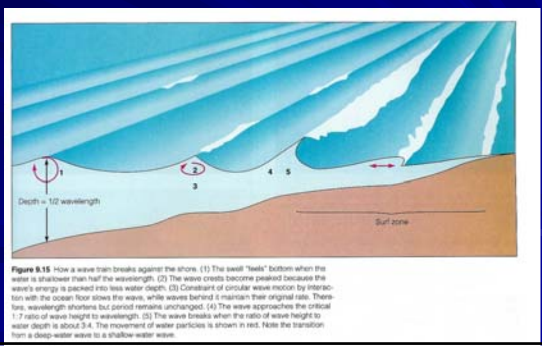
Ondas Oceânicas

- Vídeo



Ondas Costeiras

- Em águas mais rasas a resistência friccional de fundo aumenta, reduzindo movimento avante e tornando-a mais íngreme;
- Quando a profundidade for cerca de 1,3 vezes a altura da onda, ocorrerá a quebra da onda, liberando a energia.



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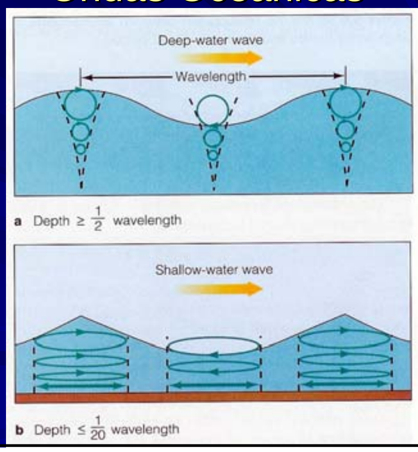

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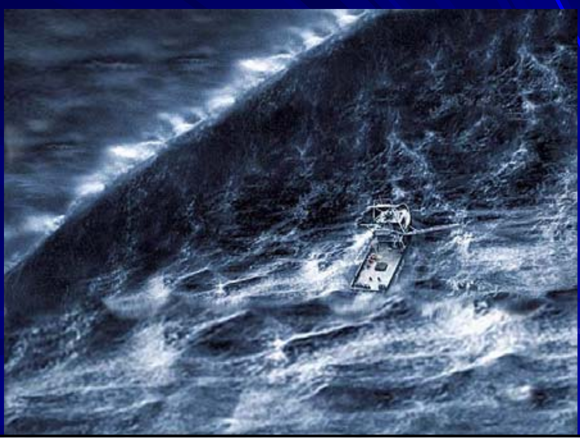

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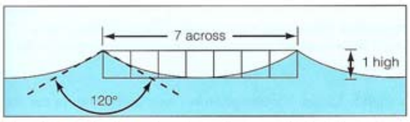
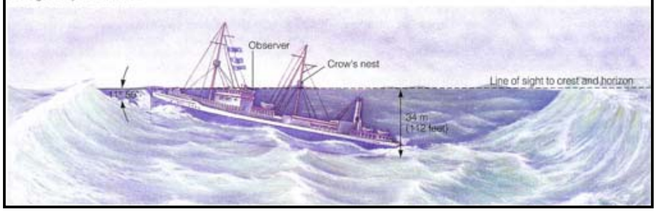


Figure 9.11 A wind wave of moderate size shown during its formation. The ratio of height to wavelength, called *wave steepness*, is 1:7; the crest angle does not exceed 120°.

Figure 9.12 How the great wave observed from the USS *Ramapo* was measured. An officer on the bridge was looking toward the stern and saw the crow's nest in his line of sight to the crest of the wave, which had just come in line with the horizon. Wave height was later calculated based on the geometry of the situation.



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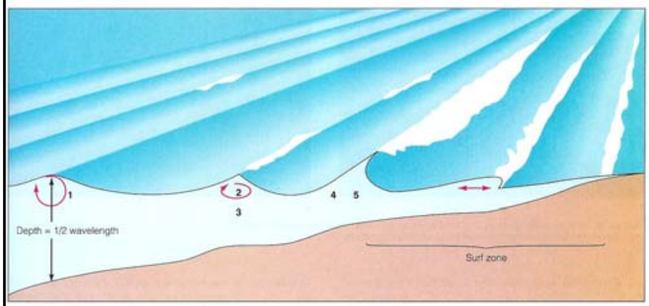
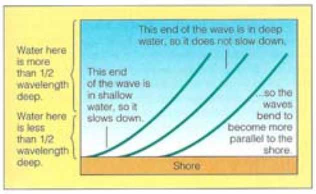


Figure 9.15 How a wave train breaks against the shore. (1) The swell "feels" bottom when the water is shallower than half the wavelength. (2) The wave crests become peaked because the wave's energy is packed into less water depth. (3) Constraint of circular wave motion by interaction with the ocean floor slows the wave, while waves behind it maintain their original rate. Therefore, wavelength shortens but period remains unchanged. (4) The wave approaches the critical 1:7 ratio of wave height to wavelength. (5) The wave breaks when the ratio of wave height to water depth is about 3:4. The movement of water particles is shown in red. Note the transition from a deep-water wave to a shallow-water wave.

Ondas Costeiras



a

b

Figure 9.18 Wave refraction. (**a**) Diagram showing the elements that produce refraction. (**b**) Wave refraction around Maili Point, Oahu, Hawaii. Note how the wave crests bend almost 90° as they move around the point.

Ondas Costeiras

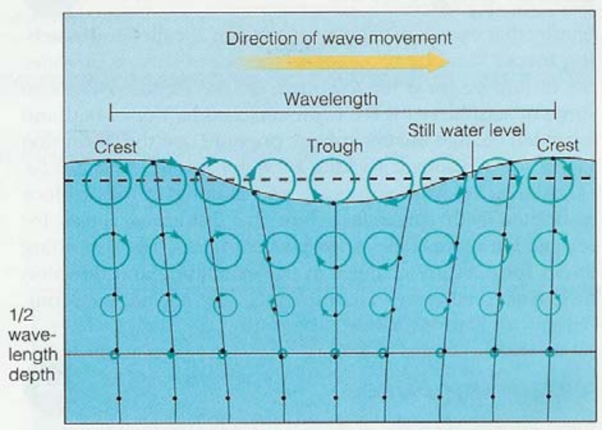
Ondas Costeiras

- Hidrodinâmica costeira

Ondas Costeiras

- Hidrodinâmica costeira X Granulometria e origem do sedimento da praia

Ondas Oceânicas



Tsunamis

Figure 9.17 *Neptune's Horse* by Walter Crane, a graphic representation of the power of breaking waves. The energy of a wave is proportional to the square of its height. Researchers report that each linear meter of a wave 2 meters (6.6 feet) above average sea level represents an energy flow of about 25 kilowatts (34 horsepower), enough to light 250 100-watt light bulbs; a wave twice as high would contain four times as much energy. A single wave 1.2 meters (4 feet) high striking the west coast of the United States may release as much as 50 million horsepower.

Tsunamis

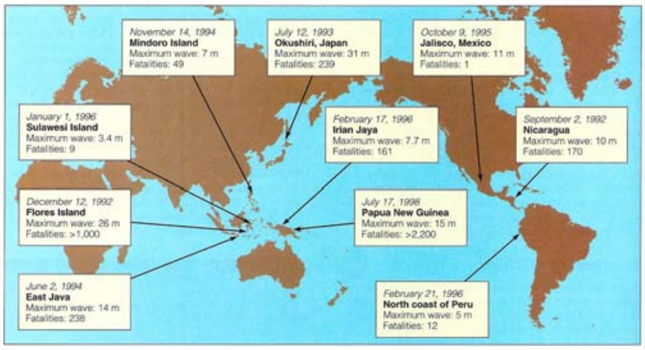


Figure 9.25 Ten destructive tsunami have claimed more than 4,000 lives since 1990.

Tsunamis

- Terremoto ao longo fossa de Peru-Chile em 22 de Maio de 1960: † >4000; Tsunami resultante no Japão (14500km de distância) † 180 (US$50milhões);
- Tsunami na costa da Nicarágua 1992: †170 (13000 sem moradia);
- 1993 Maremoto no Japão com tsunami com ondas de cerca de 29m: †120;
- 1998 tsunami com ondas de 7m: † >2200;
- Existem tsunamis mais catastróficos:
  - 1703 Awa, Japão: †100.000;
  - 27 de Agosto de 1883: Krakatoa (Indonésia) ondas de tsunamis com 35m: † >36.000 ;
  - Texas (66 milhões de anos atrás): ondas de tsunamis com mais de 91m (colisão de cometa/asteróide no Golfo do México?);
  - 27 de Dezembro de 2004: Maremoto com tsunamis de 5 a 10m no Sudeste Asiático e costa leste da África: † >175.000 (Indonésia: †115.229; Malásia: †74.229).

Tsunamis

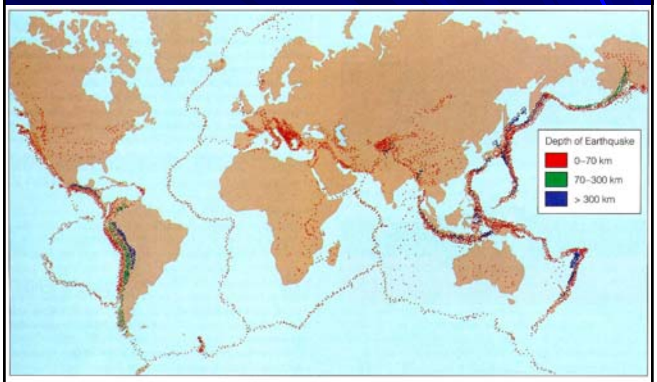


Figure 3.7 Seismic events worldwide, January 1977 through December 1986. The locations of about 10,000 earthquakes are colored red, green, and blue to represent event depths of 0–70 kilometers, 70–300 kilometers, and below 300 kilometers, respectively.

Tsunamis

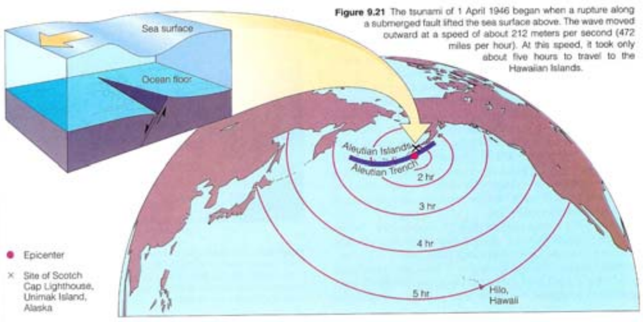
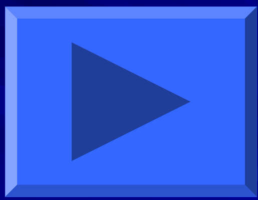
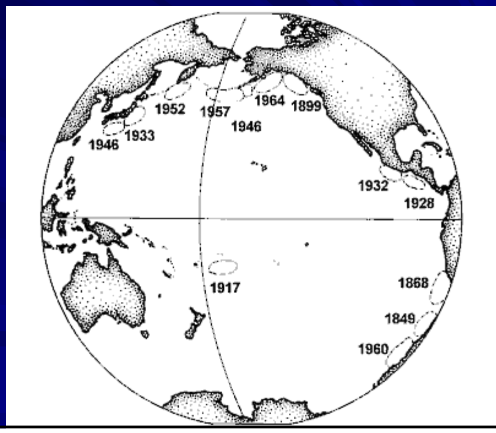


Figure 9.21 The tsunami of 1 April 1946 began when a rupture along a submerged fault lifted the sea surface above. The wave moved outward at a speed of about 212 meters per second (472 miles per hour). At this speed, it took only about five hours to travel to the Hawaiian Islands.

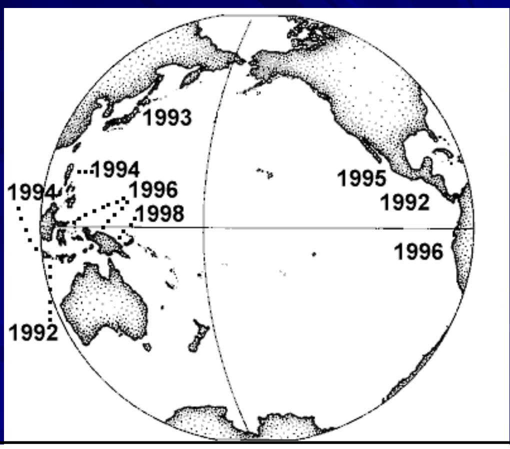
Tsunamis



Tsunamis



Tsunamis



Tsunamis

Tsunamis

Tsunamis